PRODUCTION, LOGISTICS, AND TRAFFIC: A SYSTEMATIC APPROACH TO UNDERSTAND INTERACTIONS

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ABSTRACT

Decision-makers in and around today's supply chains are facing tough decisions every day. However, when making decisions, they rarely consider what effects their decisions cause upon other participants of the supply chain or traffic management. This is mostly due to the lack of appropriate tools which help indicating the possible effects. Such tools are necessary to tackle the inherent complexity of the whole supply chain system. This paper describes how to construct and design such a tool for this interdisciplinary environment, called an Interdisciplinary Decision Map (IDM). The IDM is a powerful tool to visualise complex relationships, while at the same time retaining usability by showing relevant information only. We show how to use a specific instance of an IDM to facilitate a better understanding of the underlying processes of other supply chain participants. The soundness of our approach is backed by findings from an interdisciplinary research project.

Keywords: Production, logistics, traffic and transport, systems theory, decision-making, cross-system impact assessment, freight transport modelling

INTRODUCTION

In today's economies, supply chains are affected by decisions made in production, logistics, and traffic management. Decisions by one decision-maker often impact business of other decision-makers. For example, decisions taken by production companies, e.g., concerning the production program, indirectly determine their need for transport. As transport service providers try to fulfil this demand, their decisions will have an impact on the traffic system. Likewise, governmentally issued transport policies such as the implementation of a ban on trucks or the introduction of heavy goods vehicles (HGV) tolls can influence production processes and related transports in multiple ways. Inevitably, companies will adapt their processes to the new conditions to avoid problems or raising costs. Despite such influences, both companies and transport-related public authorities rarely take other participant's needs or workflows into account when making decisions.

However, it is desirable to optimise decision-making processes not only within a single discipline (production, logistics, traffic) but to achieve an optimum across production, logistics, and traffic. Achieving this goal poses several challenges. Typically, there is a schema to structure each discipline's workflows, specific vocabulary, and processes. However, these schemas differ vastly between disciplines in structure, organisation, and application. Furthermore, the schemas exhibit a different level of detail and aggregate at different levels of abstraction. Thus, it is virtually impossible to judge the impact of one's own disciplinary decisions by simply looking at the tools and models of other disciplines. But without a common mindset, an effective modelling and impact assessment is nearly impossible. Consequently, to achieve the desired optimisation across disciplines, it is important to overcome thinking just within one discipline. It is mandatory not only to look at other processes, but to truly understand internal processes of other disciplines and the interactions of decisions and impacts across the disciplines.

From the traffic operation and transport planning point of view, we want to illustrate this point with a realistic example: a transport authority bans trucks from a certain road to raise living quality. Such bans are usually issued because truck traffic and noise or air pollution levels exceed a certain threshold. Almost in every practical case, the ban's impacts on business processes, e.g. on processes of logistics providers, are not considered within the decision-making process. For the case of Germany, this is indicated by successful administrative appeals against such decisions. The reason for such neglect is that authorities

- are rarely communicating with business stakeholders,
- do not really know about the impacts of their decisions, and
- they have no tools available to estimate the impacts across the disciplines.

It is out of question that, vice versa, also decisions in production and logistics are usually not considering the impacts on traffic. But if the authorities took the logistics providers' needs into account and vice versa, more sustainable solutions could be possible. For our example, the usually permanent regulations for the truck ban might be changed and limited to specific situations when thresholds are really exceeded and the negative impacts for logistics providers can be justified with a significant pollution reduction.

To overcome the existing deficiencies, we have to undergo three basic steps:

- The first step is to develop a framework which allows us to describe interdependencies and interdisciplinary impacts of decisions across the disciplines. It should include descriptions and definitions of the different decision attributes and indicators in each part of the overall system. This will not only allow for a better communication and joint understanding of involved stakeholders, but it will also serve as a decision modelling framework.
- Based on this, as a second step, we can analyse and fully understand the processes in production, logistics, and traffic as well as the existing intra-disciplinary and cross-disciplinary interdependencies. Knowledge on these interrelations and impacts could be located within such a framework. For each interrelation, we could summarise the results from literature review, empirical studies or other sources.
- As a third step, we could analyse existing and potential modelling approaches for each of the identified interdependencies. We could clearly describe the limitations of already existing modelling software tools, and we could propose approaches on how to build models which help to achieve an integrated optimisation of decisions in different disciplines.

This paper focuses on the first step, the development of a decision modelling framework. This is not a trivial task, because it has to meet two very contrary requirements. On the one hand, claiming completeness, we intend to require the smallest details. The tool must support aggregated as well as fine-grained impact analyses, since decisions are made on different levels of granularity. For example, the impact analysis for dynamic, traffic-actuated signal control as a short-term decision has other requirements than the decision to build a new motorway. On the other hand, usability is a key issue and too much complexity needs to be avoided. A transport planner in a public authority pondering over a decision for a truck ban is only interested in significant impacts, not in eventualities. Consequently, since comprehensibility suffers from a too excessive degree of complexity, the framework must be limited to the information necessary for the user. Since the framework shall be used in different disciplines, some flexibility to determine the level of detail in different parts of the framework seems to be useful. Undoubtedly, this can be supported by making use of IT. Thus, IT's specific requirements in terms of digitalisation or visualisation of the framework should be considered in advance.

In this paper, we present a tool which is able to structure the decision-making framework across different disciplines to meet these requirements. It is based on findings of our interdisciplinary research project Dynamo PLV[1], which is funded by the German Federal State of Hessen within its LOEWE initiative. Our tool consists of an abstract framework and utilises the concept of an Interdisciplinary Decision Map (IDM). The framework explains how

[1] www.dynamo-plv.de

decisions across different disciplines can be modelled. We call these disciplines subsystems as part of an overall system. We further illustrate how to instantiate the framework to obtain an Interdisciplinary Decision Map (IDM) for production, logistics, and traffic. Using this methodology and our concept of an IDM, researchers can use our IDM to structure their problem spaces or create their own IDM. The IDM allows for illustrating impacts of decisions across multiple disciplines, creating chains of linked decisions and indicators, which we call *impact chains*. Furthermore, we demonstrate how our tool can be used in practice.

The remainder of this paper starts with a literature review on systems theory, decision theory, transport modelling, and performance measurement. Subsequently, the Interdisciplinary Decision Map is presented as a tool for interdisciplinary impact analysis. Its applicability is illustrated by the example of the introduction of HGV tolls and its impacts on entrepreneurial processes. Finally, we summarise our findings and give an outlook on future work.

LITERATURE REVIEW

To be able to develop the desired tool for cross-system analysis, primarily, we have to understand how a system works and how it is related to other systems and to the environment. Accordingly, we apply systems theory methods. The fundamentals of decision theory are needed to describe the underlying motivation of decisions. The internal and external impacts of decisions become measurable employing performance measurement with indicators. Also, in transport planning such a tool for decision-making support would be desirable. The necessity for such development is highlighted by illustrating the state of research for transport modelling. An interim conclusion sets the agenda for the next chapters.

Systems theory

As mentioned before, we aim at structuring decisions across different systems from various disciplines in order to make interdisciplinary dependencies transparent. Therefore, systems perspective builds the underlying basis for the present paper. According to systems theory, a system can be seen as in some way interlinked items which are somehow separated from their environment (L. von Bertalanffy (1976); Luhmann (2011)). Transferred to our specific case of production, logistics, and traffic, this abstract definition can be clarified with a simple example: a company manufacturing automobiles has different departments, e.g. manufacturing department, sourcing department, logistics department etc. These entrepreneurial systems are embedded in another system; the freight transport system. Systems can be understood as self-organising functional units with the ability to reproduce themselves (autopoiesis). Following general systems theory, in order to understand complex systems, we have to understand how the system works as a whole, as well as the functionality of a system's parts (Skyttner (2006)). Usually, two types for linkages can be identified among the parts of a system: The *strict linkage* is often observed when interlinking technical systems, e.g. the linkage of logistics transport vehicles and transport containers. Hence, in the case of strict linkage, a causal connection can be developed in order to describe the linkage. The contrary, the *loose linkage*, can, for example, be observed in practice when analysing human behaviour (Luhmann (2011)). In this case, a causal connection cannot be developed easily.

To describe the systems under discussion in our paper, we are going to apply the scheme from Leavitt as presented by March (1965). This early approach to describe and structure existing systems is often referred to as the "Leavitt Diamond" (Maier et al. (2005)). Leavitt regards the four highly interlinked categories *task*, (organisational) *structure*, *technology* and *people* (actors) as the core aspects determining an organisation (March (1965)). In the framework, *tasks* represent the tasks that have to be fulfilled in an organisation and are usually derived from an organisation's objectives. The *people* can be seen as employees in an organisation that have to fulfil the determined tasks by using adequate *technology*. The *structure* sets up a framework of rules to be followed when executing a task.

Often derived from the early ideas of Leavitt, numerous more specialised approaches to improve the understanding of systems in production, logistics, and traffic have been developed: While the idea behind the SCOR (Supply-Chain Operations Reference) Model is to describe and analyse business processes in supply-chains, such as sourcing, planning, and production (Supply-Chain Council (2010)), the approach presented by Clausen et al. (2008) is trying to build a foundation for integrated modelling of logistics and traffic in order to analyse cause-and-effect relations between those sub-systems or disciplines. The model developed by Meyr (2004) provides some basic understanding of processes in the automobile industry. Anand et al. (2012) introduce a model to improve the understanding of the different actors in city logistics networks while the model or so-called ontology presented by Lian et al. (2007) ranks among the situation-based approaches, describing the different possible situations of goods inside a logistics network.

Decision theory

All these different approaches often only give basic ideas on how to structure single systems but are not suited to describe interdisciplinary linkage. In order to understand interdependencies between different systems or disciplines, we have to understand the underlying decisions which illustrate how one decision-maker in one system is reacting to decisions made in another system. Fulfilling this task, descriptive decision models describe and explain decision-making processes and organisational behaviour in practice (Rowland & Parry (2009)) while strongly orientating themselves at the 'planning humans' and less at the (rational) task of planning (Feige, Klaus (2008)). In interdisciplinary or collective decision-making, communication and information is getting increasingly important due to the need to react and act according to the decisions of others (Laux et al. (2012)). Based on the decision-maker's underlying objectives, a decision itself can be seen as the outcome of a decision-making process which usually contains the four different steps *identification of the need for action, search for relevant alternatives*, *evaluation of alternatives and the implementation of the selected alternative* (Andler (2010); Laux et al. (2012); Schiemenz, Schönert (2005)). The first step, which involves identifying the need for action, can be interpreted as a situation in which the as-is state deviates from a certain target state (Pfohl (1977)). To evaluate the gap between as-is state and target state respectively progress towards goals reached with a certain decision, indicators are used. Due to the big variety of different targets deducible from the complex task of a system, various indicators, by definition called indicator sets, are needed (Litman (2007)). The as-is and the target state might be influenced by the decision-maker's objectives, available information or the social system the decision-maker is working and acting in (Schiemenz, Schönert (2005)). Depending on the discipline a decision-maker is acting according to different objectives. For instance, in transport planning and traffic engineering the four goal areas capacity, economy, safety, and environment are firmly established (Roth (2009)).

Performance measurement

In all disciplines considered in our work, there are lots of indicators recommended in literature. For instance, in production management several indicators can be used to measure the performance of lean production concepts (Martínez Sánchez, Pérez Pérez (2001)). Also in logistics, performance measurement by the use of indicator set is recommended (Chow et al. (1994)). A framework for performance measurement in supply chains is given by Gunasekaran et al. (2004). Accordingly, the so-called key performance indicators have arrived in management practice for quite some time. A famous example for this is the well-known Balanced Scorecard developed by Kaplan, Norton (1992). Also in transport science, the use of indicators is already discussed by academia. For example, Litman (2007) and Miranda, da Silva (2012) present lists of indicators for sustainable transport systems. However, although its importance is beyond debate, the evaluation of impacts of implemented measures is still frequently neglected in practice, like stated for the case of freight transport policies by Filippi et al. (2010).

Freight transport modelling

In transport research, passenger transport models have a long tradition. First freight transport models, which worked on an aggregated level, were built on the same principles as models for passenger transport leaving out aspect highly relevant to freight transport demand. For example, Manheim (1979) already described the freight transport system by pointing out that both the transport system and the (economic) activity system determine the flows. As a basis of each of these models a system understanding / description can be found. Recent approaches are more disaggregated and try to integrate production and logistics, thereby enhancing the model scope (Wisetjindawat (2006); de Jong, Ben-Akiva (2007); Maurer (2008); Ramstedt (2008); Liedtke (2009); Friedrich (2010); Holmgren (2010); Samimi et al. (2010)). In parallel, frameworks for describing the domain ranging from production to freight transport have been published (Clausen et al. (2008); Roorda et. al. (2010)). There is a common understanding that freight transport demand should be modelled by applying a multi-level concept, for example consisting of the layers production, trade, logistics and transport services on infrastructure (Oestlund et. al (2002)). However, there still is no clear monolithic framework for describing the interdisciplinary dependencies and impacts in this environment.

Interim conclusion

We can summarise that existing modelling and ontology building approaches provide us with solid foundation for our research. However, we also have to conclude that none of the existing approaches is suitable for modelling decision processes and interdisciplinary dependencies between production, logistics, and traffic for different reasons. Amongst other things, some of the models mentioned above only focus on selected industries or branches while others only include selected subsystems such as material flows in production or routing in logistics. Furthermore, none of the models addresses the decision processes which lie behind the interdependencies of the sub systems as done by our research. Consequently, in the following, we present an own approach called Interdisciplinary Decision Map (IDM).

METHODOLOGY

In order to create a framework, which will help to understand interdisciplinary dependencies between the systems of production, logistics, and traffic, we implemented an iterative and explorative research approach:

As a first step, based on a literature review in the area of the more generic disciplines production, logistics, and traffic, we divided the disciplines into the subsystems procurement, sourcing, production, intra-logistics, distribution and traffic. Then, for each subsystem, decision variables, alternative values and decision indicators were developed. While decision variables reflect the decision spaces of decision makers in the subsystems, decision makers can choose from various alternative values concerning each variable. Multiple indicators reflect the state of each subsystem. The decision variables, possible alternative values and indicators were integrated into multiple typologies, one for each subsystem.

The typologies of the different subsystems were then combined into an interdisciplinary diagram. The diagram allows for illustrating interdisciplinary dependencies between the various subsystems. Interdisciplinary dependencies were identified by implementing multiple case studies.

The case studies among various companies were conducted from the involved disciplines in order to deepen our understanding of the disciplinary decision spaces and to gain knowledge about interdisciplinary dependencies. All case studies were conducted by interdisciplinary research teams. Initially, we interviewed experts from the sector of mechanical engineering, the automotive industry, several transport service providers, and various transport-related public authorities. The interviews revealed manifold interdependencies. It became evident that disciplinary decisions in one discipline or subsystem have strong impacts on other disciplines/subsystems.

Based on the results of the expert interviews, we conducted three case studies focusing on selected critical links: The first case study addressed interdependencies in the field of just-in-time and just-in-sequence supply chains within the automotive industry while the second case study dealt with spare parts logistics. In a third case study, impacts of traffic measures in a midsize German city on local enterprises were considered. During the case studies we conducted expert interviews with various decision makers, which e.g. were in charge of decisions in sourcing, production planning, transportation planning, distribution planning or traffic management. In addition, we collected supporting material like organisation and process sheets. The collected data was be enriched by performing site visits at various companies and observing interdisciplinary processes in action.

The expert interviews and case studies helped us to understand and structure the decision spaces of different decision-makers, to focus on the most relevant decisions concerning different disciplines, and to create a first set of propositions about interdisciplinary interdependencies.

INTERDISCIPLINARY DECISION MAP

In this section, we first present our framework for modelling impacts of interdisciplinary decision-making. Then, we explain how this framework can be applied to our considered case of decision-making in production, logistics, and traffic. Subsequently, a detailed description of a decision impact analysis is presented.

Framework for Decision Modelling

We developed a generic framework, inspired by information theory, to be able to generalise our findings to other areas. Naturally, things are working differently in different disciplines. However, our framework is abstract enough to allow for models which capture decision impacts across disciplines. Figure 1 shows the metamodel of the developed framework, with the numbers indicating the cardinality of the associations (e.g., categories may contain any number of decision variables). We found that for each decision-maker, there are variables which can be directly influenced by decisions (e.g., production strategy) and indicators reflecting measurable observations (e.g., produced pieces/minute). Typically, decision variables and indicators belong to a category. Categories help structuring the problem space. For example, attributes might be structured along different goals or different departments. Categories may contain other categories to allow for subcategories.

Finally, there are effects between decision variables and indicators, modelling the impacts of decisions. Impacts are visualised by arrows in the figure. Our research shows that we need to be able to model effects from decision variables to indicators, reflecting the direct effect that decisions have (*decision effect*), indicators to indicators, reflecting consequences of indicator changes (*cause effect*) and indicators to decision variables, reflecting possible reactions to measurable changes (*feedback effect*). In the next section, we will see, how this allows for modelling complex interactions.

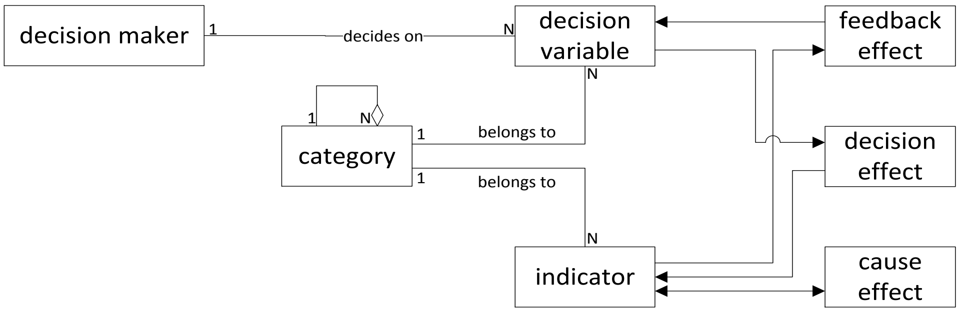

Figure 1 – Metamodel of our framework

Interdisciplinary Decision Map for Production, Logistics, and Traffic

Based on the methodology and the general framework for decision modelling described above, an instantiated framework for modelling decision processes and interdisciplinary dependencies between production, logistics, and traffic called Interdisciplinary Decision Map (IDM) has been developed. Keeping in mind the requirements for such a tool discussed in the introduction, a promising approach seems to be a multilayered design. Accordingly, the IDM contains two interdependent layers.

First of all, to be able to easily analyse cross-system impact chains, we need a significant illustration of decisions in the studied overall system. Thus, for our problem of interdependencies between production, logistics, and traffic we suggest a structure as observed in value chains (a comparable illustration is given by Porter (1985)). Based on that, the considered corporate subsystems - purchasing, inbound logistics, production, intra-logistics, outbound logistics and sales - are embedded into the freight transport system (see upper part of Figure 2).

To ensure comparability and, hence, to enable analyses of their impacts, also within the subsystems a logical structuring of decision attributes is required. Following systems theory, we make use of Leavitt's diamond to structure decisions within the subsystems.

Consequently, the IDM enables the analysis of impacts of decisions related to people, structure or technology assuming a fixed task of a system given by its definition. Within the three subgroups of decision variables we divide again into subcategories to allow for more detailed impact analyses. First, actors can be qualified in terms of their mental, functional, or physical qualification. Second, either the organisational structure or the operational structure of a system may be influenced by decisions. Third, mobile as well as immobile productions resources are needed to fulfil the system's task. In doing so, any decision in production, logistics, or traffic can be included.

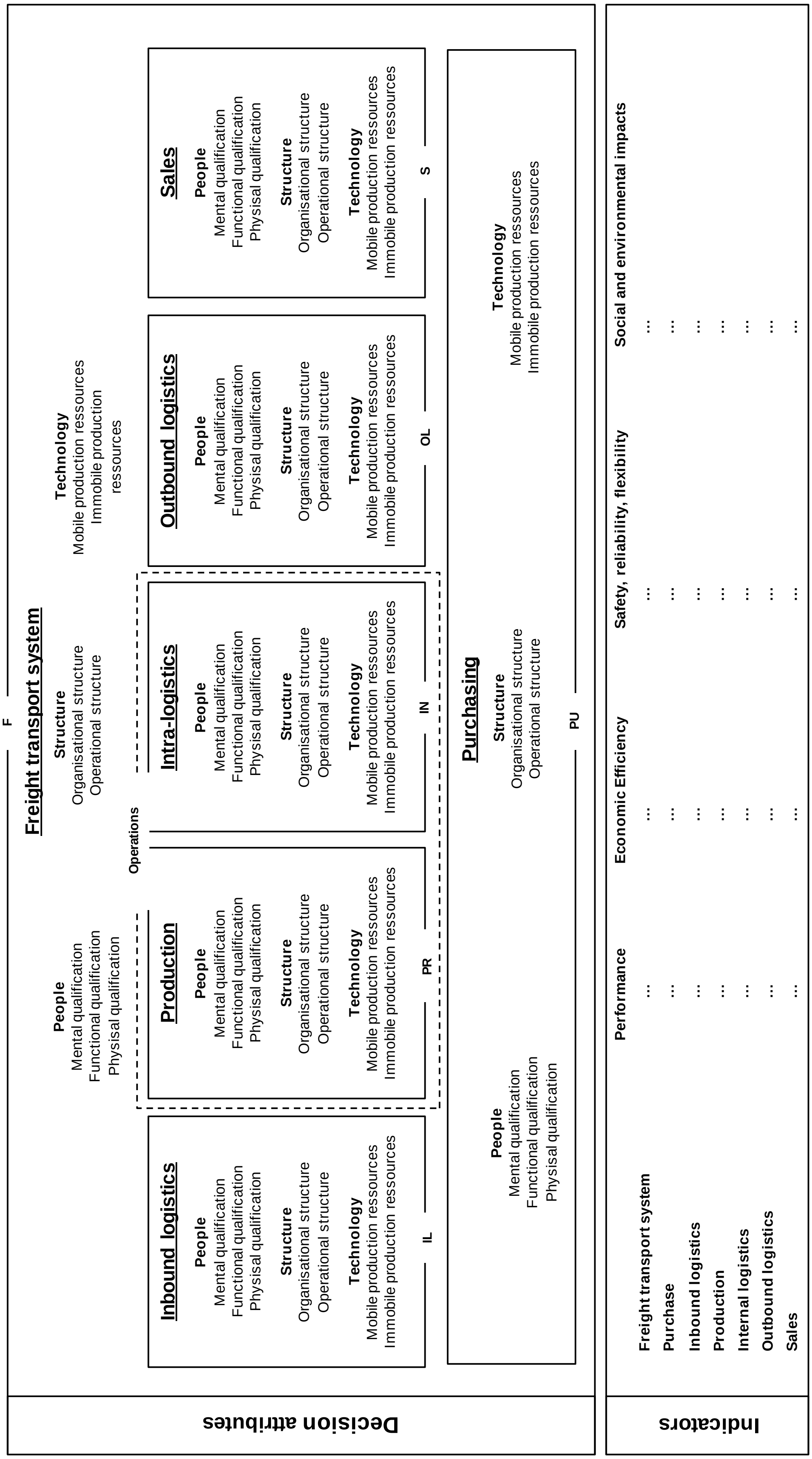

Figure 2 –Interdisciplinary Decision Map for production, logistics, and traffic

Definition

Task

To enable the transport of goods, the freight transport system consists of the entirety of transport vehicles and transport infrastructure as well as the underlying legal and institutional environment.

Decision variables

People
- Mental qualification
- Functional qualification
- Physical qualification

Structure
- Organisational structure
  - Legal environment
  - Institutional environment
- Operational structure
  - Traffic control
  - User charges
  - Terms of use
  - Legal environment

Technology
- Mobile production ressources
  - Transport vehicles
- Immobile production ressources
  - Transport infrastructure

Indicators

Performance
- Travel time
- Travel speed
- Miles travelled
- Goods lifted
- Accessibility
- Infrastructure occupancy rate

Economic efficiency
- Infrastructure costs
- Travel costs

Safety, reliability, flexibility
- Number of accidents

Environmental and social impacts
- Noise immissions
- Air pollutants

Figure 3 – Datasheet for Freight Transport System

Furthermore, to be able to evaluate decision's impacts, we gain orientation from the idea of measuring performance with key performance indicators. For this purpose, we integrate an indicator layer with quantifiable indicators for each of the systems (lower part of Figure 2). Similar to the layer of decision variables, also for the second layer a mutual structuring is needed. For this, we suggest the subcategories 'performance' (e.g. capacities for production resources), 'economic efficiency' (e.g. cost, revenues), 'safety, reliability, flexibility' and 'social and environmental impacts', following the four goals of transport planning as described by Roth (2009). Hence, our IDM simultaneously offers intuitive utilisation while still allowing for drill downs into detail (see Figures above).

Due to lack of space but also because of usability, for an impact chain analysis the illustration should only contain relevant information. Thus, we store all data needed in separate datasheets for each of the subsystems (see Figure 3 as an example datasheet for the freight transport system). These datasheets are linked with the illustration of the overall system. Following the concept of hierarchical lists, only elements necessary for the impact analysis are added to the illustration, i.e. elements can be aggregated and disaggregated as needed. By this IT-based support, we can adjust the level of detail dynamically, and thus, allow for a flexible illustration of the overall system, as data is stored independent from its presentation.

Therefore, we are now able to analyse impact chains by using decision trees making good use of that type of illustration. First, it provides a clear and intelligible illustration of the complex interrelations. Second, ceteris paribus, due to its tree structure, we can analyse changes stepwise within the whole system caused by a decision in one of the subsystems. Third, by extending the graph with additional paths, the level of detail can be increased at any time. Furthermore, the decision tree is adapted for the illustration the effects described in our framework. Within one subsystem, there may be *decision effects*, *cause effects* or *feedback effects*. Cross-system impacts are solely *cause effects*. Figure 4 illustrates this: a decision within the freight transport system may have several impacts on decision variables in the system of outbound logistics. That decision may cause a change of a certain outbound logistics indicator, whereby a decision in that subsystem may become necessary. This *feedback effect* from the indicator layer on the layer of decision variables is highlighted in Box 1. In turn, the decision in outbound logistics makes for an internal indicator change. In other words, it affects a corresponding *decision effect* within the system (Box 2). As we illustrate in Box 3, amongst other things, impacts of the second decision are still measurable in the freight transport system (*cause effect*).

In doing so, the IDM decision tree offers an easy way for illustrating impacts of decisions, since all information needed by a decision-maker is provided. However, if additional explanations are required to ensure comprehensibility, the user has recourse to the database. There, qualitative as well as quantitative descriptions of effects are stored to be able to increase the level of detail on demand.

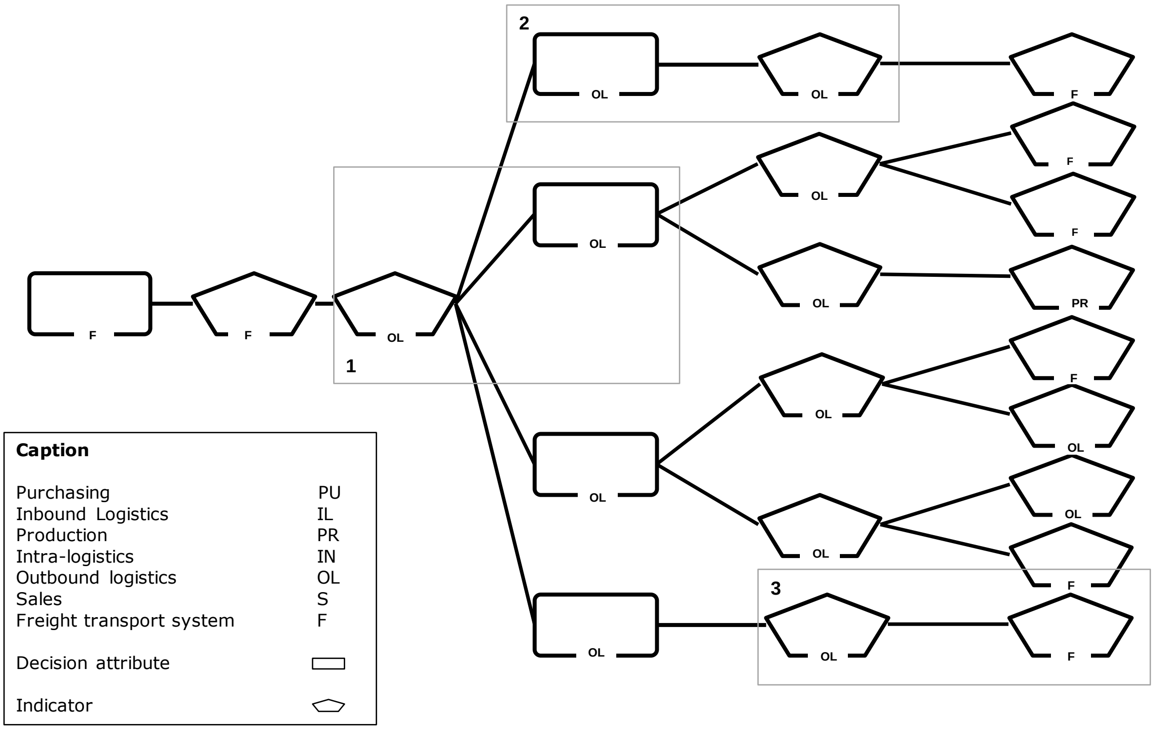

Figure 4 – Impact analysis with IDM decision tree

IDM Practical Application

To validate the IDM and identify strong interdependencies between production, logistics, and traffic, based on literature review twenty scenarios have been developed, in which impacts of decisions in different disciplines have been analysed by means of the developed tool. Exemplarily, in the following, the scenario on the impacts of a HGV tolls introduction is described.

In the last decades, HGV toll systems with different pricing variables (e.g. time-based or distance-based) have been introduced all over the world (for comprehensive overviews see Broaddus, Gertz (2008) and Conway, Walton (2009)). Beyond question, the introduction of HGV tolls can have various impacts on entrepreneurial processes since companies search for opportunities to avoid increasing costs. Several works deal with that topic (Einbock (2006); Doll, Schaffer (2007); Forss, Ramstedt (2007)). Due to possible impacts on almost each of the entrepreneurial subsystems considered by us, we use the example of the introduction of HGV tolls and its impacts on production and logistics to illustrate the applicability of IDM.

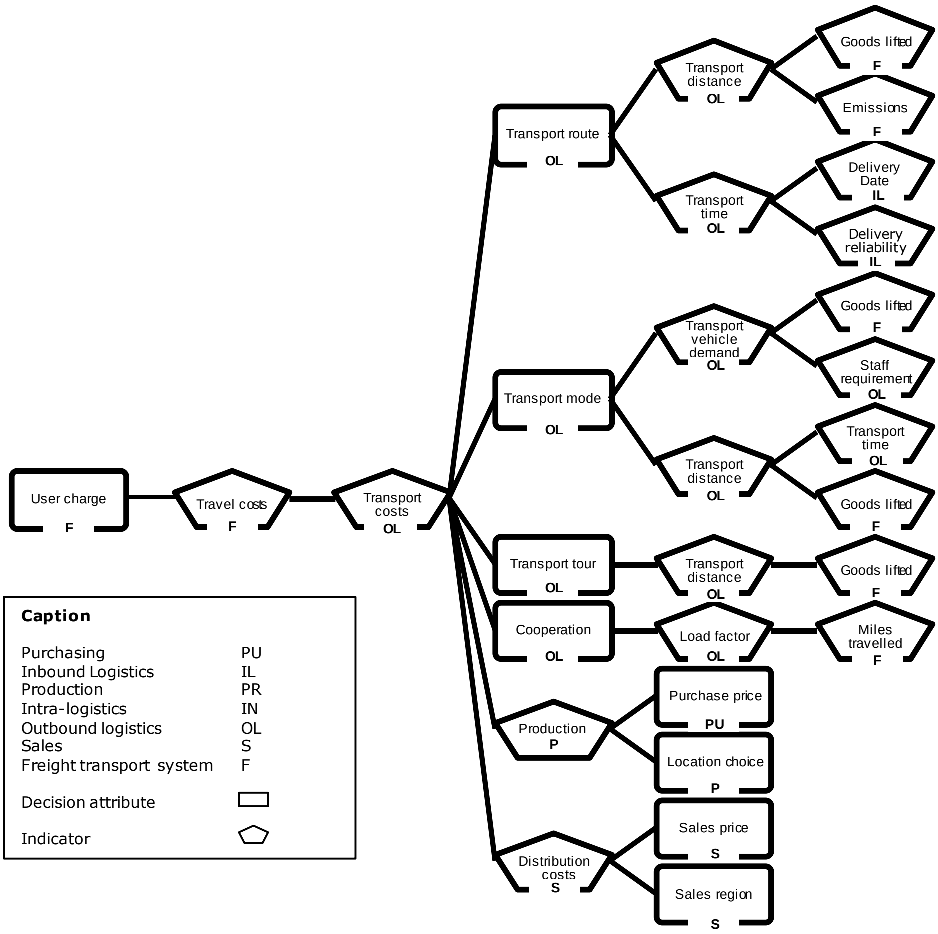

Figure 5 – Decision tree for the introduction of HGV tolls

As can be seen in Figure 5, the introduction of HGV tolls in the freight transport system represents the starting point of the impact chain analysis. As a measure for user charging, the tolls lead to an increase of travel costs and consequently, to increasing transport costs in logistics. To ensure its already tight margin, the logistics company has several opportunities to react. To avoid too much complexity, measures are only discussed from an outbound logistics point of view. However, inbound logistics is similarly affected by the introduction of tolls.

Initially, internal measures with short implementation times shall be discussed. The logistician's first opportunity is to adapt the routing, i.e. use toll-free roads to avoid costs. In the case that the new route is longer than the previous one, the indicators for goods lifted and emissions increase accordingly. If the transport time changes and the variance of the time of delivery rises, adaption in the intra-logistics processes might become necessary, e.g. the increase of safety stocks leads to higher inventory costs amongst other things. Secondly, the logistician can consider the modal choice or choice of other vehicles and switch to toll-free vehicles, e.g. vans instead of trucks. But due to the restricted load volume, more

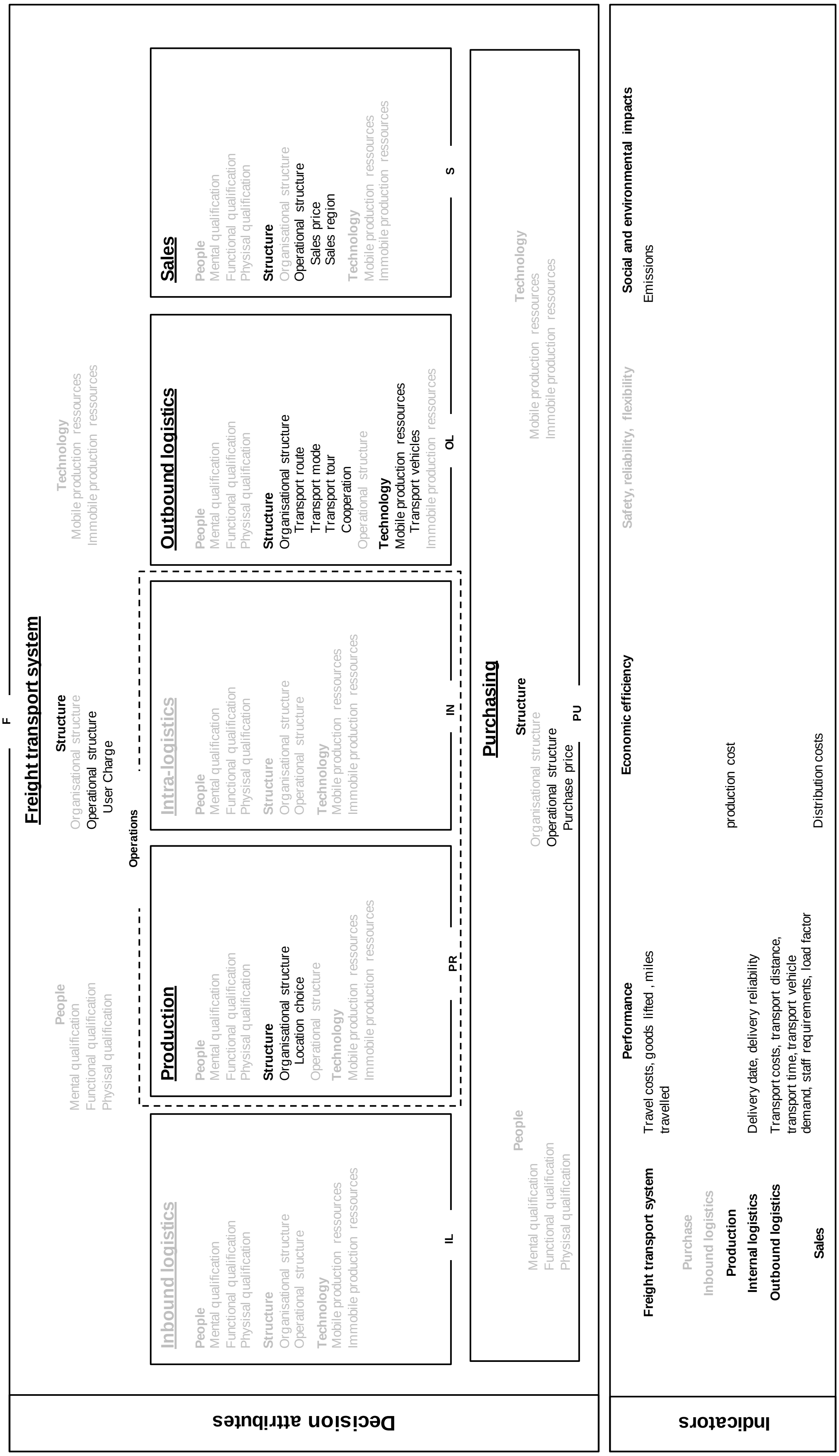

Figure 6 – IDM for the introduction of HGV tolls

vehicles and drivers are needed. Alternatively, a switch to rail might be possible. In this case, because of the totally different characteristics of the rail logistics network, increasing transport distances with, likewise, longer transport times have to be accepted. Additionally, the tour planning can be revised. Furthermore, increasing load factors, e.g. by cooperating with competitors or making use of freight exchanges, could help to save costs.

Eventually, the logistician is able to pass the cost upstream or downstream the supply chain. Passing costs upstream means increasing the production costs. Now, decision-makers in that subsystem are forced to find cost-cutting-measures. Amongst other things, depending on the market power, there might be the possibility to cut purchase prices as often done by OEMs in the automotive industry. In the long term, also the location choice might be revisited. There might also be the possibility to pass the costs downstream the supply chain, i.e. the sales is in charge for cost cutting. The most obvious measure is to increase the sales price. Moreover, one may think of adapt the size of the sales region.

As mentioned before, we mind to retain usability by reducing information to the essential. Thus, only the necessary elements are taken into the illustration of the overall system (see Figure 6). However, if new paths are identified, i.e. further impacts of HGV tolls within the overall system, or considered paths turn out wrong, the IDM and the decision tree can easily be extended or cut.

CONCLUSION AND OUTLOOK

Due to strong interdependencies between production, logistics, and traffic, a decision in one of these fields has direct impacts on the others. Thus, a tool for decision-making support which clearly illustrates the variety of impacts of a decision on the overall system would be desirable. But none of the previous approaches, for instance from transport modelling, is suitable for modelling decision processes and interdisciplinary dependencies between production, logistics, and traffic for different reasons such as editing out underlying decision-making processes or only focusing on selected industries etc.

As a consequence, in this paper we present a suitable framework to describe interdependencies and interdisciplinary impacts of measures and decisions across the disciplines, called Interdisciplinary Decision Map (IDM). This framework constitutes a powerful method for structuring and analysing direct as well as indirect impacts of decisions. The IDM can serve as a tool for decision support since it clearly illustrates consequences of decisions as easily comprehensible decision trees. However, its flexible illustration allows for a high level of detail. We have shown IDM's applicability by describing the influences on production and logistics resulting from the introduction of HGV tolls originating from a decision in a transport authority.

By using this approach, experts from industry, authorities and science are supported to identify the impacts of local decisions on connected partners from other disciplines. Regarding our example, this is of high importance for road authorities when preparing traffic-related measures. But also for decisions taken in production and logistics, e.g. on production schemes, supply chains or storage concepts, it seems well applicable to identify the consequences for actors in traffic and transport.

Thus, we intend to refine our IDM for production, logistics, and traffic to an IT-based decision-support tool for planning (e.g., estimate the impacts of transport measures). The IDM can serve as starting point for freight transport models to allow a proper system analysis. As a first step, it will help in teaching the discipline-specific terms of production, logistics and traffic and how they are related to each other, thereby fostering an efficient communication across stakeholders. To increase the quality of the modelled impacts, in a next step, we want to identify existing impact modelling approaches with further literature review. In a third step, appropriate approaches shall be linked step by step into a coherent tool to be able to model impact chains.

Another task will be to implement a software solution that is capable of rendering the IDM as a whole as well as context dependent subsets. These context dependent subsets are needed for dynamically drawing path dependencies as observed during the case studies. Attaching information about related case studies and existing research literature (if available), transforms the IDM into an interdisciplinary decision navigator. This could also be used for educational purposes to illustrate the importance of interdisciplinary thinking to students as well as experts from practice. The users will be able to verify the impact of their decisions on separate parts of the supply chain which were completely out of scope before, including the processing of real-time information (Buchmann et al. (2010)).

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