The Interdisciplinary Decision Map - A Reference Model for Production, Logistics and Traffic

Authors:
Manfred Boltze
Professor, Transport Planning and Traffic Engineering, Technische Universität Darmstadt
Otto-Berndt-Straße 2, 64287 Darmstadt, Germany
Phone: +49 61 51 16 20 25, Fax: +49 61 51 16 46 25, Email: boltze@verkehr.tu-darmstadt.de

Frederik Rühl (corresponding author)
Research Assistant, Transport Planning and Traffic Engineering, Technische Universität Darmstadt
Otto-Berndt-Straße 2, 64287 Darmstadt, Germany
Phone: +49 61 51 16 75 25 8, Fax: +49 61 51 16 46 25, Email: ruehl@verkehr.tu-darmstadt.de

Ulrich Berbner
Research Assistant, Supply Chain and Network Management, Technische Universität Darmstadt
Hochschulstraße 1, 64289 Darmstadt, Germany
Phone: +49 61 51 16 73 68, Fax: +49 61 51 16 65 03, Email: berbner@bwl.tu-darmstadt.de

Hanno Friedrich
Junior Professor, Commercial Transport, Technische Universität Darmstadt
Otto-Berndt-Straße 2, 64287 Darmstadt, Germany
Phone: +49 61 51 16 20 25, Fax: +49 61 51 16 46 25, Email: friedrich@verkehr.tu-darmstadt.de

Submitted to the Transportation Research Board (TRB) 94th Annual Meeting, Washington, D.C.
Submission Date: July 30, 2014, revised version November 14, 2014
Word Count: 6011
Number of Tables: 0
Number of Figures: 5

ABSTRACT

Due to strong interdependencies between production, logistics and traffic, a decision in one of these fields has impacts on the others. However, decision makers in and around today's supply chains rarely consider effects of their decisions on other participants of the supply chain or the traffic system. Thus, a tool for decision support, which clearly illustrates the variety of impacts of a decision, is highly desirable. Accordingly, this paper presents a reference model in the context of production, logistics and traffic, called Interdisciplinary Decision Map (IDM). The IDM allows for describing and analyzing interdisciplinary impacts of decisions across the disciplines. Thus, it can serve as decision support tool for decision makers out of the considered domains. The IDM's applicability is demonstrated by using it to analyze selected impacts of an HGV toll's introduction on production, logistics and traffic.

INTRODUCTION

There has always been a strong interference between economic activities and the transport system (1) and especially decisions in supply chains do usually not stand for their own but are highly interrelated (2). This holds especially true due to newer supply chain concepts such as just in sequence and developments towards lean supply chains, which have increased supply chain complexity over the past years (3*,* 4). Accordingly, decisions by one decision maker impact other decision maker's actions. E.g. decisions on the production program indirectly determine the need for transport. The transport service provider fulfills this demand and takes decisions such as route choice, which have an impact on the traffic system. Vice versa, traffic measures as for instance truck bans or HGV tolls can influence production processes and related transports in multiple ways. In case of implementation, companies will have to adapt their processes to new conditions to avoid problems or raising costs. Notwithstanding the above, both companies and transport-related public authorities rarely take other participant's needs into account when making decisions (*5, 6*). However, it is desirable to optimize decision making processes not only within a single discipline (production, logistics, traffic) but to realize a coordinated decision that takes the objectives of various probably affected decision makers into account. Derived from decision theory, decision processes including decision makers from different disciplines will be further addressed as interdisciplinary decision making (*7*).

The reasons for the lack of interdisciplinary decision making are numerous and can be attributed to the fields human, structure and technology (*7*). All those factors can either facilitate or impede interdisciplinary decision making. For example, decision makers who have experienced an interdisciplinary education are more likely to consider interdisciplinary effects of their decisions than others. Also, interdisciplinary structures such as comprehensive working groups can facilitate interdisciplinary decision making. Nonetheless, in order to increase effectiveness and efficiency of decisions, well-educated employees and adequate structures are not enough: Methods and instruments (technologies) are needed in order to support decision makers especially in case of rather complex decision problems.

Suitable approach in this context is the use of reference models. Reference models structure specific vocabulary, decision spaces and processes and thus, shape a common and consistent understanding among decision makers within one discipline (*8*). In the interdisciplinary context, only few such models do exist. One example is the Supply Chain Operations Reference Model (SCOR), which includes decision variables and processes from the logistics and production domain (*9*). However, there is no model describing interrelations between production, logistics and traffic.

Hence, this paper aims to propose a reference model which, first, allows for a common understanding among decision makers for the interdisciplinary domain of production, logistics and traffic. Second, the model shall allow decision-makers from that interdisciplinary domain to describe and understand impacts of own decisions across the disciplines. Thus, for instance, potential users of the presented model may be decision-makers in planning agencies who assess the effectiveness of city logistics measures as well as companies who need to estimate impacts of decisions made by their supply chain partners on their own business processes.

The development of such an integrated model is complex due to different and sometimes contrary requirements: On the one hand, claiming completeness requires the smallest details. The model 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 adaptive traffic signal control as short-term decision has other requirements than the one for analyzing impacts of clustering firms within land use management. On the other hand, subsequent users require usability and low complexity. A transport planner pondering over a decision for a truck ban, for example, is only interested in significant impacts, not in eventualities. Consequently, since comprehensibility and usability suffer from a too excessive degree of complexity, the model must be limited to the information necessary for the user. Since the model shall be used in different disciplines, flexibility to determine the level of detail in different parts of the framework is required.

As extension of Rühl et al. (2013) (*10*), the reference model presented in this paper provides a structural framework for mapping decisions from the disciplines production, logistics and traffic as well as a modeling language for describing interrelations between those decision variables. Since the developed reference model allows for mapping individual decisions and for locating interrelations of those decisions, it will be further referred to it as the Interdisciplinary Decision Map (IDM).

In the following, an overview is given concerning interdisciplinary decision making. Based on underlying theories, requirements for the IDM as an adequate reference model are derived. Subsequently, it is shown how the IDM was developed based on theory and a case study approach and how it was validated using interdisciplinary scenarios. Furthermore, the IDM's application is illustrated by the example of the introduction of HGV tolls and its impacts on business processes. The paper closes with findings and an outlook on future extendibility and utilization of the developed reference model.

UNDERSTANDING INTERDISCIPLINARY DECISIONS AND THEIR INTER-RELATIONS

Existing Reference Models in the Context of Production, Logistics and Traffic

Challenges for interdisciplinary reference models are the differing research goals and the diverse cultural imprints of the considered fields of research, but also a lack of knowledge concerning the opposite research fields and the existing terminology (*11*). This holds true for all practical circumstances where decisions have to be made in an interdisciplinary context (*7, 12*).

Various research fields and research disciplines utilize so-called reference models or ontologies to facilitate a common understanding of their domain. While reference models usually describe relevant elements with their characteristics and provide a common language for describing interrelations, ontologies also define hierarchical or constitutional relations between their elements (*13*). In literature, reference models are described as "abstract frameworks for identifying and defining concepts, as well as significant relationships among the entities of a domain" (*14*). Examples are the abovementioned SCOR model (*9*) or GenCLOn, an ontology that has been developed to model stakeholders and their objectives in city logistics (*15*).

Reference models are always designed to fulfill a certain purpose, e.g. the SCOR model's purpose is to support supply chain experts with a standardized terminology that helps them to achieve a holistic supply chain understanding and to develop integrated supply chain models (*16*). While there are already recent modeling approaches that integrate limited aspects from production, logistics and traffic (e.g. *17, 18*), most approaches do not represent general reference models. Instead they are usually highly abstracted and build by researchers from a certain discipline to fulfill a very narrow task (e.g. optimized tour planning). Describing such a reference model that enables to analyze the various interdependencies from an interdisciplinary perspective, i.e. including researchers and practitioners from production, logistics and traffic, is goal of this paper.

Systems Theory and Interdisciplinary Decisions

Systems theory and decision theory can be utilized in order to build the theoretical foundation for such a general reference model, while Porter's value chain model (*19*) can serve as a structural framework.

Systems theory is a universal approach (*20*), where a system can be seen as interlinked items or subsystems, which are separated from their environment (*20, 21*). In case of open systems, the system's border can be seen as a permeable membrane, which allows the system to interfere with its environment (*22*). Those interferences can be described by input and output relations, which e.g. might represent flows of information or materials (*23*). While those interferences, which are also referred to as structural linkages (*24*), do not allow a system to directly influence items in another system, external influences can enforce internal changes (*20*). Structural linkages can be differentiated into loose couplings and strict couplings. In case of the latter, the information received by one system (input) equals the information sent by another system (output) (*24*). In practice, this only holds true for limited cases. Usually, information has to be translated on its way from one system to another.

Decisions or decision outcomes can provide a structural linkage between various subsystems, since decisions are highly interrelated in the interdisciplinary context (*2*). Decisions in one system are usually triggered by a change, which is either caused by the environment or by another decision with relevance to the decision maker's domain.

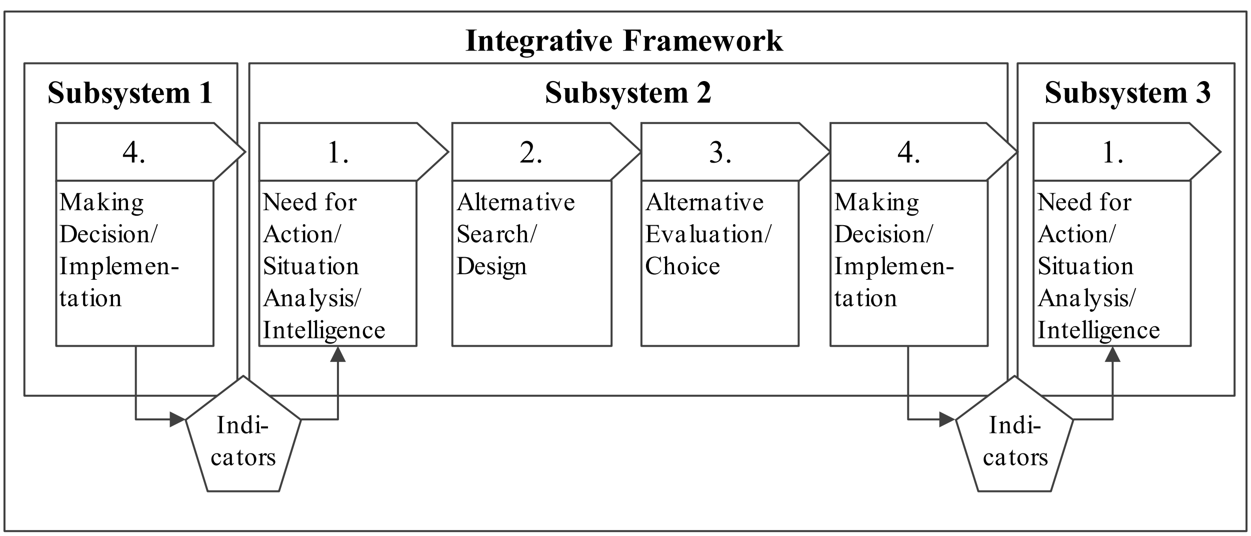

FIGURE 1 Interdisciplinary Decisions in the Integrative Framework of Production, Logistics and Traffic (*8*).

Speaking in terms of the decision making process, the last step of the inducing process (making decision/implementation) is directly linked with the first step of the triggered decision making process (need for action/situation analysis/intelligence) (Figure 1). A decision's impacts are usually monitored by various performance indicators. General indicators, which are used broadly over various disciplines, are quality, flexibility, cost and time (*25*). These indicators have always to be seen in their relevant context, e.g. costs in logistics might have a different meaning from costs in production. For examples of performance indicators from the different domains see (*26-28*). Hence, as stated above, to describe the structural coupling between two systems, multiple translation processes are required: A decision will be measured by indicators (translation 1), the indicator in one system will be translated to another system (translation 2) and then this indicator will be interpreted (translation 3) and can trigger other decisions.

The role of decisions concerning the structural linkage between various subsystems has been studied in the research project Dynamo PLV (*12*). Actors studied in Dynamo PLV comprise decision makers from public authorities (relevant for the traffic domain) and companies (relevant for the production and logistics domain). Companies are not merely split up into production and logistics departments, but rather build on a more complex and heterogeneous structure, which Porter (1985) (*19*) tried to reflect by his interpretation of the value chain. The research in Dynamo PLV has revealed, that e.g. departments like production, sourcing or inbound logistics do not share the same decision space nor objectives even so decisions made in one department often affect decisions in another (*7*). Zuber et al. (2014) provide further evidence, that the model of Porter adequately reflects the domains and decision spaces of decision makers in production, logistics and traffic by applying methods of network analysis to an interdisciplinary decision network (*8*). Also, Porter's model is well established and well known in all the disciplines addressed by the framework.

A decision maker's decision space is tightly bound to his decision domain and thus defined by the function he is working in (*7*). There are different approaches to structure decisions and decision spaces, one of the most common is the so-called Leavitt Diamond (*29*). Leavitt categorizes decisions into human, structure and technology (*30*). Decisions in the area human can e.g. address staff qualification measures, decisions in the area structure might affect processes or the organizational structure, while decisions in the area technology include the introduction of new technological equipment, e.g. new IT systems.

Requirements for a Reference Model in the Context of Production, Logistics and Traffic

Based on the findings derived from theory, the following requirements for a comprehensive reference model for production, logistics and traffic can be summarized:

- Decision makers often lack the understanding of the decision variables from other disciplines. Hence, the reference model should include a structural framework or decision map, which gives an overview of the existing subsystems and the decision makers' decision spaces.
- In order to facilitate a common and easy understanding of the framework, it should be aligned to an existing model, which is already used in research and practice and well known in the disciplines production, logistics, and traffic. Hence, the reference model should adapt decision domains as functional units of the company as described by Porter (*19*). Since traffic is not in scope of Porter's model, it needs to be implemented as a separate decision domain/subsystem.
- In order to enhance the understanding of the substantial number of possible decision variables, they should be grouped by using a common structure. Hence, the reference model should adapt Leavitt's Diamond by grouping decision variables into the fields human, structure and technology.

- The interdisciplinary impacts of decisions are not well understood. Hence, the reference model should provide a method to describe structural linkages between two or more systems.

METHODOLOGY

In order to develop the IDM, a stepwise research approach was implemented.

As a first step, based on the theoretical findings presented above, a structure was developed to map the decision spaces of the different systems. The structure heavily leans on Porter's value chain while it also allows do distinguish between decision variables and performance indicators. Furthermore, the structure enables to group decision variables by the dimensions human, structure and technology. Also, a modeling language was developed that allows a systematical description of interrelations between decision variables. By using this modeling language, the impacts of decisions can be visualized as impact chains.

In a second step, the reference model was filled with actual decision variables from production, logistics and traffic based on literature review and case studies with industrial companies from the mechanical engineering and automotive industry, several transport service providers as well as transport-related public authorities.

Finally, the developed framework was validated by defining 20 scenarios which deal with various disciplinary decisions and their interdisciplinary dependencies, i. a. the modification of the means of transport in a certain production process, the adjustment of a distribution network or the introduction of HGV tolls. In doing so, the collection of decision variables and indicators was consolidated, a variety of interdisciplinary dependencies was added and significant interrelations between the given decision variables could be identified.

INTERDISCIPLINARY DECISION MAP FOR PRODUCTION, LOGISTICS AND TRAFFIC

Elements of the Interdisciplinary Decision Map

The IDM consists of three elements: The first element is the structural framework, which facilitates the collection and location of decision variables in the interdisciplinary decision space. The second element is the modeling language, which can be used to describe interrelations. The third element is the empirical data comprising decision variables, performance indicators and actual interrelations.

Structural Framework

The Fig. 2 shows the structural framework with its two-layered design, including decision variables on the first layer and indicators on the second.

The separation into decision variables and indicators follows the idea stated above, that decisions themselves are often invisible, especially to decision makers from other subsystems. Hence, decision outcomes are usually controlled or communicated by (measurable) performance indicators. While decision variables can be directly influenced by decisions (e.g., production strategy), indicators reflect measurable observations (e.g., produced pieces/minute). Often, a decision made does not only affect a single but multiple performance indicators.

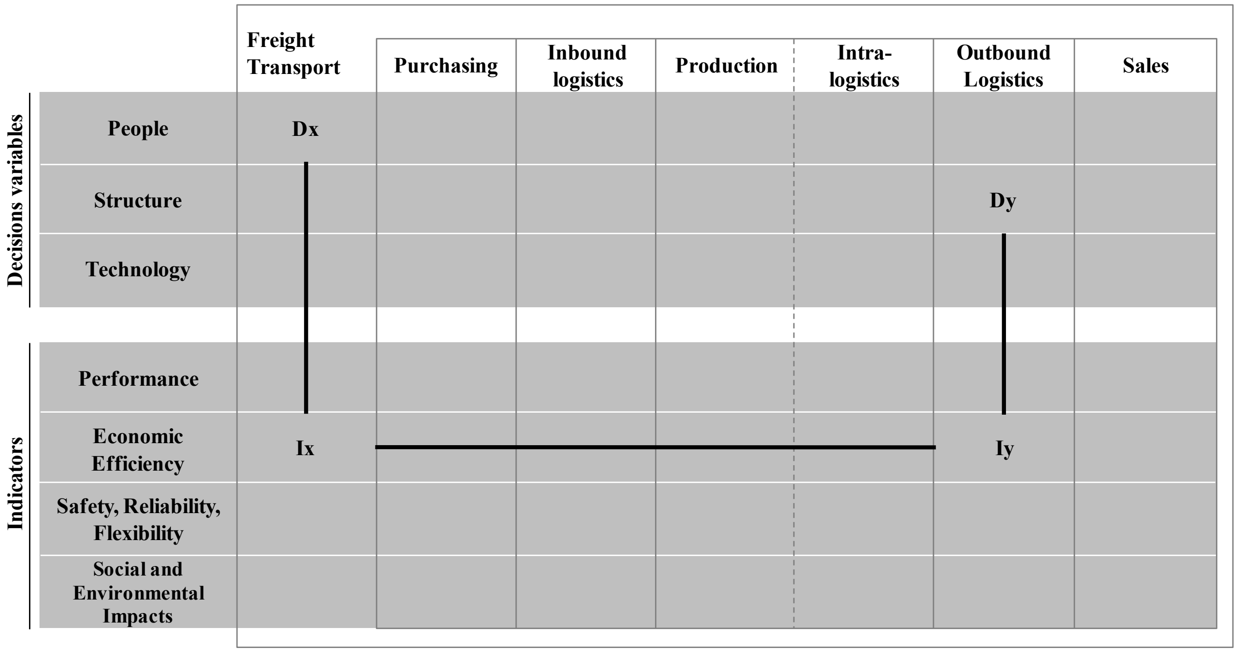

FIGURE 2 Structural Framework of the Interdisciplinary Decision Map.

The IDM's structure is aligned towards Porter's value chain (*19*). 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 Fig. 2).

To ensure comparability and, hence, to enable analyses of interrelations of decisions, Leavitt's diamond (*29*) is used to structure decisions within the subsystems. Consequently, the IDM allows the analysis of impacts of decisions related to people, structure or technology assuming a fixed task of a system given by its definition.

Furthermore, performance indicators are used to be able to evaluate decision's impacts. For this purpose, an indicator layer with quantifiable indicators for each system is integrated (lower part of Fig. 2). Similar to the layer of decision variables, also for the second layer a mutual structuring is needed. For this, subcategories 'performance' (e.g. capacities for production resources), 'economic efficiency' (e.g. cost, revenues), 'safety, reliability, flexibility' and 'social and environmental impacts' are suggested, following the four major goals of transport planning (*31*).

Modeling Language

A modeling language allows for describing the impacts and interrelationship between two decisions. As previously mentioned, the modification of a decision variable will always have an impact on at least one performance indicator. If not, the decision would either be completely irrelevant and could be excluded from the IDM, or the IDM would be missing a relevant performance indicator to allow for measuring the decision's results. The subsequent change of a performance indicator might be observed either by decision makers in the same system or by decision makers in other systems triggering follow-up decisions. In case of the latter, performance variables of one system are often not transparent to decision makers from another system. In those cases, often a structural linkage between multiple performance indicators can be

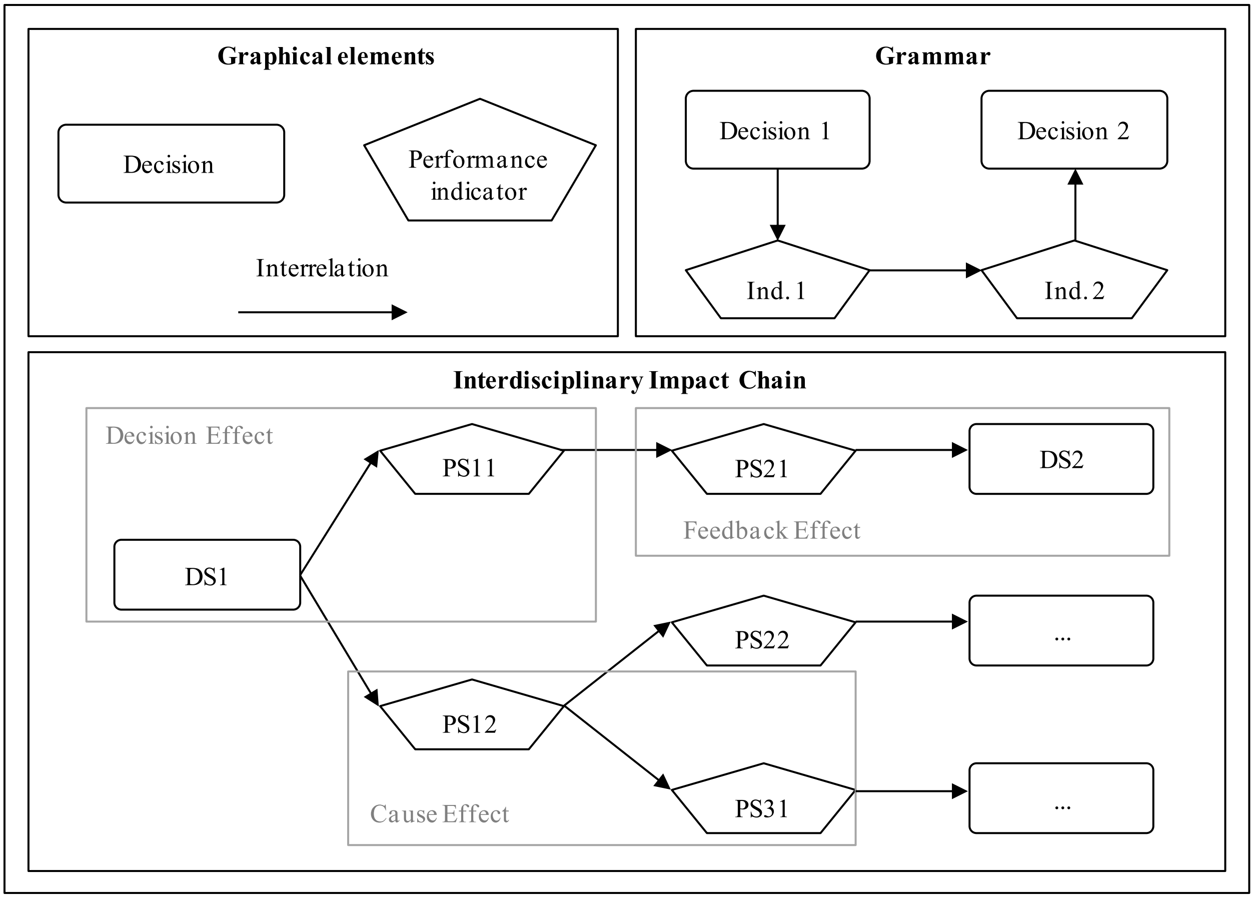

FIGURE 3 Modeling Language for Modeling Interdisciplinary Impact Chains.

observed. E.g. in practice, the indicator production lot size is usually directly linked to the indicator production cycle time. Taking this fact into account, a grammar to describe interrelations (→) between decision variables D between two systems S including various performance indicators P looks like the following:

G: DS1 → PS1 → PS2 → DS2

This grammar implies that decision DS1 influences performance indicator PS1 (called decision effect). The performance indicator PS1 might not be directly observable by a decision maker from another system but a structural link between PS1 and the observable indicator PS2 (called cause effect) might exist. When a change of PS2 is observed, a decision maker might react by making another decision DS2 (called feedback effect).

Of course, there are some cases, where an adjacent decision maker can directly observe a performance indicator PS1. In order to keep up with the developed structure of the modeling language, we suggest to use Grammar G* to describe these types of interrelations:

G*: DS1 → PS1 → PS1 → DS2

Following this grammatical rule or modeling language, interrelations can be easily visualized inside the IDM, as illustrated in Fig. 2. Combining multiple interrelations allows for modeling interdisciplinary impact chains.

As shown in Fig. 2, displaying interrelations inside the IDM is quite intuitive. However, this type of visualization is only feasible if the number of interrelations is limited. To allow modeling of extensive impact chains, graphical modeling elements and a tree-like modeling structure were developed to extend the modeling language (see Fig. 3).

The modeling language together with the developed structural framework provides a solid foundation for thoroughly analyzing interrelations: First, it allows a clear illustration of the very complex topic. Second, due to its tree structure, changes within the overall system caused by a decision can be analyzed step by step. Third, by extending the graph with additional paths, the level of detail can be increased any time.

Within one subsystem, there may be decision effects, cause effects or feedback effects. Cross-system impacts are solely cause effects. Figure 3 illustrates this: Decision DS1 influences the indicators PS11 and PS12 (decision effect). As a consequence, indicators from other systems (PS21, PS22 and PS31) change as well (cause effect). Due to this, new decisions are made (DS2) (feedback effect).

Empirical Data: Decision Variables, Performance Indicators and Their Interrelations

As mentioned above, the IDM was initially filled with decision variables, indicators and the interrelationships by means of literature review and case studies. Subsequently, the impacts of disciplinary decisions from different domains were analyzed in 20 defined scenarios (freight transport: 4; Purchasing: 2; Production/Intra-logistics: 8; Outbound logistics: 6). An exemplary impact analysis for the introduction of HGV tolls is presented below.

In Fig. 4, the IDM is filled with examples of decision variables and indicators to illustrate its broad scope. A comprehensive list of all decision variables and indicators of the IDM is available from the authors.

APPLICATION AREAS OF THE INTERDISCIPLINARY DECISION MAP

After its development, the IDM was already employed in various contexts during the research project Dynamo PLV in order to facilitate the follow up on various research questions. A selection from these applications will be outlined in the following.

Impact Analysis and Check Lists

Being able to change freight actors' habits in the context of freight transport demand management requires a profound knowledge about traffic measures' impacts on them (*32, 33*). As mentioned above, impact analyses for traffic measures often neglect consequences for production and logistics, inter alia just due to the fact that there is a lack of certain knowledge in transport authorities. Accordingly, the IDM has been used for impact analyses of traffic measures to be able to highlight the possible range of impacts. Based on that, decision making on sustainable traffic measures can be improved by developing checklists including critical interrelations to support decision makers.

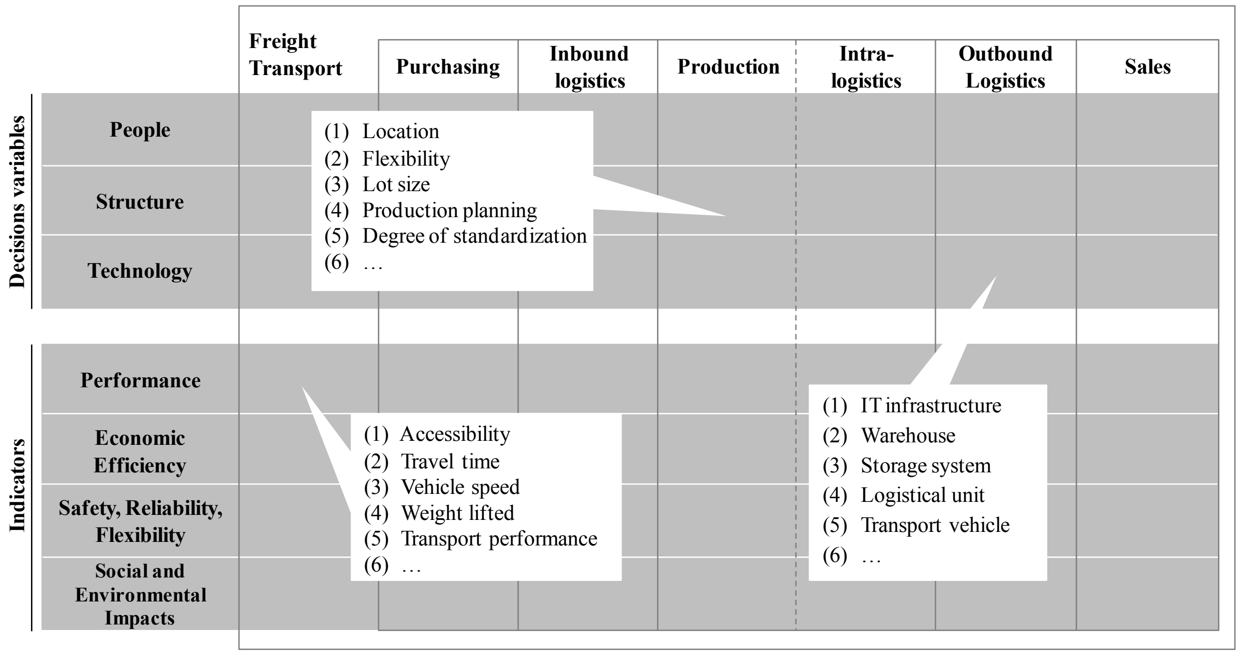

FIGURE 4 Examples for Decisions and Indicators of the Interdisciplinary Decision Map.

Decision Support Development

Research in the area of decision support is usually tightly bound to specific types of decision support or to specific disciplines, e.g. information systems. Often, there is a gap to real world decision processes. The IDM and the underlying empirical data provide researchers with the relevant knowledge on how interrelated decisions have to be supported. For example, Zuber et al. (2014) further differentiate the IDM's framework into atomic, complex and qualitative decision variables (*8*). By further investigation of the empirical determined interrelations and the resulting combinations of decision variables, adequate tools for decision support in the interdisciplinary context can be derived.

Network Analysis

The developed modeling language allows for building extensive interdisciplinary impact chains which can easily be transformed into graphs where nodes represent decision variables or performance indicators and edges represent various types of interrelations, namely decision effects, cause effects and feedback effects. The structure of those graphs can then be further analyzed by applying methods from graph theory/network analysis. E.g., Zuber et al. (2014) apply various methods from network analysis (e.g. metrics like degree centrality) to the IDM in order derive interrelation types and to allocate adequate types of decision support solutions (*8*).

USING THE INTERDISCIPLINARY DECISION MAP TO ANALYZE IMPACTS OF THE INTRODUCTION OF HGV TOLLS

Status Quo of HGV Toll Implementation

Heavy goods vehicle (HGV) tolls are strongly debated throughout politics, society and business. More and more countries, especially in the EU, are implementing HGV tolls. From the consideration to let users pay for infrastructure and ecological costs to the believe that the national transport business has to be protected against foreign competitors by road charging, there are a lot of different reasons for implementing HGV tolls. Manifold different HGV toll systems are in use. They differ regarding pricing parameters (time-based vs. distance-based) or system architecture (open vs. closed system). Descriptions of existing toll systems can be found in (*34-37*).

Economic Impacts

Various macroeconomic impacts of the introduction of a toll system have been reported: slight consumer prices increases due to higher transports costs (*38, 39*), marginal employment effects (*38*), a negative impact on accessibility (*40*) and positive impacts on pollution emissions due to induced fleet modernization (*41*).

Individual actors along the supply chain, i.e. carriers, logistics service providers as well as manufacturers, have to deal with tolls-caused price increases to different degrees. The transport logistics sector has to deal with significant price increases up to 15% while there are only marginal price effects on other industry sectors (*38, 39*). Logistics costs in other industry sectors are usually less than 5% of complete turnover. In the case of logistics service providers they stand for roughly three-quarters (*42*). Hence, being worst affected, especially the transport sector seeks for alternatives to avoid or at least minimize cost increases.

Possible Reactions of Supply Chain Actors

According to Friedrich (2010), the business decisions leading to freight transport demand are distinguishable into rather long-term strategic decisions (e.g. business location choice) and short-term decisions regarding the operations (e.g. dispatching choices) (*43*). It is assumed that on each of these hierarchical levels, actors may take action to react on HGV tolls. Thus, such decisions can be made either by the manufacturer, the logistics service provider and/or the carrier. While the manufacturer can react with a change of business location choice or sourcing choice over the long term, the logistics service provider has the competence for mid-term decisions as altering the transport chains and warehousing locations. Since the toll costs firstly occur for the carrier, he will take short-term actions concerning its operations (e.g. dispatching choices).

Academia has already paid attention to toll-caused decisions of enterprises and observable impacts within the traffic system. While research in logistics has addressed the problem from the user's perspective, in traffic engineering sciences impacts are examined on a more aggregated level. However, only Einbock (2006) addresses decisions from all different supply chain actors (*42*). European Parliament (2008) dwells on impacts on complete logistics systems, including the LSPs' and carriers' decisions (*35*). The focus in other references is restricted to the carrier's decisions (*35*, *44-46*). Usually, manufacturer's decisions are not considered.

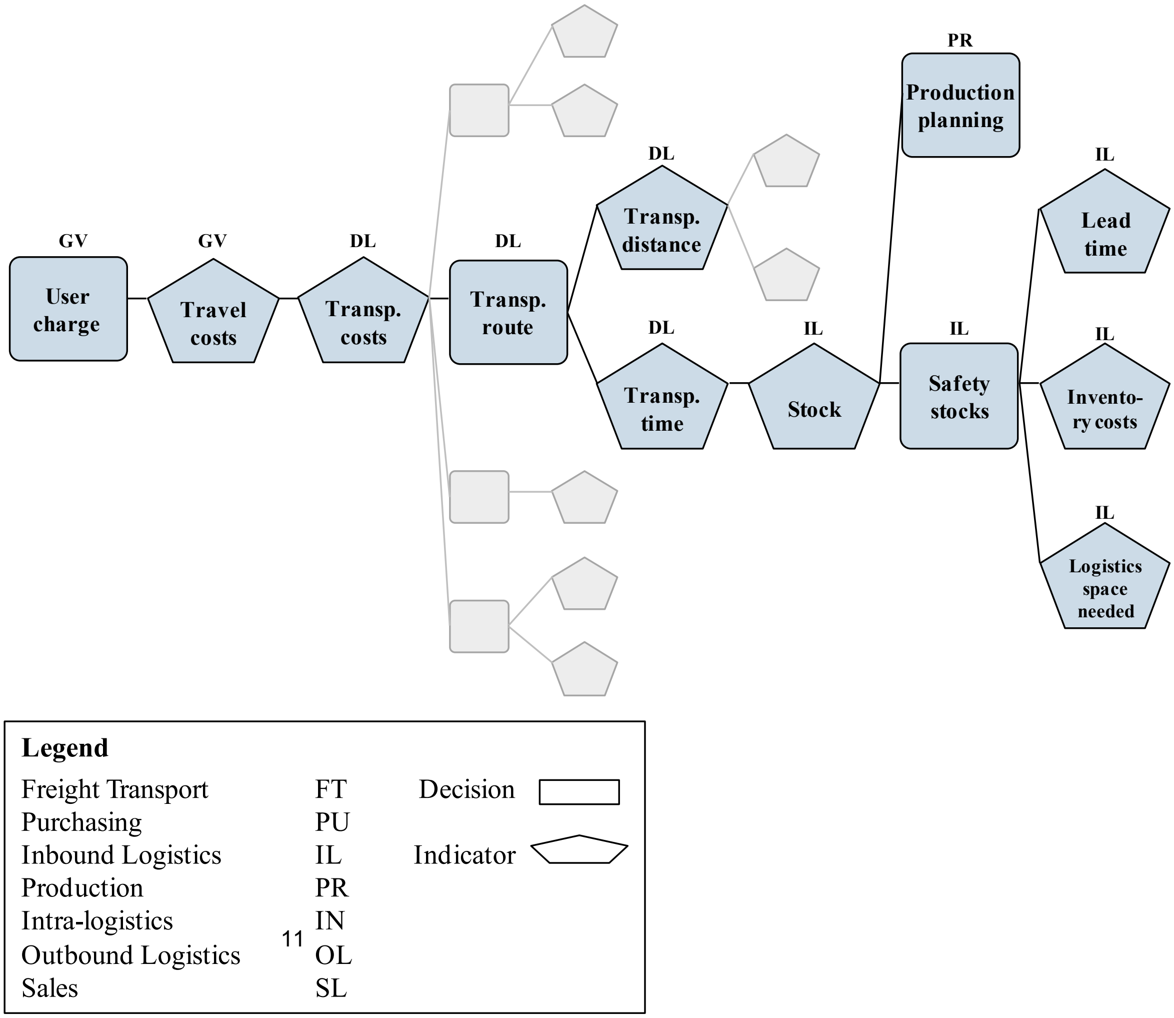

FIGURE 5 Decision Tree for the Introduction of HGV Tolls.

Impact Analysis with the Interdisciplinary Decision Map

As previously mentioned, there are various possible reactions on an HGV toll introduction. Due to the complexity of the tree, in the following it is exemplarily dwelled on the carrier's route choice by stepwise discussing decisions and their impacts on production, logistics and traffic (see Fig. 5).

- The decision in the freight transport system to introduce HGV tolls as a measure for user charging leads to an increase of travel costs and consequently, to increasing transport costs (indicator of logistics). To ensure its already tight margin, the logistics company has several opportunities to react such as to adapt the routing or to consider the modal choice. Assuming that the carrier adapts the routing, the indicators for transport distance and transport time may change.
- A change in transport time may result in a declining intra-logistics indicator measuring safety stocks, which in turn necessitates a decision on stocks, e.g. building up or increasing safety stocks.

- In the short run, changes in production planning and scheduling can cushion the effects of declining stocks on capacity utilization. In the long-run, a decision on increasing safety stocks influences indicators for lead time, inventory costs and logistics space needed, whose changes again trigger new decisions with implications for production, logistics and traffic.

CONCLUSIONS AND OUTLOOK

Due to strong interdependencies between production, logistics and traffic, a decision in one of these fields has impacts on the others. Thus, a tool, which clearly illustrates the variety of impacts of a decision, is highly desirable.

In this paper a reference model is presented to describe interdependencies and interdisciplinary impacts of measures and decisions across the disciplines, called Interdisciplinary Decision Map (IDM). This reference model constitutes a powerful method for structuring and analyzing direct as well as indirect impacts of decisions. The IDM can serve as a decision support tool since it not only structures interdisciplinary decision variables in one comprehensive framework, but also can illustrate consequences of decisions with comprehensible decision trees. However, its flexible design allows for a high level of detail, if needed. The IDM's applicability was shown by briefly outlining several areas of application and describing some influences on production and logistics resulting from the introduction of HGV tolls originating from a decision in the traffic system.

By using the developed reference model, experts from industry, authorities and science are supported to identify the impacts of decisions on interrelated decision makers from other disciplines. Regarding our example, this is a particular opportunity for road authorities, since they usually have no access to such information when preparing traffic-related measures. But also for decisions in production and logistics, e.g. on production schemes, supply chains or storage concepts, it is well applicable to identify the consequences for actors in traffic and transport.

Thus, for the future, the IDM for production, logistics and traffic provides a good basis for an IT-based decision-support tool for planning applications in production, logistics and traffic (e.g., estimate the impacts of a truck ban on processes on production and logistics). In addition, the IDM will facilitate further research in the areas of network analysis and checklist supported decision making. The IDM will also provide a solid foundation for developing adequate methods for interdisciplinary decision support.

ACKNOWLEDGMENT

This project is funded in the framework of Hessen Modell Projekte, financed with funds of LOEWE – Landes-Offensive zur Entwicklung Wissenschaftlichökonomischer Exzellenz, Förderlinie 3: KMU-Verbundvorhaben (State Offensive for the Development of Scientific and Economic Excellence).

REFERENCES

1. Manheim, M. *Fundamentals of Transportation Systems Analysis*. The MIT Press, Cambridge, Massachusetts, 1979.

2. Vidaillet, B. When Decision Outcomes are not Outcomes of Decisions. In G. Hodgkinson and W. Starbuck (Eds.) *The Oxford Handbook of Organizational Decision Making*.: Oxford University Press, Oxford, 2012.
3. Blecker, T. and W. Kersten. *Managing Risks in Supply Chains: How to Build Reliable Collaboration in Logistics*. Erich Schmidt Verlag, Berlin, 2006.
4. Craighead, C., J. Blackhurst, M. Rungtusanatham and R. Handfield. The Severity of Supply Chain Disruptions. Design Characteristics and Mitigation Capabilitis. *Decision Science*, Vol. 38, No. 1, 2007, pp. 131-156.
5. Anderson, S., J. Allen and M. Browne. Urban Logistics - How Can it Meet Policy Makers' Sustainability Objectives? *Journal of Transport Geography*, Vol. 13, No. 1, 2005, pp.71-81.
6. Stathopoulos, A., E. Valeri and E. Marcucci. Stakeholder Reactions to Urban Freight Policy Innovation. *Journal of Transport Geography*, Vol. 22, No. 5, 2012, pp. 34-45.
7. Pfohl, H.-C., M. Ehrenhöfer and U. Berbner. Fundamental Problematic Issues in Interdisciplinary Decision making: An Integrated View on Production, Logistics and Traffic & Transport. *Proceedings of the 9th International Meeting on Logistics Research*, 2012.
8. Zuber, C., H.-C. Pfohl and U. Berbner. Integrating Domains in Supply Chains – Development of Requirements for Interdisciplinary Decision Support Based on an Integrative Framework of Production, Logistics, and Traffic. *5th Annual Conference of the European Decision Sciences Institute, Denmark, Kolding*, 2014.
9. SCC, Supply Chain Council. Supply Chain Operations Reference Model SCOR Version 10.0. *The Supply Chain Council, Inc. SCOR: The Supply Chain Reference*, 2010.
10. Rühl, F., T. Freudenreich, U. Berbner, O. Ottemöller, H. Friedrich and M. Boltze. Production, Logistics, and Traffic: a Systematic Approach to Understand Interactions. *Selected Proceedings of the 13th World Conference on Transport Research Society,* 2013.
11. Sanders, N.R., Z.G. Zacharia and B.S. Fugate. The Interdisciplinary Future of Supply Chain Management Research: Interdisciplinary Future of SCM Research. *Decision Sciences*, Vol. 44, No. 3, 2013, pp. 413-429.
12. Pfohl, H.-C., C. Zuber, U. Berbner and M. Ehrenhöfer. Dynamic and Seamless Integration of Production, Logistics and Traffic/Transport – Barriers to Interdisciplinary Decision making. *Selected Proceedings of the 13th World Conference on Transport Research Society,* 2013.
13. Bera, P., A. Burton-Jones and Y. Wand. Guidelines for Designing Visual Ontologies to Support Knowledge Identification. *MIS Quarterly*, Vol. 35, No. 4, 2011, pp. 883-A11.
14. Bahm, A., H. Leone and G. Henning. SCONTO: A Supply Chain ONTOlogy That Extends and Formalizes the SCOR Model. In *Computing and Systems Technology Division,* 2011, pp. 920-922.
15. Anand, N., M. Yang, J.H.R. van Duin and L. Tavasszy. GenCLOn: An Ontology for City Logistics. *Expert Systems with Applications*, Vol. 39, No. 15, 2012, pp. 11944-11960.
16. Poluha, R.G. *Application of the SCOR Model in Supply Chain Management*. Cambria Press, London, 2007.
17. Clausen, U., U. Iddink and L. Neumann. Approaches for Modelling Commercial Freight Traffic Regarding Logistics Aspects. *Third International Symposium on Transport Simulation*. Surfers Paradise, 2008.
18. Roorda, M.J., R. Cavalcante, S. McCabe and H. Kwan. A Conceptual Framework for Agent-Based Modelling of Logistics Services. *Transportation Research Part E: Logistics and Transportation Review*, Vol. 46, No. 1, 2010, pp. 18-31.

19. Porter, M.E. *Competitive Advantage: Creating and Sustaining Superior Performance*. Free Press, New York, 1985.
20. Luhmann, N. *Organisation und Entscheidung*. Verlag für Sozialwissenschaften, Wiesbaden, 2011.
21. Bertalanffy, L.v. *General System Theory*. George Braziller Inc., New York, 1976.
22. Thom, A. *Entwicklung eines Gestaltungsmodells zum Management von Risiken in Produktionsnetzwerken: ein Beitrag zum Risikomanagement in der Logistik*. Univ.-Verl. der TU, Berlin, 2008.
23. Roggisch, N. and B. Wyssuek. Systeme und Modelle. In Krallmann, H., H. Frank and N. Gronau (Ed.): *Systemanalyse im Unternehmen: Vorgehensmodelle, Modellierungsverfahren und Gestaltungsoptionen*. Oldenbourg Wissenschaftsverlag, München, 2002, pp. 21-46.
24. Krause, D. *Luhmann-Lexikon: Eine Einführung in das Gesamtwerk von Niklas Luhmann*. UTB, Stuttgart, 2005.
25. Wang, C. and A. Masini. The Sand Cone Model Revisited: the Impact of Service Flexibility on Quality, Delivery, and Cost. Working paper, London Business School, 2009. (http://mtei.epfl.ch/webdav/site/mtei/shared/mtei_seminars/2010/Wang_Masini_2009.pdf)
26. Martínez Sánchez, A. and M. Pérez Pérez. Lean Indicators and Manufacturing Strategies. *International Journal of Operations & Production Management*, Vol. 21, No. 11, 2001, pp. 1433-1452.
27. Gunasekaran, A., C. Patel and R.E. McGaughey. A Framework for Supply Chain Performance Measurement. *International Journal of Production Economics*, Vol. 87, No. 3, 2004, pp. 333-347.
28. Miranda, H.F. and A.N. Rodrigues da Silva. Benchmarking Sustainable Urban Mobility: The Case of Curitiba. Brazil. *Transport Policy*, Vol. 21, No. 5, 2012, pp. 141-151.
29. Maier, R., T. Hädrich and R. Peinl. *Enterprise Knowledge Infrastructures*. Springer, Berlin, 2005.
30. March, J.G. *Handbook of Organizations*. Rand McNally, Chicago, 1965.
31. Boltze, M., M. Dinter and U. Schöttler. The Project FRUIT – A Goal-Oriented Approach to Traffic Management in Frankfurt am Main and the Rhein-Main Region. *Traffic Engineering & Control*, Vol. 35, No. 7+8, 1994, pp. 437-444.
32. Boltze, M., H. Friedrich and F. Rühl. Freight Transport Demand Management: A Contribution to Urban Traffic Management and Sustainability of Logistics. Presented at WCTRS – SIG10 Workshop, Vienna, 14.-16. March 2012.
33. Boltze, M. Transportmanagement: Güterverkehrsnachfrage stadtverträglich beeinflussen. In Deutsches Institut für Urbanistik (Hg.): Urbane Räume in Bewegung. Geschichte, Situation und Perspektive von Stadt. Deutsches Institut für Urbanistik, Berlin, 2013, pp. 277-286.
34. McKinnon, A. A Review of European Truck Tolling Schemes and Assessment of Their Possible Impact on Logistic Systems. *International Journal of Logistics: Research and Applications*, Vol. 9, No. 3, 2006, pp. 191-205.
35. European Parliament. *Pricing Systems for Road Freight Transport in EU Member States and Switzerland*. Brussels, 2008.
36. Broaddus, A. and C. Gertz. Tolling Heavy Goods Vehicles. *Transportation Research Record: Journal of the Transportation Research Board, No. 2066*, Transportation Research Board of the National Academies, Washington D.C., 2008, pp. 106-113.

37. Conway, A. and C.M. Walton. Policy Options for Truck User Charging, *Transportation Research Record: Journal of the Transportation Research Board, No. 2115*, Transportation Research Board of the National Academies, Washington D.C., 2009, pp. 75-83.
38. Doll, C. and A. Schaffer. Economic Impact of the Introduction of the German HGV Toll System. *Transport Policy*, Vol. 14, No. 1, 2007, pp. 49-58.
39. Vasallo, J. M. and E. López. Using Input-Output Tabels to Estimate the Effect of Charging Heavy Goods Vehicles on CPI. *Journal of Transport Economics and Policy*, Vol. 44, No. 3, 2010, pp. 317-329.
40. Condeço-Melhorado, A., J. Gutiérrez and J.C. García-Palomares. Spatial Impacts of Road Pricing: Accessibility, Regional Spillovers and Territorial Cohesion. *Transportation Research Part A*, Vol. 45, No. 3, 2011, pp. 185-203.
41. Musso, A. and W. Rothengatter. Internalisation of External Costs of Transport–A Target Driven Approach with a Focus on Climate Change. *Transport Policy*, Vol. 22, No. 9, 2013, pp. 303-314.
42. Einbock, M. Effects of the Austrian Road Toll System on Companies. *International Journal of Physical Distribution & Logistics Management*, Vol. 36, No. 2, 2006, pp. 153-169.
43. Friedrich, H. *Simulation of Logistics in Food Retailing for Freight Transportation Analysis*. Dissertation, Karlsruhe Institut für Technologie, 2010.
44. Gustafsson, I.P.,W. Cardebring and R. Fiedler. *Road User Charging for Heavy Goods Vehicles – an Overview of Regional Impact*. Hamburg, 2006.
45. Hensher, D.A. and S. Puckett. Assessing the Influence of Distance-based Charges on Freight Transporters. *Transport Reviews*, Vol. 28, No. 1, 2008, pp. 1-19.
46. Link, H. Acceptability of the German Charging Scheme for Heavy Goods Vehicles: Empirical Evidence from a Freight Company Survey. *Transport Reviews*, Vol. 28, No. 2, 2008, pp. 141-158.