FLEXINET

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FLEXINET

Deliverable [D2.1]

[Conceptual-model for business model innovation]

Work Package:	[WP2] – [Business models for global product-service production networks]
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FLEXINET Partners

Loughborough University	Loughborough University, UK
Coventry University	Coventry University, UK
ITI Instituto Tecnológico de Informática	Instituto Tecnologico de Informatica, Spain
Fraunhofer IPK Institute Production Systems and Design Technology	Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung E.V., Germany
ainia centro tecnológico	Asociacion de Investigacion de la Industria Agroalimentaria, Spain
Control 2K total solutions provider	Control 2K Limited, UK
University of St.Gallen	Universitaet St. Gallen, Switzerland
Indesit company	Indesit Company S.P.A., Italy
KSB	KSB AG, Germany
custom drinks container + beverage solutions	Customdrinks SL, Spain
Highfleet	Highfleet INC, United States
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Executive Summary (HSG)

Companies and their business models are always under pressure from external and internal forces. Namely, the legal and social environment, competitors, customer demand and technological change are influencing companies. Particularly, manufacturing industry must be able to react to change and to understand the balance of possible options when making decisions on complex multi-faceted problems. FLEXINET takes the view that new product-service global production network modelling methods and models are needed that can model business cases, identify the critical network relations and knowledge that underlies the business operation.

The conceptual model for business model innovation, documented in the deliverable at hand, has been developed to enable "what-if" comparisons of costs, risks and configuration evaluations. The model provides a comprehensive set of concepts and relationships in order to be able to model complex business models in manufacturing industry and to simulate different business model configurations. Thereby, the model reuses the knowledge of already existing models and ontologies. One major innovation of the model is the explicit incorporation of external factors like raw material prices, labour costs, or the degree of regulation of markets. New information technologies enable organisations to access ever more numerous and open sources of data that can be linked to the model. Thus the latest and most up-to-date data can be incorporated to increase the accuracy and reliability of business model simulations. To assess certain business model configurations a set of key performance indicators for new business models in product-service global production networks are provided and their mutual relationships disclosed using a balanced scorecard approach. A further important innovation is that the model comprises important risk concepts. This makes strategic risk analysis for global production network configurations possible. Thereby, the risk analysis takes advantage of the aforementioned external data sources.

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Abbreviations

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
B2B	Business-to-Business
B2C	Business-to-Consumer
BE	Business Engineering
C2C	Consumer-to-Consumer
CBM	Core Business Metamodel
DSR	Design Science Research
GOM	Guidelines for Orderly Modeling
GPN	Global production network
KPI	Key Performance Indicator
OMG	Object Management Group
PEST	Political, Environmental, Social, Technological (analysis)
PESTLE	Political, Environmental, Social, Technological, Legal, Environmental (analysis)
SBVR	Semantics of Business Vocabulary and Rules

1 Introduction

1.1 Motivation

The pressure from external and internal forces on business models in manufacturing industry is ever increasing. While in the past mainly physical products were produced and sold, today customers demand additional product-related services. Furthermore there is a higher demand for an increasing number of variants which is e.g. triggered by an increasing amount of consumerisation (Moschella *et al.* 2004). Moreover, while customers ask for affordable, customised products the lifecycle times of products are decreasing. In addition, globalisation leads to more complex and geographically distributed production networks. There is a need for operating dynamically at multiple locations around the world. A further challenge in this context is to set up new strategic alliances and partnerships. Thereby, companies need to consider the volatile economic environment in mutual dependency of fluctuating and diverse demand for products. Sustainability from a product as well as a manufacturing perspective is a further important influence upon manufacturing industry. From a technology perspective, new innovative developments lead to advanced analysis possibilities that need to be leveraged for competitive advantage. Companies have to cope with the new "data universe" to use it for their own advantage. **Error! Reference source not found.**Figure 1-1 provides a small overview on different trends that influence the innovation potential of manufacturing enterprises. In particular, the market environment and a company's core competencies frame the innovation potential.

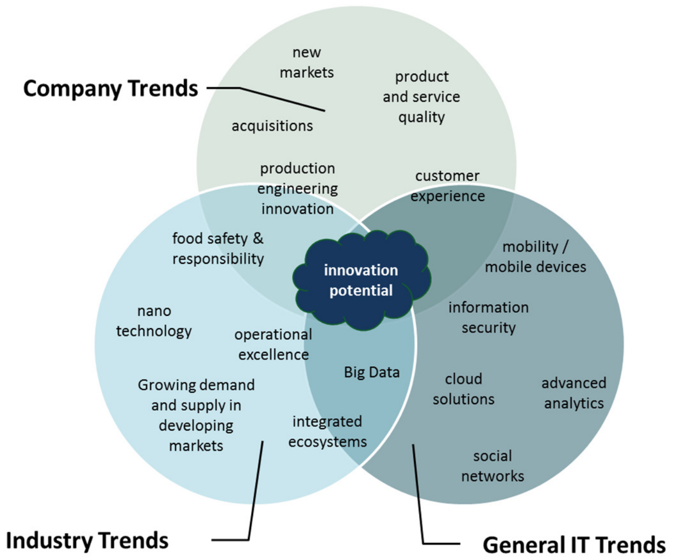

Figure 1-1: Different trends influence the innovation potential of manufacturing enterprises

Within this complex environment manufacturers need to be able to react quickly to changes and to understand the optimal balance of possible options when making decisions. Relevant decisions are, for example, where to manufacture which products and to what extent solutions consist of physical products and services. Another important question is how much standardisation should a company have in their products and to what extent products are customized. When configuring a global production network where the customisation should take place needs to be identified. From a strategic economic perspective it is crucial to understand how to best configure and re-configure a global production network. This is a complex multi-faceted problem for which companies need decision support. This becomes even more important as fast re-configuration helps to manufacture new functionally advanced products and services. Also a greater degree of personalisation may be reached through re-configuration.

Reconfiguration enables new business models that can cope with the changing environment. Through FLEXINET new business opportunities emerge. Fast reconfiguration of global production networks and manufacturing resources facilitate:

- to manufacture new functionally advanced products and services to handle the decreasing lifecycle times of products.
- a greater degree of personalisation to satisfy the increasing demand for individually customised variants which results in a higher level of customer loyalty.
- to reach new customer segments by optimized configurations and new personalized products and services which balances the fluctuating and diverse demand for affordable products.
- to provide a wider range of services through collaboration with partners.
- to manufacture products and services with higher quality levels and decrease time-to-market, allowing premium pricing.

However, there is a need for decision support in order to identify economically feasible business models with a manageable and known degree of risk. Thus, the motivation of this deliverable is to present a **conceptual model for business model innovation**. Based on this model, business model simulations can be carried out. Particularly, companies get support in structuring all relevant influencers on their new business models and can conduct "what-if" analyses. The ultimate goal is to avoid decision-making based on "gut-feeling" or "instinct" and, instead, take decisions based upon correct and sound information, and in doing so reduce risks. Thereby, the economic feasibility of configurations is a major decision criterion. For a comprehensive economic valuation many criteria (e.g. market analysis, anticipated customer demand) and restrictions (e.g. regulations) need to be considered, including the risks (e.g. environmental or economical risks) related to a configuration emerging from the aforementioned external and internal influencers. Relevant strategic network parameters of global companies in manufacturing industry are for example stability, controllability, complexity as well as the adaptability of the global production network. This goes hand in hand with economic parameters such as quality, costs, production capacity, time, resources and a company's values (Nitsche, n.d.).

1.2 Purpose and scope

The purpose of this deliverable is to present the conceptual model for business model innovation as well as the design process. However, the purpose of the deliverable is simple, yet complicated due to the great variety of perceptions and research foci that are unified in the model. Namely, research on business models and risk models together with research on performance measurement are merged with the new possibilities of the new data universe (e.g. linked (open) data). One of the most important contributions of the deliverable is to identify the most relevant concepts for designing value- and network-oriented business models in manufacturing industry. The idea is to provide a common language for business modelling in manufacturing industry from a global production network perspective. Thereby, a high emphasis is placed upon the ability to use the model as a simulation model in the future. Besides, even without any IT support the set of model constructs and its corresponding relations may assist practitioners in the task of innovating and designing their business model(s) (Mettler, 2014).

The conceptual model is a design artefact that resulted from the work in task 2.1 of the FLEXINET project. In addition, external influence factors on business models and global production networks in general are documented, including possible data sources of where to retrieve information about these factors. Finally, key performance indicators and metrics to measure the results of the economic valuation of business models based on the conceptual model are described. The conceptual model serves as the basis for the future specification of business model scenarios in task 2.4 and the development of design specifications for business modelling in task 2.3. Moreover, it will be "extended" by the business rules repository that is designed in task 2.2. Thus, task 2.2 is highly interrelated with task 2.1 as it formulates constraints and restrictions in form of business rules that narrow the configuration options. Additionally, business rules that formalise the relationships between business model concepts are identified there. Figure 1-2: gives a graphical overview on the scope of this deliverable (the darker boxes).

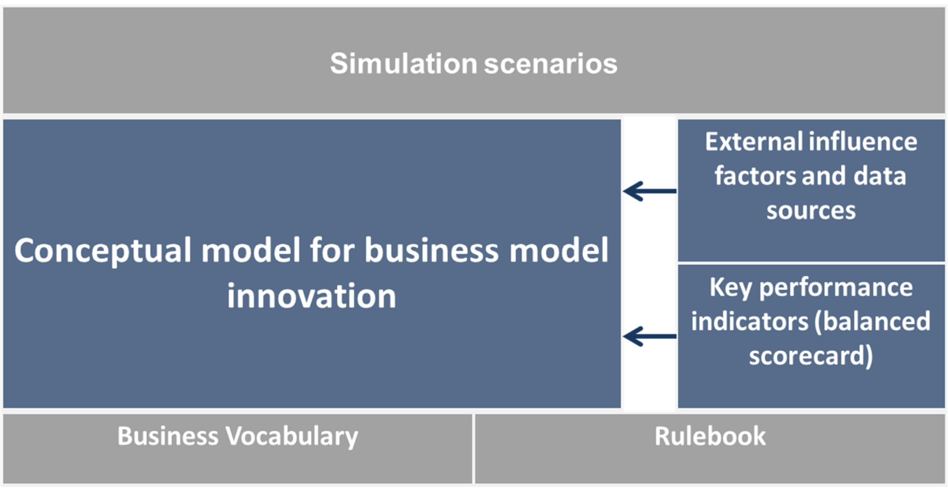

Figure 1-2: Scope of the deliverable

1.3 Research and design process

In general, the research approach followed the guidelines for Design Science Research (DSR) as for example proposed by Hevner et al. (Hevner, March, Park, & Ram, 2004). According to Peffers et al. (2007) a sequential design process that incorporates several iterations of design was used (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). Generally, the results of DSR are artefacts. Four types of artefacts are usually distinguished: constructs, models, methods and instances (Hevner et al., 2004). In particular, the resulting artefact described in the deliverable at hand is a conceptual model. The actual research process behind the design of the model is subdivided into four main activities:

- **Analysis**:
  - Identification and analysis of the scientific and practitioners' state-of-the art.
  - Requirements gathering from the use case partners (main input from WP1).
  - Discussions at consortium and technical meetings.
- **Design**:
  - Iterative design of the conceptual model for business model innovation.
  - Identification and documentation of KPIs and metrics for measuring business model feasibility.
  - Identification and categorisation of relevant external influence factors and possible data sources.
- **Evaluation**:
  - Evaluation against use case partner's requirements and against the technical capabilities of the FLEXINET application architecture.
- **Diffusion**:
  - Documentation of the state-of-the-art, the model and all other findings in the deliverable at hand.
  - Further dissemination of the model in scientific publications is planned.

Activities	Description	Timeframe of core activities
A2.1.1 (Analysis)	▪ State of the Art Analysis ▪ Requirements from WP1	July 2013 – January 2014
A2.1.2 (Design)	▪ Design of the conceptual model ▪ Integrate risk models ▪ Design interfaces to ontologies ▪ Metrics	December 2013 - April 2014
A2.1.3 (Evaluation)	▪ Evaluate the model against the FLEXINET use case partners' requirements ▪ Further design iterations	February 2014 – May 2014
A2.1.4 (Diffusion)	▪ Document the conceptual model ▪ Write deliverable ▪ Eventually further dissemination	April 2014 – June 2014

Table 1-1: Core activities of Task 2.1

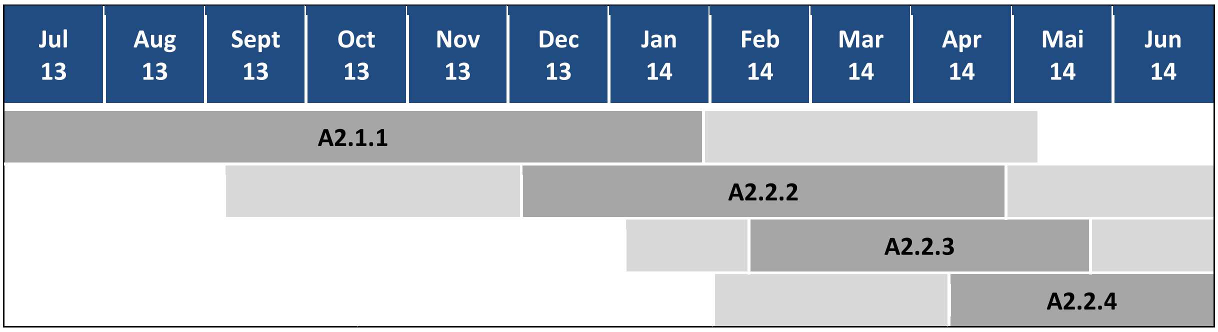

Figure 1-3: Timeplan of activities

1.4 Structure

The deliverable is structured as follows:

- Firstly, the approach for the development of the conceptual model for business model innovation is outlined. Moreover, the section comprises short explanations about the methodologies used.
- Secondly, a comprehensive description of the state of the art is provided. One important design requirement was to reuse existing and widely accepted models and ontologies. All of them are documented and it is described why they are important for the design of the new conceptual model.
- Thirdly, the conceptual model is explained and all components and perspectives that combine together to form the model are presented.
- Then, a comprehensive list of external factors is presented. External factors are categorised, described and identified data sources are documented. Particularly, external influences are analysed regarding their impact on risk.
- The external factors' section is followed by the description of key performance indicators for business models in global production networks.
- Finally, a distinct section comprehensively discusses risk modelling in global production networks. The selected risk methodologies and models for FLEXINET are described in detail as risk modelling is one of the core components that make the conceptual model for business model innovation new and unique compared to other already existing solutions.
- The last two sections demonstrate how the conceptual model can be applied in the future and present a prototypical implementation of the strategic risk analysis. The conclusion includes an outlook of future developments based on the conceptual model in work package 2.

2 State-of-the-art analysis

This section presents background information and definitions relevant for the research. First, an overview on business modelling is given. Relevant existing ontologies and models that are (re-)used for the design of the conceptual model for business model innovation are introduced. Secondly, risk models, methods and techniques that are used for the strategic risk analysis are described. The last part presents important contributions in the area of performance measurement of business models.

2.1 Business modelling

2.1.1 Overview

Information technology and e-commerce on the internet created new models for conducting business (Österle, 2001). A broad range of different definitions of business models exist in the literature. For example, Scheer, Deelmann and Loos analysed 33 different business model definitions (Scheer, Deelmann, & Loos, 2003). The most relevant definitions are presented in the following:

First, Österle provides the following definition in the context of Business Engineering (BE) taking a risk-opportunity perspective (Österle, 1996):

> *"The business model should help in understanding the new business forms, and in providing early recognition of their opportunities and dangers".*

Further, Rappa states that business models would be "the most discussed and least understood aspect of the web" and defines business models as (Rappa, 2001):

> *"the method of doing business by which a company can sustain itself -- that is, generate revenue. The business model spells-out how a company makes money by specifying where it is positioned in the value chain".*

However, both definitions are of a more general nature. A more comprehensive business model definition is provided by Österle and Blessing (Österle & Blessing, 2000):

- *"An architecture of products-, service and information flows including a description of the various business actors and their roles; and*
- *A description of the potential benefits for the various business actors; and*
- *A description of the sources of revenues"*

Klueber builds his definition on the previously mentioned one and includes partners and competitors in his business model definition (Klueber, 2000):

> *"Business models are defined as summary of the value creation logic an organization or a business network including assumptions about its partners, competitors and customers. They define the business and IS architecture, rules, potential benefits and the sources of revenue".*

Moreover, Osterwalder sees a business model as a construct consisting of different components and provides the following definition (A Osterwalder, 2004):

> *"A business model is nothing else than the value a company offers to one or several segments of customers and the architecture of the firm and its network of partners for creating, marketing and delivering this value and relationship capital, in order to generate profitable and sustainable revenue streams."*

A more technical definition emphasising the character of business models as tools which can be graphically designed and represented e.g. using Unified Modeling Language (UML) was developed by Eriksson and Penker (Penker & Eriksson, 2000):

> *"A business model is an abstraction of how a business functions. Its details differ according to the perspective of the person creating the model, each of whom will naturally have a slightly different viewpoint of the goals and visions of the business, including its efficiency and the various elements that are acting in concert within the business. […] What the business model will do is provide a simplified view of the business structure that will act as the basis for communication, improvements, or innovations, and define the information systems requirements that are necessary to support the business. It isn't necessary for a business model to capture an absolute picture of the business or to describe every business detail".*

Different approaches focus on other features in their definitions, such as Bouwman, Vos and Haaker with their services perspective on business models (Bouwman, Vos, & Haaker, 2008):

> *"A business model is a blueprint for a service to be delivered, describing the service definition and the intended value for the target group, the sources of revenue, and providing an architecture for the service delivery, including a description of the resources required, and the organizational and financial arrangements between the involved business actors, including a description of their roles and the division of costs and revenues over the business actors".*

All the authors mentioned above underline the multitude of definitions available and the broad variety of approaches towards business models. After a detailed comparison of several definitions, Weiner, Renner and Kett derive a set of common core components for a business model definition (Weiner, Renner, & Kett, 2010): examination of the model as a tool, instrument, or abstract representation; of an organization including actors and roles; of flows (financial or product and services) within an organization; of the value creation; of the value chain and value proposition; and of external influencing factors.

2.1.2 e3-Value

Dutch professor Gordijn has developed the so-called e3-value methodology to explore and describe e-business models from a value perspective (Gordijn, 2002a). The e3-value ontology is derived from scientific business literature on e-business and systems theory, it consists of different basic concepts, which are actors, value object, value port, value offering, value interface, value exchange, value activity, market segment, and composite actor.

According to Gordijin, *actors* are perceived as independent economic and/or legal entities (Gordijn, 2002a). Each actor in the model tries to generate a profit or increase utility. The different actors exchange e.g. products and services or money, which are termed *value objects* in the e3-value model, because they are of value for at least one of the involved actors. So-called *value ports* are used to signal that actors want to acquire or offer value objects. This abstraction makes it possible to concentrate on actors and other components of the business models instead of taking into account detailed internal business processes. What an actor provides or requests from the external environment is described by a *value offering*, which represents a combination of value ports (mixed bundling) exchanging value ports in the same direction. This bundling takes into account that an actor values a set of objects rather than the individual objects. Compared to the value offering, a *value interface* is bi-directional, focusing on the actual exchange, and connects the incoming and the outgoing value object. Actors can have one or several different value interfaces, combining value offerings. The connection of two value ports is termed *value exchange* and stands for at least one potential exchange of value objects. A collection of operational activities being profitable or increasing utility for at least one particular actor is termed *value activity*. A group of actors can be represented by a *market segment*, if they share the same economic valuation of certain value objects for one or several value interfaces. In certain cases, several actors might want to partner and use one common value interface to provide value objects together. This collaboration is named *composite actor*. Table 2-1: provides an overview of the general constructs of the e3-value model (Gordijn, 2002a; Mettler, 2014).

Construct	Definition
Actor	Independent economic entity with the ability to making profit (e.g. company) or increasing utility (e.g. end-consumer).
Value object	Object that is of value for one or more actors (e.g. services, goods, money).
Value port	Tracer indicating that an actor wants to offer or request a value object from its environment.
Value offering	Set of equally directed value ports indicating what an actor offers or requests from its environment.
Value interface	In its simplest form, a value interface consists of one offering. A complex value interface groups one ingoing and one outgoing value offering.
Value exchange	Connection between two value ports.
Value activity	Collection of operational activities yielding a profit or utility increase assigned to a specific actor.
Market segment	Set of actors sharing from an economic perspective one or more of their value interfaces and value objects.
Composite actor	Partnership of a number of actors offering value objects together to their environment and using a single value interface.

Table 2-1: Basic constructs of the e3-value methodology

The e3-value model is clearly focusing on the illustration of economic value exchange constellations and answers questions such as "Which actor is exchanging what economic value with whom"? Further, the model can be used to evaluate profitability, perform a sensitivity analysis or to check for business rules. In comparison to process-oriented business models which take into account operational tasks and activities, the constructs, extensions and toolset of the e3-value ontology are restricted to value creation and exchange. The methodology provides a useful, basic, and network-oriented conceptual approach, that can easily be graphically conceptualised (Mettler, 2014).

2.1.3 Business engineering

As compared to the value-oriented e3-value methodology, the Business Engineering Core-Business Metamodel (CBM) focuses more on the enterprise itself and gives more importance on describing the internal business processes (Österle, Winter, Höning, Kurpjuweit, & Osl, 2007). The model has been developed using a Business Engineering (BE) approach, which emphasises providing the fundamental modelling and methodical concepts to be able to systematically transform an organisation. Further, the BE approach tries to offer multiple intra- and inter-organisational perspectives to examine, plan and implement changes in the business model structure of enterprises. With this approach, boundaries and limited applicability of highly specific approaches can be overcome. Different extensions of the ontology's vocabulary and definitions and several modelling tools have been developed. The rather broad CBM methodology consists of several main concepts, which are market, organisation, organisational unit, consumer, producer, intermediary, business role, business goal, business process, task, activity, information, infrastructure, and service.

The first out of fourteen constructs is the *market*, which is divided into different segments and place of interaction between the different actors to generate a profit or increase utility. Further, an *organisation* is defined as an entity with a systematic structure and management pursuing collective goals on a continuing basis. Employees conducting activities for the organisation are divided into several thematic sub-groups, called *organisational units*. The CBM knows three different actors. First, the *consumer* is trying to increase utility, second, the *producer* is trying to maximise profits, and third, the *intermediary*, is connecting the two other actors to increase utility or maximise profits. A *business role* is defined as rights and duties to fulfil a task. Further, *business processes* are a group of tasks and activities with the aim to fulfil a certain *business goal*, which is defined as a targeted accomplishment of a business process. A *task* is an assignment that is logically structured and carried out by a business role. Moreover, an *activity* is defined as a task's atomic element. CBM defines the term *information* as processed data necessary to fulfil an activity. Further, *infrastructure* is a collection of resources supporting the performance of activities. Finally, the output or input of a business process is defined as *service* (Mettler, 2014). Table 2-2: offers an overview of the different main CBM constructs (Mettler, 2014).

Construct	Definition

Market	Economic environment where actors interact with each other in order to making profit or increasing utility. The market typically consists of distinct market segments.
Organisation	Systematically structured and managed entity to pursue collective goals on a continuing basis.
Organisational unit	Collection of employees grouped by business roles to perform certain tasks for the organisation.
Consumer	Actor wanting to increase its utility function by purchasing a service.
Producer	Actor wanting to maximise profit by offering a service.
Intermediary	Actor mediating between consumers and producers in order to maximise profit or increasing utility.
Business role	Set of rights and duties needed for the fulfilment of a task.
Business goal	Targeted outcome with the accomplishment of a business process.
Business process	Set of partially ordered and coordinated tasks to fulfil a specific business goal.
Task	Logically structured assignment to be performed by a business role.
Activity	Atomic elements of a task.
Information	Processed data needed for the fulfilment of an activity.
Infrastructure	Set of carbon (i.e. employee) and silicon (i.e. hardware and software) resources to support the processing of activities.
Service	Resulting output or needed input for the conduct of a business process.

Table 2-2: Basic constructs of the Core Business Metamodel

The CBM provides a comprehensive set of constructs to describe business models in a more enterprise-centric way and focusing on internal business processes. However, there is no standardised single graphic approach for CBM visualisation. Furthermore, as compared to e.g. the e3-value model, CBM is a rather complex approach and neglects the emphasis on value creation (Mettler, 2014).

2.1.4 Business model ontology

One of the most well-known business model methodologies in practice is the Business Model Ontology (BMO) developed by Osterwalder and Pigneur (2002). The BMO focuses on a single organisation, customer needs and the field where the enterprise is doing business. The methodology consists of nine major constructs, which are value proposition, value configuration, target customer, distribution channel, relationship mechanism, capability, partnership, cost structure, and revenue stream. These nine elements can be summarised into four pillars: product, customer interface, infrastructure management, and financial aspects.

The first construct of the ontology is the *value proposition*, which presents a general presentation of an enterprise’s products and services package that is of value for a specific customer. It can be divided into several value offerings and is based on an organisation’s capabilities. The *value configuration* describes the general set of activities and resources necessary for the value creation. An often used tool to illustrate a company’s value configuration is the value chain. An organisation wants to offer this value to its *target customer*, which is defined as the consumer and market segment for the value exchange. Often organisations differentiate several types of target customer segments, such as business-to-business (B2B) and business-to-customer (B2C). Further, the *distribution channel* connects the enterprise and target customer. A corporation can get in touch with its customers through many different channels, which can either be direct, such as a company website, or indirect through e.g. a broker or retailer. All activities directed towards establishing a relation between the targeted customer and the organisation are labelled *relationship mechanisms*, which can be used to e.g. retain existing customers or acquire new clients. A *capability* is the competence of performing several patterns of activities and tasks for the value creation. Capabilities are based on numerous resources of an organisation including its network. Hence, the value creation can also be reached through a *partnership*, which is an unsolicited cooperation with other organisations. Examples for partnerships with other independent companies are e.g. joint ventures or strategic alliances. Finally, the BMO covers two financial aspects. On one hand, the *cost structure* represents all the resources needed to fully operate the business model and is expressed and measured in monetary terms. On the other hand, *revenue streams* are defined as a group of actions necessary for cash flow generation, and explain how a company makes money. Different pricing methods play a very important role in this context (Osterwalder & Pigneur, 2002). Table 2-3: depicts an overview of the different major BMO constructs.

Construct	Definition
Value proposition	Overall view of an organisation’s bundle of value objects for a particular actor.
Value configuration	Arrangement of activities and resources that are necessary to create value for the targeted customer.
(Target) Customer	Intended consumer and market segment an organisation wants to pursue its value exchange.
Distribution channel	Link between the organisation and the target customer through which value is exchanged.
Relationship mechanism	Collection of activities needed to link the organisation between itself and the targeted customer.
Capability	Ability to perform a repeatable set of activities or tasks that are necessary to create value for the targeted customer.
Partnership	Voluntarily initiated cooperative agreement between the organisation and a producer or intermediary in order to create value for the targeted customer.

Cost structure	Representation in terms of cash of all the means employed to run and maintain the business model.
Revenue stream	Collection of activities needed for generating cash flows for the organisation.

Table 2-3: Basic constructs of the Business Model Ontology Source: Mettler (2014); Osterwalder & Pigneur (2002).

The BMO and related tools have been popular in practice due to its ease of application, practical orientation, and balance between value orientation and enterprise focus. Nevertheless, the rather broad nature of the concept and lack of more detailed value creation instruments and common language elements for specification can lead to superficially delineated business models. Further, there is no generic way of graphical representation (Mettler, 2014).

2.1.5 Business model innovation through change models

The different typologies of business models mostly focus on a specific point in time. However, organisations constantly need to adapt and change their business models, e.g. due to changes in the environment such as entrance of new competitors or introduction of innovative technologies. Company responses to these changes can e.g. be vertical integration, selling of excess capacity, introduction of a new customer segmentation, going public, bundle products and services, just to name a few. Linder and Catrell (2000) introduce change models to describe the main logic of changing business models to be profitable over the long-term in a constantly changing environment. They derived four different change models types from their research: realisation models, renewal models, extension models, and journey models. Portfolio management such as acquisitions or divestments of companies is not considered as a business model change, unless it is operationally integrated.

First, *realisation models* represent the least fundamental change and organisations often apply these to improve returns from their existing business model. No substantial changes are made to the present operations. The most common realisation model is geographic expansion. Other options are brand maintenance through investments in advertising, product line extensions with new and improved offerings, market penetration to increase the share of profits from existing customers, creation of a one-stop shop, establishment of additional sales or service channels, or consolidations to generate cost savings, efficiencies, and economies of scale.

Further, using *renewal models* means constant revitalisation of an organisation's product and services offerings, brand image, markets, store formats, cost structure, or technologies to respond to competitive pressure. To achieve this, a company leverages its core competencies and capabilities to generate new value propositions and generate new relationships and customers. The renewal model is very common among innovative companies.

Moreover, *extension models* are one step further towards a significant change of business model. Companies applying this model look for totally new opportunities and extend their business models to add new markets, value chain functions, or products and services lines to their existing operational structure. A common strategy for extension models is forward or backward integration. Also, extension often includes horizontal integration, such as adding new types of products and services. Other organisations try to create organic growth by turning an internal core competence into a new service or product offering.

Finally, the *journey models* present the highest degree of change of the business model core logic. An organisation fully changes its operational model. Such changes can e.g. be from a focused, local company to a globalised big player with presence all around the world. Another journey model would be moving from high quality, price and value orientation towards low-cost and price-sensitive offerings. The other way around is possible too, moving up the value curve from competing on price to a more brand and relationship oriented organisation.

2.2 Risk modelling

Many definitions have been suggested for risk, but, in a nutshell, risk is defined as a possible loss in the future or otherwise unwanted consequences as a result of actions taken now (Samantra & Sahu, 2013). Uncertainty plays a crucial part in risk and a certain outcome, no matter how undesirable, is not considered a risk. However, uncertainty alone does not define risk and there should be a possibility of loss or damage linked with the uncertainty to be considered risk (Kaplan & Garrick, 1981). Management of risk is an important part of any business as the success or failure of it may depend on such measures.

When analysing risk, it is not enough to understand the risk factors and their likelihood. It is also important to assess the impact of the risk on the business. However, to estimate the impact it is necessary to understand 'how' and in 'what way' the risk affects the business. Particularly in production networks, the path taken by the risk throughout the network should be considered.

Risk modelling in production networks requires an understanding of the risk factors that can influence each node, the interdependency between these risk factors and how the impact of these factors will be propagated throughout the production network. In this section, the literature of two main topics of risk modelling in supply chains and production networks, namely risk propagation and risk interdependency, are briefly examined.

2.2.1 Risk Propagation

Risk propagation in supply chains has been dealt with by a few types of methods. Most prominently, simulation models are used to observe and analyse the result of risk and its propagation through the network. Also, network theory is used in finding the bottlenecks of the supply network. Optimisation is another tool that has been used for determining optimal supplier selection and also dynamic planning.

Finally, qualitative analysis is necessary to understand the nature of the risk propagation in production networks.

Simulation models are valuable tools to understand the behaviour of supply networks and they are used to model propagation of risk in supply networks. For example, Bueno-Solano & Cedillo-Campos (2014) analyse the propagation of disruptions in supply chains produced by terrorist acts using System Dynamics. Also, Hua, Sun, & Xu (2011) examine the case of bankruptcy propagation in a two stage supply chain network with multiple manufacturers and multiple retailers. Additionally, Sun, Xu, & Hua (2012) apply agent-based simulation to bankruptcy propagation problems. Effects of a few contractual incentives, such as revenue sharing, price discount and quantity flexibility on bankruptcy propagation mitigation in multi manufacturer-multi retailer supply chains are examined. Furthermore, Wei, Dong, & Sun (2010) apply Inoperability Input-Output Modelling (IIM) to propagations of risk in supply chains. The IIM model considers the propagation effects of inoperability throughout the network and calculates the overall risk of inoperability for each node. Increasing the number of suppliers is suggested as a mitigation method and the IIM model and the mitigation method are both validated using a Monte Carlo simulation model. We will explore inoperability models in more details in the following sections.

Mizgier, Jüttner, & Wagner (2013) investigate bottleneck identification problem in supply networks. Two methods are used. The first one is using network theory (part of graph theory) and a few measures such as centrality degree, betweenness degree and radiality of nodes are used. The second approach is a proposed Monte Carlo based simulation method that determines the loss distribution of nodes in the network and ranks them based on the percentage of loss contribution. In the second approach, systematic risks (to all nodes of the supply chain) as well as the propagation of risk between nodes are considered. The methods are compared, enumerating the advantages of the proposed simulation based method. Also, Taquechel (2010) applied network theory and fault trees to optimise the budget spending for minimising the risk in the US maritime supply chain network. Logic gates (either 'AND' or 'OR' gates) are the fundamental elements of the fault trees which represent the way the risk propagates in the chain. An openly available piece of software by the US 'Center for Homeland Defence and Security' called Model Based Risk Assessment (MBRA) is used for this analysis.

Gaonkar & Viswanadham (2007) investigate the propagation of events due to supplier non-performance and propose two supplier selection models, one based on the Markowitz model for strategic level deviation management and the other is based on credit risk minimisation model which is introduced for disruptions management.

Bayesian Belief Networks (BBN) are probabilistic models based on directed acyclic graphs where nodes are random variables with conditional dependencies that are represented with probabilities. Two interesting research approaches, KS Shin, Shin, & Kwon (2010) and KwangSup Shin, Shin, Kwon, & Kang (2012b) use BBNs to analyse supply chain risks and both their interdependency and propagation throughout a supply network to determine a dynamic path finding method. Nodes of the supply chain have their own BNN of interrelated risk indicators and these networks can influence each other which correspond to the propagation of risk. An optimal alternative path finding method is proposed based on Dijkstra algorithm. In a similar study, KwangSup Shin, Shin, Kwon, & Kang (2012a) consider dynamic back order replenishment plans for multi echelon supply networks with stock-out and inventory costs. A heuristic method based on Reverse Dijkstra algorithm is proposed.

Huang, Behara, & Hu (2008) qualitatively compare risk propagation in Information Supply Chains from both network and supply chain perspectives. It has been concluded that a coordination policy is needed for managing activities related to information security throughout the chain. Also, Ghadge et al. (2011) provide a conceptual framework for risk propagation. A classification of risk based on their propagation properties (such as propagation dimensions, zones and duration) is introduced and validated on a case study of the Japanese 2011 tsunami.

2.2.2 Risk Inter-dependencies

Within the literature concerning risk management in the supply chain (SC), a variety of techniques have been applied for interdependency modelling. Some of these methods are Interpretive Structural Modelling (ISM), Analytical Network Process (ANP), Simulation Methods (such as Systems Dynamics) and Graph Theory based models. We will have a brief look at some of the research that applied each one, particularly in supply chain risk management.

ISM is a method to extract the structure of certain milestones, events or other types of elements. This is typically done using information of pairwise relationships which can be gathered from the experts. In risk management, ISM can be applied to create a structure for risk sources and organise them into a directed graph. Pfohl et al. (2011) have used this method to understand the interdependencies of SC risk on different levels, such as logistics providers, suppliers and the company. Using these methods, risks are classified based on their relationship with other risk factors (influential vs influenced). Relationships of the type of 'affects' are considered in this work. Also, Alawamleh & Popplewell (2011) examine the application of ISM for risk sources in a virtual organisation. This work is interested in the causal relationship within the risk factors and whether or not one can lead to the other.

AHP is a decision making method which uses a hierarchy of criteria and sub-criteria to compare between alternatives. Often, a pairwise comparison method is used to determine the weights of the sub criteria for determining the value of the main criterion in each level. However, as the AHP relies on a hierarchically structured graph, it cannot include the horizontal inter-dependencies of elements within the same level. ANP can solve this problem.

ANP is an extension to AHP where the criteria can have arbitrary relationship (as opposed to hierarchical relationship) with each other. Hence, this method is useful in modelling interdependencies within risk factors. Alawamleh & Popplewell (2012) use ANP for analysing risk sources within virtual organisations. The relationship between risk sources in the ANP model is based on the influence they have on one another. For the thirteen risk sources, thirteen pairwise comparison matrices which compare each source to the other ones as well as the objective. These pairwise comparison matrices are integrated into the ANP supermatrix to determine the final priority weights. Using ANP, Nezamoddini, Kianfar, Tash, & Supply (2011) tackle the problem of integrated strategic decision making. To do this, all important variables of supply chain and business strategy are identified in categories of assets, market, capabilities and risks; and the network of these criteria is analysed to determine the priorities of business strategy (e.g. cost leadership, lead-time reduction and product innovation) and supply chain strategy (e.g. lean, agile, leagile). Additionally, Ergu, Kou, Shi, & Shi (2014) propose a maximum eigenvalue threshold for the consistency index of ANP pairwise comparison matrices in risk assessment. Furthermore, Dağdeviren, Yüksel, & Kurt (2008) apply Fuzzy ANP for identification of faulty behaviour risk. Sub factors are categorised into three main factors including organisational factors, personal factors and job related factors and the inner dependence of these main factors are analysed. To calculate the inner dependence weights, questions such as "what is the relative importance of personal factors when compared with job related factors on controlling organisational factors?" are asked. Also, Lu, Lin, & Ko (2007) apply ANP to assessing construction risk and the inter dependence and influence between clusters of risk sources is considered. Moreover, Moeinzadeh & Hajfathaliha (2009) propose a combined fuzzy decisions making method based on fuzzy ANP and fuzzy VIKOR for supply chain risk management. A list of twenty nine risk factors are identified and classified into plan and control, process, supply and demand risks and interdependences between risk clusters in terms of their effects on each other are analysed. ANP has also been applied to assessment of storm tide risk (Zhang, Zhang, Fu, & Liu, 2009).

Similar to ANP, Graph theory provides a network structure to design the inter relationships between risk factors. Using graph theory, Wagner & Neshat (2010) quantitatively assess the vulnerability of supply chains. The data collected through questionnaire is used to filter and categorise the vulnerability drivers using principal component analysis and also to find the strength of interdependency between the major vulnerability drivers using correlation analysis. Finally, vulnerability index of various industries is compared.

One noteworthy qualitative study, Cheng & Kam (2008) propose a conceptual framework for risk assessment in supply chains. Different network configurations are qualitatively compared applying agency theory, considering several risk factors and their temporal inter-dependencies.

Monte-Carlo simulation has been used for risk assessment in real state development (Gimpelevich, 2011). Interdependence of input variables such as general inflation, market vacancy, market rent and rent escalation is considered and the range of outcomes are stochastically analysed.

2.3 Performance measurement of business models

A fast changing economy in addition to high pressure amongst competitors drives enterprises to continuously adapt their business models to overcome competitors. Business models nowadays must be flexible to cope with external or internal changes and therefore should be managed and controlled in a dynamic manner. Hence, enterprises must be aware of the interconnections between the strategic level and the operational level of business processes so as to be able to adjust their current business models relative to external or internal influencing factors. However, for enterprises it is not enough to solely adapt their business models. Enterprises must also be able to measure the quality of their adapted business model as they continuously need feedback about the quality of their current business models. Therefore, transformation mechanisms from business model into business processes have to be evaluated. A state-of-the-practice approach carried out, that business model analysis should not only be conducted top-down but also bottom-up, beginning from business process level, while focussing on analysing the interrelations between business models and the layer of business processes. To measure this interrelation, relevant KPIs for each value chain activity are needed, serving to measure parameters of the underlying business model. This contains a continuous feedback loop, which is essential for business model adaptation. Hence, business models gain flexibility, which is needed for the adaptation to influencing factors (e.g., market developments or changing prices) (Di Valentin et al. 2012).

2.3.1 Balanced Scorecard

Originally, the balanced scorecard (BSC) is a strategy performance management tool supported by design methods and automation tools that can be used by managers to keep track of the execution of activities by the staff within their control and to monitor the consequences arising from these actions. The characteristics of a balanced scorecard and its derivatives is the presentation of a mixture of financial and non-financial measures each compared to a 'target' value within a single concise report. The report is not meant to be a replacement for traditional financial or operational reports but a succinct summary that captures the information most relevant to those reading it. It is the method by which this 'most relevant' information is determined (i.e., the design processes used to select the content) that most differentiates the various versions of the tool in circulation. The balanced scorecard indirectly also provides a useful insight into an organisation's strategy - by requiring general strategic statements (e.g. mission, vision) to be precipitated into more specific / tangible forms (Shulver, Michael J; Antarkar, N.: (2001)).

In terms of the above-mentioned state-of-the-practice approach, a majority of the interviewees shared the opinion that measuring KPIs according to the underlying value chain and business model can be an indicator for successfully adapting a company’s business model. Additionally there was a consensus amongst interviewees that research on business model adaptations based on KPIs is a highly relevant topic in future research (Di Valentin et al. 2012).

2.3.2 Key Performance Indicators

For evaluating and measuring adaptations within a company’s business model, first underlying business processes and value chains have to be specified because they serve as a basis for the collection of key measures. In general, a value chain “disaggregates a firm into its strategically relevant activities in order to understand the behaviour of costs and the existing and potential sources of differentiation” (Porter 1985) whereas a business process represents a chain of logically related activities which have to be carried out in a certain order (Oesterle & Winter 2003). A state-of-the-practice approach recommends several elements for modelling a value chain with the aim of adaption analysing, which are Research, Development, Maintenance, Production, Marketing, Replacement, Implementation, Education, Support and Operations (Pussep et al. 2011). Based on the literature review and the framework for adaptive business models, illustrated in Figure 2-1 below, it is shown how relevant key measures can be derived as feedback parameters to measure the quality of business models. For this purpose, it is helpful to focus on a specific industry branch for being able to describe in detail existing interconnections of the business model in its mediating role between strategy and business processes.

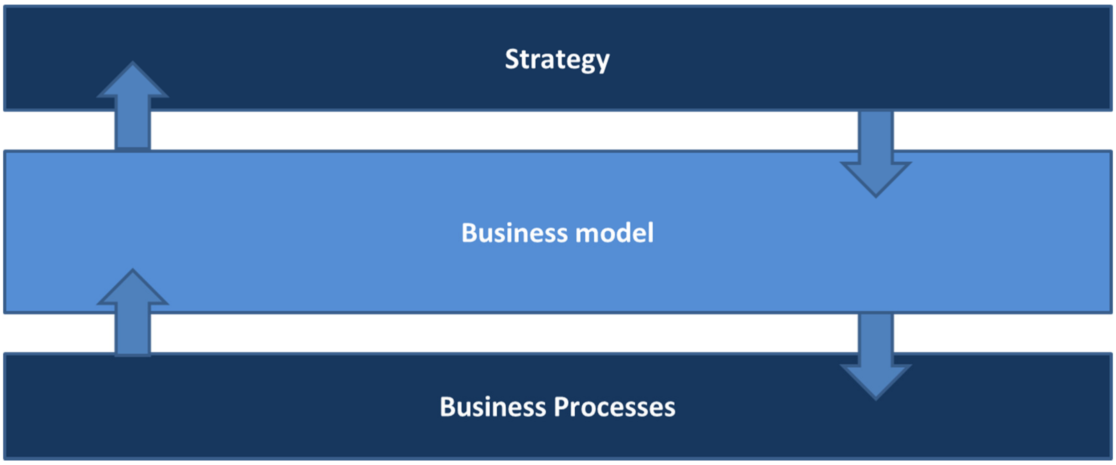

Figure 2-1: Framework for Adaptive Business Models (Di Valentin et al. 2012)

The interconnections between business models and business processes are characterised by a continuous alignment and permanent optimisation of both layers. As changes within the business model influence a company's business processes the determination of business processes should begin with the constitution of a company's strategic goals and its business model for gaining a comprehensive understanding about the issues to be modelled (Di Valentin et al. 2012).

3 Conceptual model for business model innovation in global production networks

3.1 Rationale behind the model

The conceptual model for business model innovation deals with business modelling in global production networks. That means that business models extend beyond the boundaries of a single enterprise. FLEXINET deals not only with one firm's internal manufacturing flexibility but also with supply chain flexibility. As proposed by Vickery et al. flexibility in global production networks is analysed from an integrative, customer-oriented perspective (Vickery, Calantone, & Dröge, 1999). Duclos et al. describe six supply chain flexibility components (Duclos, Vokurka, & Lummus, 2003):

- **Operations system flexibility** is the ability to configure assets and operations to react to emerging customer trends, like product changes, differing demand, product-service mix, at each node of the supply chain
- **Market flexibility** is the ability to mass customise and build close relationships with customers which includes designing and modifying new and existing products
- **Logistics flexibility** is the ability to cost effectively receive and deliver products as sources of supply and customers change resulting mainly from customer location changes and globalisation.
- **Supply flexibility** is the ability to reconfigure the supply chain, particularly to alter the supply of product in line with customer demand.
- **Organisational flexibility** is the ability to align labour force skills to the needs of the supply chain to meet customer service/demand requirements.
- **Information systems flexibility** is the ability to align information systems architectures and systems with the changing information needs of organisations as it responds to changing customer demand.

Thus, from a business model perspective all these components provide us with potential tuning parameters for defining new innovative business models through reconfiguration. Therefore, the conceptual model is based on the ideas behind these flexibility components to be able to push beyond a single enterprise's boundaries. By not focusing only on flexibility from an internal perspective, the conceptual model for business model innovation enables to gain much of the contribution from a bird's eye view on the global production network.

Secondly, the idea of the "sensing enterprise" becomes the focus of the scientific and practitioner's community. The sensing enterprise enables a continuous awareness and improvement of business operations. External factors influencing the business model of organisation can be more quickly recognised. This almost real-time knowledge about the environment results in a larger overlap between the strategic and operative enterprise layers. Therefore, the conceptual model for business model innovation incorporates the idea of the sensing enterprise by explicitly taking external data sources into account. The adaption of big data will speed up the setup of new business models as e.g. new business trends can be recognised much faster, and help avoid keeping hold of business models that are no longer viable.

3.2 Design requirements

The conceptual model needs to satisfy certain formal design requirements. Those were formulated according to the Guidelines for Orderly Modeling (GOM) (J Becker, Rosemann, & Schütte, 1995). Correctness, relevance, economic viability, clarity, comparability and systematical design were selected as the most important criteria that the conceptual model for business model innovation has to meet. Additionally, the conceptual model is the result of design-oriented research which has the objective to design artefacts that are able to solve practical problems. Thus, it is important to evaluate the model against the practical problem that motivated its design. Particularly, it requires abstracting and representing reality, to foster communication and to improve the understanding of the problem domain. Moreover, a hard requirement is that the model has to enable simulation of business models in manufacturing industry. This is very important due to the fact that the configuration of global production networks as well as corresponding business models for simulation (e.g. for "what-if"-analyses) is at the core of FLEXINET.

3.3 Meta-model

3.3.1 Conceptual model

The conceptual model is based on four different layers. At the top there are model components that aggregate concepts. Concepts can be composed by further concepts. Additionally, some concepts have certain dimensions that by themselves consist of distinct characteristics. Between concepts relationships do exist, meaning that they have e.g. mutual dependencies or one concept influences another one. Additionally, there are different perspectives on the model. Thereby, a perspective consists of different concepts. Figure 3-1: provides an overview on the meta-model on which the conceptual model for business model innovation is based on.

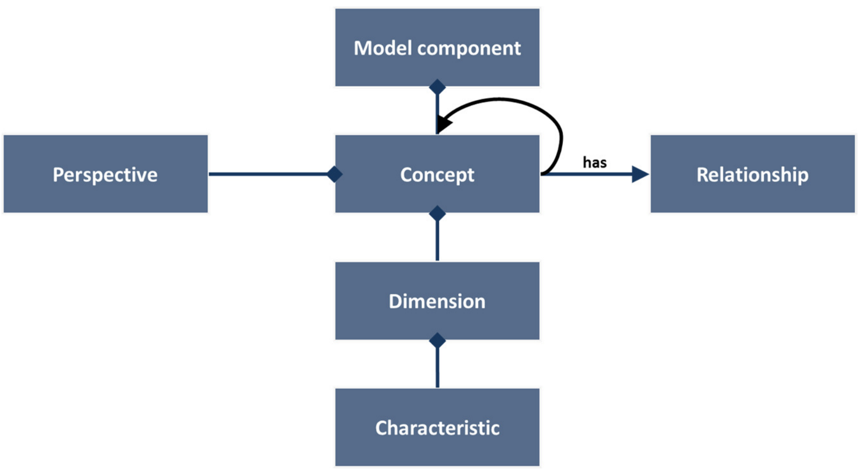

Figure 3-1: Meta-model of the conceptual model for business model innovation

3.3.2 Concept definition

Each concept is documented using a standard template. The underlying meta-model of the template is a first result from task 2.2. The meta-model uses the OMG standard called Semantics of Business Vocabulary and Rules (SBVR) (OMG, 2008). In this context a definition is understood as "a representation of a concept by a descriptive statement which serves to differentiate it from related concepts" (ISO, 2000). Thus, the guideline for writing definitions is to follow the following "formula":

Definiendum = Genus + Differentia

The definiendum is the term or concept that should be defined. The genus is the category or class which the definiendum is a part of and, finally, the differentia is the characteristic or group of characteristics that set the definiendum apart from other members of the genus. Figure 3-2: shows the standard template.

Standard Template for Business Vocabulary entries	
Natural language definition	
Formalized definition	
Synonyms	
Example	

Figure 3-2: Business Vocabulary Template

3.4 Overview on the conceptual model

3.4.1 Model components

The model consists mainly of six components:

- **Environment**: The environment component deals with the external factors that influence single manufacturing companies as well as global production network as a whole.
- **Domain concepts:** The domain concepts component comprises concepts about actors like supplier and customers as well as the relationships between the actors in a global production network.
- **Risk concepts:** The risk concepts component contains all concepts that are needed for strategic risk analyses.
- **Value creation concepts:** Value creation concepts are those concepts that represent the value creation in enterprises. This includes processes and also the resources needed.
- **Value concepts:** The value concepts component comprises value concepts. These are e.g. real physical goods or services as well as all necessary concepts to model the value exchange between actors.
- **Financial concepts**: The financial concepts represent the revenue and cost structures as well as pricing models.

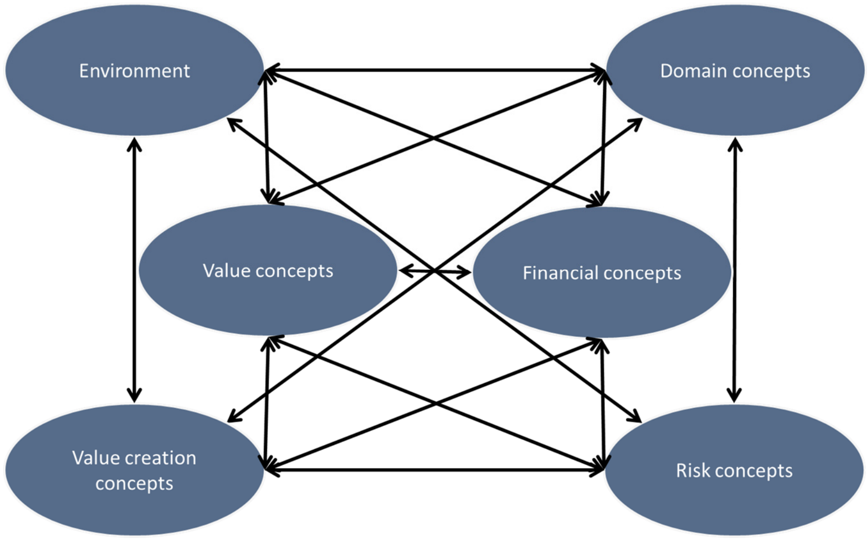

Figure 3-3: Interrelated components of the model

All these components are interrelated to each other through concept relationships (see Figure 3-3). The distinction between different components was done to reduce the complexity.

3.4.2 Environment

Today many decisions are taken based on estimates and assumptions, e.g. by incorporating average sales and only small snippets of the real world are controlled and well-known. Inexact and outdated data provides only a blurred view on the real environment. However, today's technology enables companies to incorporate many data sources in their decision making. Companies that establish sensing capabilities to close the gap between the real world and their used models can take decisions more confidently. Not all data can be "sensed" from the environment, but even the use of current data that was not used before increases the reliability of calculated models. Besides the more accurate modelling and valuation of new innovative business models, the incorporation of external factors helps to identify risks earlier. Identifying much earlier that an environmental disaster happened at a certain location enables companies to take appropriate actions quicker (re-configuration of the GPN, e.g. finding a substitute supplier).

Thus, the conceptual model for business model innovation incorporates external factors that are relevant for manufacturing companies explicitly. In particular, external factors were identified from the FLEXINET use case partners and, additionally, web resources and literature were investigated. One important input for the model are the factors that are usually considered in PEST analyses. PEST is the abbreviation of "Political, Economic, Social and Technological analysis". In addition legal and environmental factors are often added to this analysis which leads to the term PESTLE analysis. PESTLE analysis describes a framework of macro-environmental factors that provides companies with an overview of different external factors that are of importance in strategic analyses or market research (“an inTroducTion To PESTLE anaLySiS,” n.d.). Another analysis framework is STEER analysis (Socio-Cultural, Technological, Economic, Ecological) which emphasises the importance of ecological factors. In order to reduce the complexity of the overall model ecological factors are not seen separately but as part of other factor categories. This is the same with demographic and regulatory factors that are sometimes mentioned explicitly.

So, in total, six categories of external factors are distinguished in the environment component of the conceptual model for business model innovation:

- **Political factors** identify to what degree a government intervenes in the economy. Also, political factors determine health, education and infrastructure of a nation to a certain extent. Typical political factors are the tax policy, labour and environmental law as well as trade restrictions, tariffs and political stability. Moreover, political factors may include restrictions about goods (e.g. alcohol in some countries) and services (e.g. prostitution, sexual content, free internet) that a government does not want to be provided (demerit goods or merit bads) (DineshBakshi, n.d.).
- **Social factors** determine the cultural dimension which includes aspects like health consciousness, population growth rate, age distribution (demographics), career attitudes and safety. They are influencing a company’s products and services, and, particularly how a company operates. For example, demographics may influence the labour market so that e.g. an ageing population could increase the cost of labour (DineshBakshi, n.d.).
- **Environmental factors** are concerned with the general environment like weather, climate and climate change (DineshBakshi, n.d.).
- **Economic factors** have a major impact on a company’s business operations and decision-making. Examples for economic factors are the economic growth, interest rates, exchange rates and inflation rates. Particularly, exchange rates are an important factor in global production networks as they heavily affect the costs of exporting goods as well as the supply and price of imported goods (DineshBakshi, n.d.).
- **Technological factors** are related to R&D activities, automation, technology incentives. A major factor is the rate of technological change. These factors influence for example outsourcing decisions. Furthermore, they affect costs and quality (DineshBakshi, n.d.).
- **Legal factor** are concerned with the legal environment of an actor in a market. Discrimination law, consumer law, antitrust law, employment law, health and safety law are exemplary influencers. Since the last decades regulatory requirements are increasing which influences business operations, costs and the demand for products (DineshBakshi, n.d.).

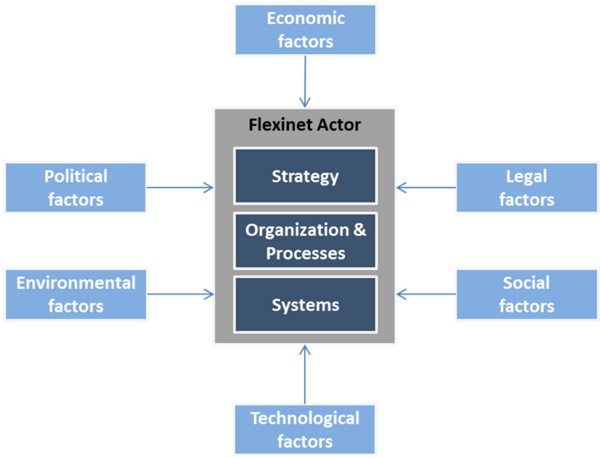

Figure 3-4: External factors influencing actors in global production networks

Figure 3-4: presents an overview of the factors that influence actors in global production networks. As FLEXINET takes on an holistic view on global production networks not only a single manufacturing company is influenced but all actors (e.g. suppliers and customers) that are part of the network.

The total list of external factors of each category is presented in chapter 4. The conceptual model for business model innovation provides further meta concepts for each external factor. In detail, an external factor has a unique name and a description. Moreover, a certain value (qualitative and/or quantitative measure) is provided by each factor that can be used for risk assessment or economic valuation purposes. Conceptually, an external factor influences certain business model components. In which way and to what extent it influences other concepts, is described by business rules. The definition of business rules is part of task 2.2 of the FLEXINET project. In deliverable 2.2 the business rules management architecture and business rules will be specified. Figure 3-5 shows an example for a relationship between external factors and the market attractiveness which is a domain concept. Often, external factors are related to a certain geographic location (e.g. GDP or weather related factors).

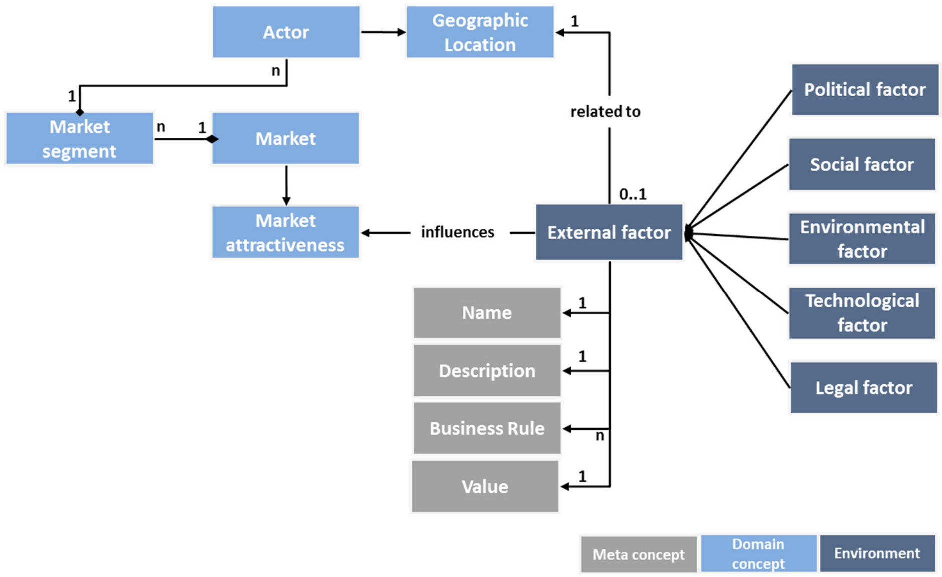

Figure 3-5: Excerpt of the influence of external factors on further model concepts

3.4.3 Domain

This component aims at the domain related business model concepts and, thus, is concerned with the actors and markets and focuses on the communication and transfer of the value object provided to the customer. In the corpus of literature, the customer party, its dimensions and characteristic as well as the various ways of communicating and distributing the value object are ambiguously described.

Bieger et al. define in their business model frameworks the domain value communication and transfer (Bieger, Zu Knyphausen-Aufseß, Krys, & Knyphausen-Aufseß, 2011). On the other hand Osterwalder & Pigneur do only provide a more abstract concept called channels. Over these channels the value object is distributed (Alexander Osterwalder & Pigneur, 2010). Johnson et al. distinguish the distribution channel, the type of distribution and necessary partnerships to distribute the value object (Johnson, Christensen, & Kagermann, 2008). Customers and suppliers are concrete instantiations of an actor. In particular, the customer is the party for which the manufactured good or service (value object) should provide value. Thereby, a customer has a certain type (e.g. consumer or client) which is important in order to know who the target of the value object is. Further dimensions of a customer are the customer segment and customer relationship (A Osterwalder, 2004). Bieger et al. and Johnson et al. subsume these dimensions under the value proposition concept (Bieger et al., 2011; Johnson et al., 2008).

The most relevant concepts and dimensions in this component are described below:

- **Market:** Economic environment where actors interact with each other in order to making profit or increasing utility. The market typically consists of distinct market segments.
- **Market segment:** Set of actors sharing from an economic perspective one or more of their value interfaces and value objects (see value concept component). It is a dimension of the market concept.

- **Actor:** Independent economic entity with the ability to making profit (e.g. company) or increasing utility (e.g. end-consumer) (Gordijn, 2002b) but also a single unit of a company (e.g. plant or organisational unit).
- **Actor type:** The actor type is a dimension of the actor concept that characterises a certain actor. Possible characteristics are for example: organisation, organisational unit, consumer, producer, supplier, intermediary or customer.
- **Distribution channel:** The distribution channel is the way the organisation communicates with its customer (see Table 3-1). For example, the distribution can be executed via the following channels: sales force, web sales, own stores, partner stores or wholesalers. It is derived from the relationship concept.

Distribution channels
Sales force
Web sales
Own store
Partner stores
Wholesalers

Table 3-1: Distribution channels

- **Distribution type:** The type of distribution describes the way the customer is addressed. The business can communicate with its customer directly or indirectly via another business (see Table 3-2). It can also provide its value object on its own to the customer or via a partner who is another actor of the global production network. It is a dimension of the distribution channel.

Distribution types
Direct
Indirect
Own
Partner

Table 3-2: Distribution types

- **Customer segment:** A group of clients categorised into sets of similar individuals that are related from a marketing or demographic perspective. Examples for segmentation categories are: gender, buying tendencies, age group, or special interests.
- **Customer relationship:** The relationship of an organisation to the customer describes how an organisation interacts with its customer and how the customer is served (see Table 3-3).

Relationship

Personal assistance
Self-service
Automated service
Community/network
Co-creation
One-time-delivery

Table 3-3: Customer relationships

- **Global production network:** The actual GPN that consists of several actors with different relationships.
- **Actor network organisation:** The actor network organisation defines how (parts) of the GPN is set up and how participating actors arrange themselves. When multiple actors work together for creating value there are different types of structures which can be chosen. It is a dimension of the relationship concept and has e.g. one of the following characteristics: strategic alliance, coopetition – that means competitors are working together in order to gain value - joint venture or buyer-supplier relationship.
- **Geographic Location:** The actual locations between which value objects are transferred

3.4.4 Risk concepts

Risk management in production networks requires consideration of many external influence factors that can adversely affect the operation of the network and also the dependencies that exist within the various elements of risk analysis. Some of the most important concepts in risk management in GPNs are as follows:

- **Risk Factor:** An internal or external factor that may influence a GPN adversely. It represents a cause for disruptions or failures within a GPN. Identification, analysis and control of risk factors constitute the building blocks of risk management.
- **Disruptive Event:** An unwanted event that is the result of a risk factor. They can be internal inherent in a GPN operations (such as reliability of equipment, quality issues), or inherent in the supplier or customer part of the GPN (for example, availability of raw material, suppliers' reliability, changeable demands, problem with order processing, payments), or external risks inherent in environments in which the GPN operates (for example, various regulations, severe weather conditions or accidents).
- **Propagation:** The indirect effect of a disruptive event as a result of the dependencies within a GPN's nodes that spread the disruption from the source node(s) to the rest of the GPN. These dependencies could be due to the supply, demand or other types of relationships among the GPN nodes.

- **Risk Interdependency:** Risk factors can influence each other in terms of their likelihood and impact they have on a GPN. Risk interdependency is a measure of these influences between risk factors.
- **Inoperability:** The reduced percentage of operability of a GPN node as a result of the original disruption and propagation of that original disruption, compared with the expected level of operability. A value of 0% represents the normal operation of a node while a value of 100% express the total and complete suspension of activities in a node.
- **Perturbation:** The direct effect of disruption on a GPN node. The perturbation value, which is also expressed as a percentage, represents a part of inoperability that is directly influencing the node as a result of a disruptive event. To calculate the inoperability, the perturbation and the propagation effect should be considered simultaneously.
- **Resilience:** Resilience is the ability of a GPN node to react to the disruptive event and its agility to compensate for inoperability that has arisen.
- **Mitigation:** An effort to reduce the impact and likelihood of risk. An important part of risk management is to identify, understand and analyse the risk factors in order to prioritise the likely mitigation plans that can be exercised. Having proper mitigation plans in place for the likely risk factors should improve the resilience of a GPN.
- **Economic Loss of Risk:** The expected loss of future income in a GPN due to disruptive events. This represents the reduction in a total economic value of all nodes' operation in comparison with its expected value. It is a function of the nodes' inoperability. This value provides a quantification of the cost of risk that can be compared with other cost elements in order to choose the best possible configuration of a GPN among alternatives.

3.4.5 Value creation concepts

The value creation component defines how the business and the resources for creating value are set up and how they interact. In particular it comprises the value creating processes with its tasks and activities which have to be performed to establish the value object as well as the needed resources. In the literature there is a consensus about the concepts for value creation, although they are differently named. In general, processes and resources need to be combined. Osterwalder & Pigneur differentiate between key partnerships, key activities and key resources (Alexander Osterwalder & Pigneur, 2010). Johnson et al. use two dimensions key processes and key resources (Johnson et al., 2008). Key Processes contain the processes, rules and metrics and norms to produce the value object. The key resources contain people, technology, equipment as well as necessary partnerships and alliances to establish the value object. A more value network related view is provided by Bieger et al. (Bieger et al., 2011). They introduce the concept domain value creation which defines how resources and capabilities are combined within a value creation network to create the value object.

For the conceptual model for business model innovation the following concepts are of relevance. They explicitly consider the dependency to other work packages in FLEXINET. Particularly, the dependency to work package 4 is incorporated through the introduction of the main concepts (e.g. activity, function, action) that are used for the operational level of FLEXINET.

- **Domain value creation:** The domain value creation concept defines how resources and capabilities are combined within a value creation network to create the value object.
- **Macro process:** Macro processes are concerned with high level behaviours while micro-processes deal with the more detailed internal work. A macro process consists of several business processes or at least a particular business process configuration.
- **Business process:** Set of partially ordered and coordinated tasks to fulfil a specific business goal.
- **Information:** Processed data needed for the fulfilment of an activity.
- **Resource:** Resources represent all means, including organisational units and IT systems which are necessary to carry out any activity in an enterprise (Mertins & Jaekel, 2006) (see Table 3-4). In detail they are a set of carbon (i.e. employee) and silicon (i.e. hardware and software) resources to support the processing of activities (Mettler, 2014).

Resource
People
Technology
Products
Facilities
Equipment
Channels
Brand
Hardware
Software

Table 3-4: Resources

- **Business role:** Set of rights and duties needed for the fulfilment of a task (Mettler, 2014).
- **Task:** Logically structured assignment to be performed by a business role (Mettler, 2014).
- **Action:** An action is a generic element for a process, task, process step or procedure (Mertins & Jaekel, 2006).
- **Function:** Describes the processing of objects via an action as a transformation from one determined (beginning) state to another determined (ending) state (Mertins & Jaekel, 2006).
- **Activity:** Specifies the order(s), which controls the execution of the function and the resource(s) which are in charge of executing the function (Mertins & Jaekel, 2006). They are atomic elements of a task (Mettler, 2014).

3.4.6 Value concepts

The value concepts component describes the product or service a business deals with to create value. Therefore, the value object itself has to be described as well as its form. In addition, the component deals with the concepts that are assigned to a value object to enable value exchange between actors. In the literature the value object is called synonymously value offering or offering (Johnson et al., 2008). Most of the concepts of this component are borrowed from e3-Value which has tool-support for simulation (Gordijn, 2002b). Services are understood as single or composed value objects. Their nature is mostly intangible and they are receiving increasing interest over the past few decades. Lev describes the reason for the importance of intangibles as follows (Lev, 2001):

> *"The intensified competition in practically all business sectors brought about by the globalisation of trade, far-reaching deregulation, and technological changes (like the Internet) forces business enterprises to radically change their operating models. Most of these changes revolve around deverticalisation and innovation. Intangibles are the fundamental drivers of both: deverticalisation is achieved by a substitution of intangibles for physical assets, and innovation is achieved primarily by investment in intangibles. Hence the recent growth of and focus on intangible assets."*

- **Value Object:** A generic value object can be a product/good which simply represents the principal results of the entire enterprise process (Mertins & Jaekel, 2006) or a certain service object that can be offered in combination with a product or another service or standalone (see Table 3-5).

Value Object
Hardware / Physical good
Software
Service
Network

Table 3-5: Value object offerings

- **Service Object:** A service object represents a service that is provided to a customer. It is a specialisation of the value object concept. A service object can be decomposed into smaller service objects if the smaller elements can be offered separately (Baidav, 2006).
- **Object type:** The object type details the kind of object with which an organisation creates value (see Table 3-6). This can be physical, financial, intangible or manpower.

Object Type
Physical
Financial
Intangible
Manpower

Table 3-6: Value object types

- **Value bundle:** Value bundles consist of different services as well as physical goods/products which are offered in combination to customers who perceive this combination as valuable (Jörg Becker, Beverungen, & Knackstedt, 2009; Hamilton & Koukova, 2008). In other words they comprise marketable services and physical goods and can be offered as individual value propositions for customers. The benefits from value bundles as perceived by customers can be tangible as well as intangible. By integrating services and goods, value bundles can create outcomes for customers superior to the aggregated outcomes of their single components (Jörg Becker et al., 2009).
- **Value proposition:** The value proposition defines the benefit a target customer is going to receive by buying or using the value object/value bundle offered (see Table 3-7). It describes which benefit is provided to the customer by a certain offering. An offering can be (a combination of) e.g. hardware, software, service or access to a network or community.

Value proposition
Newness
Usability
Getting job done
Performance
Cost reduction
Customisation
Price

Table 3-7: Generic value propositions

- **Target group**: An organisation aims at providing its value object to a certain segment of customers (see Table 3-8). A business normally provides value for another business (business-to-business) or to a customer (business-to-customer). Some businesses also aim at connecting customers and support the exchange between customers (customer-to-customer). The target group is a dimension of the value proposition and is related to the concepts market segment and customer segment, and, thus to a set of actors.

Target group
Business-to-business (B2B)
Business-to-consumer (B2C)
Consumer-to-consumer (C2C)

Table 3-8: Value object types

- **Value port:** Tracer indicating that an actor wants to offer or request a value object from its environment.
- **Value interface:** In its simplest form, a value interface consists of one offering. A complex value inter-face groups one ingoing and one outgoing value offering.
- **Value exchange:** Connection between two value ports.
- **Value transaction:** A value transaction groups value transfers (the exchange of exactly one value object between two actors), which as a consequence of the value ports and value interfaces should all happen, or none at all.
- **Value activity:** Collection of operational activities yielding a profit or utility increase assigned to a specific actor.

We base the idea of delivering value bundles, as combinations of products and services, to customers on the idea of a product-service system as described by Becker et al. (Jörg Becker et al., 2009). The idea is that there are mainly two scenarios for product-service systems. These scenarios will be explicitly examined based on the conceptual model for business model innovation in upcoming tasks of FLEXINET. One scenario is that only one company provides products and services as a value proposition for customers (Scenario A). The second scenario deals with a value network of FLEXINET actors that provide products and services (Scenario B). Customers as actors in the global production network are thereby co-creators of the value. Figure 3-6: depicts the two scenarios.

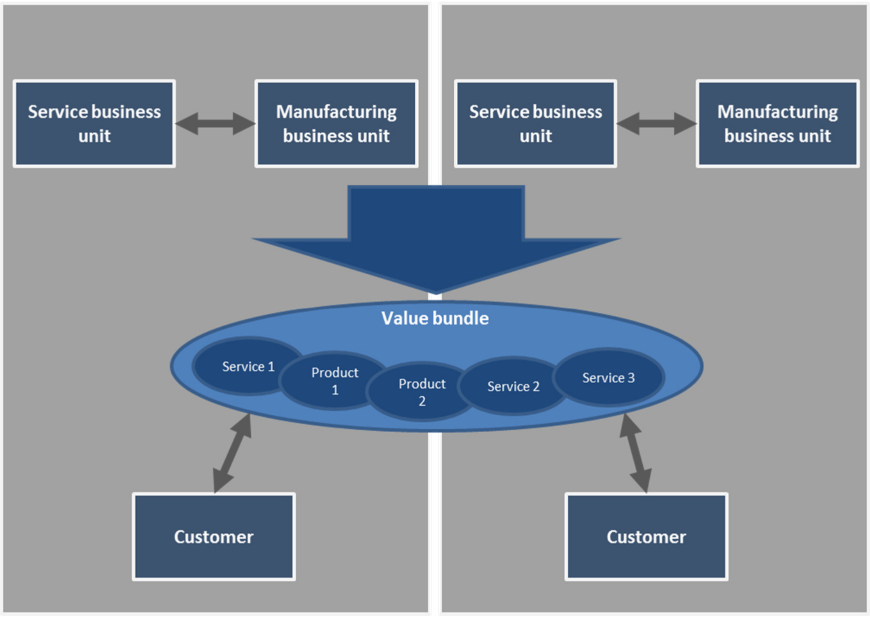

Figure 3-6: Product-service scenarios in FLEXINET

3.4.7 Financial concepts

This component depicts from an external perspective how an organisation gains money directly from the customer or indirectly from another stakeholder by pricing the value object. From an internal perspective it defines how costs are allocated within the organisation or between business partners. Johnson et al. (2008) call this dimension the profit formula and include revenue model, cost structure, margin model and resource velocity. In this context, resource velocity means the timing in which resources are needed to support the targeted production volume. Osterwalder & Pigneur (2010) differentiate the external and internal view in the dimensions revenue model and the cost structure.

- **Revenue model:** The revenue model defines what the customer is paying for and therefore how the product is priced and revenue generated (see Table 3-9). The revenue can be created by selling or renting the value object. This is normally used for physical objects or hardware offerings. It is also possible to sell licenses for using the value object or charge a usage fee. With the former, the fee depends on how often the value object is used. With the latter a subscription fee is paid once or in regular intervals. These are often used for software, service or network offerings. Another way to generate revenue is to charge brokerage fees for establishing a transaction or exchange or to charge for advertisings which are shown to the customer when consuming the value object.

Revenue model
Asset sales
Renting
Licensing
Usage fee
Subscription fee
Brokerage fee
Advertising

Table 3-9: Revenue models

- **Pricing model:** The pricing model states how the price for the value object with which the organisation earns money is determined (see Table 3-10). The price can be fixed for a given object or dynamic, i.e. it is set according to the amount a customer buys or depending on the usage of the product or service.

Pricing model
Fixed
Dynamic
Direct
Indirect

Table 3-10: Pricing models

- **Costing model:** The costing model describes how the expenses are accounted for internally (see Table 3-11). Standard costing models are for example activity based costing, full costing, direct or indirect costing. In general the accounting can be cost or value driven. Cost driven models aim at the minimisation of costs and therefore intend a value proposition providing a low price. Whereas value driven approaches are merely used when premium value objects, like luxurious goods, or intangible assets are traded.

Costing model
Cost-driven
Value-driven

Table 3-11: Value object types

3.4.8 Further concepts

- **Business rules**: The relationships between concepts and the outcomes and consequences are modelled by business rules
- **Key performance indicators**: KPIs measure the performance of business model configurations. In total xx categories are distinguished that are described in section xx in more detail.

3.5 Model perspectives

Duclos et al. (2003) point out that a prerequisite for flexibility in global production networks is the flexibility between all partners in the value network. Affected actors are for example departments within an organisation, external partners like suppliers, third-party companies or even information systems providers (Duclos et al., 2003). Activities in the value network that need this flexibility are the delivery of a product from raw material through to the customer, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, delivery to the customer and the information systems that allow monitoring these activities (Duclos et al., 2003). Therefore, to consider this cross-business transparency and traceability beyond a single enterprise's boundaries three different perspectives on the model were created:

- Global production network perspective
- Enterprise perspective
- Performance perspective

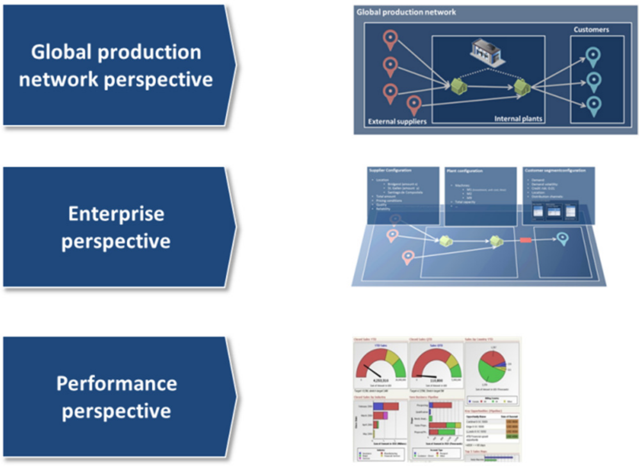

Figure 3-7: Three different mode perspectives

While the global production network perspective models the complete value network from the suppliers through manufacturers and service providers to customers, the enterprise perspective is concerned with the configuration parameters of a single actor in the network. Of course, the configuration of a single actor influences linked actors from a network perspective. One example is the adjustment of customer demand which necessarily influences the needed amount of raw materials in a manufacturing plant. Thus, the enterprise perspective and the global production network perspective have mutual dependencies. The performance perspective is a layer on top of the other perspectives. The performance perspective consists of a set of KPIs that are dependent on the configuration and a set of high level concepts that have an influence on individual actors and/or the whole network. The KPIs measure potential business model success, the feasibility of business models or the risk related to a configuration. High level concepts are for example the expected market volume for a certain product or service. Adjusting this volume affects the economic valuation of a business model and possibly influences risk analysis results.

In addition, each of these perspectives comprises several sub-perspectives. For example, the global production network perspective has a strategic risk perspective to identify critical nodes or edges in the network.

3.5.1 Global production network perspective

The global production network perspective comprises all concepts that are needed to model the value network. Generally, a value network is a web of relationships that generates value (Allee & Kong, 2003). The network actors can be individuals, groups or organisations. A simple value network would be for example a supplier who delivers raw materials to a plant of an enterprise (customer of the supplier) that manufactures a product and a customer who receives products directly from the enterprise. The flow of money would be the same vice versa. The value created in the value network can be both tangible (e.g. real product) and intangible (e.g. customer satisfaction).

The most important concepts in the global production network perspective are:

- Actors: instances of an actor are for example supplier or customer.
- Value objects: instances of a value object are for example goods, services or money.
- Geographic locations: these are the actual locations between which a value object is transferred.
- Value transaction: the process of exchanging goods between different actors at possibly different locations.

Actors can be understood as nodes in a network having the property geographic location. The edges between different actors represent the value transaction which has value objects as properties. A simple GPN configuration using these concepts is shown in Figure 3-8:

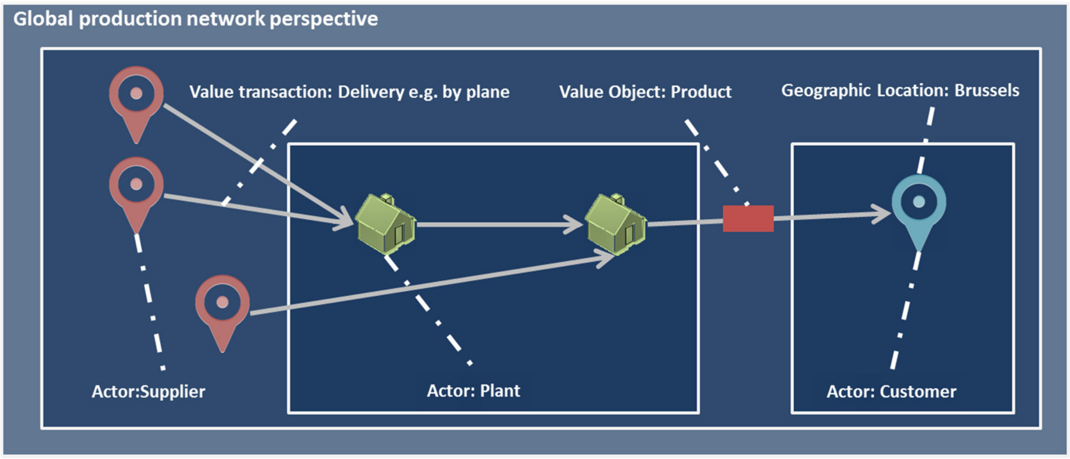

Figure 3-8: Example of a simple network

In other words, the GPN perspective provides an overview on the value network. It is a business analysis perspective that describes value flows within and between businesses. The nodes represent actors that are connected by interactions that represent tangible and intangible value objects or combinations of them in form of value bundles. Additionally, a certain value proposition is provided through the edges. Actors have both internal and external value networks.

Within this perspective the logistics flexibility and the supply flexibility are represented. For simulation purposes the supply chain may be altered by adding a new supplier with lower prices and decreasing the amount of ordered raw materials due to anticipated changes in the customer demand. In the model this means that a new supplier node would be added, instantiated with a new price structure and the amount of value objects between all suppliers and the plant as well as the amount of value objects between the plant and the customer would be adjusted. Beforehand, a new edge (value transaction) between the new supplier and the plant would be added and the characteristics of the value transaction (e.g. means of transportation) would be calibrated.

Overall, the perspective is:

a) the basis for strategic risk analyses with respect to risk propagation in the network.
b) the basis for the analysis of value flows.

c) the basis for the setup of a global production network from a strategic business model perspective.

3.5.2 Enterprise perspective

Within the enterprise perspective single actors that are part of the global production network are modelled in detail. Thereby, actors can be distinguished whether they are external like customers and suppliers or internal like internal plants. Thereby, configurations on the enterprise level have mutual dependencies to the GPN perspective. For example, if an enterprise configuration leads to a higher risk then it would have influence on the risk propagation on the GPN perspective.

Generally, all actors have the same concepts that can be configured as we assume the ultimate goal of transparency within the whole value network. However, while internal actors can be modelled in detail, the concrete values for external actors may not be available. Thus, assumptions can be used as well as results e.g. from market and customer segment analyses. Figure 3-9 provides a conceptual overview on the interrelationship between the enterprise and global production network perspective. For each actor configurations can be assigned.

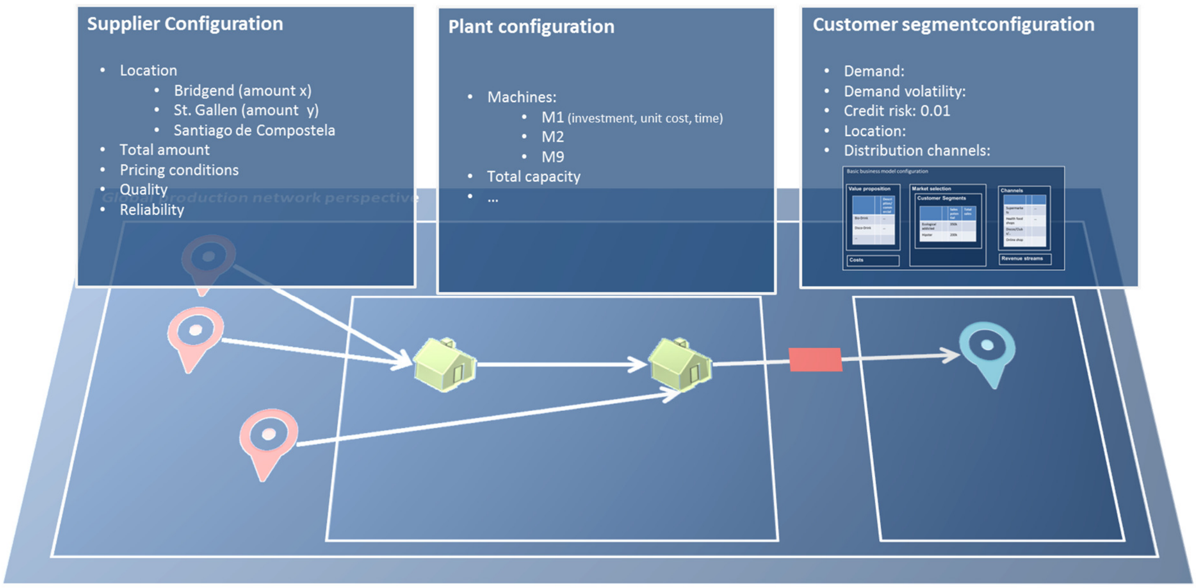

Figure 3-9: A conceptual overview on the interrelationship between the enterprise and GPN perspective

In addition, the enterprise perspective is highly interrelated with the operational perspective on a FLEXINET actor modelled in work package 4. For example, the selection of a certain distribution channel has consequences for the underlying processes of an enterprise. On the other hand, certain process configurations resulting from the operational perspective lead to costs (e.g. employees) and therefore determine the cost structure of the configured actor.

There are some predefined configuration options. However, the model is flexible enough to add more complexity if necessary. Generally, the configuration of a business model from a strategic perspective is the selection of options from the morphology shown in Figure 3-9. However, due to the network character some options refer to other actors. For instance, if a customer segment for a value bundle is chosen only those customer's demands of actors within this segment are used for the economic valuation. Within the GPN perspective certain customer segments could be defined as one actor and configured in their "own enterprise perspective" (e.g. regarding demand and demand volatility) or explicit customers may be configured. The selection of business model characteristics influences the enterprise perspective e.g. if a fixed pricing model is selected, no dynamic pricing options are available for configuration. Behind each option more detailed configurations are available e.g. when people and technology is selected employee costs could be determined as well as machine capacities and costs for the technology option.

Concept/Dimension	Characteristics						
Value object	Physical	Financial	Intangible	Manpower			
Value object type	Hardware	Software	Service	Network			
Value proposition	Newness	Usability	Getting the job done	Performance	Cost reduction	Customisation	Price
Target group	B2B	B2C	C2C				
Customer segment	Segment 1 (e.g. budget)	Segment 2	Segment 3	Segment 4 (e.g. premium)			
Customer relationship	Personal assistance	Self-service	Automated service	Community/Network	Co-creation		
Revenue model	Asset sale	Renting	Licensing	Usage fee	Subscription fee	Brokerage fee	Advertising
Pricing model	Fixed	Dynamic	Direct	Indirect			
Cost model	Cost-driven	Value-driven					
Resources	People	Technology	Products	Facilities	Equipment	Channels	Brand
Distribution channel	Sales force	Web sales	Own stores	Partner stores	Wholesalers		
Distribution type	Direct	Indirect	Own	Partner			

Table 3-12: Basic business model configuration options

3.5.3 Performance perspective

The performance perspective uses the balanced scorecard approach for providing a strategic view by representing relevant, aggregated information from different fields. A distinction has to be made between a global production network perspective and an enterprise perspective, as factors from one perspective may influence the other perspective's factors. Different categories of key performance indicators have to be included, as they are for exemplary service KPIs or quality KPIs. These metrics will appear in a dashboard, supporting the managing user at any level in an organisation, and provide a quick overview for optimised decision-making. The Dashboard focusses on high-level measures of performance and partly benefits from static snapshots of data, which means daily, weekly, monthly, that are not constantly varying, but mostly remain stable for a certain duration. Dashboards focusing on analytical metrics may typically support interactions with this data, e.g. drilling down into the underlying layer.

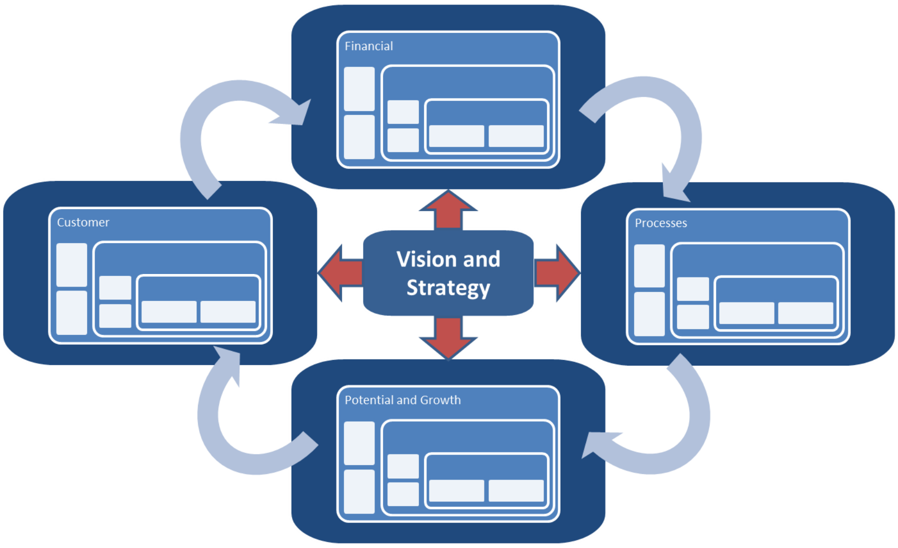

Figure 3-10: Balanced Scorecard Perspective

3.6 Model mechanisms

3.6.1 Transactions between network actors

The conceptual model needs mechanisms to allow arbitrary configurations (but constrained by business rules) and to analyse the influence of the adjustment of certain parameters on e.g. selected KPIs. An exemplar of this is if the price-structure of a raw material from a supplier changes other network nodes like manufacturing plants are affected. However, also the raw material itself needs to be "virtually" transferred between the network nodes for simulation. For doing this, the conceptual model reuses the idea behind e3-Value to enable interoperability between actors in the model. Through interoperation, e.g. exchange of goods between suppliers and customers, value is created collaboratively. Figure 3-11: depicts the concepts behind the value transactions between actors.

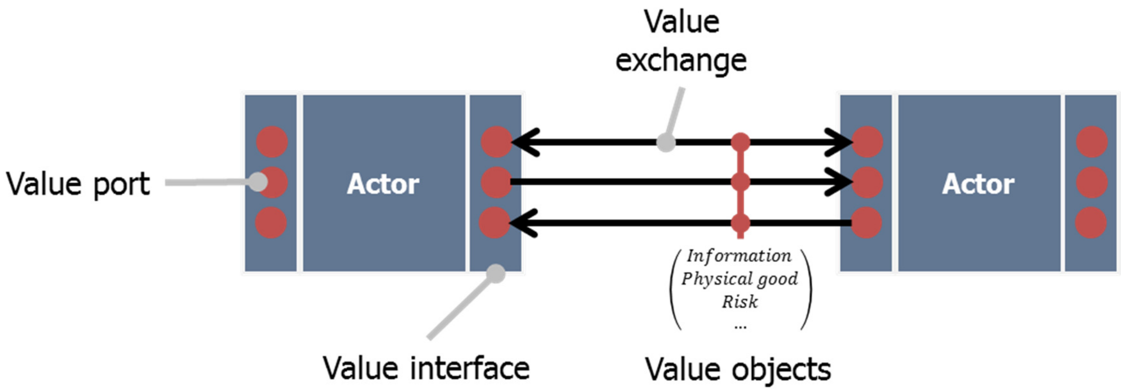

Figure 3-11: Value transactions between network actors

The mechanisms for value exchange used in the model are as follows: each actor has a value interface through which value objects are exchanged with other actors. Particularly, an input and output value interface per actor does exist. A value interface has several value ports. Through each port a different value object or a whole value bundle can be provided. Normally, there is a mutual value flow as the receiver exchanges for example money for the value objects received. Additionally, the ports are not constrained to value objects. Risk values or other information can be exchanged through the ports. The different values that are transferred between ports are represented in a vector which size equals to the amount of ports. The exchange of value objects leads generally to certain costs. This can be e.g. logistics costs or export/import tariffs. These costs are attributed to the value exchange concept. By doing this, these costs can be used for further calculations like the economic valuation of a business model configuration.

3.6.2 Business rules interface

The relationships between concepts and the outcomes and consequences are modelled by business rules. A business rules repository is specified in task 2.2 and will be documented in D2.2. Thus, business rules are the mechanism to operationalise the model. Business rules in general are statements about guidelines and restrictions on an enterprise's behaviour. The importance of their formulation and explicit and separate management has been recognised and there are different standardisation activities (P Jayaweera & Petit, n.d.). Particularly, there is an OMG standard called Semantics of Business Vocabulary and Rules (SBVR) that describes a meta model for the documentation of business rules.

One example for the application are pricing models which are a representation of how a company plans to set its prices (Daly, 2002). So, particularly business rules provide the knowledge about how a price is derived e.g. in the form of a mathematical formula.

Each concept and relationship of the model has an interface to the business rules repository where the (business) logic is defined. In concrete cases these are:

- Influence of external factors on other concepts. This includes risk relationships and resulting costs.

- Constraints on configurations. So, impossible configurations are avoided.
- Guidance of the value exchange between actors.
- Design of value bundles that adhere to business rules like legislative restrictions or strategic business decisions like the choice of preferred business partners.

Business rules on which the logic of the conceptual model is based can be distinguished as:

- Structural business rules (OMG, 2008).
- Operative business rules (OMG, 2008).
- Transformation business value rules (Prasad Jayaweera & Petit, n.d.).
- Interface business value rules (Prasad Jayaweera & Petit, n.d.).
- Exchange business value rules (Prasad Jayaweera & Petit, n.d.).
- Transaction business value rules (Prasad Jayaweera & Petit, n.d.).

While the definition of transformations business value rules and interface business value rules is mainly based on a single actor's perspective (enterprise processes related), exchange business value rules and transaction business value rules are defined from the perspectives of two actors (value exchange related) (Prasad Jayaweera & Petit, n.d.).

4 External business model influencers and risks in global production networks

4.1 Overview and Classification

The importance of the capability of enterprises to care about their environment and influencing external factors is best explained with an example. Hurricane Sandy hit the east coast of the United States in November 2012. The result was that retail supply chains collapsed, leading to stores running out of stock. This also had an influence on areas that were not directly affected by the hurricane. The storm hit the US retail sector at an unfavourable time as it was before Thanks Giving and Christmas which are holidays that are highly relevant for annual profitability in the retail market.

Shipping terminals were damaged as well as warehouses. Roads and railroads that interconnect ports and warehouses became impassable. As a result, even distant areas could not be adequately supplied. "Many economists expect the storm to shave up to half a percentage point from growth in the fourth quarter. That is a big reduction, with growth estimated to reach an annual rate of 1 to 2 percent before the storm". So, Sandy had an enormous impact on economy and showed that it is absolutely important to sense the environment.

However, the described situation is not manageable with the currently existing analysis solutions. What is missing is the view on the entire system that visualises shifting and outages at each stage and on each level in the value network. A natural, close to real-time reflection can be achieved by incorporating big data, thereby closing the gap between the real world and the virtual model.

According to the PESTLE-analyses, the external influence factors are classified into six categories:

- Political factors
- Economic factors
- Social factors
- Technological factors
- Legal factors
- Environmental factors

The following section provides an overview on relevant external factors, possible measures and data sources where data can be retrieved, e.g. through web-services.

4.2 Detailing external influence factors

Class	Factor	Measure
Political factors		4.2.1.1.1
	Economic policies	Income tax rates %
	Tax policy	Added value tax % Taxes on profits %

	Level of government interference with markets	High-medium-low
	Trade policies	Degree of regulation
	Trade restrictions	Yes/no
	Tariffs	High-medium-low
	Trade Unions	Yes/No
	Infrastructure	Good-average-bad
	Public transportation	Good-average-bad
	Highways	Good-average-bad
	Water and energy infrastructure	Good-average-bad
	Communication and postal services	Good-average-bad
	Education	Good-average-bad
	Public Health	Good-average-bad
	Political stability	High-medium-low
	Government funded research Funding, grants and initiatives	Investment: High-medium-low
	International organisations (membership)	Yes/no
	Legislation	Good-average-bad
	Current Legislation	Good-average-bad
	Future expected Legislation	Good-average-bad
	International Legislation	Good-average-bad
	Policy and values of political party in power	Right-centre-left
	Regulatory bodies and processes	Efficient-inefficient
	Government policies	Liberal-socialist
	Government term and change	Right-centre-left
	Lobbying/pressure groups:	Impact: High-medium-low
	Home market	Impact: High-medium-low
	International	Impact: High-medium-low
	Wars and conflicts	Yes/no
Social factors	Culture	High-medium-low
	Health consciousness	High-medium-low
	Demographics	Dependency ratio

	Social mobility	High-medium-low In %
	Career attitudes	Sparse - available
	Population growth rates	High-medium-low In %
	Living standard	GDP per Capita
	Quality of life	Life satisfaction index or Quality of life index
	Leisure facilities	Good-average-bad
	Security	High-medium-low or crime rate
	Values	Liberal-conservative
	Ethics	Target-country related
	Consumer buying patterns	Target-country related
	Religion	Yes/no or Christian / Islamic
	Consumption	In % GDP
	Consumer attitudes and opinions	Analogue / digital
	Buying access and trends	Urban-rural
	Lifestyle trends	Urban-rural
	Lifestyle	Urban-rural
	Fashion and role models	Target-country related
	Media views	Target-country related
	Law changes affecting social factors	% of Total Number
	Public relations	Level of Awareness
	Brand, company, technology image	Brand value
	Advertising and publicity	Level of Awareness
	Major events and influences	Target-country related
	Climate change	Affected-unaffected
Environmental factors	Weather	Good – average - bad
	Climate	Good – average - bad
	Environmental issues	Yes/no
	Energy consumption	High-medium-low
	Infrastructure	Good-average-bad
Economic factors	Economic growth	GDP growth %

	Interest rate	In %
	Inflation	In %
	Exchange rate	Overvalued-undervalued
	Labour market	Size
	Labour market size	Total workforce
	Unemployment rate	Unemployment rate in %
	Education level/ human capital	Human capital index
	Labour productivity	Labour productivity index
	Labour costs	Unit labour costs
	Purchasing power	Purchasing power index
	Financial sector	% of GDP
	Competition/ market concentration	High-medium-low
	Economy as a whole	Worldwide Ranking
	Home economy situation	GDP per capita
	Home economy trends	Predicted GDP-growth
	Business cycles	Boom/recession
	Overseas economies and trends	GDP growth of countries with important markets
	Taxation	Good-average-bad
	General taxation issues	Income tax rates % Added value tax % Taxes on profits %
	Taxation specific to product/services	High-medium-low
	Market and trade cycles	Increasing-Decreasing
	Specific industry factors	Target-country related
	Market routes and distribution trends	Target-country related
	Customer/end-user drivers	High-medium-low
	International trade	Balance of trade: Surplus-deficit
	Consumer confidence	Up-stable-down
Technological factors	R&D activities	High-medium-low
	Automation	High-medium-low
	Technology incentives	High-medium-low
	Rate of technological change	High-medium-low

	New products	High-medium-low
	New business processes	High-medium-low
	Competing technology development	Technological progress: High-medium-low
	Associated/dependent technologies	High-medium-low
	Replacement technology/solutions	High-medium-low
	Maturity of technology	Stage in product lifecycle
	Manufacturing maturity and capacity	Total production of relevant industry
	Information and communications	High-medium-low
	Global communications	High-medium-low
	Consumer buying mechanisms/technology	High-medium-low
	Technology legislation	Incentive for innovation: High-medium-low
	Innovation potential	High-medium-low
	Technology access	High-medium-low
	Licensing	High-medium-low
	Intellectual property issues	Yes/no
Legal factors	Consumer law	Business friendly: Yes-no
	Environmental law	Restrictive-not restrictive
	Competition law, cartel law	Enforcement: High-medium-low
	Labour law	Protective- not protective
	Health law	Target-country related
	Security law	Target-country related
	Corporate law	Business friendly: Yes-no
	Distribution laws	Business friendly: Yes-no
	IP law	Incentive for innovation: Yes-no

Table 4-1: Detailing the external influencing factors

4.3 Risk classification and factors

Risk factors are classified based on the zone of their influence in GPNs. The classes are

1) Supply; the risks affect the GPNs from the suppliers' side,

2) Production Process; these risks are inherited in the core production process in the GPNs,

3) Information and Control; these risks are related to problems with IT systems, management and control mechanisms in the GPNs,

4) Logistics; these risks are related to transportation, inventory and other logistics activities that connect the partners in the GPNs,

5) Demand; the risk is related to uncertainty in customer demand,

6) External; these are general geopolitical, environmental or economic issues which can affect a GPN, but are outside its control.

In this section, the risk factors identified throughout the interviews with the FLEXINET industrial partners are listed and classified. Additionally, possible mitigation plans for identified risks have been proposed. Interdependency between risk factors is a centre point of risk modelling in FLEXINET and some of these relationships are pinpointed accordingly.

4.3.1 Food Safety Issues

Relevant to Partners: CD

Referred to in the Literature: /

Class: Supply, Production Process, Logistics

Possible Mitigation: Comply with limitations for ingredients, use of reliable suppliers and logistics providers.

Interdependent Risk Factors: Environmental Pollution, Unreliable Supply, Legal Requirements' Infringement.

4.3.2 Risk of Global Sourcing

Relevant to Partners: KSB

Referred to in the Literature: (Moeinzadeh & Hajfathaliha, 2009)

Class: Supply, Logistics, Information and Control

Possible Mitigation: Local Sourcing, Limit Variety of Global Suppliers.

Interdependent Risk Factors: Legal Requirements' Infringement, Political Instability, Import or Export Controls, Price and Currency Risks/Inflation, Unreliable Supply, Dependency on Supplier(s), Delayed Deliveries, Legal Uncertainty.

4.3.3 Inadequate Product/Service Quality

Relevant to Partners: INDESIT

Referred to in the Literature: (Ghadge, Dani, & Kalawsky, 2011; Prinz & Bauernhansl, 2013)

Class: Supply, Logistics

Possible Mitigation: Avoid suppliers with unacceptable quality, use certified companies.

Interdependent Risk Factors: Unreliable Supply, Financial Instability of Suppliers, Unavailability of Ingredients/Materials.

4.3.4 Delayed Deliveries

Relevant to Partners: CD

Referred to in the Literature: (Pfohl, Gallus, & Thomas, 2011; Prinz & Bauernhansl, 2013)

Class: Supply, Logistics

Possible Mitigation: Use more reliable suppliers, increase inventory.

Interdependent Risk Factors: Unreliable Supply, Financial Instability of Suppliers, Risk of Global Sourcing, Unavailability of Ingredients/Materials.

4.3.5 Unreliable Supply

Relevant to Partners: KSB, CD

Referred to in the Literature: (Prinz & Bauernhansl, 2013)

Class: Supply

Possible Mitigation: Avoid dependence on one supplier, research the supplier.

Interdependent Risk Factors: Financial Instability of Suppliers, Dependency on suppliers, Risk of Global Sourcing, Unavailability of Ingredients/Materials, Import or Export Control, Delayed Deliveries, Food Safety Issues.

4.3.6 Dependency on Supplier(s)

Relevant to Partners: INDESIT

Referred to in the Literature: (Pfohl et al., 2011; Prinz & Bauernhansl, 2013; Wagner & Neshat, 2010)

Class: Supply

Possible Mitigation: Increase the number of suppliers, research the supplier.

Interdependent Risk Factors: Unreliable Supply, Supplier Solvency, Risk of Global Sourcing.

4.3.7 Financial Instability of Suppliers

Relevant to Partners: INDESIT, CD

Referred to in the Literature: Illiquidity and insolvency of suppliers, and bankruptcy (Moeinzadeh & Hajfathaliha, 2009)

Class: Supply

Possible Mitigation: Avoid at risk suppliers, Insurance, Consider alternative suppliers.

Interdependent Risk Factors: Dependency on Supplier(s), Unreliable Supply, Inadequate Product/Service Quality, Delayed Deliveries.

4.3.8 Unavailability of Ingredients/Materials

Relevant to Partners: CD, KSB

Referred to in the Literature:

Class: Supply

Possible Mitigation: Discover new suppliers, use alternative materials/ingredients.

Interdependent Risk Factors: Unreliable Supply, Inadequate Product/Service Quality, Delayed Deliveries.

4.3.9 Technological Challenge

Relevant to Partners: KSB, CD

Referred to in the Literature: /

Class: Production Process, Information and Control

Possible Mitigation: Use of familiar methods / technologies.

Interdependent Risk Factors: Significant Changes to Business Model, Major Technological Change.

4.3.10 Machine Modification Issues

Relevant to Partners: CD

Referred to in the Literature: /

Class: Production Process

Possible Mitigation: Use of already established production process.

Interdependent Risk Factors: Technological Challenge, Major Technological Change.

4.3.11 Significant Changes to Business Model

Relevant to Partners: KSB

Referred to in the Literature: /

Class: Information and Control

Possible Mitigation: Reject proposed changes.

Interdependent Risk Factors: Technological Challenge, Major Technological Change

4.3.12 High Cost of Ownership

Relevant to Partners: KSB

Referred to in the Literature: /

Class: Demand

Possible Mitigation: Design and produce for cost effective maintenance and longevity.

Interdependent Risk Factors: Readiness to Adapt Technology

4.3.13 Readiness to Adapt Technology

Relevant to Partners: KSB

Referred to in the Literature: /

Class: Demand

Possible Mitigation: Use of less advanced technologies.

Interdependent Risk Factors: High Cost of Ownership, Uncertainty in New Markets

4.3.14 Uncertainty in New Markets

Relevant to Partners: KSB

Referred to in the Literature: /

Class: Demand

Possible Mitigation: Research the new market, limited trial offering or avoid the new market altogether.

Interdependent Risk Factors: Unanticipated level of Demand, Changes in Market Trends, Price and Currency Risks/Inflation, Insolvency of Clients, Legal Uncertainty.

4.3.15 Unanticipated Level of Demand

Relevant to Partners: KSB

Referred to in the Literature: (Moeinzadeh & Hajfathaliha, 2009; Prinz & Bauernhansl, 2013)

Class: Demand

Possible Mitigation: Improve Demand Forecasting.

Interdependent Risk Factors: Uncertainty in New Markets, Changes in Market Trends.

4.3.16 Insolvency of Clients

Relevant to Partners: CD

Referred to in the Literature: (Prinz & Bauernhansl, 2013)

Class: Demand

Possible Mitigation: Avoid at risk clients, Insurance, Consider alternative clients.

Interdependent Risk Factors: Uncertainty in New Markets, Price and Currency Risks/Inflation

Possible Data Source: 3rd party business evaluation services

4.3.17 Changes in Market Trends

Relevant to Partners: CD

Referred to in the Literature: (Moeinzadeh & Hajfathaliha, 2009)

Class: Demand

Possible Mitigation: Observe the market trends and adapt.

Interdependent Risk Factors: Uncertainty in New Markets, Unanticipated level of Demand.

4.3.18 Import or Export Controls

Relevant to Partners: KSB

Referred to in the Literature: (Moeinzadeh & Hajfathaliha, 2009)

Class: External

Possible Mitigation: Local sourcing/production.

Interdependent Risk Factors: Future Regulation, Risk of Global Sourcing, Legal Requirements' Infringement, Unreliable Supply, Legal Uncertainty.

4.3.19 Legal Requirements' Infringement

Relevant to Partners: KSB (regulations, regulatory requirements), CD

Referred to in the Literature: /

Class: External

Possible Mitigation: Comply with legal requirements.

Interdependent Risk Factors: Future Regulation, Political Instability, Import or Export Controls, Food Safety Issues, Risk of Global Sourcing, Legal Uncertainty.

4.3.20 Future Regulation

Relevant to Partners: KSB

Referred to in the Literature: (Prinz & Bauernhansl, 2013)

Class: External

Possible Mitigation: Predict the changes and avoid what is likely to become illegal

Interdependent Risk Factors: Legal Requirements' Infringement, Political Instability, Import or Export Controls, Legal Uncertainty.

4.3.21 Major Technological Change

Relevant to Partners: CD

Referred to in the Literature: (Moeinzadeh & Hajfathaliha, 2009)

Class: External

Possible Mitigation: Research new technologies and prepare.

Interdependent Risk Factors: Significant Changes to Business Model, Machine Modification Issues, Technological Challenge.

4.3.22 Political Instability

Relevant to Partners: KSB

Referred to in the Literature: (Moeinzadeh & Hajfathaliha, 2009; Prinz & Bauernhansl, 2013)

Class: External

Possible Mitigation: Avoid at risk regions, prepare contingency plans.

Interdependent Risk Factors: Future Regulation, Environmental Pollutions, Price and Currency Risks/Inflation.

Note: Includes strike, taxes, war, terrorist attacks, embargo, political labour conflicts, industrial disputes

4.3.23 Price and Currency Risks/Inflation

Relevant to Partners: KSB, CD (critical markets)

Referred to in the Literature: (Moeinzadeh & Hajfathaliha, 2009; Prinz & Bauernhansl, 2013)

Class: External

Possible Mitigation: Use reliable currencies, avoid economically unstable regions.

Interdependent Risk Factors: Risk of Global Sourcing, Political Instability, Uncertainty in New Markets, Insolvency of Clients.

4.3.24 Environmental Pollutions

Relevant to Partners: KSB, INDESIT

Referred to in the Literature: (Ghadge et al., 2011; Prinz & Bauernhansl, 2013)

Class: External

Possible Mitigation: Relocate.

Interdependent Risk Factors: Food Safety Issues, Political Instability.

4.3.25 Legal Uncertainty

Relevant to Partners: KSB

Referred to in the Literature: /

Class: External

Possible Mitigation: Use better legal advice, avoid uncertain jurisdictions.

Interdependent Risk Factors: Legal Requirements' Infringement, Future Regulation, Risk of Global Sourcing, Uncertainty in New Markets, Import and Export Controls.

4.3.26 Other Candidate Risk Factors

Other risk factors, relevant to the GPNs, which have been discussed in the literature, are listed in Table 4-2.

#	Factor	Supply	Production Process	Information and Control	Logistics	Demand	External
1	Inadequate collaboration agreement (Alawamleh & Popplewell, 2011; Prinz & Bauernhansl, 2013)	X	X	X	X	-	-
2	Unqualified staff (Pfohl et al., 2011; Prinz & Bauernhansl, 2013)	X	X	-	X	-	-
3	A lack of sufficient equipment, staff or transport/warehouse capacity (Pfohl et al., 2011)	X	X	-	X	-	-

#	Factor	Supply	Production Process	Information and Control	Logistics	Demand	External
4	Primarily capacity variances/bottlenecks on the supply market (Pfohl et al., 2011)	X	-	-	-	-	-
5	Monopoly situations (single sourcing) (Moeinzadeh & Hajfathaliha, 2009)	X	-	-	-	-	-
6	New strategic alignment of suppliers (Moeinzadeh & Hajfathaliha, 2009)	X	-	-	-	-	-
7	Increase in cost of products (Ghadge et al., 2011; Prinz & Bauernhansl, 2013)	X	-	-	-	-	-
8	Lack of flexibility to adopt changes/innovations (Prinz & Bauernhansl, 2013)	X	-	-	-	-	-
9	Long term production down times (Pfohl et al., 2011; Prinz & Bauernhansl, 2013)	-	X	-	-	-	-
10	Short term production down times (Pfohl et al., 2011; Prinz & Bauernhansl, 2013)	-	X	-	-	-	-
11	Lack of top management commitment (Alawamleh & Popplewell, 2011)	-	X	-	-	-	-
12	Capacity bottleneck (Moeinzadeh & Hajfathaliha, 2009)	-	X	-	-	-	-
13	Machine damage (Moeinzadeh & Hajfathaliha, 2009)	-	X	-	-	-	-
14	Human error (Moeinzadeh & Hajfathaliha, 2009)	-	X	-	-	-	-

#	Factor	Supply	Production Process	Information and Control	Logistics	Demand	External
15	Faulty planning (Moeinzadeh & Hajfathaliha, 2009)	-	X	-	-	-	-
16	Inefficient production (Ghadge et al., 2011)	-	X	-	-	-	-
17	Longer lead times (Ghadge et al., 2011)	-	X	-	-	-	-
18	Production quality (Prinz & Bauernhansl, 2013)	-	X	-	-	-	-
19	Ramp-up (Prinz & Bauernhansl, 2013)	-	X	-	-	-	-
20	Planning and communication flaws in sales department (Moeinzadeh & Hajfathaliha, 2009)	-	-	X	-	X	-
21	Heterogeneity of partners (IT systems) (Alawamleh & Popplewell, 2011)	-	-	X	-	-	-
22	Ontology differences (Alawamleh & Popplewell, 2011)	-	-	X	-	-	-
23	Loss of communication (Alawamleh & Popplewell, 2011)	-	-	X	-	-	-
24	Culture differences (Alawamleh & Popplewell, 2011; Prinz & Bauernhansl, 2013)	-	-	X	-	-	-
25	Lack of information sharing (Alawamleh & Popplewell, 2011)	-	-	X	-	-	-
26	Lack of knowledge about risks (Alawamleh & Popplewell, 2011; Prinz & Bauernhansl, 2013)	-	X	X	-	-	-
27	Wrong partner/s selection (Alawamleh & Popplewell, 2011)	-	-	X	-	-	-

#	Factor	Supply	Production Process	Information and Control	Logistics	Demand	External
28	IT systems (breakdown, introduction or change of IT systems, virus damage, change of interfaces, data loss) (Moeinzadeh & Hajfathaliha, 2009; Prinz & Bauernhansl, 2013)	-	-	X	-	-	-
29	Information security (Ghadge et al., 2011; Prinz & Bauernhansl, 2013)	-	-	X	-	-	-
30	Hauling claim (Pfohl et al., 2011)	-	-	-	X	-	-
31	Poor performance of (logistics) subcontractors (Pfohl et al., 2011)	-	-	-	X	-	-
32	Damage to cargo (Moeinzadeh & Hajfathaliha, 2009)	-	-	-	X	-	-
33	Trouble with third-party logistics provider (Moeinzadeh & Hajfathaliha, 2009)	-	-	-	X	-	-
34	Lean inventory (Wagner & Neshat, 2010)	-	-	-	X	-	-
35	Supply chain complexity (Wagner & Neshat, 2010)	-	-	-	X	-	-
36	Centralized storage of finished products (Wagner & Neshat, 2010)	-	-	-	X	-	-
37	Cancellations (of demand)(Moeinzadeh & Hajfathaliha, 2009)	-	-	-	-	X	-
38	Inflexibility (of customer) (Moeinzadeh & Hajfathaliha, 2009)	-	-	-	-	X	-
39	Short products life cycles (Wagner & Neshat, 2010)	-	-	-	-	X	-
40	Market constraints (Ghadge et al., 2011)	-	-	-	-	X	-

#	Factor	Supply	Production Process	Information and Control	Logistics	Demand	External
41	Loss of customer (Prinz & Bauernhansl, 2013)	-	-	-	-	X	-
42	Quality at customer's site (Prinz & Bauernhansl, 2013)	-	-	-	-	X	-
43	Market strategies of competitors (Prinz & Bauernhansl, 2013)	-	-	-	-	X	-
44	Reverse Logistics Risks (Prinz & Bauernhansl, 2013)	-	-	-	-	X	-
45	Customers dependency (Wagner & Neshat, 2010)	-	-	-	-	X	-
46	Terrorist attacks (Pfohl et al., 2011; Prinz & Bauernhansl, 2013)	-	-	-	-	-	X
47	Natural disasters (fire, earthquake, flood, rock fall, risk landslide, avalanche, etc.) (Moeinzadeh & Hajfathaliha, 2009; Prinz & Bauernhansl, 2013)	-	-	-	-	-	X
48	Weather (iciness, storm, heat) (Moeinzadeh & Hajfathaliha, 2009)	-	-	-	-	-	X
49	Social and cultural grievances (Moeinzadeh & Hajfathaliha, 2009)	-	-	-	-	-	X
50	Crime (Theft, Vandalism, etc.) (Moeinzadeh & Hajfathaliha, 2009)	-	-	-	-	-	X
51	Power shortage (Ghadge et al., 2011)	-	-	-	-	-	X
52	Infrastructure breakdown (Ghadge et al., 2011)	-	-	-	-	-	X
53	Stock market volatility (Ghadge et al., 2011)	-	-	-	-	-	X
54	Skills shortage (Ghadge et al., 2011)	-	-	-	-	-	X
55	New technology delays (Ghadge et al., 2011)	-	-	-	-	-	X
56	Slowing economy (Ghadge et al., 2011)	-	-	-	-	-	X
57	Administrative barriers (Prinz & Bauernhansl, 2013)	-	-	-	-	-	X
58	Diseases and epidemics (Prinz & Bauernhansl, 2013)	-	-	-	-	-	X

#	Factor	Supply	Production Process	Information and Control	Logistics	Demand	External
59	Fraud (Corruption) (Prinz & Bauernhansl, 2013)	-	-	-	-	-	X
60	Storage risk (Prinz & Bauernhansl, 2013)	-	-	-	-	-	X
61	Product liability (Prinz & Bauernhansl, 2013)	-	-	-	-	-	X
62	Transfer of intellectual property (Prinz & Bauernhansl, 2013)	-	-	-	-	-	X

Table 4-2: Other Risk factors in Production Networks

4.4 Links between risks and external and internal factors

Risk factors are usually dependent on the related internal and external factors. Consequently, risk factors classified as 'external' depend on external factors while the other risk factors classified in 'supply', 'production', 'information and control, 'demand' and 'logistics' groups are dependent on both internal and external factors. For example, 'environmental pollution', which is an external risk factor, depends on external factors such as 'Weather', 'Environmental issues' and 'Energy consumption'. However, 'insolvency of clients', as a risk factor related to demand, is not only dependent on internal factors of the clients but also on external factors such as 'Inflation' and 'Interest rate'.

To determine the likelihood or impact of each risk factor, its relationship with the external factors can be utilised. Risk factors can be estimated, once the data sources to measure these external factors are established and the relationships between the risk factors and external factors are determined. Relevant data sources can be monitored to obtain the current measurement of relevant external factors and automatically calculate an estimate of the likelihood/impact of the risk factors. Obviously, other elements, such as internal factors or expert judgements need to be incorporated into the calculations as well.

4.5 Characterising FLEXINET partner's use cases

Each use case partner provided answers to a wide range of questions regarding external influencers. The interviews were performed as part of WP1. We selected the relevant answers for each partner and document them in this section, see Table 4-3, Table 4-4 and Table 4-5.

4.5.1 Relevant external factors and risks for KSB

What are the things that matter to your business when defining a global production network?	Main forces which are driving Global Production networks: Institutional change: liberalisation / Deregulation; The impact of information and Communication Technologies(IT); Competition and industrial organisation (the firm must be present in all major growth markets and must also integrate its activities on a worldwide scale), awareness, partners in target markets delivering the right quality to interesting costs
What factors affect the change of systems in your global supply network?	Regulation, international Standards (driven by: ISO, IEC, ITU) and other guidelines, IT technology, competition between organisations, growing markets, awareness, partners in target markets delivering the right quality to interesting costs, technology evolution, globalisation, location synchronisation, process synchronisation between locations, licenses, certifications, improvements in manufacturing knowhow
What factors influence <u>the company's cost model?</u>	Prices for: semi-finished products, Castings, standard parts, raw and auxiliary materials, energy sources (coal, gas, oil, electrical energy)
What factors influence <u>strategic risk</u> in your global supply network?	Change of regulations, dealing with rights and patents, dealing with piracy (products an innovations), reputation of products, attitudes, life and work habits, social systems, education and training systems, row material availability
What factors influence <u>operational configuration</u> in your global supply network?	Logistic, interoperability, the common architecture of the IT infrastructure with same software and versions allows data exchange, this is the basis for production control and capacity balancing, in the KSB: GLOBAL PUMP project all specifications were designed so that all the requirements of the destination countries have been met
What factors affect the choice of supplier or factory?	The costs to obtain a prescribed quality, a global supplier qualification and certification (by the department: global strategic purchasing)
How do you model and manage your value chain?	Make or buy decision for parts, to ensure high quality and delivery reliability for castings, KSB operates worldwide 9 foundries

How do you assess the risk of your value network and which role do scenarios play in this context?	One element is the analysis of the patent situation, another element is the SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) for the strategic planning. These are aspects such as: competition, economic strength, technologies level; logistics, research and development etc.
Which external environmental factors are influencing your production?	Environmentally-friendly production methods, energy efficiency goals, prevention of rare or problematic materials (this includes the collection, processing, use and recycling), Life Cycle Management. Generally, equity production is safer than purchase
How do you gather information about these factors?	Access and use of third-party information service providers, permanent evaluation of publications in the areas of technology, environment, research, development and patents
Do you use data from external data providers?	yes
What factors influence <u>information compliance</u> in your global supply network?	Exclusive use of official data sources

Table 4-3: Relevant external factors and risks for KSB

4.5.2 Relevant external factors and risks for Indesit

What are the things that matter to your business when defining a global production network?	Total cost (including delivery, quality control, etc.) Quality of the product/service offered by suppliers Reliability of suppliers Satisfaction by suppliers of the project specification (technical, functional, availability, etc.) Market demand and distribution (e.g. decision to produce dryers in UK where there is a strong demand from the market)
What factors affect the change of systems in your global supply network?	Variations in economic conditions (exchange rates, labour costs, customs duties. Market demand variation, Competitors scenario evolution (new product/service offer on the market), New markets (e.g. demand of dryers from new countries), Delivery strategy and cost, International agreements, National incentives for local production and employment

What factors influence the company's cost model?	**Product- Service cost model.** Product-Service costs are composed of several components such as: - costs of the single components (produced or purchased): raw material + operations or semi-finished products including also components for service implementation and delivery (e.g.: sensors, displays, devices) - cost of assembly, quality controls, reworks - costs for service delivery infrastructure - cost of equipment amortization - cost of manpower - indirect costs (logistics, plant, energy) - calculated as annual or monthly rates Usually final price is levelled among different countries even when the production costs are different (Mark-up/Mark-down strategy to keep final costs uniform having countries with different costs commissions)
What factors influence strategic risk in your global supply network?	Risk factors in supply selection: National incentives Product-Service quality (e.g. certified companies) Avoiding unique supplier (especially for critical components to avoid shortage risks) Financial stability of suppliers Company size to guarantee production volumes Flexibility of production and service configuration (e.g. ability to adapt production to new specifications)
What factors influence operational configuration in your global supply network?	Global production cost (operative costs) Relations with the target market - see above example on UK based production due to high demand in the country Customs duties Logistics (e.g. supplier distance, transport costs and means, insurance costs, material/product delivery time from suppliers, packaging costs) Stock management Quality controls
How do you assess the risk of your value network and which role do scenarios play in this context?	Risks can be divided into technical & economical, but they are not formalised. They are evaluated for each phase of the value chain along the network, e.g. having a unique supplier for a same component, etc.
Which external environmental factors are influencing your production?	**(eco) Environmental factors**: ecological regulations, availability of raw materials; changes in competitors market **Political factors**: regulations in different countries (even if they are known and adopted), external norms, legislations, privacy issues, increase of safety standards, political stability **Social factors**: average skills level of manpower; manpower availability and contracts (e.g.: flexibility of contracts); IT readiness of consumers and manpower (especially relevant for the service) **Technological**: IT infrastructure; digital divide; new production technologies, new service technologies, new materials **Economical**: energy costs, transaction costs, material costs,

	transport/logistic costs, economic incentives from the governments, custom duties etc.
How do you gather information about these factors?	Consumers' expectations and competitors variations are provided by external agencies; Information about Legislation and regulations changes are provided by the association of appliances manufacturers; R&D department monitors technological evolution through partners, suppliers, research centres, specialised journals; applied research outsourced to third parties; economical/financial information acquired by the Purchasing department through specialised websites and information channels
How do you forecast the trends regarding these factors?	Reports of third parties specialised in the financial sector; Research & Analysis in different fields, market trends forecast are done using BI on historical information done by the marketing dept., etc.
Do you use data from external data providers?	Yes, reports and results of researches outsourced from specialised agencies

Table 4-4: Relevant external factors and risks for Indesit

4.5.3 Relevant external factors and risks for CustomDrinks

What are the things that matter to your business when defining a global production network?	Availability of ingredients, availability of spare parts, and packaging materials
What factors affect the change of systems in your global supply network?	New technologies and new consumer trends
What factors influence <u>the company's cost model?</u>	The great variety of raw and auxiliary materials for manufacturing our products
What factors influence <u>strategic risk</u> in your global supply network?	Availability, minimum order quantities (suppliers) and delivery times
What factors influence <u>operational configuration</u> in your global supply network?	Since our catalogue and offer is based on richness (many references, customisation), negotiation with suppliers cannot be based on high volumes. Instead the philosophy is to keep several providers with competitive offers according to the volumes we produce. Also trust is a factor.
What factors affect the choice of supplier or factory?	Quality, Cost and service

How do you assess the risk of your value network and which role do scenarios play in this context?	By trials and queries to providers. Sometimes to 3rd party service, in particular for legal requirements and economical solvency (of customer)
Which external environmental factors are influencing your production?	World economy, lack of raw materials (glass, aluminium), cost rises, logistics costs, petrol, supplier's bankrupt, consumer trends and habits
How do you gather information about these factors?	direct contact, through the main corporation (Hijos de Rivera) channels, specialised media
How do you forecast the trends regarding these factors?	specialised media, Beverage Innovation subscription
Do you use data from external data providers?	Yes, for legal requirements, Beverage Innovation subscription, providers catalogues
What factors influence information compliance in your global supply network?	Quality and safety regulations: ISO22000, 9000, regional norms of regional bodies, traceability, HACCP

Table 4-5: Relevant external factors and risks for CustomDrinks

4.6 Exemplary data sources

The European Commission provides a broad range of data regarding the aforementioned factors. Also the US and other countries have internet portals that provide open big data. The following Table 4 6 provides a small overview on relevant data sources:

Legal data sets	• EUR-Lex Access to European Union law via http://eur-lex.publicdata.eu/ • N-Lex via http://n-lex.publicdata.eu • European Patent Office via http://epo.publicdata.eu • EU Agencies via http://agencies.publicdata.eu • Prelex via http://prelex.publicdata.eu • UNODC via http://unodc.publicdata.eu
Business data sets	• EU Commission Financial Transparency System via http://fintrans.publicdata.eu • Community Research and Development Information Service (CORDIS) viahttp://www4.wiwiss.fu-berlin.de/cordis/ • European Employment Services (EURES) via http://www4.wiwiss.fu-berlin.de/eures/ • EURAXESS - Researchers in Motion via http://www4.wiwiss.fu-berlin.de/euraxess/ • EC Competition via http://www4.wiwiss.fu-berlin.de/eccompetition/

Table 4-6: Exemplary data sources

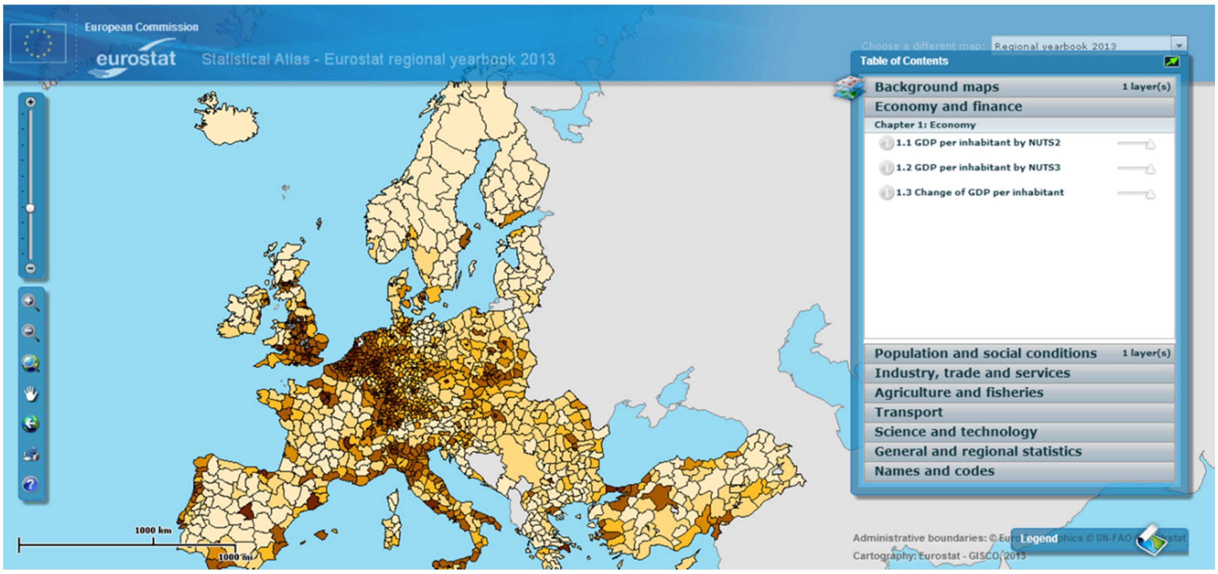

Figure 4-1: European statistical atlas

5 Key Performance Indicators for business models in global production networks

5.1 Overview

A balanced scorecard is applied for measuring the "performance" of business models. Thereby, enterprise KPIs and global production network KPIs are distinguished. Network KPIs are for example the stability, controllability, complexity and flexibility of the GPN. Enterprise KPIs are for example time-to-market or product variability. The enterprise and GPN KPIs do affect each other. Figure 5-1 below depicts the approach.

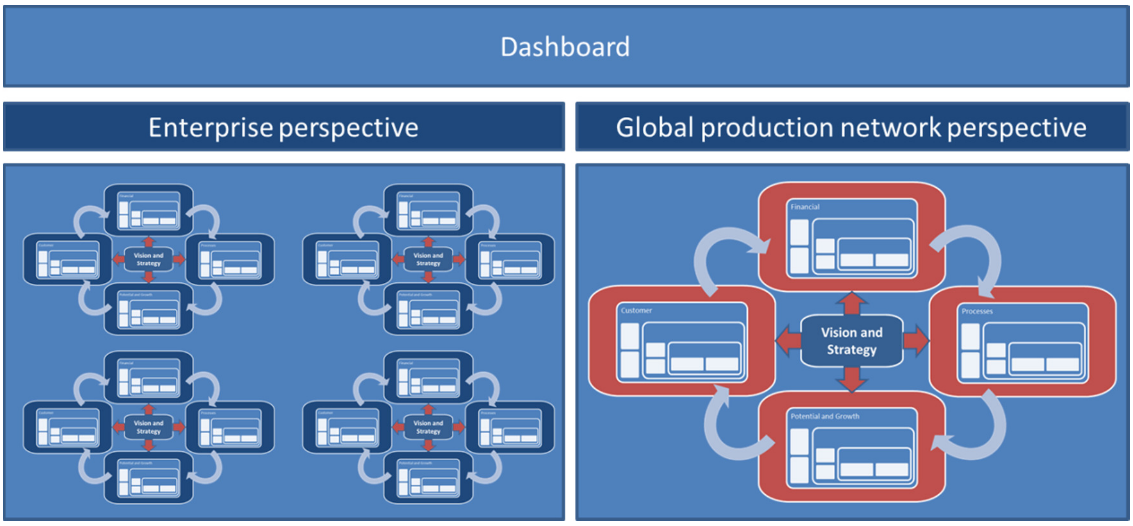

Figure 5-1: Enterprise and GPN perspective

The balanced scorecard approach takes particular care of quality, cost and risks. For measuring and evaluating business models different Key Performance Indicators have to be considered. The following Table 5-1 shows a choice of general KPIs, including their Metrics and Level of business engineering.

Benefit dimension	KPI	Metric	Business Engineering level (influenced BM object)
Productivity	Overall Equipment Effectiveness (OEE)	Availability x Performance Rate x Quality Rate	Strategy (Cost structure)
	(Planned) Downtime	Monthly/weekly amount of unplanned downtime	Strategy (Cost structure) Process (Value Configuration)

	Plant/Production Process Availability (Variance)	Ideal or optimised lead time / actual lead time	Strategy (Cost structure) Process (Value Configuration)
	Plant Productivity	Revenue per plant	Strategy (Revenue Model)
	Lead time/Cycle time	Time from receipt of order to finalisation of product	Strategy (Cost structure) Process (Value Configuration)
	Process Predictability	Overtime hours per week/month	Process (Value Configuration)
	Time-to-market	Time from first idea to delivery to the customer	Strategy (Value Proposition)
Costs	Operational costs	Costs that can be assigned to production process	Strategy (Cost structure) Process (Value Configuration)
	Process transformation costs / Re-Configuration costs	Costs arising due to a change to the production process (e.g. re-configuration)	Strategy (Cost structure) System (capability to re-configure)
	Set-up costs	Costs for establishing a completely new configuration	Strategy (Cost structure) System (capability to re-configure)
Variability	Product Variability	# of variants for a specific product	
Innovation	Product Innovation	# of new products released per year	

Table 5-1: Key Performance Indicators

Additionally, a broad set of KPIs was identified (see Table 5-2):

- Financial KPIs
- Internal business process KPIs
- Customer KPIs
- Education and Growth KPIs
- HR KPIs

KPI Category	KPIs
Financial KPIs	■ Total assets holdings ■ Asset value per one employee ■ Capital productivity ratio ■ Sales volumes for new products/services ■ Working efficiency of personnel ■ Profitability of assets ■ Revenue from new products/services ■ Revenue per employee ■ Market price per share ■ Profitability of net assets ■ Added value per one employee ■ Efficiency of assets ■ Profitability of investment ■ Efficiency of sales volumes ■ Ratio of marginal revenue ■ Marginal revenue per employee ■ Cash flow ■ Ratio of equity capital to total assess holdings ■ Profitability of investment ■ Total expenses
Internal business process KPIs	■ Specific weight of administered if expenses in total revenue ■ Ratio of timely completed orders ■ Average product labor-output ratio ■ Average development time of a new product ■ Average time from placing the order to its completion ■ Supplier frequency ■ Average decision-making time ■ Turnover of material assets ■ Labor productivity growth ■ Efficiency of information systems ■ Increasing number of IT Systems; Computer Equipment

	■ Specific weight of expenses on IT Systems in the total amount of administrative expenses ■ Emission of hazardous substances to the environment ■ Influence of company products to the external environment ■ Expenses related to correction of mistakes in managerial decisions ■ Number of properly executive orders ■ Administrative expenses per employee
Customer KPIs	■ Number of customers ■ Market share (%) ■ Average annual sales volume per customer ■ Number of lost customers ■ Average time of taking an order ■ Number of customers per employee ■ Specific weight of concluded agreements in the total number of contacts with customers ■ Customer satisfaction ■ Customer loyalty ■ Expenses per customer ■ Number of visits/contacts with customers ■ Number of advertising campaigns ■ Trademark index ■ Marketing expenses ■ Average contact duration with a customer ■ Average amount of products shipped to one customer ■ Number of customer visits to the company ■ Average time between first contact with the customer and signing of agreement ■ Average annual expenses to serve one customer
Education and Growth KPIs	■ Expenses for research and innovation ■ Specific weight of expenses on research and innovation in the total amount of expenses ■ Specific weight of expenses on improvements in total amount of expenses related to IT technologies ■ Length of research and innovation projects ■ Resources allocated on research and innovation ■ Investment in training of personnel dedicated to customer relations ■ Investments in innovation and research ■ Expenses related to preparations and study of new products ■ Investments in exploration of new markets ■ Frequency of direct contacts with customers ■ Number of registered patents ■ Average time company patents are in force ■ Number of rational and creative ideas per employee ■ Average training cost per employee ■ Employee satisfaction index ■ Marketing expenses per customer ■ Employee trust rate to the company

	■ Specific weight of employees who have not reached a certain age in the total number of employees ■ Non production expenses per customer ■ Specific weight of new products in the total amount of products
HR KPIs	■ Leadership index ■ Personnel motivation index ■ Number of employees ■ Personnel turnover rate ■ Average employment time in the company ■ Average employee age ■ Time spent for education and training of personnel ■ Ratio between temporary and permanent employees ■ Percentage of employees with college degree ■ Average employee absence time ■ Number of female managers ■ Number of job applications to the company ■ Personnel trust rate to the company ■ Ratio of employees under 40 y.o. ■ Annual expense for re-education of personnel ■ Number of fulltime employees who spend less than half of working time in office ■ Ratio of fulltime employees ■ Number of temporary fulltime employees ■ Number of part time employees ■ Number of employees with a per hour compensation system

Table 5-2: Identified Key Performance Indicators

Table 5-3 shows additional KPIs for evaluating business model reconfiguration for a specific company from the software industry (Di Valentin et al, 2012). These will be very important when developing additional app-based services like some use case partners plan to do in future.

Vale Chain Activity	KPIs	Effects on Business Model Elements
Development	• Implementation Time • Number of Implementation Inquiries • Time Units for Definition and Test • Number of Customer Complaints • Product Quality • Number of Bugs • Developers per Software Project • Profit Margins	The faster the software development the higher is the chance for being innovative and successfully sell the software product. These aspects have a positive effect on the **Revenue Model**

		The quality of the developed software product influences the perceived **Value Proposition**
Operations	• Number of Participants • Transactions per Time Unit • Data Volume per Time Unit • Employee Satisfaction	The number of carried out transactions and participants of value chain activities have an effect on a company's **Architecture of Value Creation** and the **Revenue Model**
Marketing	• Sales Growth • Degree of Brand Awareness • Number of Business Contacts • Effort per Marketing Activity • Revenue per Marketing Activity • Number of Customers that know the Software Product	The number of fulfilled customer requests has a positive impact on the customers' **Value Proposition.** Sales Growth and Revenue per Marketing Activity directly influence the **Revenue Model** whereas the Number of Business Contacts is related to a company's **Architecture of Value Creation**
Support	• Amount of Support • Average Support carried out per Employee • Effort per Support • Average Processing Time • Effort of Rework	Amount of Support, Average Support carried out per Employee, Effort per Support and Effort of Rework have a strong influence on a company's **Revenue Model** and **Resources**. The Average Processing Time is positively correlated to the perceived **Value Proposition** of customers
Maintenance	• Number of Complaints • Number of Bugs	Key measures within Maintenance are related to the **Value Proposition** as they indicate the satisfaction of a company's customers
Replacement	• Number of carried out Software Updates	The Number of carried out Software Updates have an impact on the **Value Proposition**

Table 5-3: Exemplary KPI Catalogue and effects on business model of a software company (Di Valentin et al. 2012)

5.2 Characterising FLEXINET partner's use cases

The three use case partners have different focal points in terms of relevant Key Performance Indicators. After consideration of the use case partners' interviews, the following first set of KPIs can be identified based on the interviews in WP1 as set out in Table 5-4 below.

Interview analysis
KSB KPIs for measuring success of business models

Evaluation metrics for new business opportunities
Efficiency in design and delivery
Customer satisfaction
Customer growth rate
Possible contribution to strategic objectives
Indesit KPIs for measuring success of business models
Number of new Product-Service sold per year should increase of 20%
Company turnover from Product-Service selling
Efficiency in design and delivery
Customer satisfaction
Time to market
Customer growth rate
Product-Service sustainability assessment (environmental, economic, social)
ROI for each product-service
Product-Service performance and capabilities
Product-Service design cost
Product-Service engineering cost
Product-Service delivery costs
Product Reliability
Customer satisfaction
CustomDrinks KPIs for measuring success of business models
Customer satisfaction
Repetition of orders
Response Time
Flexibility
Appearances of products in specialised media per year
Quantity of beverages brought to the market per year

Table 5-4: Key Performance Indicators for business models use case partner

6 Risk modelling

6.1 Overview

Modelling disruptive events and their propagation in GPNs is a crucial part of risk analysis in FLEXINET. For this purpose risk propagation models are examined in this section. Firstly, we will present inoperability models, which can be utilised used for risk propagation modelling in GPNs. Secondly, an approach based on inoperability models to be developed in FLEXINET is discussed. Finally, relationships between the proposed risk modelling approach, the business model concepts and KPIs are examined.

6.2 Inoperability Models

Inoperability models (IIM) have been introduced based on the original economics Input Output model (Haimes & Jiang, 2001; Santos & Haimes, 2004). These models deal with the risk in a network in terms of the inoperability that is caused to each individual node directly and also as a result of propagation of risk/inoperability through the network. In this section, an IIM and its dynamic variant are discussed and the key elements and relevant concepts are introduced. We also take a look at the possibility of integrating multiple risk factors within IIMs.

6.2.1 Inoperability Input Output Model

The Input Output Model, introduced by Leontief, is a well-established economics model that is used to determine the relationship between interconnected sectors of economics (Santos, 2006). Each sector relies on products/services provided by other sectors (this creates a dependency) and also, by offering products/services of its own, other sectors are also dependent on this sector too. However, part of the necessary products/services enter the market from outside, such as foreign markets, which constitute the inputs to the system. On the other hand, part of the provided products/services will be consumed by the final customers and/or exported, and it constitutes the outputs of the model. The formula which links the outputs and inputs of the sectors is as follows (Santos & Haimes, 2004):

$$x_i = \sum_j a_{ij} x_j + c_i \qquad \text{for all } i.$$

where x_i and x_j are the outputs of sectors i and j respectively, a_{ij} is the ratio of the output of sector i that is used by sector j and c_i is the final demand of sector i's output. This can be formulated in a matrix format as follows:

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{c}.$$

where $\boldsymbol{x}$ is the vector of sectors outputs, $\boldsymbol{A}$ is the sectors' interdependency matrix and $\boldsymbol{c}$ is the vector of final demands.

The Inoperability Input Output model (IIM) is a risk model based on the Input Output model described above (Santos & Haimes, 2004). Similar to the Input Output Model, IIM assumes interconnected nodes that receive independent "perturbations" as the input. The model determines the output "inoperability" values for all nodes by considering the propagation of risk throughout the network. Inoperability shows the rate at which the actual activity level deviates from the planned activity level and acts as a measure of risk materialisation for each node. This model can be formulated as follows (Wei et al., 2010):

$$q_i = \sum_j a_{ij} q_j + c_i \quad \forall i.$$

where q_i and q_j are the inoperabilities of nodes i and j, a_{ij} is the interdependency coefficient that presents a probability of a disruption propagation from node j to node i, and c_i is the perturbation of node i which is independent risk of inoperability that is directly induced by disruptive events. This is formulated in vector format as follows:

$$\boldsymbol{q} = \boldsymbol{A}\boldsymbol{q} + \boldsymbol{c}.$$

where $\boldsymbol{q}$ is the vector of nodes' inoperabilities, $\boldsymbol{A}$ is the interdependency matrix and $\boldsymbol{c}$ is the vector of input perturbations. Assuming that $(I - A)^{-1}$ exists, inoperability vector can be calculated by the following formula (Wei et al., 2010):

$$\boldsymbol{q} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{c}.$$

where I is the identity matrix with the diagonal elements equal 1 while other elements are 0.

6.2.1.1 Interdependency between Nodes

Network nodes can be dependent on each other; relationships between nodes can be either two-way or one-way or it is possible for two nodes to be directly independent. These relationships are utilised to determine the effect of inoperability arising in one node on dependent nodes and ultimately to determine the propagation of risk throughout the network. An interdependency matrix that quantifies these dependencies is required.

Interdependency matrix shows the relationships and the level of dependence between the nodes in the network. Each row corresponds to one node and represents the dependencies of the node to all other nodes. A value of 1 demonstrates the maximum possible dependence, where any inoperability at the source node will propagate at the same level to the dependent node, while a value of 0 stands for complete independence.

Several approaches have been proposed to determine the interdependency matrix. A traditional method is to consider the supply of products from each sector/node to the other nodes and calculate the interdependency based on the value of supplies (Santos & Haimes, 2004). This method is very similar to the way interdependency is determined in the original input output model. However, we will introduce an alternative method proposed by Wei et al. (2010) that utilises dependency criteria between nodes of GPN to determine the interdependency matrix.

6.2.1.1.1 <u>Dependency Criteria</u>

To determine the interdependency matrix, we need to analyse the relationships between the network nodes. The approach proposed by Wei et al. (2010) is to examine each relationship based on a number of dependency criteria, including:

1) Trading volume
2) Substitutability (of the product/service with alternatives)
3) Number of suppliers or distributors
4) Buffer capacity

Each of these criteria need to be determined for each relationship between nodes. Depending on the type of the criterion, the criteria need to be normalised and then aggregated into a single interdependency coefficient of the relationship. For the purpose of normalisation, criteria are treated differently if they contribute positively to the interdependency coefficient, such as trading volume (the higher the trading volume, the higher the interdependency), or contribute negatively, such as substitutability (the higher the substitutability, the lower the interdependency),number of suppliers or buffer capacity.

6.2.1.1.2 Normalisation

As the values of different criteria are possibly of different units and can have widely different ranges, it is necessary to normalise the criteria values of nodes before aggregating them into a single coefficient. This will allow the values to be comparable and have equal effect on the final coefficient. Normalisation is done for each criterion and for each dependent node separately so that all values given for the criterion for the particular node's dependency relationships are scaled into the interval [0, 1].

For normalisation, criteria are split into two sets: Either they contribute positively to the interdependence coefficient, known as *benefit-type*, or they contribute negatively which is known as *cost-type* (Wei et al., 2010). For the former type, we want to have a higher (lower) normalised value for higher (lower) original values while for the latter, a lower (higher) normalised value is expected for a higher (lower) original value.

The following formula is adapted for benefit-type (Wei et al., 2010):

$$r_{lk} = \frac{y_{lk}}{\sum_i y_{ik}}, \quad l \in N$$

where N is the set of dependency relationships for a particular node, r_{lk} is the normalised value of relationship l of criterion k and y_{lk} is the original value of relationship l of criterion k.

For cost-type, the following formula is used:

$$r_{lk} = \frac{\frac{1}{y_{lk}}}{\sum_i \frac{1}{y_{ik}}}, \quad l \in N$$

6.2.1.1.3 Aggregation using Ordered Weighted Averaging

Wei et al. (2010) propose using an Ordered Weighted Averaging (OWA) operator to aggregate the normalised values of the criteria into the interdependency coefficient. OWA operators are aggregation methods that weight the input parameters based on their order. Common operators such as mean, minimum, maximum and arithmetic mean can be classified as OWA operators. The paper proposed $[0.4, 0.3, 0.2, 0.1]$ to be the weighting vector for the above mentioned criteria.

6.2.1.2 Economic Loss of Risk

Inoperability shows the degree to which the node is underperforming. Assuming that the overall value of the node's operation is known, it is trivial to calculate the cost of underperformance for a particular inoperability, by multiplying the inoperability level by the overall value of the node's operation. This is the basis for calculating the overall economic loss in the network. Essentially, by using the IIM model, the inoperabilities of all nodes throughout the network are determined and then, individual economic loss of inoperability is calculated for each node. Finally, a summation of these individual economic losses will yield the total economic loss of the network. In the context of FLEXINET, this value can be used to evaluate the suitability of possible network configuration alternatives.

6.2.2 Dynamic IIM

In the IIM model, the inoperability measure is assumed to be constant over time. However, the inoperability could change over time due to the resilience of the node to the inoperability and its ability and time needed to react to a disruption. This has led to the introduction of the dynamic version of the IIM model that considers changes in inoperability values over time. This model is based on the Dynamic Input Output model.

6.2.2.1 Dynamic Input Output Model

The Input Output model can be extended into a dynamic model, which considers time varying input parameters and outputs, by reformulating it as follows (Lian & Haimes, 2006):

$$\boldsymbol{x}(\boldsymbol{t}) = \boldsymbol{A}\boldsymbol{x}(\boldsymbol{t}) + \boldsymbol{c}(\boldsymbol{t}) + \boldsymbol{B}\dot{\boldsymbol{x}}(\boldsymbol{t}).$$

where $\boldsymbol{x}(\boldsymbol{t})$ is the vector of sectors outputs at time period $\boldsymbol{t}$, $\boldsymbol{A}$ is the interdependency matrix, $\boldsymbol{c}(\boldsymbol{t})$ is the vector of final demands at time period $\boldsymbol{t}$, B is the capital coefficient matrix and $\dot{\boldsymbol{x}}(\boldsymbol{t})$ represents the change in the outputs of sectors at the time period $\boldsymbol{t}$.

The added term $(\boldsymbol{B}\dot{\boldsymbol{x}}(\boldsymbol{t}))$ represents the change in the output of sectors as a result of investment in capital resources, resilience toward disruptive events or generally an adjustments made into the sectors. Assuming $\boldsymbol{B} = \boldsymbol{0}$, the dynamic Input Output model will become the original Input Output model.

6.2.2.2 Dynamic Inoperability Model

Lian & Haimes (2006) introduced the dynamic IIM based on the dynamic Input Output model given above. The proposed continuous time formulation is as follows:

$$\dot{\boldsymbol{q}}(\boldsymbol{t}) = \boldsymbol{K}[\boldsymbol{A}^{*}\boldsymbol{q}(\boldsymbol{t}) + \boldsymbol{c}^{*}(\boldsymbol{t}) - \boldsymbol{q}(\boldsymbol{t})].$$

where $\boldsymbol{q}(\boldsymbol{t})$ is the inoperability of the sectors at time period $\boldsymbol{t}$, $\boldsymbol{A}^*$ is the normalised interdependency matrix, $\boldsymbol{c}^*(\boldsymbol{t})$ is the vector of percentage reduction of final demands at time period $\boldsymbol{t}$, $\boldsymbol{K}$ is the resilient diagonal matrix and $\dot{\boldsymbol{q}}(\boldsymbol{t})$ represents the change in the inoperability of sectors at the time period $\boldsymbol{t}$.

In the dynamic IIM, $\boldsymbol{K}$ can be interpreted as $\boldsymbol{K} = -\boldsymbol{B}^{-1}$ and each of its diagonal elements represents the resilience of the respective sector to the disruptive events and its agility to respond to risk (Lian & Haimes, 2006). It could also be interpreted as the coefficient of risk management investment for that particular sector which is more in line with the original definition. It is worth noting that non-diagonal elements of $\boldsymbol{K}$ are all assumed to be zero.

The dynamic IIM can also be formulated in discrete time as follows:

$$\boldsymbol{q}(\boldsymbol{t}+\boldsymbol{1}) = \boldsymbol{q}(\boldsymbol{t}) + \boldsymbol{K}[\boldsymbol{A}^*\boldsymbol{q}(\boldsymbol{t}) + \boldsymbol{c}^*(\boldsymbol{t}) - \boldsymbol{q}(\boldsymbol{t})].$$

In order to analyse dynamic propagation of disruptive events, it is possible to introduce the direct inoperability i.e., perturbation of a node in two ways:1) By introducing a reduction in demand (or supply) through non-zero values for $\boldsymbol{c}^*(\boldsymbol{t})$**,** 2) By setting the initial inoperability $\boldsymbol{q}(\boldsymbol{0})$ (Lian & Haimes, 2006). The second method is used widely in the literature and will be used in the context of FLEXINET as well (Barker & Santos, 2010; Lian & Haimes, 2006; Orsi & Santos, 2010).

6.2.2.3 Resilient Factor

Resilience represents the rate at which the node can recover from disruptive events. This factor is fundamental to the dynamic IIM as it provides the basis for the changes in the inoperabilities. The resilience matrix $\boldsymbol{K}$ is a diagonal matrix of resilience coefficients of the nodes. These resilience coefficients can be calculated by considering the initial inoperability level and the time it takes for the node to recover to a specific level of inoperability. The following formula can be used to calculate the resilience coefficient k_i (Lian & Haimes, 2006; Orsi & Santos, 2010):

$$k_i = \frac{ln\left[q_i(0)/q_i(T_i)\right]}{T_i(1-a_{ii}^*)}$$

where $q_i(0)$ is the initial inoperability, $q_i(T_i)$ is the reduced inoperability expected as a result of recovery at time period T_i and a_{ii}^* is the normalised dependency rate of node i on itself. The denominator represents that the greater the dependency of a node on itself (hence, lower dependency on other nodes), the higher is the recovery rate or resilience coefficient for that node.

6.2.2.4 Incorporating Time Varying Perturbations

Perturbation is the initial impact of disruptive events on the node which has been directly affected by the events. The purpose of the IIM or Dynamic IIM is to understand the indirect impact of these direct effects on the network and observe the propagation of these effects throughout the network. However, in the dynamic model, perturbations do not necessarily happen at the beginning of the time horizon. In fact, it is possible to have recurring or long term perturbations in certain risk scenarios. To address this requirement, it is necessary to adapt the Dynamic IIM to allow for further perturbations to be introduced at later time periods. Orsi & Santos (2010) proposed such an extensions by using an iterative process which first considers the effects of perturbations in each time period separately and then aggregates them to constitute the final inoperabilities.

In the proposed iterative process, first, only the initial perturbation is considered ($\boldsymbol{q_p(0)}$) and the dynamic IIM is constructed considering this perturbation only. The calculated inoperabilities, $\boldsymbol{q^1}$, constitute the first iteration of inoperabilities. In the next iteration, a dynamic IIM model is constructed from the second period only. It considers the direct perturbation in the second period $\boldsymbol{q_p(1)}$ plus the calculated inoperability in the first iteration for the first period $\boldsymbol{q^1(1)}$ as the initial perturbations to calculate a new set of inoperabilities $\boldsymbol{q^2}$. This process is repeated for each new period, using the following formula to determine the initial perturbation in the iteration $\boldsymbol{t}$:

$$\boldsymbol{q^t(t) = \max\left(q^1(t), q^2(t), \dots, q^{t-1}(t)\right) + q_p(t)}.$$

Please note that in each iteration t, only the perturbation of the corresponding period t and the inoperability of the later periods are calculated and the inoperability of previous periods, for that iteration, is assumed to be zero.

Finally, assuming the final time period is $\boldsymbol{T}$, the aggregated inoperability of nodes for all time periods $\boldsymbol{\hat{q}}$, is calculated as follows:

$$\boldsymbol{\hat{q}(t) = q^T(t)}.$$

6.2.2.5 Economic Loss of Risk

Economic loss of risk is an important measure of quantifying the impact of risk on the network. This measure is already introduced and calculated in the IIM model in Section 6.2.1.2; however, it can also be calculated for the dynamic version of IIM. Unlike the IIM model, inoperability measure in the dynamic IIMs varies over time and it could also lead to varying costs of each node. Essentially, in order to calculate the economic loss of risk of the node it is necessary to multiply the node's expected economic output by the inoperability value of that node in the respective time period and then aggregate the values to calculate the loss of risk for that node. Then, these values need to be aggregated for all nodes to calculate the overall economic loss of risk of the network. Hence, the total economic loss of risk can be calculated as follows:

$$\boldsymbol{Q = x^T \sum_{i=1}^{T} q(i)}$$

where $\boldsymbol{Q}$ is the economic loss of risk of the network, x^T is the vector of expected economic outputs of all nodes for a single time period and $\boldsymbol{q(i)}$ is the inoperability vector at time period i.

6.2.3 Fuzzy Inoperability Models

In practice, it may be difficult or even impossible to determine IIM's parameters precisely. Therefore, inoperability models have been modified to include uncertainty in parameters such as the interdependency rates, perturbations or resilient Traditionally, uncertainty has been modelled using probability distributions that concern the occurrence of well defined events. Corresponding probabilities are assessed or estimated taking into consideration repetition of the events. However, historic data may not always be available. In this case, practitioners may estimate the disruption occurrences based on vague or imprecise knowledge or accumulated experience. Fuzzy logic provides a suitable framework for modelling this type of vague and imprecise data (Zimmermann, 2001).

Fuzzy logic relies on the concept of fuzzy sets. Fuzzy sets are an extension of the classical sets where members can have partial memberships to the set, in contrast with classical sets that a member can either be a member or not a member. In order to achieve this, a membership function is defined for each fuzzy set that determines the degree of membership of the input to the corresponding fuzzy set. Fuzzy sets allow for better modelling of everyday concepts that are easy for humans to understand but hard to be modelled by classical logic. For example, when dealing with everyday concepts such as 'hot weather', a human would not define it by choosing a specific temperature as the minimum value for which the temperature is considered to be hot, while a classical logic definition would demand such a threshold. However, fuzzy set allows for a gradual transition in membership of temperatures to the concept of 'hot', making 35°C definitely 'hot', 15°C not at all 'hot', while 25°C is only 'half-hot'! This is more in line with the understanding of concepts by humans.

In order to utilise fuzzy logic, typically fuzzy numbers are used to model parameters. A fuzzy number is a special type of fuzzy sets that represents a vague number. Fuzzy numbers allow for basic mathematical operations to be used in a similar way as ordinary numbers. A popular type of fuzzy numbers, which is often used in applications, is triangular fuzzy numbers (TFNs). TFNs are identified by three numbers, first representing the lowest possible value, second the value with the highest possibility and third that represents the highest possible value. TFNs are simple, easy to interpret and linguistic values such as 'around 3' or 'between 4 and 10 but likely 6' can be readily translated into an appropriate TFN. However, while addition and subtraction are closed operations on TFNs i.e. the result is also a TFN, multiplication and division are generally not closed on TFNs. Two types of approaches are used to deal with this issue: either an approximation of the operators are used that yields TFNs as outputs or the precise result of the computation is determined by using interval calculations at different levels of satisfaction (also known as α-levels) (Oliva, Panzieri, & Setola, 2011).

Panzieri & Setola (2008) consider failure propagation as well as inoperability by using fuzzy numbers to model uncertain parameters, such as inoperability and interdependency coefficients. An approximation of TFN multiplication operation is used. The absence of resources and presence of failure are distinguished as different sources of risks which cause inoperability and its propagation and they are modelled separately. Additionally, Setola, De Porcellinis, & Sforna (2009) examine an Italian infrastructure case study where the dependency matrix is determined using experts' judgments and specified using fuzzy linguistic values. Confidence and reliability of experts were considered using linguistic terms.

Additionally, the interval calculation at satisfaction levels using TFNs is applied in a fuzzy inoperability model by Oliva et al. (2011). They considered fuzzy dependency matrix coefficients, fuzzy initial inoperability values and fuzzy external perturbations. In this method, the outputs (inoperabilities) were calculated at various α-levels to generate the corresponding membership function. As usual, α-levels between 0 and 1 with equal steps were used (e.g. 0, 0.1, 0.2, …, 1) where the step size determines the accuracy of the method. At each α-level, a fuzzy number essentially became an interval of numbers. It was proved that the output inoperability intervals could be determined by calculating the outputs for the lower bounds of input intervals which determine the lower bounds of outputs and, also, by calculating the outputs for the upper bounds of input intervals which determine the upper bounds of outputs. Hence, for each α-level, the crisp inoperability calculation is required to be run twice. The formula used in the fuzzy inoperability model is as follows:

$$\tilde{q}(k+1) = \tilde{A}\tilde{q}(k) + \tilde{c}, \quad \tilde{q}(0) = \tilde{q}_0$$

where $\tilde{q}(k)$ is the fuzzy inoperability vector at time period k, $\tilde{A}$ is the fuzzy interdependency matrix, $\tilde{c}$ is the fuzzy external perturbation vector and $\tilde{q}_0$ is the fuzzy initial inoperability vector.

6.2.4 Multi risk factors

An IIM assumes a single but general risk (perturbation) that can affect each node directly. However, in practice, several sources of risk can lead to disruptions in the network simultaneously. Although the IIM does not explicitly consider situation, it is possible to use other methods to aggregate these risk factors into a general perturbation value and then use the IIM for the risk propagation analysis. For example, an ANP can be developed to examine the interdependent relationships between different risk factors and also to aggregate them into a single perturbation. Further on, it is worth mentioning that a single risk factor may affect more than one node directly. For example, a regional issue such as flooding affects several facilities at the same time and this should be adequately modelled. In such scenarios, a novel risk aggregation model should be developed to include these relationships among risk factors.

6.3 Proposed Approach

The risk model to be used for strategic risk assessment of GPNs will be based on the inoperability models. Fuzzy models will be used, as the main source of data will be provided by experts who will be able to estimate the parameters using linguistic values. The dynamics and resilience of the network will be considered. The user will be allowed to define risk scenarios that include expected disruptive events (based on relevant risk factors), timing and impact of each factor in each scenario. These will form be the inputs to a dynamic inoperability model that will determine the expected inoperability of network nodes, for each time period in a time horizon, and will estimate the economic loss of risk. Alternative proposed networks can then be compared using the aggregated economic loss of risk for different risk scenarios.

7 Demonstration

7.1 Application of the model in the FLEXINET project

The conceptual model defines what a business model is and what elements belong into it. It describes what elements need to be considered and how the business model elements relate to each other on a conceptual level. The model can be operationalised by defining business rules. Within the FLEXINET project this is done in task 2.2.

For applying the model in the context of the FLEXINET use case partners' design specifications are developed in task 2.3. This includes the definition of business model design patterns. For the moment, different business model types do exist. This taxonomy of types defines which business models resemble to each other. Based on the design patterns instances of the business models of the FLEXINET use case partners are created. These instances can then be evaluated regarding risk and economic profitability.

This approach is based on the business model concept hierarchy by Osterwalder et al. (Alexander Osterwalder & Pigneur, 2005). Figure 7-1: depicts the approach.

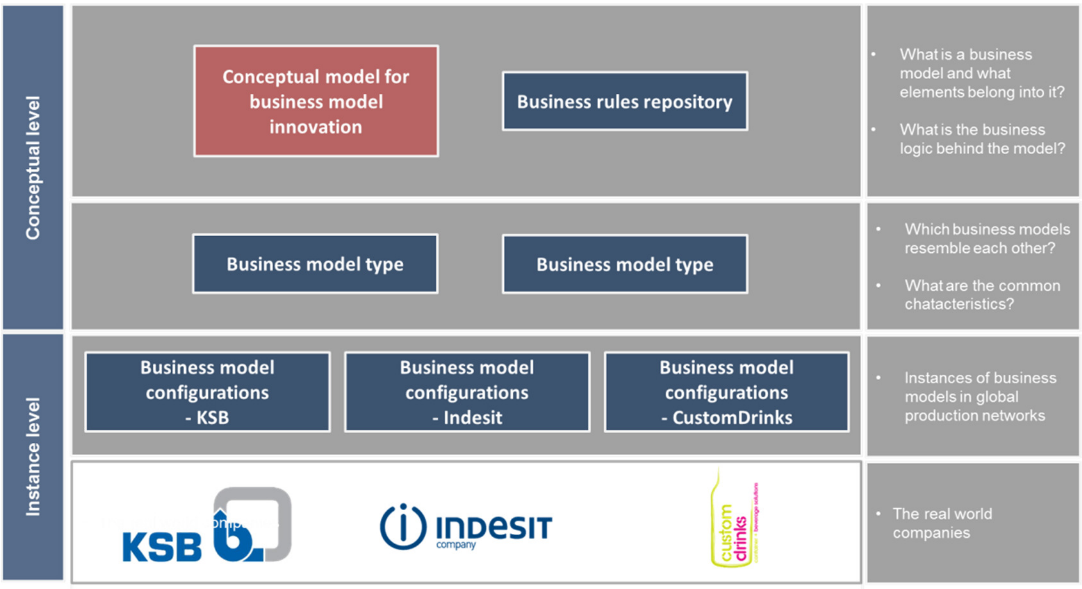

Figure 7-1: Business model concept hierarchy in FLEXINET

7.2 Exemplary instantiation of risk models

7.2.1 Overview and description

The introduced inoperability models are very useful in assessing the risk throughout the production network. Different entities of the production network such as suppliers, customers, production facility and even logistic providers can be modelled as a node in the GPN structure and used for risk assessment and propagation by the inoperability model.

7.2.2 Prototype demonstration

To demonstrate the functionality of stand-alone risk strategic assessment application, a prototype has been developed using .NET framework and in C# language. The prototype utilises the basic IIM model and visualises the propagation of risk throughout a simple fictional network structure, inspired by the CustomDrinks network.

The interdependency matrix has been determined using a method similar to the one described by Wei et al. (2010). Three criteria, including trading volume, substitutability and buffer capacity are used. For each identified directed relationship within the network, each of the criterion is rated as either 'Low', 'Medium' or 'High'. Each of these linguistic values is translated into a single numerical value to be used by the model. The process described by Wei et al. (2010) is followed to determine the interdependency matrix.

Perturbation values are entered by the user through a set of sliders. As the user modifies a perturbation value, the software immediately reflects the immediate impact of the disruption and the result of propagation of the disruptive event in the network by updating the network inoperability diagram. To improve visualisation of the inoperability, each node is coloured based on the level of inoperability; green for low inoperability, yellow for medium, orange for high, red for very high and purple to reflect a disastrous event that leads to suspension of activity in the node. Figure 7-2: presents an example of the user interface, when the inoperability of 'suppliers of yeast' is set to 0.7 using the respective slider.

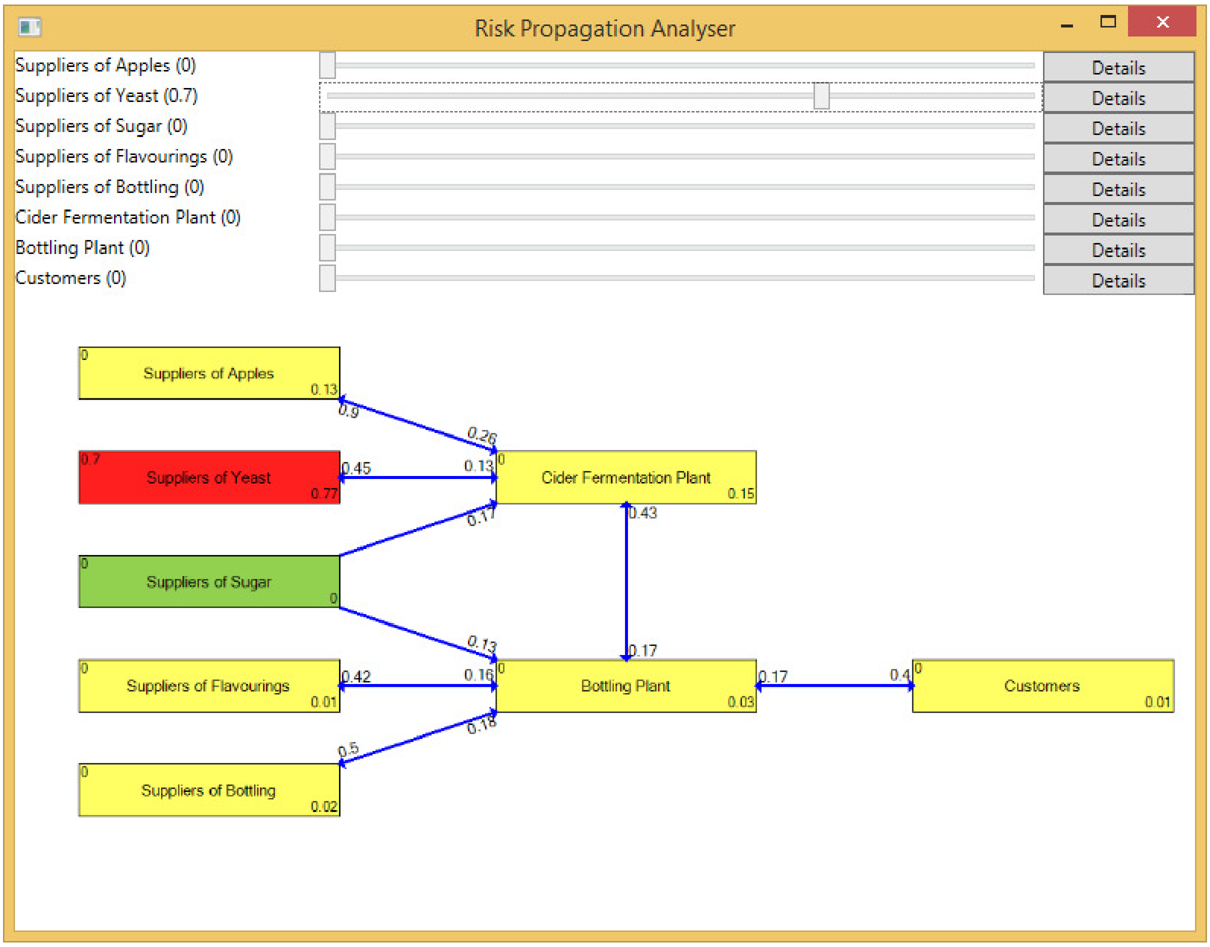

Figure 7-2: Software interface showing the network under a 0.7 inoperability in the 'suppliers of yeast'

In Figure 7-2:, the numbers at the top-left of each box represents the perturbation of the node (it is set using the sliders at the top of the page), while the number at the bottom left shows the calculated inoperability of the node. For example, the node for the 'Suppliers of yeast' has a 0.7 perturbation and a 0.77 inoperability. Numbers on the arrows are the inter-dependency coefficients of the respective relationships. For example, node for the 'Suppliers of apple' has a 0.9 dependency coefficient with 'Cider fermentation plant', while 'Cider fermentation plant' has a dependency of 0.26 with 'Suppliers of apples'.

The software also allows for investigating the details of analysis of each node that is available through the respective 'Details' button in the top right of the screen. Details such as the identified dependencies, linguistic ratings of each criterion and the respective numerical value as well as current perturbation and inoperability values are shown. An example is presented in Figure 7-3:.

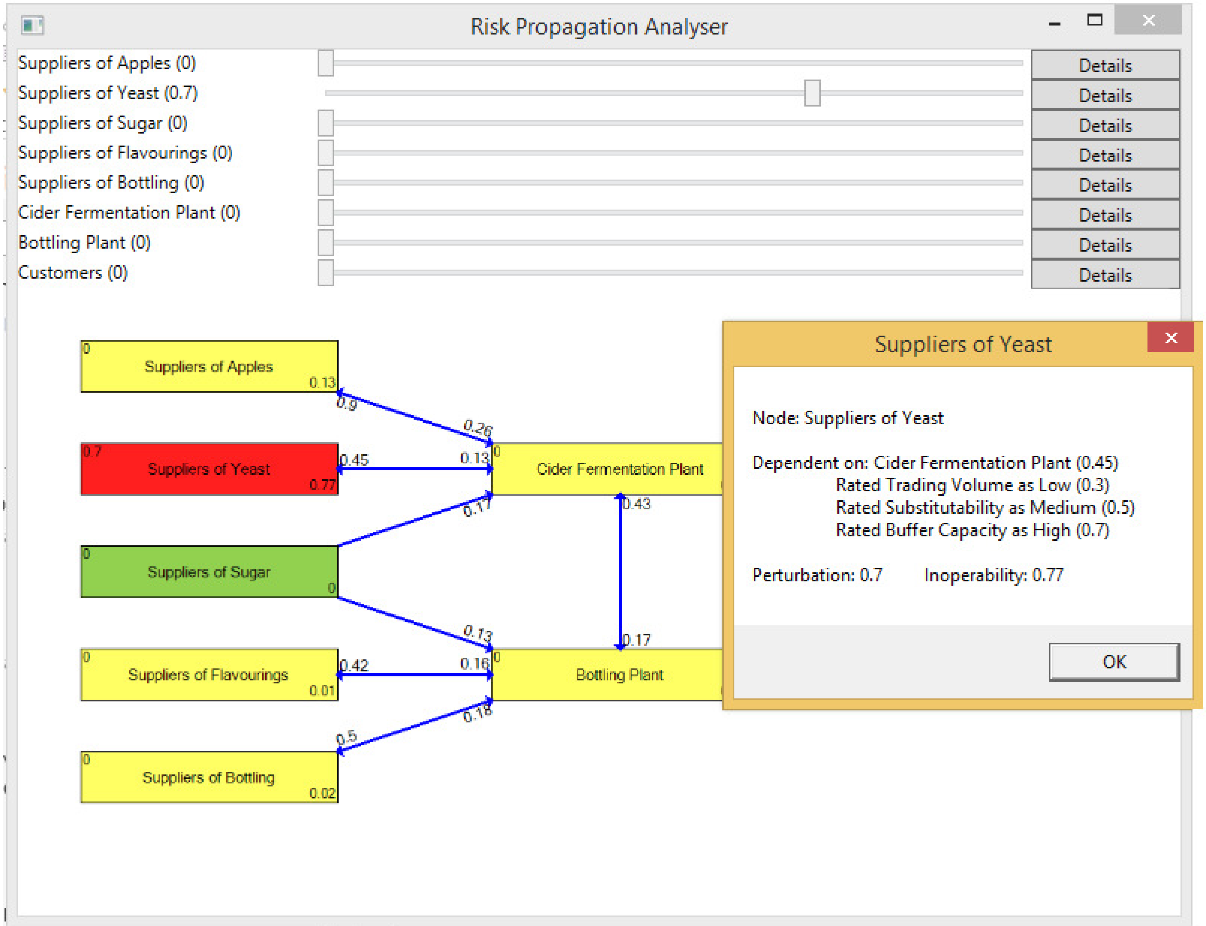

Figure 7-3: An example of the 'Details' dialog

In Figure 7-3:, the details of the node for 'Suppliers of yeast' are shown. As shown, this node is dependent only with the 'Cider fermentation plant' with a dependency coefficient of 0.45. This value is calculated using the rates for the three criteria that are set using linguistic values and then converted into the respective number (Low = 0.3, Medium = 0.5 and High = 0.7). The current perturbation and inoperability of the node are also shown.

8 Conclusion

8.1 Impact for and relation to future work in work package 2

Various types of inoperability models exist that analyse disruption propagation as a result of supply and/or demand dependencies and can also consider buffers/inventories, uncertainty, resilience of a GPN and other parameters. Regardless of the specifics, inoperability models are well suited for risk propagation analysis in production networks, especially as they are at an acceptable level of granularity for the purpose of WP2. Inoperability models can be used to determine the total economic loss of risk that is comparable with other cost elements in a business model and can be utilised to compare alternative GPN configurations. However, inoperability models provide more detailed insights that can be used for risk management purposes either in a selection process of alternative GPN configuration or in later phases of GPN design and implementation. Additionally, fuzzy logic provides a convenient framework for uncertainty analysis that can be incorporated within the inoperability models to allow for describing vague and uncertain quantities within a GPN. Finally, dynamic behaviour of a production network in the presence of disruption is of interest and can be modelled and analysed using dynamic inoperability models.

Besides the consideration of risk modelling the conceptual model for business model innovation explicitly takes care of external influence factors and provides companies with a broad range of key performance indicators. Based on the model's concepts business model scenarios will be created in upcoming work packages while the next deliverable D2.2. will provide the business logic that underlies the conceptual model. By considering external factors and corresponding data sources, simulations based on real data can be performed. In task 2.3. design specifications for business models will be defined. The methodology developed there has its foundation on the conceptual model for business model innovation. KPIs and external factors can be selected in future and assigned to the new design of a business model. Due to this flexibility in configuring the model, the influence of external events can be assessed quite thoroughly.

8.2 Summary and outlook

The presented conceptual model represents all necessary concepts for business model innovation. By structuring the model into different components and perspectives it is able to cope with the complexity of business model innovation. A comprehensive analysis of GPN risks and the integration of risk models into the conceptual model allow for future strategic risk analyses. Moreover, the model enables the economic valuation of business models on an enterprise and global production network level of abstraction. Due to its intermeshing with the operational level, ad-hoc strategic analyses can be performed based on real process data (e.g. resources and time). This is very important in order to execute what-if analyses that are very close to the real world in which companies operate.

The next steps are to define business rules that describe the business logic behind the conceptual model. In future the business rules provided can be authored by the user of the model (e.g. for simulations). A business vocabulary will support him with definitions of the model's concepts in a business understandable language using the SBVR standard. A design specification enables companies to apply the model by setting up simulation scenarios. Moreover, business model archetypes will be developed that facilitate business model configuration.

Currently, there are only a few tools that enable the simulation of business models. The existing tools on the market do not consider external influence factors. Thus, simulations, and respectively decisions, rely only on partial information. Therefore, the conceptual model for business model innovation provides a very important contribution to the scientific and practitioners' state of the art.

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