FLEXINET

FP7-2013-NMP-ICT-FOF (RTD) Project 608627

Deliverable [D2.3]

Design specification for business model innovation

Work Package:	WP 2 – Business models for global product-service production networks
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Executive Summary

The deliverable at hand provides the design specifications for business modelling in global production networks, based on the first two deliverables within work package 2 of the FLEXINET project, deliverable D2.1 the conceptual model for business model innovation and D2.2 the rulebook.

The required design specification sets the concepts and models of the aforementioned deliverables into the FLEXINET context as needed for the development of the FLEXINET applications in work package 5. The derived models as well as the procedures to simulate the effects of FLEXINET on business models are presented taking into account the profitability and risk of new or changed business models and the added business value. The goal is to evaluate the profitability of these business models as well as the added business value considering the interplay of all mentioned perspectives on the strategic level as well as the influencing external factors.

The profitability model, helping the end-user to assess the profitability of a specific business model, will be presented as a main achievement. The necessity for such a profitability model within FLEXINET is to enable the user to evaluate the profitability of a specific business model with different level of granularity. Thus, the application of the profitability model within FLEXINET is possible at many different stages of the product lifecycle. At the idea generation or rough planning stage, the application can provide approximate evaluations, but, as the level of detail and accuracy increases by working on the detailed planning or realisation of a business model the application can provide for succinct evaluations.

Furthermore, the evaluation of business models with respect to the corresponding global production network must also consider a variety of external factors and performance indicators. Therefore, in addition to the aforementioned quantitative evaluation of profitability, we have also developed a how to evaluation of business models in a more qualitative way by using both certain and uncertain data and assessing the strategic value. By the normalisation of different indicators and factors and the utilisation within a user-customised fuzzy balanced scorecard framework, we allow the user to do such an evaluation on a qualitative basis, resulting in a quantitative strategic value as an overall score. By drilling down to the different balanced scorecard levels and key performance indicator (KPI) views, the user gets insight of the evaluation aspects and decision support to decide on new or changed business models.

For assessing the risk within a global production network a new fuzzy dynamic inoperability input-output model, based on earlier inoperability models presented within work package 2, has been developed. This model aims at determining the output "inoperability" values for all nodes, considering the propagation of risk throughout a global production network. The model takes into account various risk scenarios relevant to the global production network under consideration and the likelihoods of their occurrences. Thereby, inoperability shows the rate at which the actual level of operation differs from the planned activity level and acts as a measure of risk impact on each node. Different forms for risk related data input are created, including the forms for risk incidents, risk factors, risk scenarios and interdependencies between nodes in a global production network.

Another result is the generic ruleset for business modelling in global production networks. The framework of this ruleset provides different categories of rules, which have been analysed for the requirements within FLEXINET. An example of this is business rules considering different external factors can be applied on a GPN, acting as a constraint and providing the user decision support by selecting target markets or suppliers.

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Purpose and scope

The purpose of this deliverable is to present the design specifications for business modelling in global production networks. Based on the first two deliverables within work package 2 of the FLEXINET project, deliverable D2.1 the conceptual model for business model innovation and D2.2 the rulebook, the proposed design specification is described, as set out in Figure 1.1.

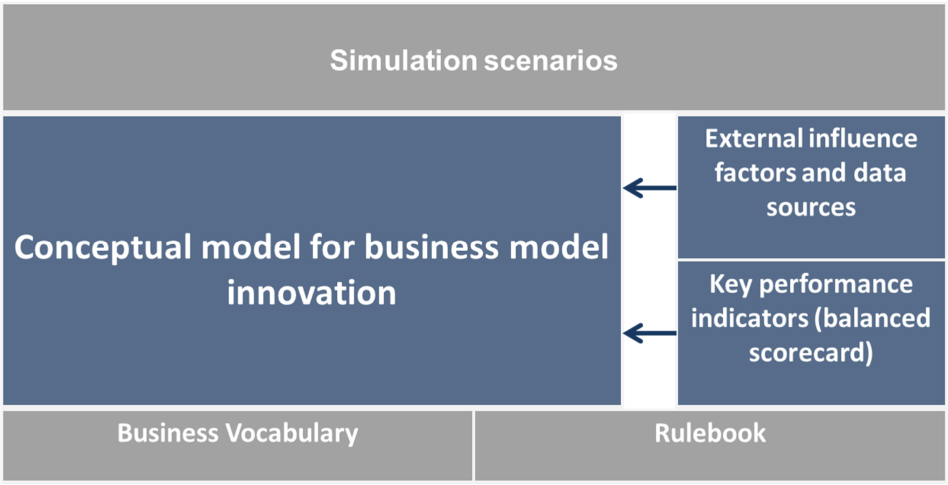


Figure 1-1: Scope of the deliverable

As work within task T2.3, the required design specification set the concepts and models of the aforementioned deliverables into the FLEXINET context as needed for the development of the FLEXINET applications in WP5. The derived models as well as the procedures to simulate the effects of FLEXINET on business models will be presented in this deliverable, especially taking into account the profitability and risk of new or changed business models and the added business value. Thus, task 2.3 aims at evaluating the profitability of these business models as well as the added business value considering the interplay of all mentioned perspectives on the strategic level as well as the influencing external factors.

One main aspect to develop is the proposed procedure to calculate the profitability of business models to enable the user to evaluate new or changed business models. As this evaluation can take place at different stages of the product lifecycle, different levels of granularity have to be possible to cover requirements of both the idea stage and rough planning phase, as well as a more specific evaluation at the detailed planning phase. As the impact of a certain business model for the company is not only relevant in terms of revenue and cost, we also need to consider qualitative aspects, which are covered within the strategic value of a business model. The user needs to get decision support to decide on new or changed business models. By the normalisation of different indicators and factors and their utilisation within a user-customised balanced scorecard framework, we want to enable the user to do such an evaluation on a qualitative basis, resulting in an overall score – the strategic value.

Another necessity to provide the user the best possible decision support is the consideration of risk within a global production network. Of high relevance is the inoperability of specific actors within the network, helping the user to evaluate whether a business model related global production network will remain operable or not, by considering the propagation of risk throughout that network. This deliverable also focusses on the application of constraints within the global production network. The generic ruleset for business modelling in global production networks from D2.2 has been further developed and needs to provide different categories of rules. For example, business rules considering different external factors have to be applied on a GPN, acting as a constraint and providing the user decision support while selecting target markets or supplier.

1.2 Structure

The deliverable is structured as follows:

- Firstly, the state-of-the-art concerning required models from literature is described.
- Secondly, the models to be used within FLEXINET are shown in the second chapter.
- As a main section, the procedures to simulate the effects of FLEXINET on business models with the objective to evaluate the profitability of business models as well as the added business value, are introduced in chapter three. Furthermore, the fuzzy dynamic inoperability input output, for assessing the risk within a global production network, is described.
- An additional section is included for the description of the generic set of business rules with relevance to FLEXINET and global production networks.
- Finally, the conclusion and the explanation of the next steps are described.

2 State-of-the-art section

2.1 Generic Balanced Scorecard approach

With the Balanced Scorecard Robert S. Kaplan and David P. Norton have developed a strategic management tool that converts the company's mission and strategy into precise indicators. The foundation of the indicators is their derivation from the interrelation of cause and effect. Hence, the balanced scorecard expresses the common vision of an organisation. By eliminating the shortcomings of classical performance measurement systems, steering and managing of the business which is implementation-oriented and aligned to the corporate strategy will be enabled (Horvath & Kaufmann, 1998).

The financial indicators of the traditional accounting are supplemented by additional indicators to control the resources and the processes in the company. For that, Kaplan and Norton take (in addition to this financial perspective) the internal business processes perspective, the customer perspective and the learning and growth perspective into account (Kaplan & Norton, 2007). Thus, building such a Balanced Scorecard allows the company to link its strategic goals with its financial budgets (Kaplan & Norton, 1996).

The main goal of the Balanced Scorecard is to translate strategy into action: The practical implementation of the strategy in the operative day-to-day business (Friedag & Schmidt, 2007).

2.1.1 Financial perspective

The classical financial indicators such as ROI (Return on Investment) and EVA (Economic Value-Added) give the management an overview of the economic consequences of past actions. Beyond that, not only financial metrics are recorded in the Balanced Scorecard perspectives, the most important non-financial variables for achieving the long-term targets of earnings are also specified. These variables are the so-called performance drivers. They are assigned to industries, competitive environments and business unit strategies. For the creation of a Balanced Scorecard for each business unit, the management must determine the appropriate financial indicators for the implementation of the business strategy. These indicators vary with the stage of the life cycle of a business unit. In the growth phase, one performance indicator is, for example, the earnings and sales growth, because in this phase of the life cycle earnings growth and a mix good mix of revenues is most important. In the mature phase, profitability ratios such as ROI (Return on Investment), ROCE (Return on Capital Employed) and EVA (Economic Value-Added) should be used, since business depends on cost reduction and productivity improvement. In the phase of saturation, indicators such as cash flow and working capital (net current assets) may be considered, because the use of assets by improving processes in investment projects and the acceleration of the investment process are the topics of the business strategy (Kaplan & Norton, 2007).

2.1.2 Customer perspective

By considering the customer perspective customer and market segments are identified, in which the company wants to be competitive. The business strategy is translated into specific targets of the business unit in terms of target customers and market segments. At the same time the performance of the business unit in these market segments is measured by indicators such as customer satisfaction, customer loyalty, customer acquisition and customer profitability, as well as market and customer proportion of the target segments. With the consideration of this perspective, the focus shifts from the internal point of view to the customer. To complement the reflection of the past with the future, the customers' wishes in the target markets have to be worked out and then an appropriate value proposition has to be developed for the customers. Value propositions serve for loyalty and customer satisfaction. They consist of product and service characteristics such as functionality, quality and price, customer relations such as the quality of the buying experience and personal relationships as well as image and reputation (Kaplan & Norton, 2007).

2.1.3 Internal business process perspective

- The internal perspective identifies those critical processes in the company, which need to be improved by the organisation in the first place.
- New processes that are needed for the achievement of the ideal customer satisfaction are identified.
- The integration of the innovation process as a main part of the internal business process perspective is an innovation of the Balanced Scorecard approach. Firstly, the management has to define a complete value chain in the internal processes: starting with the innovation process, via the existing operational processes (production and delivery of existing products and services to the customer) to the customer service (services for the customer after the purchase of the product or service, e.g. guarantee and maintenance work).

The innovation process includes the identification of current and future customer needs and the development of new solutions to meet these needs by the company. Firstly, the characteristics of the market segments are observed by performing market research. Secondly, products and services are developed, which can cover the target segments. The research and development department has to solve the following tasks:

- basic research for the development of entirely new products and services that create value for the customer.
- applied research to take advantage of existing technologies for the products and services of the next generation.
- focused work in development in order to bring new products and services to market.

With this approach, the company can put considerable emphasis on research, design and development processes to develop new products and services and to enter new markets. The indicators for this are quality, response time, costs and introduction of new products (Kaplan & Norton, 2007).

2.1.4 Learning and growth perspective

As one can see in the abovementioned sections, the financial, customer and internal business perspective define objectives that a company has to provide special services to achieve them, whereas, the learning and growth perspective provides the necessary infrastructure to achieve these objectives. In particular, this means investment in training, information technology and information systems.

The three most important potentials are:

- Employee potential: Employee satisfaction is the driving factor for the two indicators of staff loyalty and employee productivity. Employee satisfaction is a necessary condition for increasing productivity, responsiveness, quality and customer service. Employee satisfaction can, for example, be measured by surveys. After the finding of satisfaction, loyalty and productivity, special situation-specific drivers of learning and development processes are to be identified in the Balanced Scorecard approach and then strengthened through training and refresher programs for employees. One performance indicator can thereby be the strategic task coverage. It indicates the ratio between the number of employees who are qualified for special strategic tasks due to specific skills, and the estimated need for qualified employees. Another performance indicator could be revenue per employee (Kaplan & Norton, 1995).

- Potential in information systems: One of the performance indicators is, for example, the strategic information coverage ratio. It indicates the ratio of the information available and the estimated need for information (e.g. proportion of processes with real-time information about their quality).
- Motivation, empowerment and targeting: The effect of motivated employees who act on their own responsibility is, for example, measured by the number of improvement suggestions per employee, that is, the continued participation of employees to improve the company's performance (Kaplan & Norton, 1995).

In conclusion it becomes clear that strategies for a better business performance require significant investments in people, systems and processes that underpin the business potentials (Kaplan & Norton, 2007).

2.2 Fuzzy Balanced Scorecard

There have been a few applications of fuzzy approaches to model uncertainty in BSC. Yüksel and Dağdeviren (2010) applied fuzzy Analytic Network Process (ANP) for strategic business performance evaluation by considering visions and strategies that use both financial and non-financial indicators in the BSC. ANP weights are acquired from experts using linguistic values and triangular fuzzy numbers. Also, Wu et al. (2009) considered a fuzzy Multi Criteria Decision Making (MCDM) approach for the BSC for banking performance evaluation. Three MCDM approaches, namely SAW, TOPSIS and VICOR, are considered. Again, fuzziness in the criteria weights have been considered by triangular fuzzy numbers and performance values of the criteria are assumed to be crisp. Additionally, Bobillo et al. (2009) proposed a semantic fuzzy expert system which uses an ontology to formally represent the knowledge about balanced score card views and underlying fuzzy IF-THEN rules.

2.3 Meta-modelling and alignment of the Business Model Canvas

The Business Model Canvas (BMC), together with the morphologic box approach of WP4, will be used within FLEXINET for the description and definition of business models for global production networks.

Since the Business Model Canvas is a popular approach for the creation and communication of business models, it is often cited in literature. On one hand it is easy to use due to its characteristic as a high-level approach with a great amount of informality, while on the other hand there is only a low quantity of scientific work available which deals with the application of the approach in a manner of information technology. Thus, in this section we provide an alignment of the BMC, based on the work of Hauksson and Johannesson (Hauksson & Johannesson, 2014). This results in an application of the BMC with the use of the Unified Modelling Language (UML) is presented as the BMC meta-model below.

Recently there has been an increase in interest for business models, despite the general interest in business modelling, there has been a lack of definition of the business model concept and the modelling approach. Hence, the Business Model Ontology (BMO) by Osterwalder (Osterwalder, 2004) was an attempt to define the business model concept. Also, Osterwalder and his colleague Pigneur (Osterwalder & Pigneur, 2011) created the BMC for the creation and visual presentation of business models which has the characteristics as a high-level and semi-formal modelling approach, which is based on the nine building blocks of the BMO.

An advantage of the BMC is its use with a high level of freedom which comes with the disadvantage of a lacking support for computer-aided tools. Despite this fact, support for such computer-aided tools is important since it may help business modellers by providing (amongst other things) consistency checking, modelling constraints and guidelines. Considering the literature, a more formalised and clearer preparation of the BMC in a formalised modelling-language would aid communication between the involved protagonists such as business modellers, requirements engineers, software architects and developers (Hauksson & Johannesson, 2014).

Ostensibly, the Business Model Canvas is a framework, providing categories (building blocks) to let the user autonomously describe their business models. The disadvantage, of course, is the lack of relationships between the different categories. So one has either to adapt, respectively extend or develop relationships between the categories. This has been done in work package 2, as the following Business Model Canvas meta-model will be necessary within FLEXINET, especially for the development of the strategic business model evaluator, programmed within work package 5. To address this, a detailed BMC meta-model is proposed next.

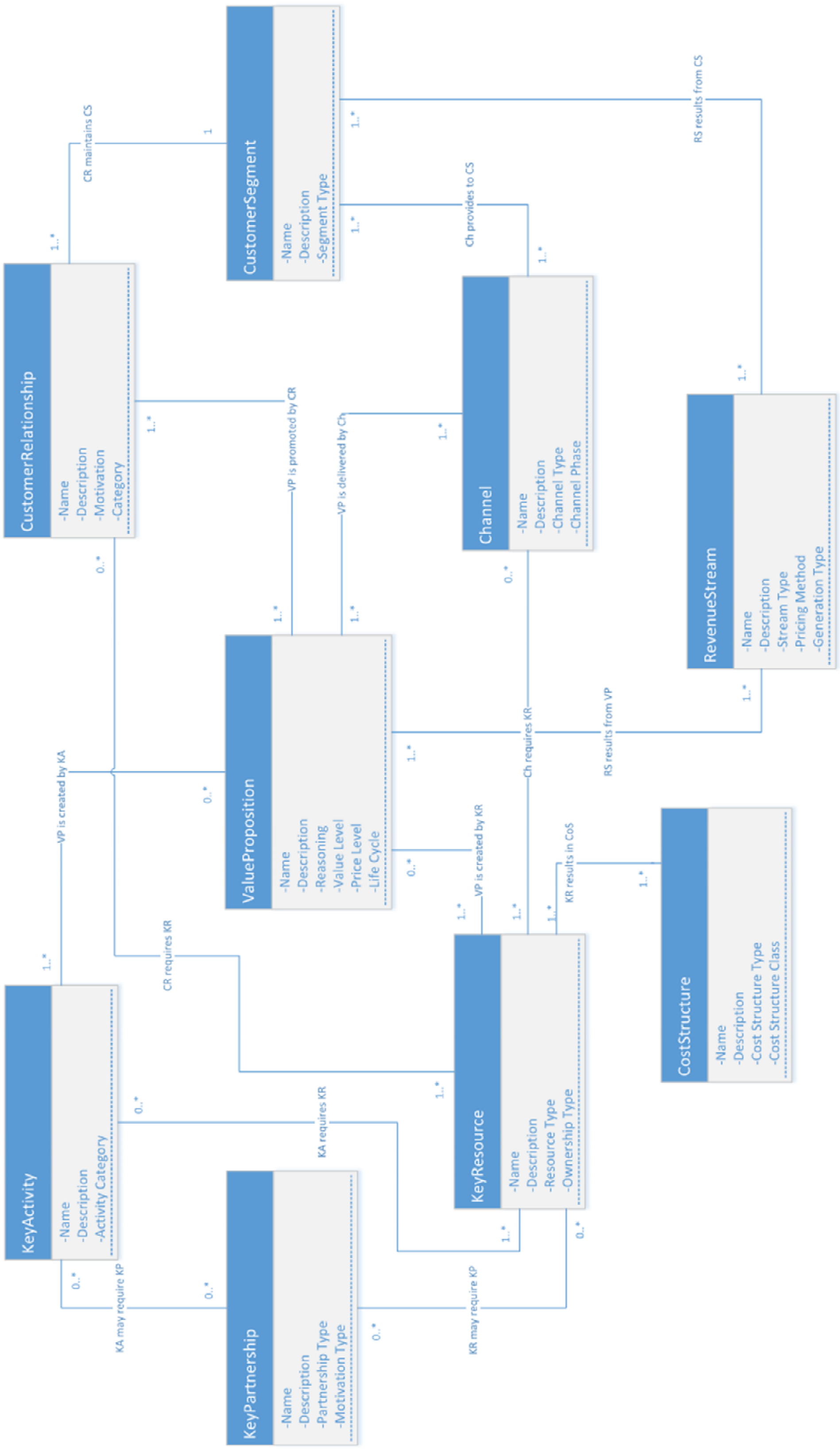
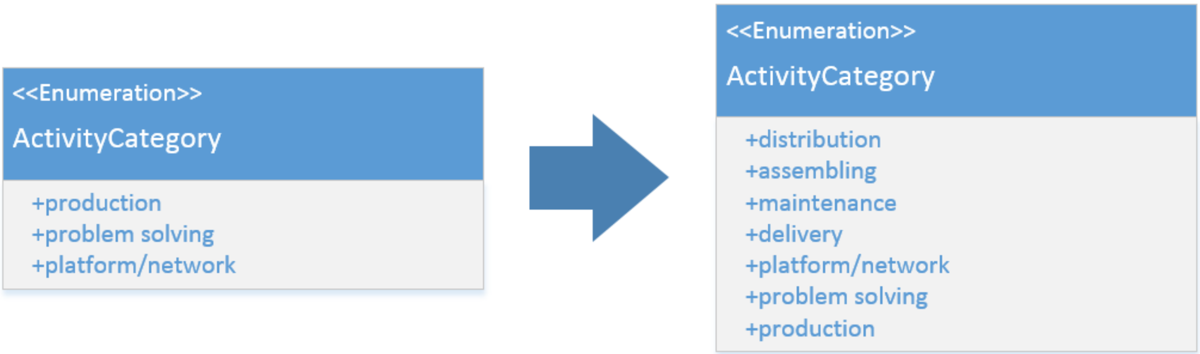


Figure 2-1: Business model canvas meta-model

As depicted in Figure 2-1, the building blocks of the original BMC are Key Activity, Key Partnership, Key Resource, Value Proposition, Cost Structure, Customer Relationship, Customer Segment, Channel and Revenue Stream. Based on these 9 building blocks, the BMC meta-model has been created. Hauksson and Johannesson (2014) do so by adding attributes and relationships as specified in the Business Model Generation Book as well as adding further details from the BMO definition (Hauksson & Johannesson, 2014).

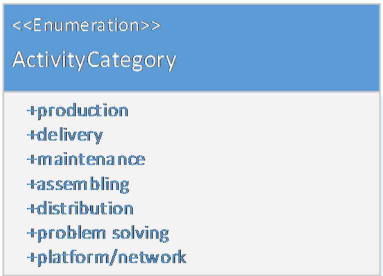
Figure 2-1 above, shows each of the 9 building blocks of the original BMC is represented by a single class, while attributes are added to specify the classes and to represent different types. The multiplicities as stated above are provided by the BMO definition (Hauksson & Johannesson, 2014). Furthermore, all the attributes within the classes are defined by enumerations, except *Name* and *Description* since these two attributes are determined using free text.

In a presentation Hauksson and Johannesson gave at the VMBO 2014 conference in Berlin (Hauksson & Johannesson, 2014), they go into detail in terms of the attributes in the BMC meta-model. Each attribute is defined by a number of enumerations. For example, the attribute PartnershipType within the class KeyPartnership lets the user choose between the enumerations "strategic alliance between non-competitors", "strategic alliance between competitors", "joint ventures" or "buyers-supplier relationship". Moreover, it is important to say that slight adaptions where made regarding the enumerations. Thus, in addition to the given enumerations of the attribute ActivityCategory within the class KeyActivty, we added the enumerations "distribution", "assembling", "maintenance" and "delivery" for a more extensive selection.

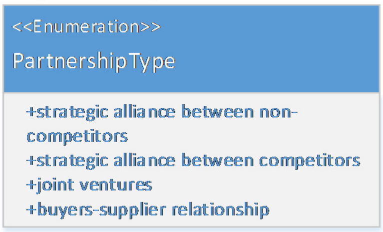


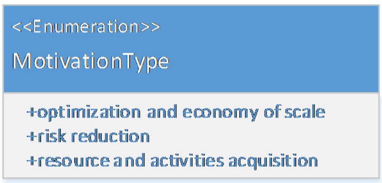
All the enumerations are listed below:

KeyActivity attribute

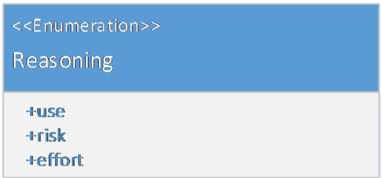


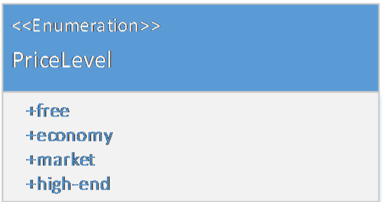
KeyPartnership attributes

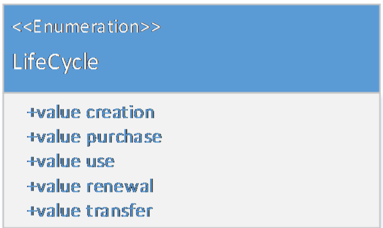




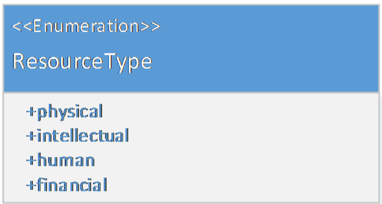
ValueProposition attributes

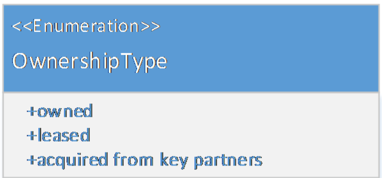




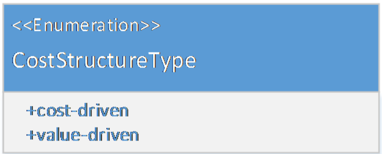


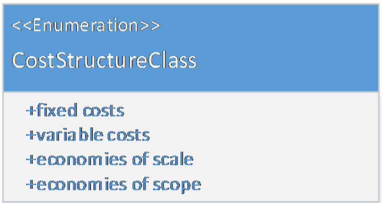
KeyResource attributes

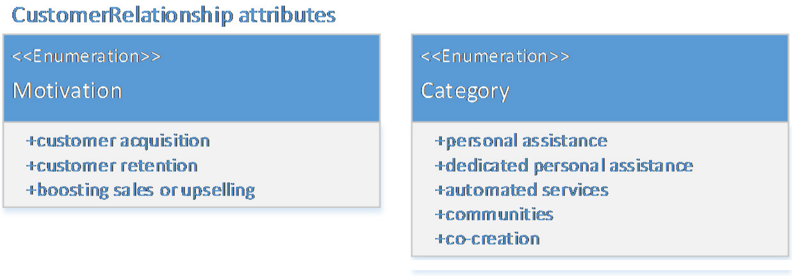




CostStructure attributes







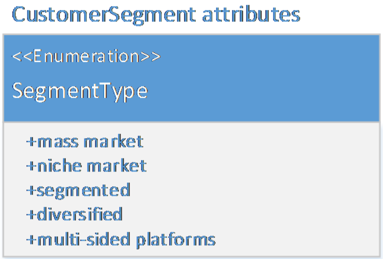
CustomerRelationship attributes

<<Enumeration>>
Motivation

- +customer acquisition
- +customer retention
- +boosting sales or upselling

<<Enumeration>>
Category

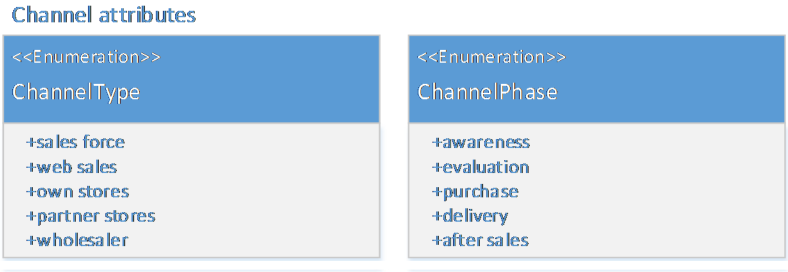
- +personal assistance
- +dedicated personal assistance
- +automated services
- +communities
- +co-creation



CustomerSegment attributes

<<Enumeration>>
SegmentType

- +mass market
- +niche market
- +segmented
- +diversified
- +multi-sided platforms



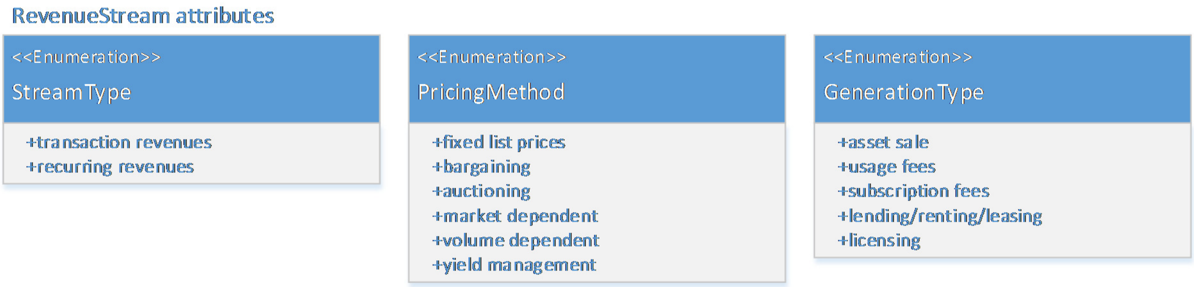
Channel attributes

<<Enumeration>>
ChannelType

- +sales force
- +web sales
- +own stores
- +partner stores
- +wholesaler

<<Enumeration>>
ChannelPhase

- +awareness
- +evaluation
- +purchase
- +delivery
- +after sales



RevenueStream attributes

<<Enumeration>>
StreamType

- +transaction revenues
- +recurring revenues

<<Enumeration>>
PricingMethod

- +fixed list prices
- +bargaining
- +auctioning
- +market dependent
- +volume dependent
- +yield management

<<Enumeration>>
GenerationType

- +asset sale
- +usage fees
- +subscription fees
- +lending/renting/leasing
- +licensing

2.4 Incorporation of e3-value

The e3-Value methodology allows to explore and describe business models from a value perspective (Gordijn, 2002). Its basic concepts are incorporated in the conceptual model for business model innovation as described in Deliverable 2.1. These are actors, value object, value port, value offering, value interface, value exchange, value activity, and market segment.

The basic mechanism for exchanging value objects between actors in a global production networks were developed based on the findings of e3-value (cf. p. 50 of D2.1). In particular, as the foundations of value transactions in the conceptual model are based on e3-value, it is possible to identify business rules for/in GPNs by explicitly studying the basic e3-value concepts in the model.

In detail the following methodology is applied which is extended and adapted from (Jayaweera and Petit, n.d.),

1) Study the value creation activities (cf. p39 in D2.1) of actors and identify the rules that govern these activities.
2) Study the value interface of an actor (in- and out-ports) and identify the rules that govern the sequence of value transfers.
3) Make a structured analysis on the actual value exchange between actors and identify rules that impact all actors that participate in the value exchange (e.g. how to deal with chemical substances, cf. e.g. the European REACH regulation)
4) Study the actual value objects and identify how bundles of value objects that are exchanged need to look like (e.g. money/price and actual delivered good or service).

Having identified the rules they need to be structured and classified according to the proposed categories provided in section 5 of this document. By applying this methodology, rules are heavily intertwined with the concepts of the conceptual model for business model innovation. E.g. rules resulting from step 4) do directly influence the pricing model and cost model.

3 Models

3.1 Overview

The required models, based on the outcome of the first two deliverables of work package 2, are described below and have been used in the development of the FLEXINET applications in WP5.

3.2 Balanced scorecard (BSC) model

The following section introduces the updated balanced scorecard model, which has been explained in deliverable D2.2, showing the changes and extensions that have been made.

The adapted balanced scorecard model consists of different relationships between external factors and indicators, organised within different customised levels (see Figure 3-1). The top-level result is the strategic score or strategic value, composed of five categories. These level 1 categories consist of different indicator groups on the balanced scorecard level 2, the key performance indicators (KPI). Finally, each KPI considers different external factors and / or indicators. The influence of each single factor / indicator, KPI and level 1 view can be changed, so that a user can generate his own evaluation framework.

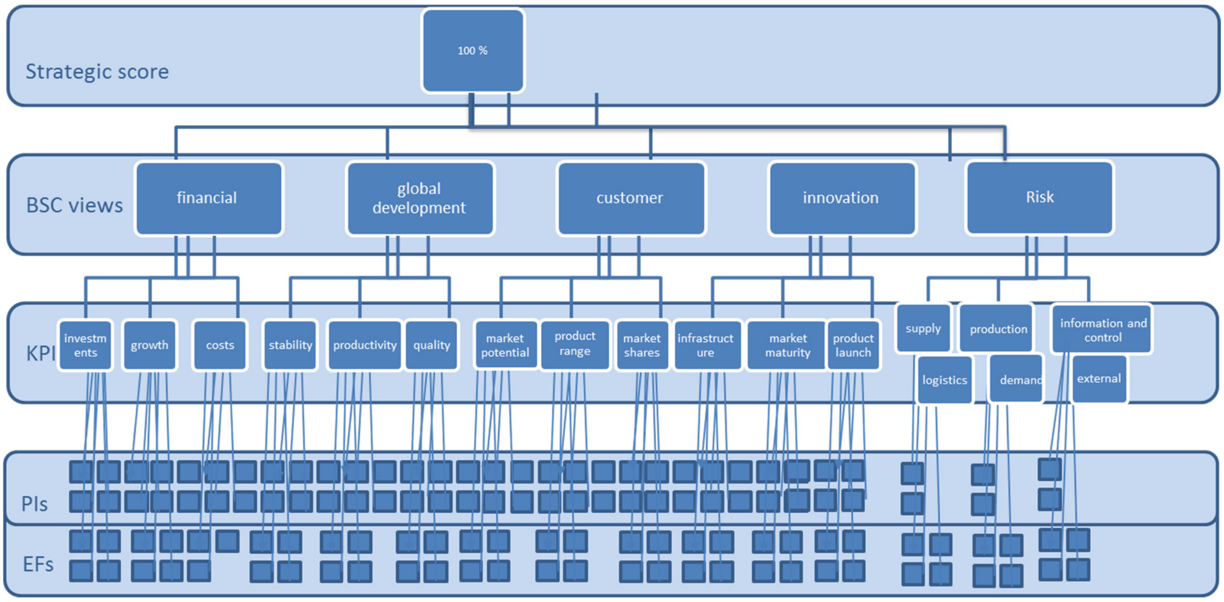


Figure 3-1: Balanced scorecard evaluation model

Taking into account the characteristics of global production networks the BSC consists of classical views, like financial, customer and innovation, together with the adapted views of global development and risk.

3.3 Risk model

The following section introduces the risk model, again explained in deliverable D2.2, setting out the changes and extensions that have been made.

The proposed risk model aims to identify various sources of risks in GPNs and determine the impact of propagation of identified risks on GPNs performance. This risk model can be used to compare alternative GPN configurations at a strategic level with respect to the expected risk.

Risks can be a result of various factors that affect a GPN at regional or actor specific levels. Considering these factors, strategic decision makers should construct a set of risk scenarios that can represent the possible situations that a potential GPN can be affected by. Also, GPN nodes are interconnected and the risks can propagate throughout the network as a result of the interdependencies between nodes. These interdependencies need to be identified based on various criteria. Furthermore, GPN nodes can have different levels of resilience to the risks that determine the speed of nodes' reaction to disruptions. These concepts are introduced in the following sections.

3.3.1 Regional and Actor-specific Risks

Disruptions can arise in the GPN due to many different factors, named as risk factors. To analyse the risk in GPNs, it is necessary to identify and understand these factors and analyse them. These factors can be due to causes that are either external to the GPN or internal operations of the actors. Accordingly, we classify risk factors into two main groups: 1) regional risk factors: that are due to causes external to GPN nodes such as political and social issues and, 2) actor specific risk factors: which are due to issues arising within a specific node.

We classify regional risk factors into different levels of the zone of influence, as presented in Figure 3-2. Also, Table 3-1 shows a few examples of each of these levels.

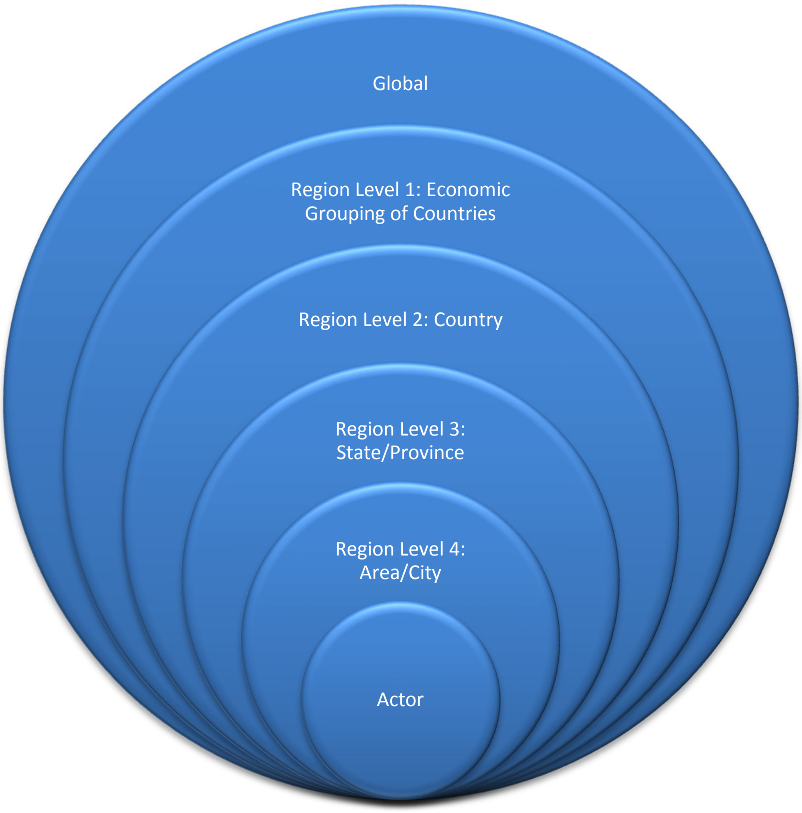


Figure 3-2: Hierarchy of zones of influence for different risk factors

Level	Examples
Global	Changes in Market Trends, Risk of Global Sourcing, …
Region Level 1: Economic Grouping of Countries	Readiness to Adapt Technology, High Cost of Ownership, …
Region Level 2: Country	Import or Export Controls, Political Instability, Price and Currency Risks, …
Region Level 3: State/Province	Legal Requirements' Infringement, Future Regulation, …
Region Level 4: Area/City	Environmental Pollutions, …
Actor	Food Safety Issues, Inadequate Product Service Quality, Financial Instability of Suppliers, …

Table 3-1: Examples of risk factors on different regional levels and actor specific

The level of the risk factor determines which data sources can be utilised to quantify the risk (see Table 3-1). For example, performance indicators such as the company's credit score can be used for actor specific risks, while, Political Risk Index of countries and Heating/Cooling Degree Days of cities, are examples of data sources that can be utilised for regional risks.

3.3.2 Risk Scenario

To evaluate GPN configurations, different situations with regard to risk need to be considered to form a complete picture of GPN's susceptibility to risks. For example, political instability in various regions, financial instability of suppliers, insolvency of clients, etc., can all have different effects on a GPN and need to be considered separately for different GPN configurations. Each of these situations can be modelled as a risk scenario. A risk scenario defines a timeline of perturbations that can affect a GPN, including the risk that causes the perturbation, level of perturbation, starting time and end time. These scenarios need to be defined by the production company, based on historical information and the judgement of experts.

Risk scenarios are defined for a fixed time horizon which determines the length of time that analysis is considered for. We have developed a discrete Fuzzy Dynamic Inoperability Input Output model (IIM) which means each perturbation is defined by an integer start period and also an integer end period. Perturbation values are represented by triangular fuzzy numbers in the range of 0 to 1, 0 representing no perturbation and 1 representing a total disruption of the activities. Also, each scenario is assigned a likelihood value, which is also fuzzy, it determines the likelihood of the scenario as a whole. Perturbation and scenario likelihood describe two different aspects relevant to risks. For example, a risk scenario that describes a machine malfunction can be more likely as opposed to a scenario that represents political and economic issues in a region. However, the latter could have a higher perturbation and impact in comparison to the former.

Causal links between risk factors are explicitly considered in the risk scenario. For example, knowing that the political issues are interdependent with economic risks, this knowledge can be incorporated in the risk scenario relevant to either of the factors by including both factors of perturbation, one original and one interdependent risk factor.

Risk factors and scenarios are all identified and constructed in the Initial Risk Analysis and Documentation Application (IRADA).

3.3.3 Risk Incidents

A key concept of the proposed risk model is a risk incident which represents an actual occurrence of a risk event or disruption in the GPN. These could be incidents related to external events (strikes, weather, etc.), internal issues (machine breakdowns, contamination, etc.) or partners/network (supplier unreliability, customer insolvency, accreditation issues, etc.). The incidents should give a representative view of the risks that are relevant to the company and this information can be used to identify risk factors and determine relevant risk scenarios.

Risk incidents need to be continuously logged by the end-user and used in constructing risk scenarios. Although reporting incidents is a continuous effort that can be contributed to by various company agents, the construction of the risk scenarios based on the recorded incidents is likely to be to be handled by the relevant experts in the company.

Information about risk incidents including the description, timing, type, involved partners, etc. needs to be logged. A complete template for this purpose is provided in Section 4.7.

The logging of incidents is handled by the Initial Risk Analysis and Documentation Application (IRADA).

3.3.4 Interdependencies

A key concept behind the propagation of disruptions within GPNs is the interdependencies that exist between nodes. An interdependency between two nodes recognises that the dependent node relies on the supporting node to function and, as a result, a disruption in the supporting node will affect the dependent in proportion to the rate of interdependency. Two nodes can have many types of interdependency relationships which will all contribute to the interdependency rate.

A list of nine interdependency criteria is suggested to determine the interdependency between two dependent and supporting nodes:

1. Trade volume: the expected level of trade between two nodes. Higher trade volume increases the difficulty of mitigating the impact of risk and, as a result, interdependency has a direct relationship with trade volume. The higher (lower) the trade volume, the higher (lower) the inter dependency.
2. Inventory: the expected level of inventory kept between the nodes. The inventory could be either at dependent node, supporting node, a 3rd party warehouse or a combination of these. Inventory acts as a buffer that reduces the impact of disruption on the dependent node and

the interdependency has an inverse relationship with this criterion; the higher (lower) the inventory, the lower (higher) the interdependency.

3. Substitutability of the product or service: the degree to which the product or service that is being delivered to the dependent node is substitutable. A higher substitutability of the product or service means that, in dire circumstances, it can be substituted with a similar product that has higher availability in the market. As such, there is an inverse relationship with interdependency; the higher (lower) the substitutability, the lower (higher) the interdependency.
4. Substitutability of the supplier/customer: it's the degree to which the supporting node, for example, a supplier or customer, can be substituted by another partner. Higher substitutability allows for replacing the partner, if needed, and as a result, the relationship is inverse. The higher (lower) the substitutability, the lower (higher) the interdependency.
5. Lead-time: the time it takes to receive an order from submitting it. Higher lead-time means the dependent node will realise the existence of disruption later than when the lead-time is lower and it could be slower to react. Interdependency has a direct relationship with led-time; the higher (lower) the lead-time, the higher (lower) the interdependency, as it is most likely to need more time to react to any disruption.
6. Distance: the physical distance between nodes. Similar to lead-time, a longer distance would be reducing the speed of reaction to disruptions by the dependent node. Interdependency has a direct relationship with distance; the higher (lower) the distance, the higher (lower) the interdependency.
7. Information transparency: the amount of information that is being shared by the supporting node with the dependent node. The more information the dependent node receives from the supporting node, the earlier it can recognise signs of a disruption and the faster it can react to them. Interdependency has an inverse relationship with information transparency; the higher (lower) the information transparency, the lower (higher) the interdependency.
8. Collaboration agreement: how well the collaboration agreement is prepared and if it gives enough flexibility to the dependent node. Interdependency has an inverse relationship with collaboration agreement; the more (less) flexible the collaboration agreement, the lower (higher) the interdependency.
9. Compatibility of IT systems: the degree of compatibility of IT systems of the partners. Compatible IT systems allow for better and faster information sharing that improves responses to disruptions and hence, interdependency has an inverse relationship with compatibility of IT systems; the higher (lower) compatibility, the lower (higher) the interdependency.

Interdependencies are determined as part of the Strategic Risk Analysis Application (SRAA).

3.3.5 Resilience

The resilience factor represents the speed of individual node's response to changes in the inoperability. For example, when recovering from a disruption, the resilience factor shows the rate at which the node recovers. The value is between 0 and 1, where 1 represents the fastest response possible and 0 means that there is no response at all.

Resilience has a relationship with the state of risk management practices within the node. The better the risk management is implemented and its procedures are followed, the higher the rate of recovery is for the node.

The resilience factor of a node can be determined by analysing the node's history of managing disruptions and the speed of recovery. The following formula can be used for this purpose (Haimes and Horowitz, 2005):

$$k_i = \frac{-ln\left[\frac{q_s(T)}{q_s(0)}\right]}{T}$$

Where s represents a scenario where the node is recovering from a disruption, T is the number of periods that is needed for the node to reach 99% recovery from the initial disruption, $q_s(T)$ is the level of inoperability at time T and $q_s(0)$ is the initial level of inoperability as a result of the disruption.

This formula is derived from recovery trajectory formulation found in reliability literature (Haimes and Horowitz, 2005) and it is based on the assumption that the interdependency of the node on itself is considerably less than 1 $(a^*_{i,i} \ll 1)$. Such an assumption is not trivial in economic sectors where various actors within a sector can rely on other in the same sector. However, this assumption is valid in the case of GPNs, as the GPN nodes are considered to have no interdependency on themselves $(a^*_{i,i} = 0)$ i.e. they do not use their own output.

3.4 Risk model within BSC

We have already discussed the BSC model and the risk model separately. Now, we combine the two models to constitute a unified model of business evaluation. This is done through the new scorecard for risk that considers various aspects of risk in the business model and scores a configuration based on its susceptibility to risk. The aspects of risk considered at Level 3 are in line with the classification of risks proposed in Deliverable 2.1 and are as follows:

1. Supply
2. Production
3. Demand
4. Information and Control
5. Logistics
6. External

At Level 4, a set of risk scenarios is assigned to each of the risk categories and analysed using the risk model described in Section 3.3 and the method described in Sections 4.6.2 and 4.9. As the inoperability values are already normalised, the best and worst values are considered to be 0 and 1, respectively. All the other calculations are carried out as outlined in Section 4.5.

A list of possible scenarios that can be used in Levels 3 and 4 of Risk BSC are presented in Table 3-2.

Level 3	Level 4
Supply	Inoperability of Scenario 1: Supplier Insolvency
	Inoperability of Scenario 2: Unreliability of Supplier
	Inoperability of Scenario 3: Unavailability of Materials
	Inoperability of Scenario 4: Inadequate Product Quality
Production	Inoperability of Scenario 5: Machine Failure
	Inoperability of Scenario 6: Technological Challenge
	Inoperability of Scenario 7: Machine Modification Issues
Demand	Inoperability of Scenario 8: Insolvency of Customers
	Inoperability of Scenario 9: Unanticipated level of Demand
	Inoperability of Scenario 10: Changes in Market Trends
Information and Control	Inoperability of Scenario 11: Technological Issues
	Inoperability of Scenario 12: Significant Changes to Business Model
Logistics	Inoperability of Scenario 13: Delayed Deliveries
	Inoperability of Scenario 14: Transportation Strike
External	Inoperability of Scenario 15: Political Issues
	Inoperability of Scenario 16: High Inflation
	Inoperability of Scenario 17: Import or Export Controls

Table 3-2: List of example scenarios for Risk BSC Levels 3 and 4

4 Procedures

4.1 Overview

Within the following subsections, the derived procedures to simulate the effects of FLEXINET on business models are presented, especially taking into account the profitability and risk of new or changed business models and the added business value, stated as the strategic value within this deliverable. The main target is to evaluate the profitability of these business models as well as the added business value considering the interplay of all mentioned perspectives on the strategic level as well as the influencing external factors and risk. There are on-going discussions between WP2 and WP5 to support the implementation of these procedures within the Strategic Business Model Evaluator (SBME).

The profitability model, helping the end-user to assess the profitability of a specific business model, is presented as a main achievement. The necessity for such a profitability model within FLEXINET is to enable the user to evaluate the profitability of a specific business model with different levels of granularity. Thus, the application of the profitability model within FLEXINET is possible at many different stages of the product lifecycle. A rough estimate is possible at the idea generation or rough planning stage, whereas the level of detail and accuracy increases by working on the detailed planning or realisation of a business model.

Furthermore, the evaluation of business models with respect to the corresponding global production network must also consider a variety of external factors and performance indicators. Therefore, in addition to the aforementioned quantitative evaluation of profitability, we also developed an evaluation of business models in a more qualitative way to identify an assessment of strategic value. By normalisation of different indicators and factors and its utilisation within a user-customised balanced scorecard framework, we allow the user to undertake an evaluation on a qualitative basis, resulting in the strategic value as an overall score. By drilling down to the different balanced scorecard and key performance indicator (KPI) views the user gets insight of the evaluation aspects and decision support to decide on new or changed business models.

For assessing the risk within a global production network the development of the fuzzy dynamic inoperability input output model, based on earlier work within work package 2, will be introduced. This model aims at determining the output "inoperability" values for all nodes, considering the propagation of risk throughout a global production network. Hereby, inoperability shows the rate at which the actual level of operation differs from the planned activity level and acts as a measure of risk impact on each node.

4.2 Strategic value

Weighting and evaluating new business models with respect to the related global production networks must consider a number of different environmental factors and key performance indicators. Despite the fact that there is a high number of these factors, it is possible to consider only specific parts of the total collection of factors and indicators or to give more evaluation impact to several situation-related indicators, dependent on the specific weightings the user can define for the different levels of the balanced scorecard evaluation model – which are, to specify this, the weightings of the BSC views (level 1), the KPIs (level 2) and the PIs/EFs (level 3). However, for that purpose a flexible and clearly defined evaluation has to be possible, which also has to provide the chance to build up a customised evaluation calculation model.

The strategic value is calculated by the simple addition of the weighted normalised factors, please see the example in deliverable D2.2 or, for a more extensive explanation of the calculation within the edited balanced scorecard evaluation framework, please see chapter 4.10.

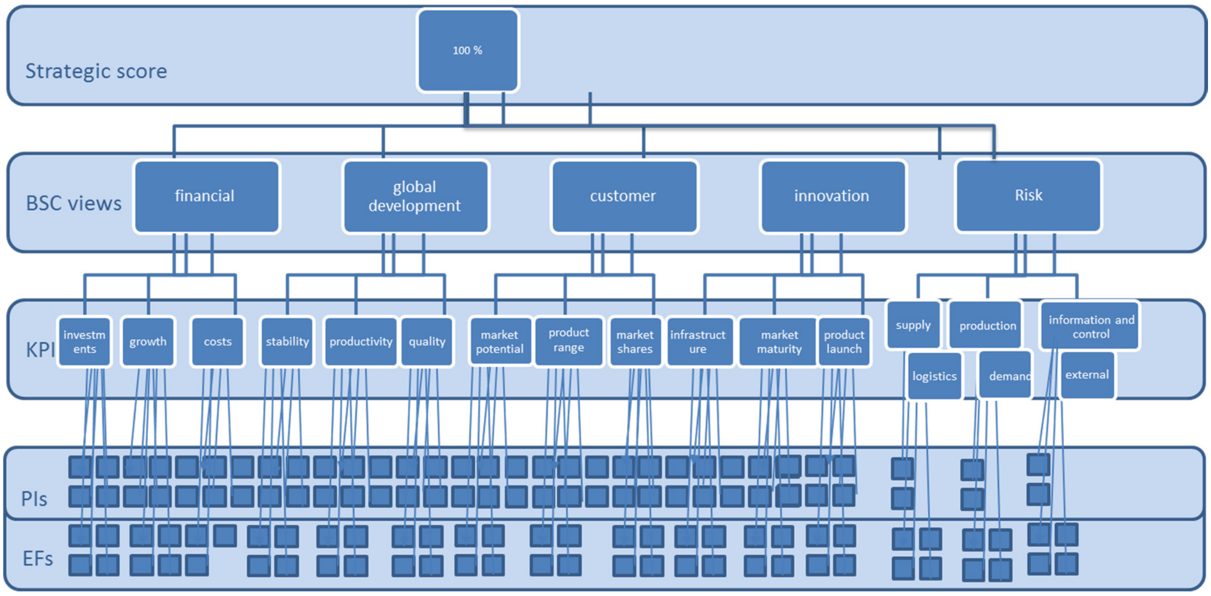


Figure 4-1: Balanced scorecard evaluation model

A set of specific factors for each KPI group (financial, global development, customer, innovation and risk (see Figure 4-1) was collected, together with a corresponding threshold type and threshold value. These are presented in the following subchapters in Table 4-1, Table 4-2, Table 4-3, Table 4-4 and Table 4-5. The threshold values are supposed to be changed and updated by the user.

Within the following tables, in addition to the real value for each KPI, a threshold is required which can be of type max or min based on the KPI's nature. For instance, "Cost to Export" is a max threshold type while the user always wants the lowest possible failure rate and this threshold would be the maximum tolerated value accepted by user. In the last column there is a default threshold value for each KPI stored in the program defined according to the available databases and expert knowledge. The user is able to modify each threshold value based on their requirements. Software will only consider the entered value from the user during the evaluation process.

4.2.1 Financial

KPI	text	Factor / Indicator	Unit	Threshold type	Threshold value
investments	Interest rates, market entry,	Deposit interest rate	%	min	User-input
		Lending interest rate	%	min	User-input

	corruption issues, …	Real interest rate	%	max	User-input
		Foreign direct investment	BoP, current US$	min	User-input
growth	growth rates, GDP, …	GDP	current US$	min	User-input
		GDP growth	annual %	min	User-input
		Household final consumption expenditure per capita growth	annual %	min	User-input
costs	External cost data, such as labour costs, electricity prices, raw material prices, …	Cost to export	US$ per container	max	User-input
		Cost to import	US$ per container	max	User-input
		Pump price for diesel fuel	US$ per litre	max	User-input
		Pump price for gasoline	US$ per litre	max	User-input

Table 4-1: Financial factors

4.2.2 Global development

KPI	text	Factor / Indicator	Unit	Threshold type	Threshold value
stability	Political stability, terrorism indicators, literacy rates, life expectancy, …	Life expectancy at birth, total	years	min	User-input
		Literacy rate, adult total	% of people ages 15 and above	min	User-input
		Literacy rate, youth total	% of people ages 15-24	min	User-input
		CPIA transparency, accountability, and corruption in the public sector rating	1=low to 6=high	max	User-input
productivity	Labour productivity, …, also company-internal data related to productivity	Labour force participation rate for ages 15-24, total (modelled ILO estimate)	%	min	User-input
		Labour force participation rate, total (modelled ILO estimate)	% of total population ages 15+	min	User-input
		Labour force participation rate, total (modelled ILO estimate)	% of total population ages 15-64	min	User-input
quality	Infrastructure data, availability of experts, efficiency data, …, also company-internal data	CO2 emissions	metric tons per capita	min	User-input
		Nitrous oxide emissions	thousand metric tons of CO2 equivalent	min	User-input
		Other greenhouse gas emissions	thousand metric tons of CO2 equivalent	min	User-input

	related to quality	Alternative and nuclear energy	% of total energy use	min	User-input

Table 4-2: Global development factors

4.2.3 Customer

KPI	text	Factor / Indicator	Unit	Threshold type	Threshold value
market potential	Market size, demographic data, purchasing power, market barriers, …	Consumer price index	2010 = 100	min	User-input
		Ease of doing business index	ranking 1 -189, 1=most business-friendly regulations	max	User-input
		Exports of goods and services	% of GDP	min	User-input
		Imports of goods and services	% of GDP	min	User-input
		Industry, value added	% of GDP	min	User-input
		Services, etc., value added	% of GDP	min	User-input
		Population ages 0-14	% of total	min	User-input

		Population ages 15-64	% of total	min	User-input
		High-technology exports	% of manufactured exports	min	User-input
product launch	company-internal data, such as number of offered products in market, …	number of products in market	% of products	min	User-input
market shares	company-internal data, such as market-shares, changes of market shares, competitors relevance, …	market share per product / segment	%	min	User-input
		change in market share	%	min	User-input

Table 4-3: Customer factors

4.2.4 Innovation

KPI	text	Factor / Indicator	Unit	Threshold type	Threshold value
infrastructure	Investment in IT, condition of goods	Access to electricity	% of population	min	User-input
		Access to non-solid fuel	% of population	min	User-input

	traffic, public transport, railway, …	Quality of port infrastructure, WEF	1=extremely underdeveloped to 7=well developed and efficient by international standards	min	User-input
		Railways, goods transported	million ton-km	min	User-input
		Air transport, freight	million ton-km	min	User-input
market maturity	Level of education, Higher education, experts availability, investments in high-tech industry, number of high-tech companies, …	Population ages 0-14	% of total	min	User-input
		Population ages 15-64	% of total	min	User-input
		Listed domestic companies	total	min	User-input
		Labour force with primary education	% of total	min	User-input
		Labour force with secondary education	% of total	min	User-input
		Labour force with tertiary education	% of total	min	User-input
		Technicians in R&D	per million people	min	User-input
product launch	Company-internal	launch of new products	total (company-internal)	min	User-input

	data, such as number of new products launched, company-internal innovation potential evaluation,..	innovation potential	% of new products of total product categories	min	User-input

Table 4-4: Innovation factors

4.2.5 Risk

This is the additional BSC view "risk", containing exemplified risk indicators which may be of relevance for the GPN configuration.

KPI	text	Factor / Indicator	Unit
supply	Supply and supplier related risks	Supplier insolvency	% of inoperability
		Unreliability of supplier	% of inoperability
		Unavailability of materials	% of inoperability
		Inadequate product quality	% of inoperability
production	Risks related to the production process and facilities	Machine failure	% of inoperability
		Technological challenge	% of inoperability
		Machine modification issues	% of inoperability
demand	Risks related to customers, markets and demand	Insolvency of customers	% of inoperability
		Unanticipated level of demand	% of inoperability

		Changes in market trends	% of inoperability
Information and control	Risks related to the information, management, control	Technological issues	% of inoperability
		Significant changes to business model	% of inoperability
logistics	Risks related to transport and logistics of products	Delayed deliveries	% of inoperability
		Transportation strike	% of inoperability
external	Risks due to external events that affect the GPN	Political issues	% of inoperability
		High inflation	% of inoperability
		Import or export controls	% of inoperability

Table 4-5: Risk indicators

Risk view uses the results of the Fuzzy Dynamic Inoperability Input Output Model, described in Section 4.9. The risk indicators mentioned in Table 4-5 are provided as examples and, once customised by the end-user, the risk view will present the risk scenarios defined as described in Section 4.7. The values are the inoperability values determined for the respective scenario and, as they are normalised (between 0 and 1), A maximum threshold value of 1 will be applied. Hence, the risk view of the strategic value does not require any direct user-input.

4.2.6 Environmental Factors Measurement

Considering the comments from the last deliverable review (D2.2), we have included this subsection with the target to clarify the environmental factors measurement against their relevance to our end user needs. Table 4-6 shows the mapping of the use cases to the Social, Technological, Environmental, Economical and Political (STEEP) factors.

Corresponding measures for each factor are provided by the STEEP application. However, users do not have to enter these values by themselves but are supported by crawling the data from external data sources. Exemplary data sources are web services and structured data of the OECD, UN and European Commission. Additionally, only those measures that are of interest for a certain use case need to be captured.

Additionally, Table 4-7, Table 4-8, Table 4-9, Table 4-10 and Table 4-11 set out the measurement of Environmental factors which has been adapted from deliverable D2.2 and updated to match with the expectations from the D2.2 review. The different classes of factors within the table were mapped with the end users use cases as described in D1.3.

- **Indesit**
    - UC 1: Ideas generation and management
    - UC 2: Business model definition
    - UC 3: Product-Service architecture design / check
    - UC 4: Production network configuration
- **Custom Drinks**
    - UC 1: Feasibility study - flexible configuration of production: Risk & economic management
    - UC 2: GPN Configuration and reconfiguration: Decision support systems for selecting the best production network
    - UC 3: Innovation management – product/service co-evolution
- **KSB**
    - UC 1: New application areas for smart drive
    - UC 2: GPN design
    - UC 3: Final decision about GPN

End-user	Class of factors				
Indesit	**Political**	**Social**	**Environmental**	**Economical**	**Technological**
UC 1: Ideas generation and management	x	x	x	x	x
UC 2: Business model definition	x	x	x	x	x
UC 3: Product-Service architecture design / check					
UC 4: Production network configuration	x			x	x
Custom Drinks	**Political**	**Social**	**Environmental**	**Economical**	**Technological**
UC 1: Feasibility study - flexible configuration of production: Risk & economic management	x	x	x	x	x
UC 2: GPN Configuration and reconfiguration: Decision support systems for selecting the best production network	x			x	x

UC 3: Innovation management – product/service co-evolution		x		x	

KSB	**Political**	**Social**	**Environmental**	**Economical**	**Technological**
UC 1: New application areas for smart drive	x	x	x	x	x
UC 2: GPN design	x		x	x	x
UC 3: Final decision about GPN	x	x	x	x	x

Table 4-6: Use cases mapped to factor classes

Class	**Factor**	**Measure**	**Type**	**Relevance to use-case**		
Political factors				**Indesit**	**Custom Drinks**	**KSB**
	Economic policies	Quantitative	% Tax on income, Percentage value; Scale 1-7, Total tax rate; Scale 1-7, Number of procedures required to start a business	**UC 1** **UC 2** **-** **UC 4**	**UC 1** **UC 2** **-** **-**	**UC 1** **UC 2** **UC 3** **-**
	Tax policy	Quantitative	% Tax on goods and services, Percentage value; % Tax on corporate profits, Percentage value			
	Government efficiency	Quantitative	Scale 1-7, Burden of government regulation; Scale 1-7, Efficiency of legal framework in challenging regulations			
	Trade policies	Qualitative	Degree of regulation high-medium-low			
		Quantitative	Scale 1-7, Trade tariffs			
	Trade restrictions	Qualitative	Yes / No			
		Quantitative	Scale 1-7, Prevalence of trade barriers			
	Tariffs	Quantitative	Scale 1-7, Trade tariffs			
	Trade Unions	Qualitative	Yes/No			
	Infrastructure	Quantitative	Scale 1-7, Quality of overall Infrastructure			
	Public transportation	Quantitative	Scale 1-7, Quality of railroad infrastructure; Scale 1-7, Quality of air transport infrastructure			
	Highways	Quantitative	Scale 1-7, Quality of roads			

Table 4-7: Political factors measurement

	Water and energy infrastructure	Qualitative	Good-average-bad		
	Communication and postal services	Qualitative	Good-average-bad		
	Education	Qualitative	Good-average-bad		
		Quantitative	Scale 1-7, Primary education; Scale 1-7, Higher education and training; Scale 1-7, Quality of education		
	Public Health	Qualitative	Good-average-bad		
		Quantitative	Scale 1-7, Health; Scale 1-7, Life expectancy		
	Political stability	Quantitative	Scale 1-7, Institutions security		
	Government funded research Funding, grants and initiatives	Qualitative	Investment: High-medium-low		
		Quantitative	Scale 1-7, R&D Innovation; Scale 1-7, Capacity for innovation		
	International organisations	Qualitative	Yes/no		
	Lobbying/pressure groups	Qualitative	Impact: High-medium-low		
		Quantitative	Scale 1-7, Effectiveness of anti-monopoly policy		
	Home market	Qualitative	Impact: High-medium-low		

Class	Factor	Measure	Type	Relevance to use-case		
Social Factors				Indesit	Custom Drinks	KSB
	Culture	Qualitative	High-medium-low	**UC 1** **UC 2** - -	**UC 1** - -	**UC 1** - **UC 3**
	Health consciousness	Qualitative	High-medium-low			
		Quantitative	Scale 1-7, Life expectancy			
	Demographics	Quantitative	Average age			
	Social mobility	Qualitative	High-medium-low			
		Quantitative	Scale 1-7, Quality of overall mobility			
	Career attitudes	Qualitative	Sparse - available			
	Population growth rates	Qualitative	High-medium-low			
		Quantitative	Percentage value			
	Living standard	Qualitative	High-medium-low			
	Quality of life	Quantitative	Percentage value, Satisfaction			
	Leisure facilities	Qualitative	Good-average-bad			
	Security	Qualitative	High-medium-low			
	Climate change	Qualitative	Affected-unaffected			

Table 4-8: Social factors measurement

Class	Factor	Measure	Type	Relevance to use-case		
Environmental Factors				**Indesit**	**Custom Drinks**	**KSB**
	Weather	Qualitative	Good-average-bad	**UC 1** **UC 2** **-** **-**	**UC 1** **-** **-**	**UC 1** **UC 2** **UC 3**
	Climate	Qualitative	Good-average-bad			
	Environmental issues	Qualitative	Yes / No			
	Energy consumption	Qualitative	High-medium-low			
	Infrastructure	Qualitative	Good-average-bad			

Table 4-9: Environmental factors measurement

Class	Factor	Measure	Type	Relevance to use-case		
Economic Factors				**Indesit**	**Custom Drinks**	**KSB**
	Economic growth	Quantitative	Percentage value, Growth rate; Scale 1-7, Home market growth	**UC 1** **UC 2** **-** **UC 4**	**UC 1** **UC 2** **-**	**UC 1** **UC 2** **UC 3**
	Interest rate	Quantitative	Percentage Value, Average interest rate			
	Inflation	Quantitative	Percentage value, Inflation rate			
	Exchange rate	Qualitative	Overvalued-undervalued			
	Labour market	Quantitative	Scale 1-7, Labour market efficiency; Scale 1-7, Cooperation in labour-employer relations			

	Labour market size	Quantitative	Percentage value, labour capacity to total population		
	Unemployment rate	Quantitative	Percentage value, unemployment rate		
	Education level/ human capital	Quantitative	Scale 1-7, Primary education; Scale 1-7, Higher education and training; Scale 1-7, Quality of education		
	Labour productivity	Quantitative	Scale 1-7, Labour productivity		
	Labour costs	Quantitative	Scale 1-7, Labour pay		
	Purchasing power	Quantitative	Percentage value, Average available income for consumption		
	Financial sector	Quantitative	Scale 1-7, Financial market development; Scale 1-7, Trustworthiness and confidence		
	Competition/ market concentration	Qualitative	High-medium-low		
		Quantitative	Scale 1-7, Intensity of local competition; Scale 1-7, Domestic competition		
	Economy as a whole	Quantitative	Scale 1-7, Economic environment		
	Home economy situation	Quantitative	Scale 1-7, Domestic competition; Scale 1-7, Extent of market dominance		
	Home economy trends	Quantitative	Scale 1-7, Technological adoption; Scale 1-7, Availability of latest technologies		
	Business cycles	Qualitative	Boom/recession		
	Overseas economies and trends	Quantitative	Scale 1-7, Foreign competition		
	Taxation	Qualitative	Good-average-bad		

	General taxation issues	Quantitative	Percentage value, tax on personal income		
			Percentage value, tax on goods and services		
			Percentage value, tax on corporate profits		
	International trade	Quantitative	Scale 1-7, Imports as a percentage of GDP		
	Consumer confidence	Qualitative	Up-stable-down		
		Quantitative	Scale 1-7, Quality of demand conditions; Scale 1-7, Degree of customer orientation; Scale 1-7, Buyer sophistication		

Table 4-10: Economic factors measurement

Class	**Factor**	**Measure**	**Type**	**Relevance to use-case**		
Technological Factors				**Indesit**	**Custom Drinks**	**KSB**
	R&D activities	Qualitative	High-medium-low	**UC 1** **UC 2** **-** **UC 4**	**UC 1** **UC 2** **-**	**UC 1** **UC 2** **UC 3**
		Quantitative	Scale 1-7, Technological readiness			
	Automation	Qualitative	High-medium-low			
	Technology incentives	Qualitative	High-medium-low			
	Manufacturing maturity and capacity	Quantitative	Scale 1-7, Technological adoption; Scale 1-7, Firm-level technology absorption; Scale 1-7, FDI and technology transfer			

Table 4-11: Technological factors measurement

	Information and communications	Qualitative	High-medium-low		
	Global communications	Qualitative	High-medium-low		
	Licensing	Qualitative	High-medium-low		
		Quantitative	Scale 1-7, Strength of investor protection		
	Intellectual property issues	Qualitative	Yes/no		
		Quantitative	Scale 1-7, Intellectual property protection; Scale 1-7, Property rights		

4.3 Profitability

Based on the canvas framework for business model generation (see Figure 4-2), the procedure for assessing the profitability of a business model is described. As the business model canvas is basically a framework, providing categories (building blocks) to let the user autonomously describe their business models, it has the disadvantage of missing relationships between these different categories. User input in terms of cost structure and revenue streams needs to build the basis for profitability assessment.

The required attributes and details for the profitability assessment were developed within the past task 2.3. This profitability assessment procedure, helping the end-user to assess the profitability of a specific business model, will be presented as a main achievement. The necessity for such a profitability model within FLEXINET is to enable the user to evaluate the profitability of a specific business model with different levels of granularity.

Thus, the application of the profitability model within FLEXINET is possible at many different stages of the product lifecycle. A rough estimate is possible at the rough planning stage, whereas the level of detail and accuracy increases by working at a more detailed business planning level. The implementation of this profitability assessment will be part of the work in WP5, especially for the strategic business model evaluator application (SBME).

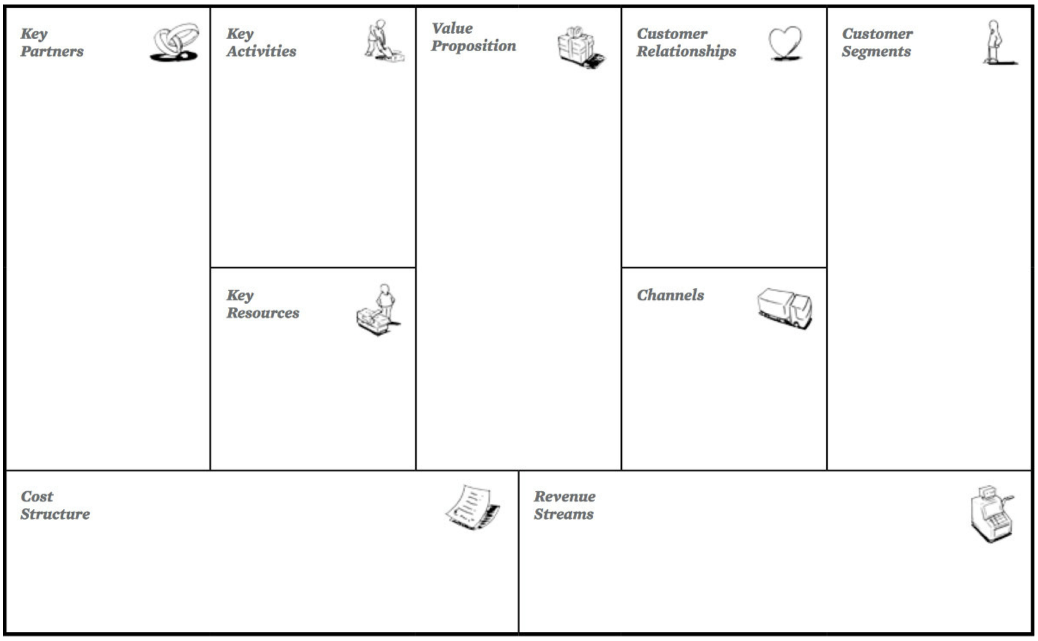


Figure 4-2: Business model canvas framework

Assessing the profitability of a business model (described in morphological box /canvas structure) is made with the help of different models (as set out in Figure 4-3) in particular:

- Profitability model
- Revenue model
- Pricing model
- Cost model

This uses user-generated input, based on assumptions to estimated revenue structure, pricing characteristics and cost structure of the product/service to enable a profitability evaluation.

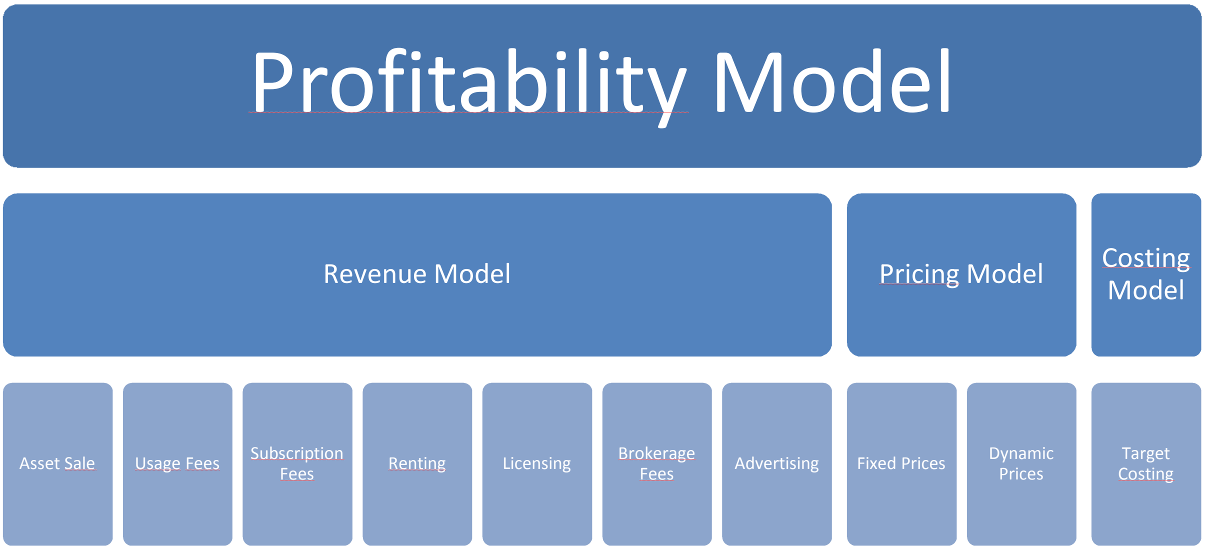


Figure 4-3: Profitability model overview

On the first level, the profitability model is sub-classified into the revenue model, the pricing model and the costing model. The revenue model defines the values the customer is willing to pay for and thus, how the pricing of the product occurs and how value is generated. The pricing model is directly linked with the revenue model as one can see in Figure 4-4 of the following chapter. The pricing model defines how the price of the value object with which the organisation earns money is determined. The costing model is a top-down-approach, fixing the overall costs of a product.

4.3.1 Revenue model

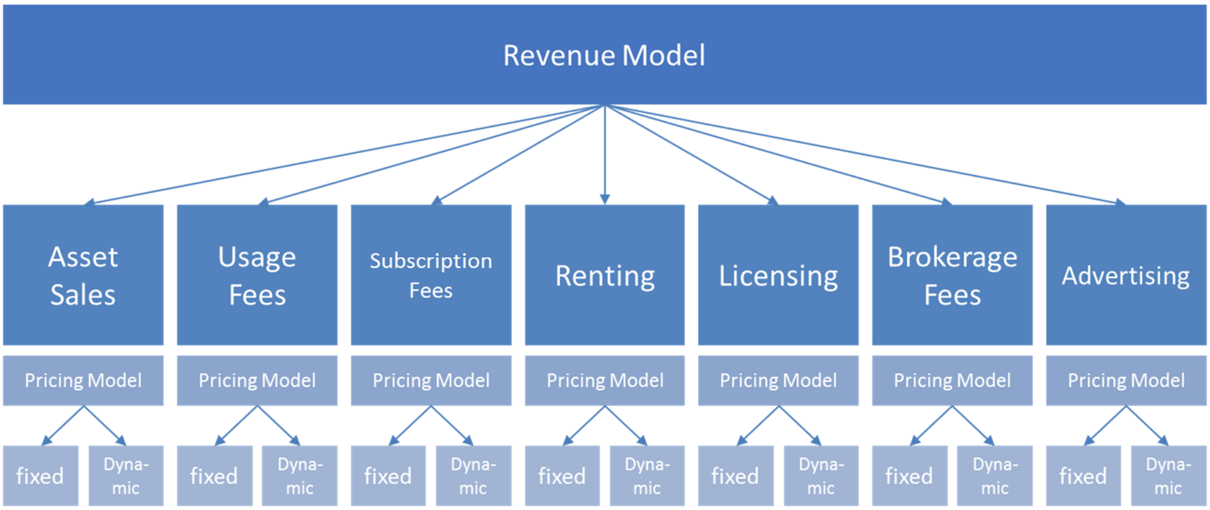


Figure 4-4: Revenue model overview

4.3.1.1 Asset sales

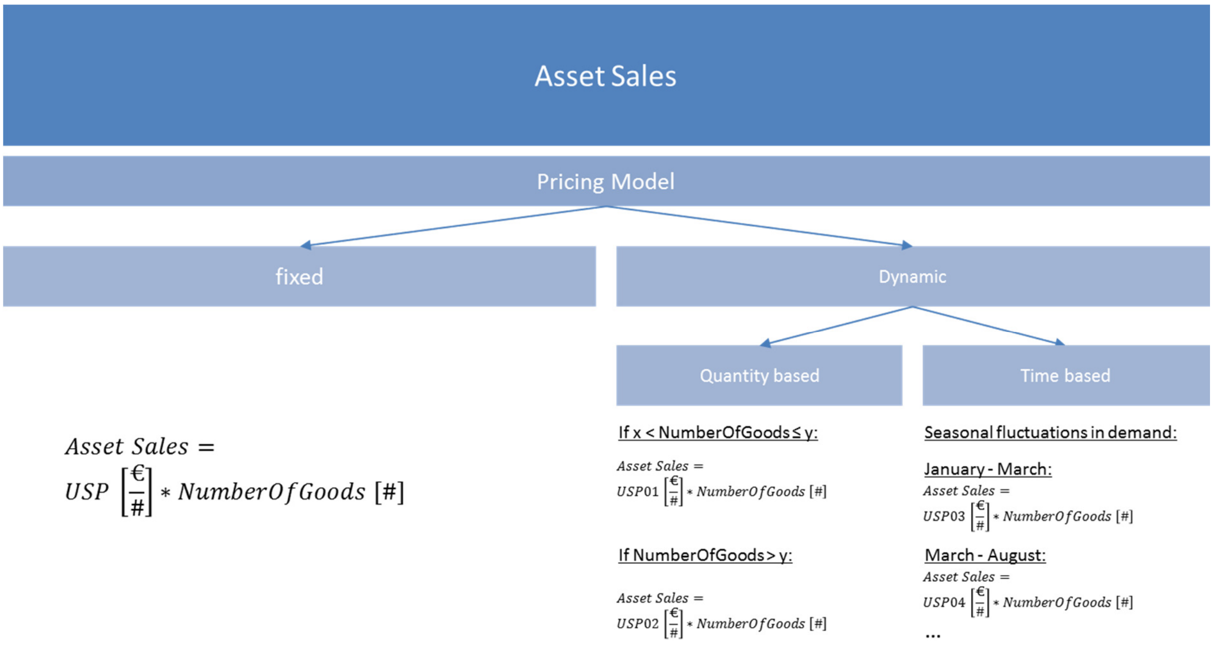


Figure 4-5: Revenue model for asset sales

Asset sales is the most common revenue stream (see Figure 4-5). It is the selling of the ownership of physical goods. Since the pricing model is directly linked with the revenue model, the pricing model states how the price of the value objects of the revenue streams are generated. These prices can be of fixed or dynamic nature and will be more precisely explained in two subchapters later. In fixed pricing, the price of an asset sale is defined by the unit sales price (USP, in €/quantity) times the Number of goods (quantity).

Dynamic pricing is again sub-classified in a quantity based and in a time based view. The quantity based view defines the price by the quantity of the value object the customer orders. Hence, if the customer orders a quantity of the value object in excess of y, the unit sales price (USP02) is different to the unit sales price when the quantity is below or equals y. In this matter, quantity discounts can be implemented. The time based view will be explained in a separate subchapter.

4.3.1.2 Usage fees

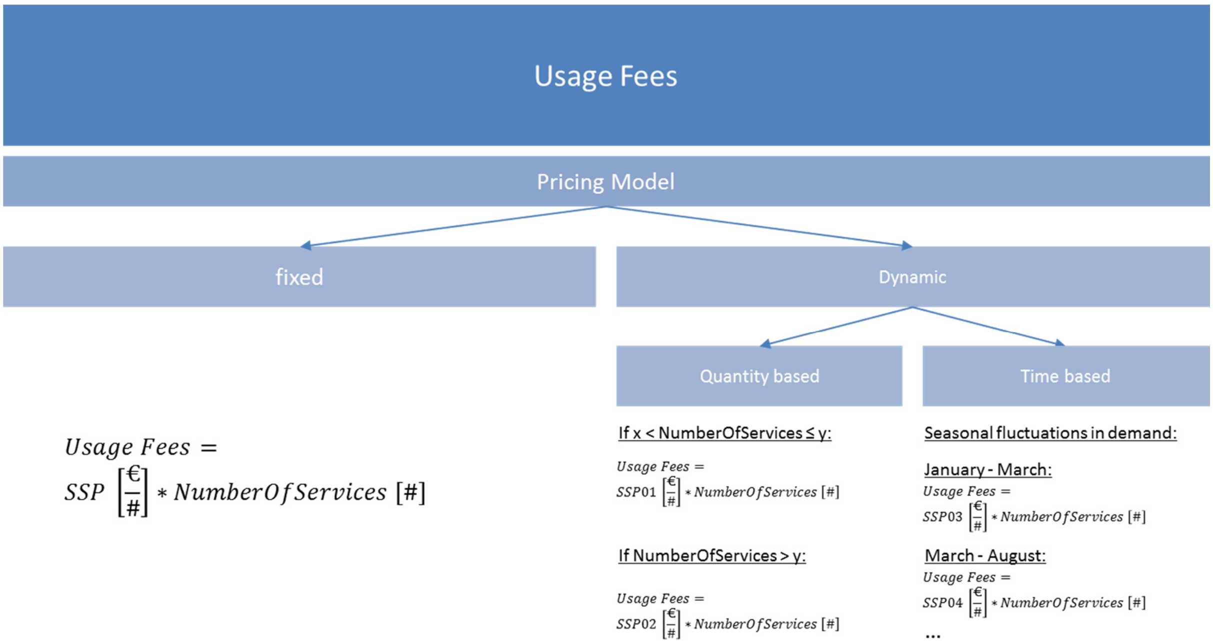


Figure 4-6: Revenue model for usage fees

Another common revenue stream is usage fees as shown in Figure 4-6. This source of revenue is generated by selling the usage of a specific service. One can see the linkage of the pricing and the revenue model in this view as well, since prices can again be of fixed or dynamic nature. In fixed pricing, the price of the usage of a service is defined by the service sales price (SSP, in €/quantity) times the Number of services (quantity).

Dynamic pricing is again sub-classified in a quantity based and in a time based view. The quantity based view defines the price of a service by the quantity of the service the customer consumes. Hence, if the customer orders services in excess of y, the services sales price (SSP02) is different to the service sales price when the quantity is below or equals y. In this matter, quantity discounts can be implemented. The time based view will again be explained in a separate subchapter at the end of this chapter.

4.3.1.3 *Subscription fees*

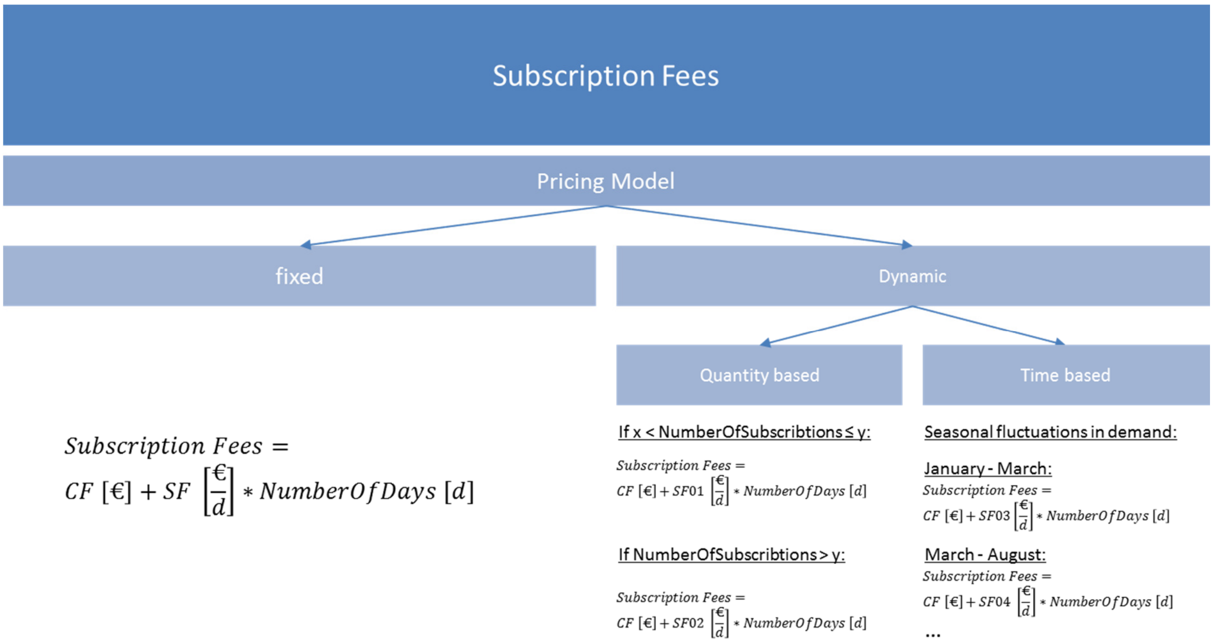


Figure 4-7: Revenue model for subscription fees

The next revenue stream is subscription fees (see Figure 4-7). This source of revenue is achieved by selling a continuous subscription of a specific service to the customer. Pricing in this revenue steam is, just as in the other streams, subdivided in a fixed and a dynamic view. In fixed pricing, the price of the subscription for a service is determined by the conclusion fee (CF, in €) plus the subscription fee (SF, in €/days) times the number of days for which the service is subscribed.

In dynamic pricing, a quantity based and a time based view exists. The quantity based view defines the price of a subscription of a service by the quantity of the subscriptions for which a customer will subscribe. Hence, if the customer subscribes for services in excess of y, the subscription fee (SF02) is different to the subscription fee when the quantity of subscriptions is below or equals y (SF01). In this matter, quantity discounts can be implemented. The time based view will again be explained in a separate subchapter at the end of this chapter.

Note that the possibility to choose a time period (e.g. months or years instead of days) may exist.

4.3.1.4 Renting

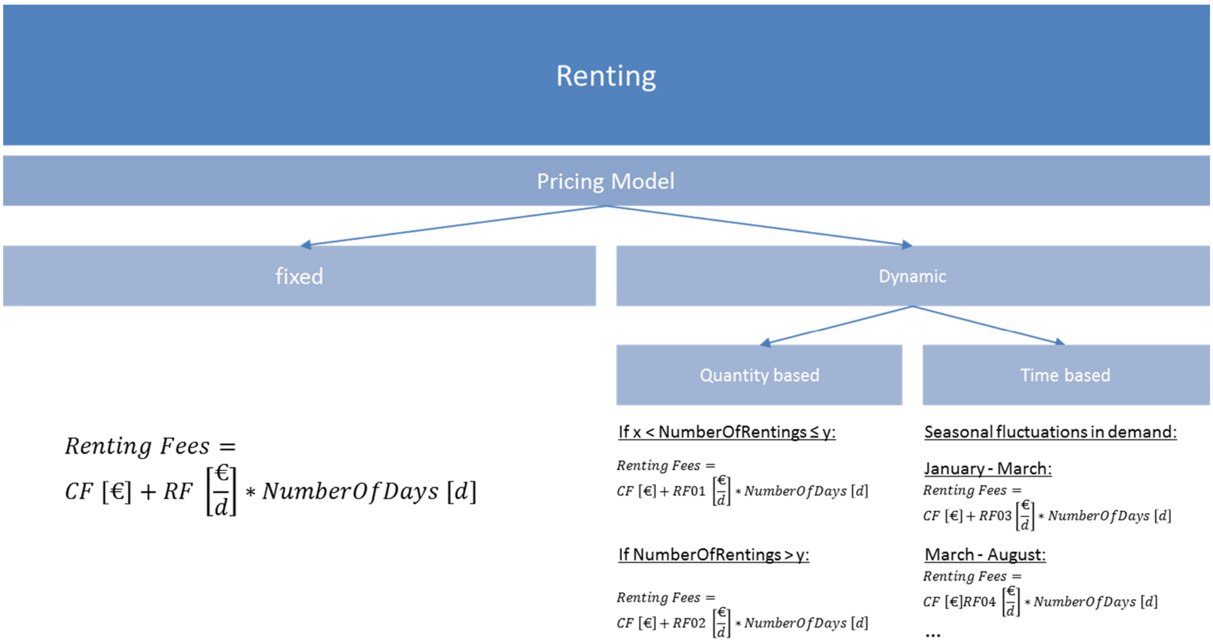


Figure 4-8: Revenue model for renting

The revenue stream for renting (see Figure 4-8) is based on the temporary, exclusive usage right for goods. While this results in recurrent revenue streams for the lender, the benefit for the renter are costs which are temporary and limited in time instead of full costs for the purchase of goods. Just as in the other categories, the pricing model is directly linked with the revenue model, stating how the price of the value object "renting fees" of this revenue stream is generated. These prices can be of fixed or dynamic nature. In fixed pricing, the renting fee is defined by a conclusion fee (CF, in €) plus a renting fee (RF, in €/days) times the number of days the renting is performed.

Dynamic pricing is again sub classified in a quantity based and in a time based view. The quantity based view defines the price by the number of rentings the customer performs. Hence, if the customer orders a quantity of rentings in excess of y, the renting fee (RF02) is different to the renting fee when the quantity is below or equals y (RF01). In this matter, quantity discounts can be implemented. The time based view will be explained in a separate subchapter.

Just as in the subscription fee view, the possibility to choose a time period (e.g. months or years instead of days) exists.

4.3.1.5 Licensing

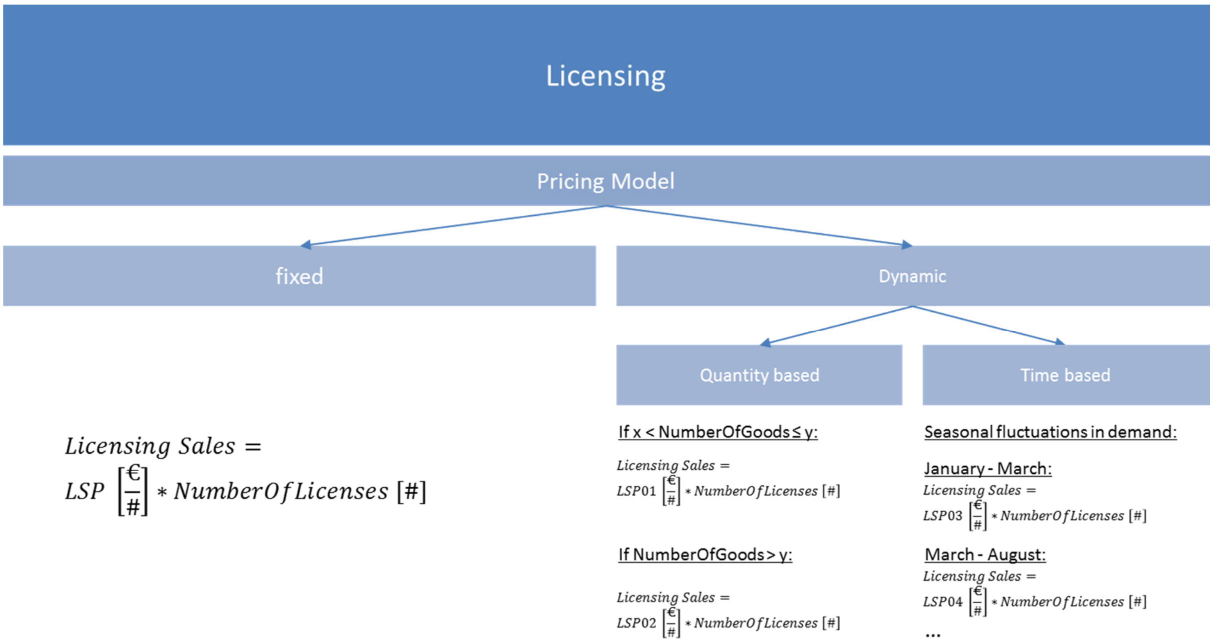


Figure 4-9: Revenue model for licensing

The revenue stream for licensing (see Figure 4-9) is defined as the right of the customer to use a specific intellectual property which is generally protected. One can see the linkage of the pricing and the revenue model in this view as well since prices for licensing can again be of a fixed or a dynamic nature. In fixed pricing, the price of the usage of the intellectual property is defined by the licensing sales price (LSP, in €/quantity) times the number of licenses sold.

Dynamic pricing is divided in a quantity based and in a time based view. The quantity based view defines the price of a service by the quantity of the service the customer consumes. Hence, if the customer orders services in excess of y, the licensing sales price (LSP02) is different to the licensing sales price (LSP02) when the quantity is below or equals y. In this matter, quantity discounts can be implemented. The time based view will again be explained in a separate subchapter at the end of this chapter.

4.3.1.6 *Brokerage fees*

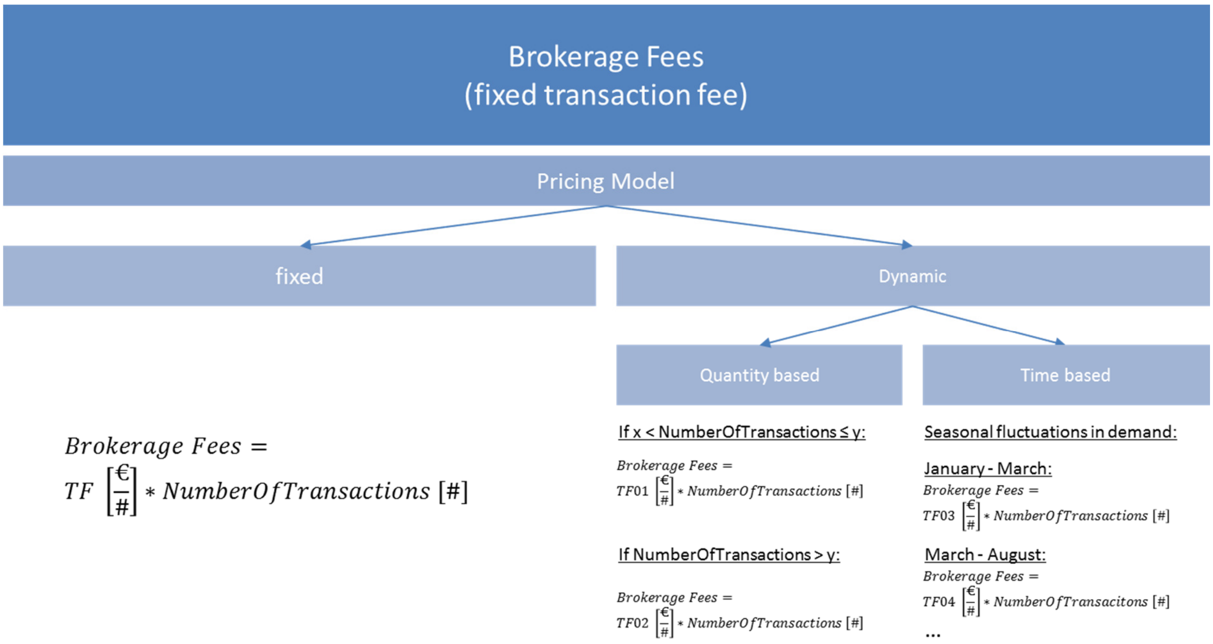


Figure 4-10: Revenue model for fixed brokerage fees

The next revenue stream is brokerage fees. Brokerage fees are a revenue stream that is generated by the brokering of specific services. As one can see in Figure 4-10 and Figure 4-11, brokerage fees can be defined in two different ways: by a fixed transaction fee per transaction or by a transaction rate, depending on the value of the transaction.

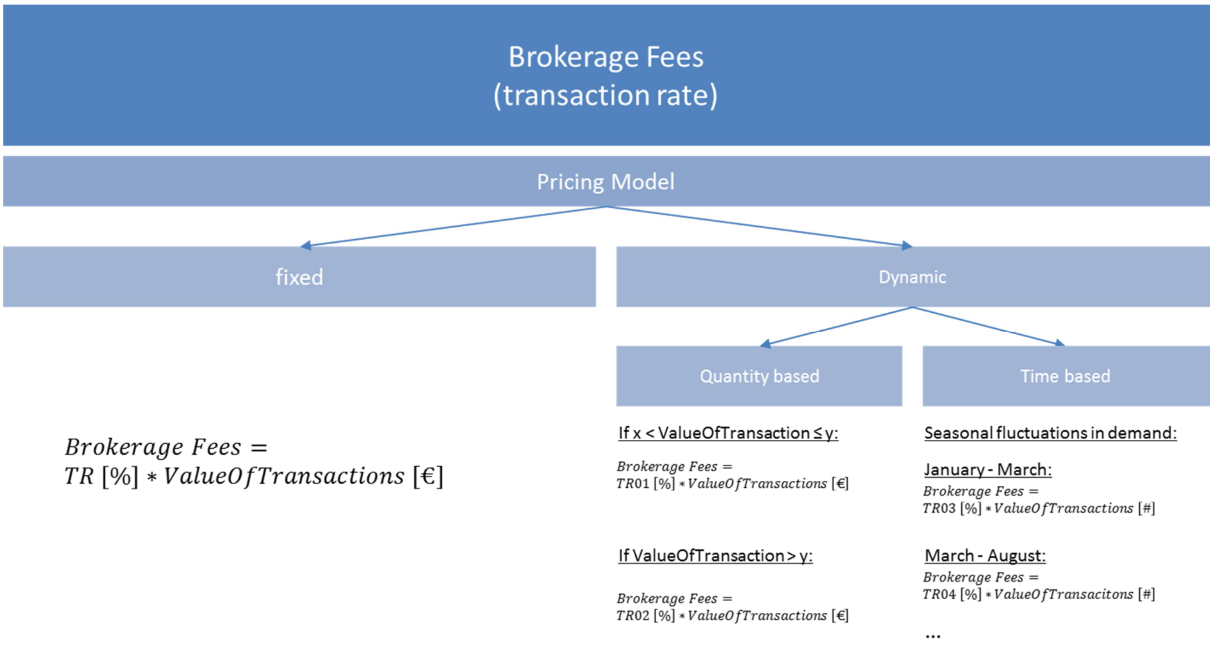


Figure 4-11: Revenue model for partial brokerage fees

Pricing in this revenue steam is, just as in the other streams, subdivided in a fixed and a dynamic view. In fixed pricing, the price of a brokerage is either determined by a transaction fee (TF, in €/quantity) times the number of transactions or by a transaction (in %) times the value of the brokerage (in €).

In dynamic pricing, a quantity based and a time based view exists. The quantity based view defines the fee for a brokerage service either by the quantity of brokerages performed for a customer or by the value of the brokerage performed. In both views discounts in terms of quantity or value of the brokerage can be implemented, with the granting of discounts performed as described in the other value streams. The time based view will again be explained in a separate subchapter at the end of this chapter.

4.3.1.7 Advertising

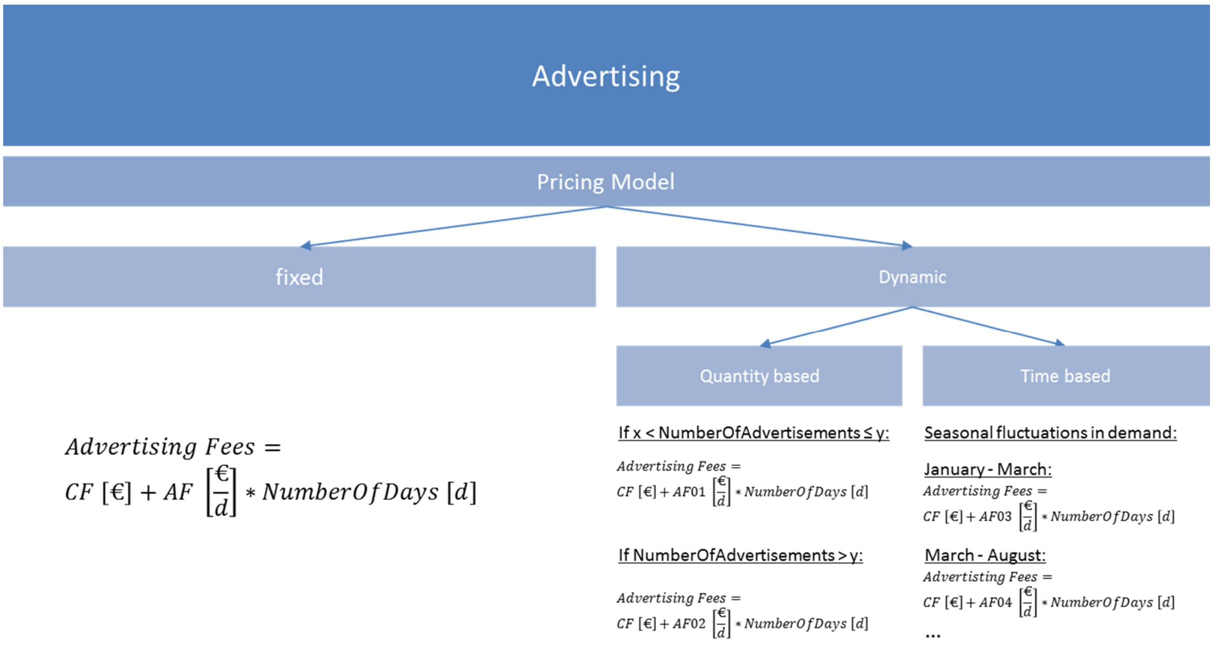


Figure 4-12: Revenue model for advertising

The last revenue stream is for advertising (see Figure 4-12). Revenue in this stream is generated due to the advertisement of specific goods or products. The media industry and the events sector are especially driven by this kind of revenue. Just as in the other categories, the pricing model is directly linked with the revenue model, stating how the price of the value object "advertisement" of this revenue stream is generated. These prices can be of fixed or dynamic nature. In fixed pricing, the advertising fee is defined by a conclusion fee (CF, in €) plus an advertising fee (AF, in €/days) times the number of days the advertising is performed for the customer.

Dynamic pricing is again sub classified in a quantity based and in a time based view. The quantity based view defines the price by the number of advertisements performed for the customer. Hence, if the customer orders a quantity of advertisements in excess of y, the advertising fee (AF02) is different to the advertising fee when the quantity is below or equals y (AF01). In this matter, quantity discounts can be implemented. The time based view will be explained in the next subchapter.

Just as in some of the abovementioned revenue streams, the possibility to choose a time period (e.g. months or years instead of days) exists.

4.3.1.8 Consideration of the time based view

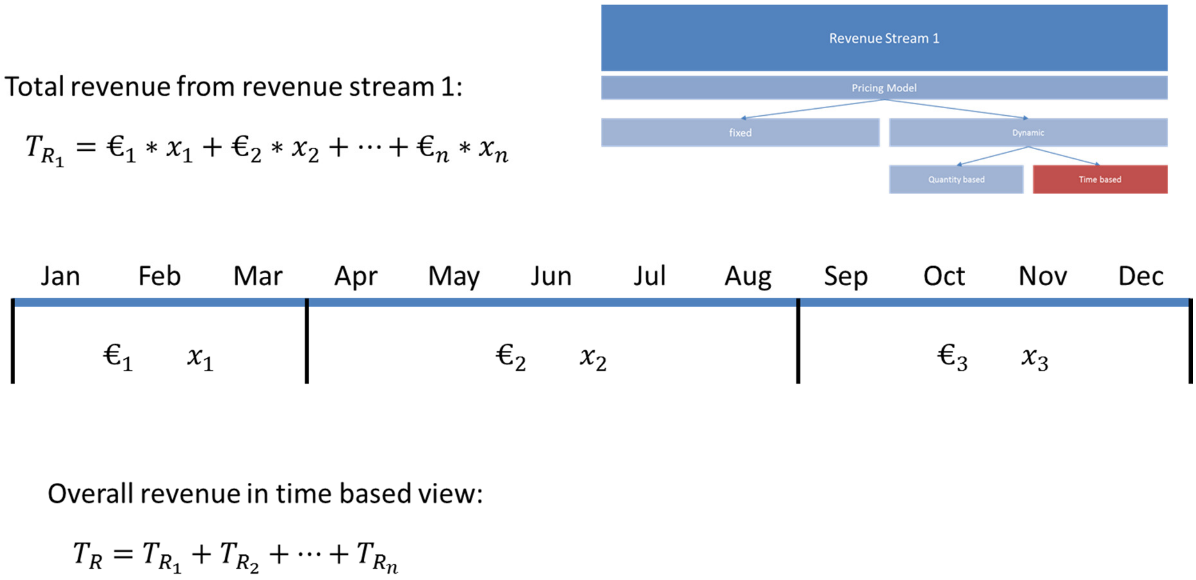


Figure 4-13: Time based view for revenue streams

In this chapter the time based view will be explained for all revenue streams together (see Figure 4-13). Consider seasonal fluctuations in demands occur in a revenue stream which is here called revenue stream one. The seasonal fluctuations in demand result in different prices or fees (depending on the revenue stream) for the value object which is sold (see Figure 4-13 above). Exemplified are three classifications of seasonal demand: January to March, April to August and September to December. Thus, there are three different prices/fees for this revenue stream. Formulated in a general manner, the total revenue of this revenue stream, if the time based view in the dynamic pricing model is considered, is the sum of all single multiplications of the classifications of seasonal demand (price or fee times quantity of value object): $T_{R_1} = €_1 * x_1 + €_2 * x_2 + \cdots + €_n * x_n$. Hence, in the abovementioned example, this would be $T_{R_1} = €_1 * x_1 + €_2 * x_2 + €_3 * x_3$.

Considering every revenue stream that is performed, it results in an overall revenue of: $T_R = T_{R_1} + T_{R_2} + \cdots + T_{R_n}$.

4.3.2 Pricing model

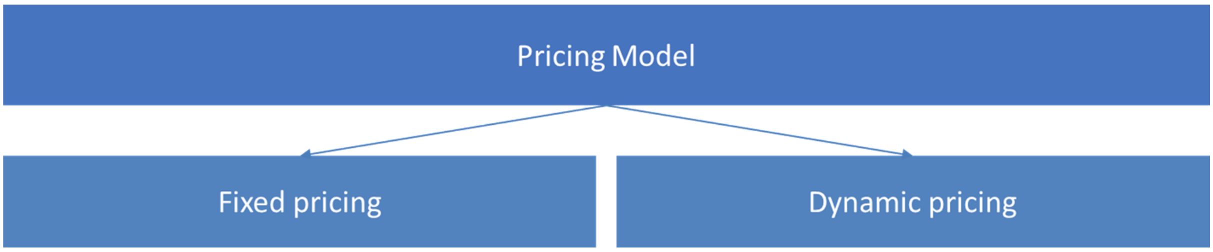


Figure 4-14: Pricing model overview

4.3.2.1 *Fixed pricing*

Fixed pricing is one of the two possibilities of the pricing model (see Figure 4-14). These are prices which are determined in advance, based on statistics. For example, based on the income that has to be accomplished to generate profit. No discounts in pricing are possible, which is a disadvantage for the customer. Nevertheless, an advantage for the customer is that there are also no price increases possible.

4.3.2.2 *Dynamic pricing*

The second possibility in performing pricing in the pricing model are dynamic prices (see Figure 4-14). These are prices which change with the conditions of the market. Dynamic pricing can be of a quantity based or a time based nature. In the quantity based view pricing is performed by the amount of value objects sold, e.g. goods sold or services performed. In the time based view, pricing depends on the demand and supply of the market segment considered, e.g. on seasonal fluctuations in demand. This could result in price drops but also in price increases for the customer.

4.3.3 Costing model

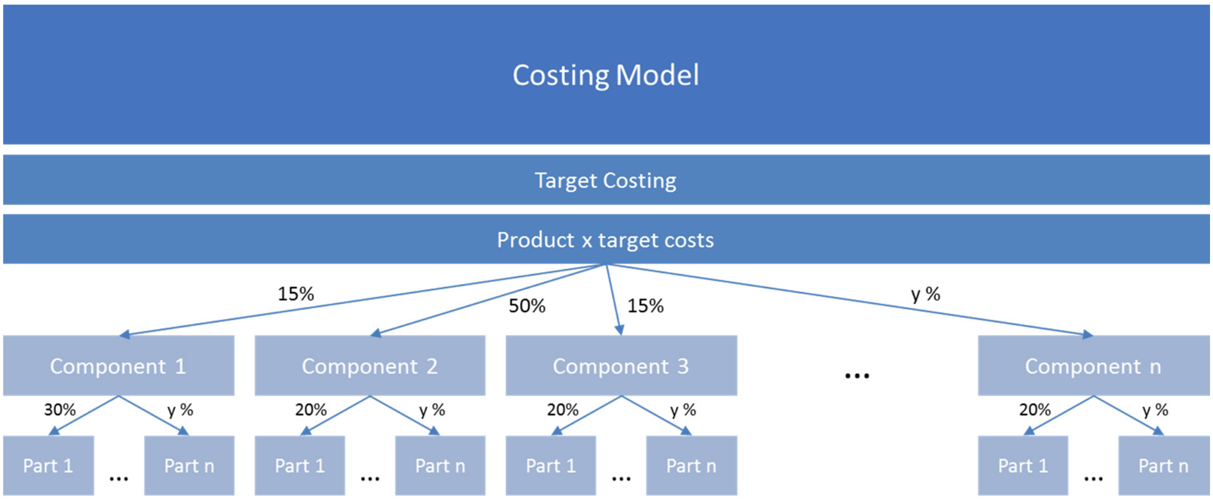


Figure 4-15: Costing model overview

The last model in the profitability model is the costing model (see Figure 4-15). In this view, a top-down-approach is performed, considering target costing for a product which is yet to be developed. This approach focuses on target costs as the maximum amount of costs that can be incurred by a product. Thus, in a top-down-manner, the allowable costs for every component are calculated with an allocation of the share of the total target costs. This is done by reflecting what the share of the component in the total costs of the product should be. On the next level, this allocation of shares is also performed for the different parts of a component.

4.3.3.1 *Cost accounting: Break-even analysis*

The Break-even analysis, also called the cost-volume profit analysis, deals with the question when profits start to be collected. This is the point where the costs equal the revenues. In other words, at this break-even point, the contribution margin equals the fixed costs of the product or the profit equals zero at the break-even point. When the break-even point is exceeded, profits are gained, when it is underrun, the company makes a loss.

For that, the break-even quantity and the break-even revenue are to be determined:

The total costs (C) consists of the fixed (FC) and the variable costs (VC), while the variable costs are the variable costs per production unit (v) times the the production quantity (Q):

$$C = FC + VC = FC + v * Q$$

Next, the revenue (R) is defined as follows, while p is the price per unit of product:

$$R = p * Q$$

The profit (Pr) is the difference between the revenue and the cost:

$$Pr = R - C = p * Q - (FC + v * Q)$$

Since the profit equals zero at the break-even point, the break-even quantity (BEQ) equals the production quantity at the break-even point and is calculated as

$$\begin{aligned} 0 &= p * Q - (FC + v * Q) \\ 0 &= p * Q - FC - v * Q \\ 0 &= Q(p - v) - FC \\ Q &= \frac{FC}{p - v} \\ \rightarrow \quad BEQ &= \frac{FC}{p - v} \end{aligned}$$

Now, for calculating the break-even revenue (BER), we state that the break-even revenue is the revenue at the break-even point. Thus, we use the formula for the revenue as declared above and replace Q by BEQ:

$$\begin{aligned} R &= p * Q \\ R &= p * \frac{FC}{p - v} \\ R &= \frac{FC}{1 - \frac{v}{p}} \\ \rightarrow \quad BER &= \frac{FC}{1 - \frac{v}{p}} \end{aligned}$$

Knowing the break-even quantity and the break-even revenue, a company can now determine and coordinate its operations to cover the operating costs and time the earning of profits, depending on the sales volume and the production level (Alhabeeb, 2012).

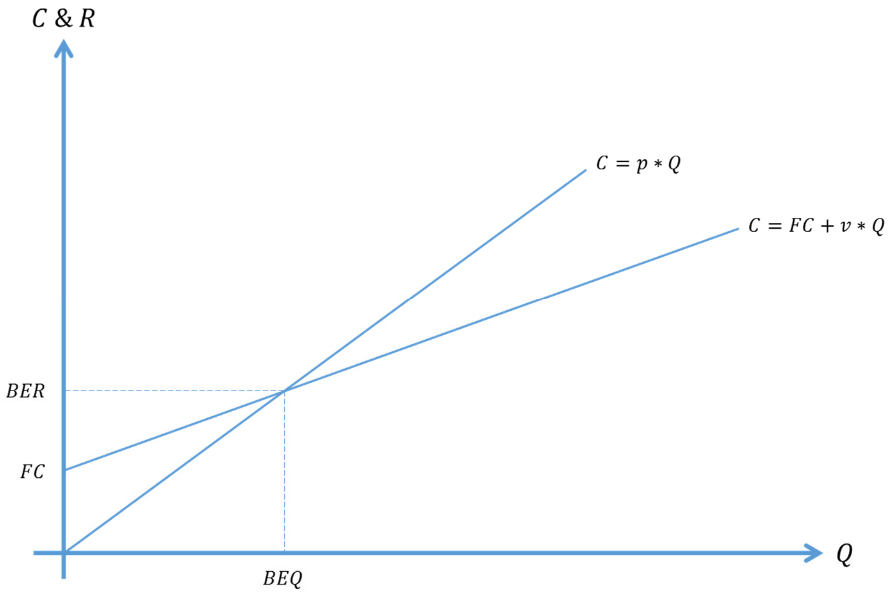


Figure 4-16: Break-even analysis

Applying the break-even analysis (see Figure 4-16) to the profitability model, respectively to the asset sales inside the revenue model, the unit sales price (USP) would equal the price (p) and the number of goods ($NumberOfGoods$) would equal the break-even quantity (BEQ).

Hence, the break-even quantity which is to be calculated to determine the number of goods the company has to sell to start making a profit is:

$$BEQ = \frac{FC}{p - v}$$

$$NumberOfGoods = \frac{FC}{USP - v}$$

The corresponding break-even revenue is:

$$BER = \frac{FC}{1 - \frac{v}{p}}$$

$$BER = \frac{FC}{1 - \frac{v}{USP}}$$

4.3.3.2 Direct and indirect costs

Direct costs occur due to the production of goods. These costs can be directly assigned to one single cost unit, whereas indirect costs might also occur during production processes, but they can only be assigned to cost units due to an indirect cost coding.

Although special direct costs can not directly be assigned to cost units (and thus, they are eventually indirect costs), they can be assigned to an identifiable group of products or a production order. Often they are costs that relate to custom consumer specifications. A distinction is made between special direct production costs and special direct distribution costs. Special direct production costs are, for example, costs for special tools that are only required for a specific product variation, or specific development costs (e.g. initial batch). Special direct distribution costs are, for example, transportation costs to the customer, costs for special packaging, customs duty for international delivery or costs for a separate transportation insurance (Horsch, 2015; Korndörfer, 1980). An overview of direct and indirect costs in provided in Figure 4-17.

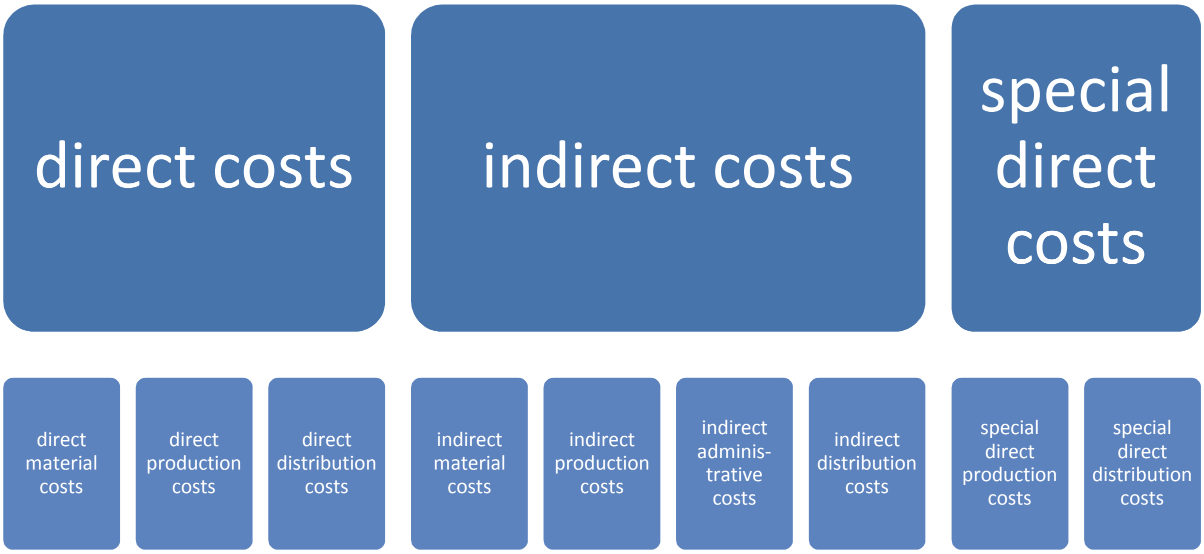


Figure 4-17: Overview of direct and indirect costs

In the following matrix representation set out in Table 4-12, a classification of costs in terms of the mode of occupation (fixed, variable) is contrasted with a classification of costs in terms of the accountability to cost drivers (direct, indirect) (Horsch, 2015).

	Direct costs	**Indirect costs**
Fixed costs	• Not existent	• Salary • Depreciation based on time period • Interest • Insurance fees • Rental fees • Basic tariffs for energy
Variable costs	• Raw materials (if the consumption amount is recorded separately) • Vendor parts • Piecework salary	• Auxiliary materials • Operating materials • Repair and maintenance depending on the machine running time • Sales commission • Office supplies • Energy • Water

Table 4-12: Classification of costs matrix

4.3.3.3 Scenarios model

As a decision support, different scenarios are to be considered: a best case, a mean case and a worst case scenario (these are set out in Table 4-13, Table 4-14 and Table 4-15). The scenario models are to be presented in two ways: First, as a consideration of a series of costs and revenues with a change within the costs and revenues of the contemplated revenue stream, and second, as a comparison of three single cost and revenue incomes. In both approaches, a change in the quantity is the decisive factor that determines the different costs and revenues (Kontos, 2004).

Exemplifying this, considering the formulas for the cost ($C = FC + VC = FC + v * Q$) and the revenue ($R = p * Q$) as mentioned above and applying them to the revenue stream asset sales, the cost and the revenue are: $C = FC + v * NumberOfGoods$ and $R = USP * NumberOfGoods$. In addition to that, the earnings ($E_t = R_t - C_t$) and the present value of the earnings (PV_t) is calculated. The latter is the earnings at the considered points in time, discounted with the interest rate i: $PV_t = \frac{E_t}{(1+i)^t} = \frac{R_t - C_t}{(1+i)^t}$ (Weber & Kabst, 2009).

Firstly, considering a series of costs and revenues (for example twelve payments; hence the sales quantity changes every month) with $FC = 5$, $v = 10$, $USP = 13$ and $i = 6\%\, p.a.$, the three scenarios are, depending on different sale quantities per period ($Q_t : NumberOfGoods_t$):

Best case scenario

t	1	2	3	4	5	6	7	8	9	10	11	12
Q_t	110	110	110	110	110	110	110	110	110	110	110	110
C_t	1105	1105	1105	1105	1105	1105	1105	1105	1105	1105	1105	1105
R_t	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430
E_t	325	325	325	325	325	325	325	325	325	325	325	325
PV_t	323,4	321,8	320,2	318,6	317	315,5	313,9	312,3	310,8	309,2	307,7	306,2

Table 4-13: Best case scenario

As can be seen, the best case represents the scenario that all the produced goods could be sold (with a maximum production capacity of $Q_t = 110$).

Mean case scenario

t	1	2	3	4	5	6	7	8	9	10	11	12
Q_t	10	55	65	60	50	60	55	70	70	50	55	55
C_t	105	555	655	605	505	605	555	705	705	505	555	555
R_t	130	715	845	780	650	780	715	910	910	650	715	715
E_t	25	160	190	175	145	175	160	205	205	145	160	160
PV_t	24,9	158,5	187,2	171,6	141,5	169,9	154,6	197	196,1	138	151,5	150,8

Table 4-14: Mean case scenario

The mean case represents the scenario which will occur most probably. This scenario shows low up- and downturns in sales volume.

Worst case scenario

t	1	2	3	4	5	6	7	8	9	10	11	12
Q_t	10	0	0	5	90	10	5	0	15	115	5	0
C_t	105	5	5	55	905	105	55	5	155	1155	55	5
R_t	130	0	0	65	1170	130	65	0	195	1495	65	0
E_t	25	-5	-5	10	265	25	10	-5	40	340	10	-5
PV_t	24,9	-5	-5	9,9	258,5	24,3	9,7	-4,9	38,3	323,5	9,5	-4,8

Table 4-15: Worst case scenario

The worst case represents the scenario in which high up- and downturns in sales volume occur with a very low average sales volume. As you can see, there are also periods in which no units are sold, but due to the fixed costs, costs occur nevertheless.

Note that in the three abovementioned scenarios a yearly interest rate of $i = 6\%$ is considered. For the calculation of the monthly present value streams, the interest rate has to be converted into a monthly interest rate: $i_m = \frac{i}{12}$. Thus, the present value is: $PV_t = \frac{R_t - C_t}{(1+i)^t} = \frac{R_t - C_t}{(1+i_m)^t}$.

In Table 4-16, the means of the three scenarios are displayed for a clear comparison:

Scenario	Best case	Mean case	Worst case
$Q_{total}=\frac{\sum_{t=1}^{n} Q_t}{t}$	110	54,6	21,3
$C_{total}=\frac{\sum_{t=1}^{n} C_t}{t}$	1105	550,8	217,5
$R_{total}=\frac{(\sum_{t=1}^{n} R_t)}{t}$	1430	709,6	276,3
$E_{total}=\frac{(\sum_{t=1}^{n} E_t)}{t}$	325	158,8	58,8
$NPV=\sum_{t=1}^{n} PV_t$	314,7	153,5	56,6

Table 4-16: Comparison of all three scenarios

Finally, the net present value would be:

$$NPV = \sum_{t=1}^{n} PV_t = \sum_{t=1}^{n} \frac{E_t}{(1+i_m)^t} = \sum_{t=1}^{n} \frac{R_t - C_t}{(1+i_m)^t}$$

All in all, these scenarios model provides decision support for the user. Due to the user's input of three different time series of sales volumes, a clear comparison of the possible outcomes can be provided and displayed. Due to these scenario models, the user does not have to calculate a whole new model every time he changes the estimated values of the sales volumes, but can display different scenarios next to each other in a clear way.

4.4 Fuzzy Arithmetic

In practice, it is not easy to determine parameters required for GPN business and risk evaluation, such as interdependency, resilience or perturbation values, precisely. Especially, in the absence of statistical data, where for example, a manager needs to make a strategic decision with little historical data and actual figures but has insights of the experts. In such situations, fuzzy numbers can be used along with linguistic labels to collect experts' insights and carry out the analysis in the presence of uncertainty.

The general motivation for using fuzzy sets to model uncertainty is particularly relevant to production network risk management at a strategic level where there is little or no precise data available and hence, we apply fuzzy arithmetic to deal with uncertainty. In this approach, uncertain values are modelled using fuzzy numbers and then, using the extension principle, usual arithmetic operations are carried out. These concepts are introduced in the following sections.

4.4.1 Fuzzy numbers

Fuzzy sets are an extension to the conventional sets that allow for uncertainty in the membership of elements to the set. Fuzzy sets are identified by a membership function that determines the degree of membership of an element to the set. A membership degree of 1 shows the total membership, which is similar to the membership of elements to a conventional set. On the other hand, a degree of 0 shows no membership, which is equivalent to an element not being in a conventional set. However, in addition to membership degrees 1 and 0, in fuzzy sets, degrees between 0 and 1 are also possible and present partial membership of an element to the fuzzy set.

A fuzzy number is an uncertain value that is represented as a fuzzy set over real numbers. Hence, the membership function of a fuzzy number identifies the membership degree of any real number to the fuzzy number. In addition to this, fuzzy numbers are assumed to have a piece-wise continuous and convex membership function and are normalised, i.e., have exactly one point with a membership degree of 1. A fuzzy number $\tilde{p}$ is identified by the membership function $\mu_{\tilde{p}}(x)$ where x is a real value if there is only one real number m where $\mu_{\tilde{p}}(m) = 1$. This point is called the peak value of the fuzzy number (Klimke, 2006).

A normal crisp number can be represented as a fuzzy number which has a membership of 1 of one value and a membership of 0 to all other values. In this way, fuzzy numbers and fuzzy arithmetic are an extension of the real numbers and conventional arithmetic.

A large subclass of fuzzy numbers is often represented in a parametric format known as LR fuzzy numbers. In this approach, a fuzzy number is identified by two monotonically decreasing functions, L (left) and R (right), that have a value of 1 at point 0 and a value 0 at point 1 and also, their respective spreads, α for left-hand spread and β for right-hand spread. Using this approach, the membership function of the value $\tilde{p} = \langle m, \alpha, \beta \rangle_{LR}$ is as follows (Klimke, 2006):

$$\forall x{:}\, \mu_{\tilde{p}}(x) = \begin{cases} L\left(\dfrac{m-x}{\alpha}\right) & \text{if } x < m \\ 1 & \text{if } x = m \\ R\left(\dfrac{x-m}{\beta}\right) & \text{if } x > m \end{cases}$$

4.4.2 Triangular fuzzy numbers

Triangular fuzzy numbers are one of the most popular types of fuzzy numbers that are identified by a triplet: $\tilde{V} = [V_1, V_2, V_3]\ where\ V_1 \leq V_2 \leq V_3$ with the membership function as follows:

$$\forall x{:} = \begin{cases} 0 & x \leq V_1 \\ \dfrac{x - V_1}{V_2 - V_1} & \text{if } V_1 < x < V_2 \\ 1 & \text{if } x = V_2 \\ \dfrac{V_3 - x}{V_3 - V_2} & \text{if } V_2 < x < V_3 \\ 0 & V_3 \leq x \end{cases}$$

This membership function is also shown in Figure 4-18.

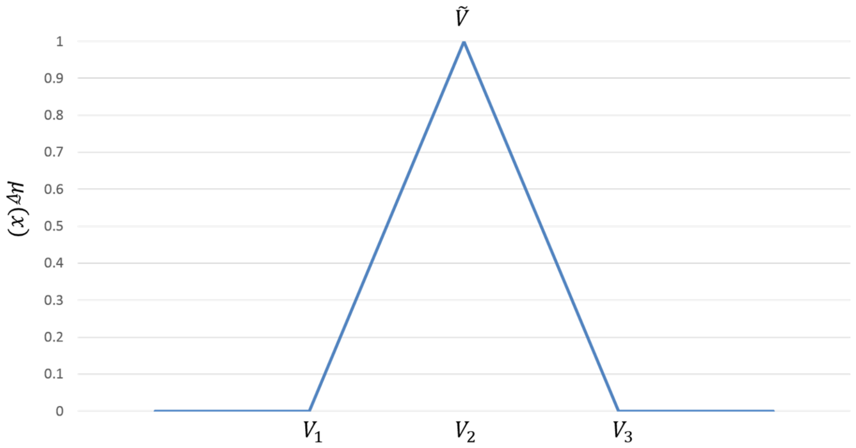


Figure 4-18: Membership function of a triangular fuzzy number

Triangular fuzzy numbers are typically used to model uncertain values such as "about V_2". The basic arithmetic operations such as addition and subtraction are easily carried out on triangular fuzzy numbers.

4.4.3 Extension principle

The extension principle, introduced by Zadeh (1975), is a crucial method which defines the way fuzzy calculations are performed on fuzzy numbers. This principle defines that for any function, the membership degree of the output of the function is the supremum of the minimum memberships of all input values to their corresponding fuzzy number that will result in the output value; or in other words, for function $f: S_1 \times S_2 \times \ldots \times S_n \rightarrow S$ where S_1, S_2, …, S_n and S are sets of real numbers, then for fuzzy numbers $\widetilde{X_1} \subseteq S_1$, $\widetilde{X_2} \subseteq S_2$, …, $\widetilde{X_n} \subseteq S_n$:

$$\mu_{f(\widetilde{X_1},\widetilde{X_2},\ldots,\widetilde{X_n})}(y) = \sup_{x_1 \in \widetilde{X_1},\ldots,x_n \in \widetilde{X_n} \wedge y = f(x_1,x_2,\ldots,x_n)} \min\left[\mu_{\widetilde{X_1}}(x_1), \mu_{\widetilde{X_2}}(x_2), \ldots, \mu_{\widetilde{X_n}}(x_n)\right]$$

However, the extension principle is computationally prohibitive. More efficient calculations methods have been proposed. Fuzzy addition, unary negation, and scalar multiplication of triangular fuzzy numbers $\tilde{X} = [X_1, X_2, X_3]$ and $\tilde{Y} = [Y_1, Y_2, Y_3]$ and real non-negative scalar value β, which are used in the model proposed, can be efficiently calculated as follows:

1) $\tilde{X} + \tilde{Y} = [X_1 + Y_1, X_2 + Y_2, X_3 + Y_3]$
2) $-\tilde{X} = [-X_3, -X_2, -X_1]$
3) $\beta\tilde{X} = [\beta X_1, \beta X_2, \beta X_3]$

4.4.4 Definition of α-cuts

α-cut of a fuzzy number (or fuzzy set) is a crisp set of values that have a membership degree of at least α. The membership function of fuzzy numbers is assumed to be convex, which means that any α-cut of fuzzy number is an interval that can be identified by its lower and upper endpoints. Fuzzy calculations can be simplified by discretising α and using the interval calculations to determine the corresponding endpoints of α-cuts. This approach is used for our fuzzy dynamic inoperability input output models described in Section 4.9. An α-cut of the triangular fuzzy value $\tilde{V}$ at $\alpha = 0.5$, identified by $[V^{L_{0.5}}, V^{U_{0.5}}]$, is shown in Figure 4-19.

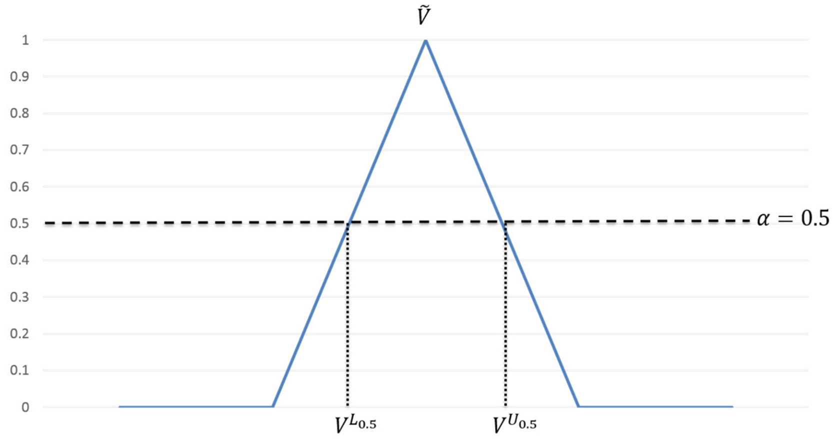


Figure 4-19: An example of an α-cut of a triangular fuzzy number

4.5 Fuzzy BSC

Values for the BSC model are collected from a variety of sources with different characteristics. However, one characteristic they have in common is the presence of error or uncertainty in the values. We consider uncertainty to be representative of our limit of knowledge about a certain value.

For example, when lacking precise statistical data, experts' estimates can be used with different uncertainty in estimated values; if necessary, uncertainty in values can be corrected by gathering statistics later on. Using this approach, it is possible to avoid unnecessary and expensive data collection. However, if this route is being taken, it is important to understand, explicitly identify and track the level of uncertainty in values using the developed mathematical models. Otherwise, the uncertainty can build up and invalidate any conclusions drawn from the results while there is false confidence in them.

Fuzzy logic has been successfully applied to modelling uncertainty in various fields. It is particularly useful in strategic decision making, where a broad mixture of information is needed and they are not always readily available. In such decision making scenarios, the decision maker can rely on the incomplete knowledge about the values of indicators by using fuzzy arithmetic that allows for uncertainty in values to be identified by linguistic descriptions such as *between 2 and 5 but most possibly 4*.

Fuzzy logic has been applied extensively to Multi-Criteria Decision Making (MCDM) problems, including BSC models. As an example, Wu et al. (2009) applied Fuzzy AHP to determine fuzzy weights of the indexes used for a BSC model of performance evaluation in banking. Also, Yüksel & Dağdeviren (2010) utilised Fuzzy Analytical Network Process (ANP) to determine business performance level for a manufacturing firm using a BSC model.

In our approach, we only consider the values for indexes to be fuzzy while the weights and the minimum-maximum values are assumed to be crisp. The fuzzy numbers are modelled as triangular fuzzy numbers, described in the next section, that consider three parameters for each value: a lowest point (pessimistic), a central value (most likely) and a highest point (optimistic). In addition to uncertainty in parameters, we also consider model uncertainty values to be assigned on level 2 score cards. The model uncertainties are combined with parameter uncertainties to determine the total uncertainty in the outcome of the model.

4.5.1 Model (Structural) Uncertainty

Uncertainty is not limited to the parameters of the model only. The model itself can suffer from uncertainty. For example, a model's structural elements, such as KPIs, can often be incomplete. While it is not cost effective or even possible to consider all relevant factors, we may have different levels of coverage that can be identified by the uncertainty level.

By including an uncertainty level, the expert developing the BSC model can start with an initial structure, albeit with a high uncertainty level. Then, as the model is being refined it is possible to reduce the perceived uncertainty level in the model. The advantage of this approach is that it is possible to carry out the analyses at any stage of the model development, because the uncertainty in the model is tracked and can be taken into account in decision making. For example, if the difference between alternative GPNs is too high, it may be possible to make a choice between them, even with a coarse grained model with high uncertainty. However, if there is little difference between the alternatives, the expert may conclude that a finer grained model is needed. In this way, the model needs refinements in some situations and the costs required to collect necessary data or reduce uncertainty can be avoided.

To include model uncertainty in the BSC, two percentages need to be identified for each of the level 2 score cards: a lower bound uncertainty and an upper bound uncertainty. The lower bound uncertainty determines a minimum percentage of the score that the actual score of the level can be less than, while the upper bound uncertainty determines the maximum percentage of the score that the actual score can be higher than. The formulation is provided in the following section.

4.5.2 Calculations using Fuzzy Arithmetic

The proposed BSC model is quite simple from an arithmetic perspective. At each level, a score is determined using the Simple Additive Weighting (SAW) method. SAW aggregates the sub-criteria by a weighted sum, as follows (Dragisa et al., 2013):

$$Q = \sum_{j=1}^{n} w_j r_j \tag{1}$$

where Q is the overall score, w_j is the weight of the j-th criterion and r_j is the normalised value of j-th criterion.

The values of the criteria need to be normalised before using this formula, as otherwise larger numbers can have significantly more influence on the results than the smaller numbers. In order to do this, in this approach, we use Linear Scale Transformation with Min and Max. In this method, a minimum and maximum value for each criterion need to be provided in advance and can be used to normalise the value in the range between the two numbers. The following formula is used:

$$r_j = \begin{cases} \dfrac{x_j - x_j^-}{x_j^+ - x_j^-}; & j \in \Omega_{max} \\ \dfrac{x_j^+ - x_j}{x_j^+ - x_j^-}; & j \in \Omega_{min} \end{cases} \tag{2}$$

where x_j^+ is the maximum value of the criterion j, x_j^- is the minimum value of the criterion j, x_j is the absolute value provided for criterion j, Ω_{max} is the set of benefit criteria and Ω_{min} is the set of cost criteria.

In our approach, we assume that the value x_j is fuzzy while the minimum x_j^-, maximum x_j^+ and weight w_j are all crisp. Using this assumption, formulas (1) and (2) will be fuzzified as follows:

$$\tilde{Q} = \sum_{j=1}^{n} w_j \tilde{r_j} \tag{3}$$

$$\tilde{r_j} = \begin{cases} \dfrac{\tilde{x_j} - x_j^-}{x_j^+ - x_j^-}; & j \in \Omega_{max} \\ \dfrac{x_j^+ - \tilde{x_j}}{x_j^+ - x_j^-}; & j \in \Omega_{min} \end{cases} \tag{4}$$

where $\tilde{Q}$ is the fuzzy overall score, $\tilde{r_j}$ is the fuzzy normalised value of j-th criterion and $\tilde{x_j}$ is the fuzzy absolute value of j-th criterion.

If the absolute values $\tilde{x_j}$ are provided as triangular fuzzy numbers, it is straightforward to calculate fuzzy overall score as a triangular fuzzy number using the efficient formulation provided in Section 4.4.3.

At level 2, we also want to incorporate model (structural) uncertainty. This can be done by adjusting the calculated score by the relevant model uncertainty values; if $\tilde{Q} = [Q_1, Q_2, Q_3]$ represents the triangular fuzzy score calculated using formula (4), the adjusted score can be calculated as follows:

$$\widetilde{Q^*} = [Q_1 - L * Q_1, Q_2, Q_3 + U * Q_3]$$

Where $\widetilde{Q^*}$ is the adjusted fuzzy triangular score, L is the lower bound model uncertainty and U is the upper bound model uncertainty.

4.6 Capturing Risk Incidents

Risk incidents, introduced in Section 3.3.3, are used to capture historical data about risks and are used to construct risk scenarios and risk models. For this purpose, a template is provided to log incidents, as presented in Table 4-17.

Incident X	
Brief Description	
Start Date/Time	Click here to enter a date.
End Date/Time	Click here to enter a date.
Type	☐ Supply ☐ Production ☐ Demand ☐ Logistics ☐ External ☐ Information and Control (including Management)
Cause	
Likelihood to happen in the next time period	Time Period: ☐ days ☐ months ☐ years Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High
Consequences	
Estimated Financial Loss	Between € ………… to € ………… but most likely € …………
Solution	
Lessons Learned	
Originated from Partners / Regions	

Table 4-17: Risk Incident Template

The data fields in the incident log are as follows:

- Brief description: a description of the event.
- Timeline (start and end date/time): when the incident started and when its impact is considered to have been neutralised.
- Type: category of risks that are related to supply, production, demand, logistics, external and information and control (described in Deliverable 2.1). More than one type may apply.

- Cause: the root of the problem that has led to the incident.
- Likelihood to happen in the next time period: estimation of the frequency of the risk. An estimate value and the expert's confidence in the estimate value are required.
- Consequences: the impact of the incident.
- Estimated financial loss: expert's estimate of the financial loss that was imposed as a result of this incident.
- Solution: how the issue was addressed by the company.
- Lessons learned: what can be done to mitigate the risk next time?
- Originated from partners/regions: either the partners that the disruption originated from (e.g. suppliers, customers, etc.) or regions involved (e.g. for weather issues, what regions were affected)

4.7 Defining Risk Factors and Risk Scenarios

The risk model requires risk factors to be identified and risk scenarios to be constructed. This task is the responsibility of risk experts that should be done through the analysis of recorded risk incidents and also, especially when previous incidents are not available, through the use of other sources including experts' judgement. This task is done in two steps: (1) identification of risk factors: a list of relevant risk factors that can have an impact on the company need to be identified. For this purpose we have proposed a list of generic risk factors for GPNs that can be consulted and adapted for the purpose of the company (2) a list of risk scenarios need to be constructed by providing the details of specific possible perturbations on the GPN.

A template for identifying risk factors is provided in Table 4-18.

Risk Factor X	
Name	
Brief Description	
Type	☐ Supply ☐ Production ☐ Demand ☐ Logistics ☐ External ☐ Information and Control (including Management)
Zone of influence	☐ Global ☐ Region Level 1: Grouping of Countries ☐ Region Level 2: Country ☐ Region Level 3: State/Province ☐ Region Level 4: City/Area ☐ Actor-specific
Company Definition of the Risk X	
Company History of the Risk X	

Mitigation Methods	

Table 4-18: Risk Factor Template

The data fields required for the risk factors include:

- Name: the name of the risk factor.
- Brief Description: a brief description of the risk factor.
- Type: this is the category of risks, the same as for incidents. More than one type may apply.
- Zone of influence: the zone of impact or influence of the risk that can be as wide as a global zone or as narrow as an actor-specific risk.
- Company Definition of the risk: company specific notes about the risk factor's definition.
- Company History of the risk: a brief description of the history of the company with this risk factor.
- Mitigation Methods: a list of identified mitigation methods – can be updated as needed.

A template for risk scenarios is provided in Table 4-19.

Risk Scenario X			
Description	[a brief description of the scenario]		
Likelihood	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High		
Perturbation 1			
Impact	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High		
Start Period	[start time. default: 0]	Length	[length]

	Region	[region affected]	
	Partner	[partner affected]	
Risk Factor	[relevant risk factor]		
Perturbation 2 (optional)			
Impact	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High		
Start Period	[start time. default: 0]	Length	[length]
	Region	[region affected]	
	Partner	[partner affected]	
Risk Factor	[relevant risk factor]		
…			

Table 4-19: Risk Scenario Template

The data fields for the risk scenario are:

- Description: a description of the risk scenario.
- Likelihood: The likelihood of risk scenario's occurrence. Using linguistic labels, the expert is required to give both their estimate of the value and the confidence in their estimate.

Also, for each risk scenario, a number of perturbation events affecting the network can be defined (at least one but can be more). For each of these perturbation events, the following information needs to be provided:

- Perturbation impact: this is given as a pair of estimated value of impact and confidence in estimation, specified using provided linguistic labels.
- Start Period: the beginning time period of the event. This is by default zero.
- Length: the number of time periods the event will sustain at the same level of perturbation.
- Region: if the perturbation affects the GPN on a regional level, the affected region is provided in this field.
- Partner: if the perturbation is actor-specific, the affected partner is provided in this field.
- Risk Factor: the name of the risk factor causing the perturbation.

The expert needs to describe the likelihood and perturbation impact considering two aspects: the estimated value and the expert's confidence in the estimate. The estimated value can be described as either very low, low, fairly low, medium, fairly high, high or very high. The confidence is used to determine the corresponding uncertainty in the result and can be specified using one of the mentioned linguistic labels.

The corresponding crisp values for the linguistic labels are assigned as shown in Table 4-20.

Linguistic Label	**Crisp Value**
Very Low	0
Low	0.167
Fairly Low	0.333
Medium	0.5
Fairly High	0.667
High	0.833
Very High	1

Table 4-20: **Crisp values corresponding to the linguistic labels for both estimated value and confidence**

Using the crisp values of both the estimated value and confidence estimation, the following formula is proposed to generate the corresponding fuzzy triangular number for both the likelihood and perturbation values:

$$\tilde{X} = [max(\mathrm{X_v} - (1 - \mathrm{X_c}), 0), \mathrm{X_v}, min(\mathrm{X_v} + (1 - \mathrm{X_c}), 1)] \qquad (5)$$

where $\tilde{X}$ is the calculated fuzzy triangular number (for either the likelihood or impact value), $X_v \in [0,1]$ is the crisp value corresponding to the estimated value and $X_c \in [0,1]$ is the crisp value of the corresponding confidence. So, the peak value of the fuzzy triangular number is the estimated value (X_v) while the confidence value (X_c) determines the deviation of the fuzzy number from its peak, i.e. the higher (lower) is the confidence, the lower (higher) is the deviation from the peak.

4.8 Fuzzy multi-criteria method for determining interdependencies

In the original inoperability model, which is considering economic sectors, it is possible to determine the interdependencies based on statistical data that have been gathered nationally or regionally for the corresponding sectors. In a GPN, however, such information is not necessarily available. Especially at the early stages of GPN design, some of the actors can be new to the company and hence have no record to rely on for statistical analysis. Therefore, we propose a fuzzy multi-criteria method to estimate the interdependency rates using experts' judgements.

Similar to specifying the likelihood and perturbation value for the risk scenarios, the expert needs to describe each link between two nodes considering two aspects of each of the interdependency criterion given in Section 3.4.4 of estimated value and confidence in estimation. A template provided to the expert to rate interdependency is presented in Table 4-21.

Dependency of X on Y	
Description	[a brief description of the dependency/relationship]
Trade volume	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High
Inventory	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High
Substitutability of the product or service	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High
Substitutability of the supplier or customer	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High
Lead-time	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate:

	☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High
Distance	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High
Information transparency	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High
Collaboration agreement	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High
Compatibility of IT systems	Estimated value: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High Confidence in estimate: ☐Very low ☐ Low ☐ Mildly Low ☐ Medium ☐ Mildly High ☐ High ☐ Very High

Table 4-21: Template provided for rating interdependencies

The expert is allowed to select as many or as few of the dependency criteria that they found to be applicable to the relevant relationships and leave the other criteria blank. The dependency will be calculated based on the ratings that have been provided.

Once the estimated value and the corresponding confidence are determined, a fuzzy interdependency weight for each link between the nodes and each interdependency criterion is calculated. The weight is considered to be a fuzzy triangular number where the peak value of the weight is either the crisp equivalent of the estimated value in case of direct interdependencies or "1 - the crisp value" for inverse interdependencies. The confidence value represents the deviation of the number from the peak value. Hence, the left and right boundaries of the membership function are getting closer to the peak value, when confidence is increasing, and further away from the peak value, when confidence is decreasing.

The following formula for direct and inverse interdependency is used:

$$\widetilde{w_{r,l}} = \begin{cases} [max(v_{r,l} - (1 - c_{r,l}), 0), v_{r,l}, min(v_{r,l} + (1 - c_{r,l}), 1)] & direct\ interdependency \\ [max((1 - v_{r,l}) - (1 - c_{r,l}), 0), 1 - v_{r,l}, min((1 - v_{r,l}) + (1 - c_{r,l}), 1)] & inverse\ interdependency \end{cases} \quad (6)$$

where $\widetilde{w_{r,l}}$ is the fuzzy interdependency weight of link l for criterion r, $v_{r,l} \in [0,1]$ is the crisp value corresponding to the estimated linguistic value of the link l for criterion r and $c_{r,l} \in [0,1]$ is the crisp value of the corresponding confidence value.

To aggregate the interdependency based on the fuzzy weights of all criteria, in line with Wei, Dong, & Sun (2010), we use an Ordered Weighted Averaging (OWA) method. This method aggregates the fuzzy weights while giving more importance to the criteria with higher weights. The advantage of using the OWA method is that criteria with higher weights, which suggest higher interdependency, will have a higher effect than the criteria that have lower weights. For example, if a link is considered to have high dependency due to a low substitutability of both the product and the supplier, but it is considered less dependent due to all other criteria, it will still be considered as a high interdependency link, as the two criteria with high weights will be considered more important than the ones with lower weights.

The following formula is proposed for the OWA aggregation:

$$\widetilde{w_l^*} = \left(\sum_{r=1}^{R} y_r \, \widetilde{w_{r,l}} \right) \Big/ L \quad (7)$$

where $\widetilde{w_l^*}$ is fuzzy interdependency of link l on all criteria relative to the number of links to the node, R is the total number of criteria that has been rated for the link, y_r is the importance assigned to the criteria r, and, L is the total number of dependency links of dependent node i. The calculation requires summation and scalar multiplication of fuzzy numbers described in Section 4.4.3.

In order to assign importance to criteria weights, the criteria weights are sorted in a descending order. As the criteria weights are fuzzy numbers, they are sorted by comparing their peak values. The following formula for determining criteria importance is proposed:

$$y_{f(r)} = \frac{2(R - f(r) + 1)}{R(R+1)}; \mathrm{r} = 1, \dots, \mathrm{R} \quad (8)$$

where $f(r)$ gives the position of criterion r in the sorted vector of criteria weights and is determined empirically. For example, the first criterion weights in the sorted vector is mapped into $2R/R(R+1)$, the second criterion weight is mapped into $2(R-1)/R(R+1)$ and so on.

4.9 Fuzzy dynamic inoperability input output model

As mentioned in Deliverable D2.1, Leontief's Input Output Model is a well-established economics model that is applied to determining the relationship between interconnected sectors of the economy. The interdependencies are the result of the reliance of each sector on products/services provided by other sectors. Additionally, part of the necessary products/services are procured from outside, such as foreign markets, which constitute the inputs to the system, while, part of the provided products/services will be consumed by the final customers and/or exported, and this constitutes the outputs of the model.

IIM is a risk model founded on the Input Output model (Santos and Haimes, 2004). Similar to the Input Output Model, IIM assumes interconnected nodes that receive external "perturbations", i.e.

independent disruptive events affecting the node, as the input. The model determines the output "inoperability" values for all nodes, considering the propagation of risk throughout the network. Inoperability shows the rate at which the actual level of operation differs from the planned activity level and acts as a measure of risk impact on each node. This model can be formulated in vector format as follows (Santos and Haimes, 2004):

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

where $\boldsymbol{q}$ is the vector of nodes' inoperabilities, $\boldsymbol{A}^{*}$ is the interdependency matrix, where each coefficient presents a degree of dependency and coupling from one node to the other, and $\boldsymbol{c}^{*}$ is the vector of input perturbations, which are normalised levels of disruptions that is directly induced by external events.

IIM can be extended to a dynamic version which considers time variations in perturbations and inoperabilities, which is discussed in the next section. Also, fuzzy arithmetic can be applied to these models to incorporate uncertainty information about the input and output values. We present a novel method for fuzzy dynamic IIM (DIIM) in the following section. The corresponding calculation is described in detail.

4.9.1 Dynamic Inoperability Input Output Model

DIIM extends the IIM by including the dynamic variations of the nodes' operations within the time horizon. These variations could be the result of changes in the external perturbation values, e.g. changes in weather conditions that affect a node, which ultimately lead to variations in the final inoperability values of the node. Another important aspect of the DIIM is the resilience of the nodes to the changes which represents their speed of reaction to the external variations. A discrete-time DIIM can be formulated in vector format as follows (Haimes and Horowitz, 2005):

$$q(t+1) = KA^{*}q(t) + Kc^{*}(t) + (I - K)q(t)$$

Where $q(t)$ is the inoperability vector of the nodes at time period t, K is the diagonal resilience matrix of nodes, A^{*} is the matrix of interdependencies between the nodes, $c^{*}(t)$ is the external perturbation of nodes at time period t and I is the identity matrix.

Figure 4-20 shows an example of application of the DIIM to a GPN relevant to Custom Drinks. This example shows the final outcome of the network's inoperability that is affected by simultaneous political instability and price and currency risks in a particular region.

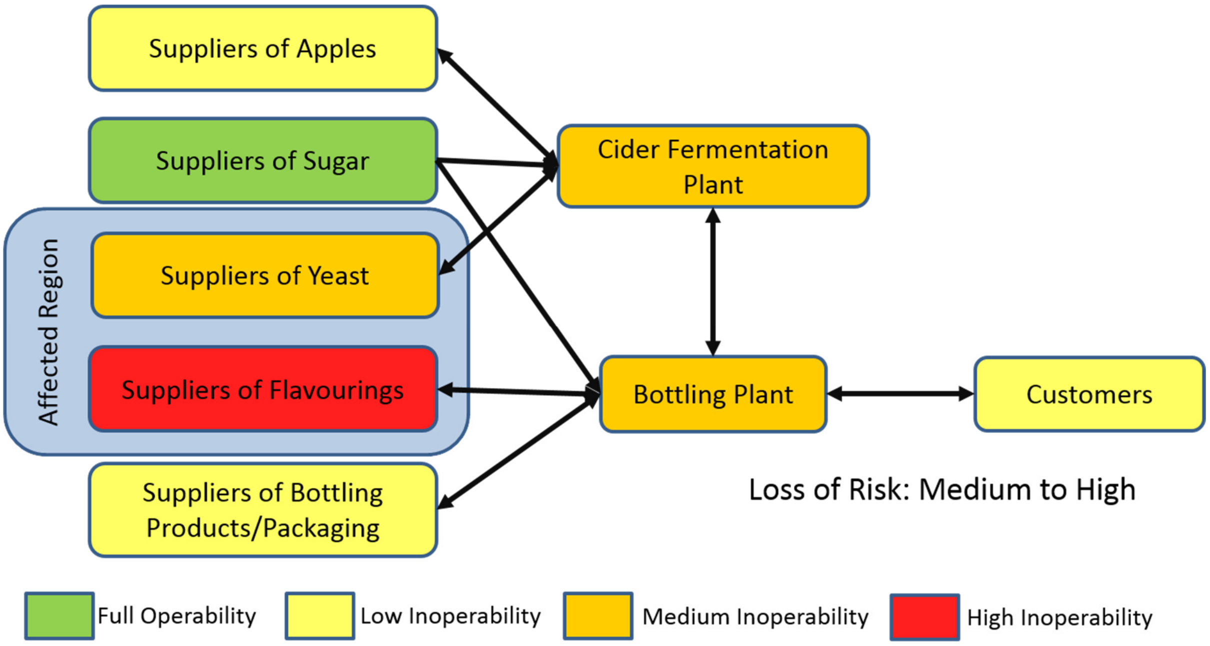


Figure 4-20: Illustrative example of the outcome of the DIIM model on a GPN

Nodes in Figure 4-20 represent suppliers of Apples, Sugar, Yeast, Flavourings and Bottling Products, production facilities for Cider Fermentation and Bottling and Customers. Final inoperability values are marked by different colours and a total loss of risk is estimated to be Medium to High.

We will carry out extensive experimentation using the proposed DIIM model on business cases of the end-users to better understand the relationships and sensitivity of the model's outcomes to its inputs. The results will be reported in D2.4.

4.9.2 Model Formulation

The following discrete fuzzy DIIM is as proposed:

$$\tilde{q}(t+1) = \tilde{K}\widetilde{A^*}\tilde{q}(t) + \tilde{K}\widetilde{c^*}(t) + \left(I - \tilde{K}\right)\tilde{q}(t) \qquad (9)$$

where $\tilde{q}(t)$ is the vector of fuzzy inoperability values of the nodes at time period t, $\tilde{K}$ is the fuzzy diagonal resilience matrix of nodes, $\widetilde{A^*}$ is the matrix of fuzzy interdependencies between the nodes, $\widetilde{c^*}(t)$ is the fuzzy external perturbation of nodes at time period t and I is the identity matrix. In this model, it is assumed that all fuzzy parameters are modelled using triangular fuzzy numbers, although the proposed algorithm can work on any LR fuzzy number (Pedrycz and Gomide, 1998).

The inputs of the model are as follows:

- GPN Nodes and Interdependency links: GPN nodes are determined through the GPN model (in GPN Configuration Application).
- Ratings of the Criteria of interdependencies: the interdependencies and ratings of criteria are determined using the Fuzzy multi-criteria method (in Application SRAA) which results in fuzzy interdependency matrix $\widetilde{A^*}$.

- Fuzzy resilience for individual nodes $\widetilde{K}$: which is the recovery speed of the individual node (provided by the user in SRAA).
- Intended revenue for individual nodes x: the intended revenue of the node in one period (set by the user in SRAA) that is used to calculate the economic loss of risk.
- Risk Scenarios: identified by Likelihood, Risk factors involved, Affected (region or node), Perturbation and Timeline which ultimately result in $\widetilde{c^*}(t)$ (risk scenarios are defined in IRADA).

The following are outputs of the model:

- Inoperability timeline: a chart showing the variations in inoperability for a particular node in a particular risk scenario.
- Average inoperability of all nodes over all scenarios: a measure to evaluate the average impact of risk on the GPN.
- Total loss of risk over all scenarios: another measure to determine the financial impact of risk on the company.

4.9.3 Calculation Procedure

In order to determine fuzzy inoperability values in equation (9), a novel method based on fuzzy extension principle and interval arithmetic is developed. An advantage of this method is that all parameters, including perturbations, interdependencies and resilience, are allowed to be fuzzy. The developed method provides an accurate and efficient approach to carry out fuzzy arithmetic, instead of using approximations.

Triangular fuzzy numbers are often used in applications because they can conveniently represent standard linguistic terms such as "about a certain value" or "close to a certain value" and the basic arithmetic operations on triangular fuzzy numbers are simple. However, while triangular fuzzy numbers are closed for addition and subtraction, they are not closed for multiplication and division. Different procedures which approximate results of multiplication and division and express them as triangular fuzzy numbers have been proposed in the literature (Giachetti and Young, 1997). However, as equation (2) includes multiple multiplications and is applied iteratively, we decided to develop an exact method for fuzzy arithmetic in DIIM model based on α-cuts. This means that inoperability is determined by finding α-cut intervals that represent the inoperability value at various membership degrees $\alpha \in [0,1]$. The lower and upper endpoints of the α-cut interval for inoperability of node i at time period t for membership degree α, $q_i^{\mathrm{L}\alpha}(t)$ and $q_i^{\mathrm{U}\alpha}(t)$ respectively, are calculated as follows (details are provided in Appendix):

From $\mathrm{t} = 0$ to all time periods in the time horizon.

From $i = 1$, to all the nodes in the network.

For $\alpha = 0$ to $\alpha = 1$ with an arbitrary step increment.

Beginning

Step 1: If $\sum_j A_{i,j}^{*\mathrm{L}\alpha} q_j^{\mathrm{L}\alpha}(t) + c_i^{*\mathrm{L}\alpha}(t) \geq q_i^{\mathrm{L}\alpha}(t)$ then $K'_{min}=K_{i,i}^{\mathrm{L}\alpha}$

Else $K'_{min}=K_{i,i}^{\mathrm{U}\alpha}$.

Step 2: If $\sum_j A^{*\mathrm{U}\alpha}_{i,j} q^{\mathrm{U}\alpha}_j(t) + c^{*\mathrm{U}\alpha}_i(t) \geq q^{\mathrm{U}\alpha}_i(t)$ then $K'_{max}=K^{\mathrm{U}\alpha}_{i,i}$

Else $K'_{max}=K^{\mathrm{L}\alpha}_{i,i}$.

Step 3: $q^{\mathrm{L}\alpha}_i(t+1) = K'_{min} \sum_j A^{*\mathrm{L}\alpha}_{i,j} q^{\mathrm{L}\alpha}_j(t) + K'_{min} c^{*\mathrm{L}\alpha}_i(t) + (1 - K'_{min}) q^{\mathrm{L}\alpha}_i(t)$.

Step 4: $q^{\mathrm{U}\alpha}_i(t+1) = K'_{max} \sum_j A^{*\mathrm{U}\alpha}_{i,j} q^{\mathrm{U}\alpha}_j(t) + K'_{max} c^{*\mathrm{U}\alpha}_i(t) + (1 - K'_{max}) q^{\mathrm{U}\alpha}_i(t)$.

End

Steps 1 and 2 find the corresponding resilience values from the α-cut of $K_{i,i}$, i.e., interval $\left[K^{\mathrm{L}\alpha}_{i,i}, K^{\mathrm{U}\alpha}_{i,i}\right]$ that can yield the lower and upper endpoint values of the α-cut of the inoperability $q^{\mathrm{L}\alpha}_i(t+1)$ and $q^{\mathrm{U}\alpha}_i(t+1)$ respectively, following the rules of multiplication of negative and positive α-cuts of fuzzy numbers. One can notice that depending on the value of resilience's coefficients, resilience can have either a direct impact on inoperability when $K'_{min}=K^{\mathrm{L}\alpha}_{i,i}$ and $K'_{max}=K^{\mathrm{U}\alpha}_{i,i}$ or an inverse impact when $K'_{min}=K^{\mathrm{U}\alpha}_{i,i}$ and $K'_{max}=K^{\mathrm{L}\alpha}_{i,i}$.

Based on the method described above, it is possible to generate an inoperability timeline. The inoperability timeline shows the changes in the level of inoperability for a particular node in the GPN where the level of uncertainty is identified by showing different α-cuts' lower and upper endpoints, shown as Min and Max respectively, as different lines in the chart. An example of an inoperability timeline is shown in Figure 4-21 where y-axis is the level of inoperability and the x-axis is the timeline.

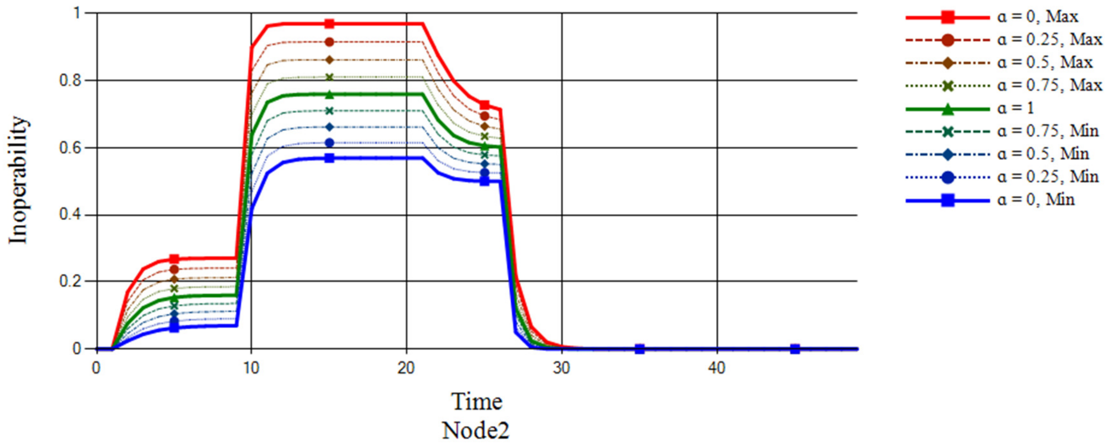


Figure 4-21: An example of inoperability timeline

In Figure 4-21, the Max line for $\alpha = 0$ represents the most pessimistic option while the Min line for $\alpha = 0$ is the most optimistic scenario. At $\alpha = 1$, there is only one line, as the Min and Max values are the same, and it shows the most likely inoperability.

4.9.4 Economic Loss of Risk

Fuzzy DIIM can analyse the level of inoperability of nodes as a consequence of perturbations. Through a list of risk scenarios, an overall picture of risks can be constructed and used to evaluate a proposed GPN by applying the Fuzzy DIIM. While this is quite useful, it needs to be compared with the economic aspects of the proposed GPN. Therefore, the results of the inoperability model need to be translated into financial figures. With this aim, the concept of economic loss of risk is introduced to allow for the estimation of the economic effect of risk.

An important concept required to calculate the economic loss of risk is intended revenue. Intended revenue of a node is the revenue that can be achieved by that node when it is fully operable during a single time period. For example, the intended revenue of a production facility can be estimated as the value added of the produced product multiplied by the expected output of the facility per one period.

Having the intended revenue of all nodes, the economic loss of risk for a node in the GPN at a certain time period can be determined as the product of the intended revenue and the inoperability of the node at the time (Wei et al., 2010).

To assess a GPN configuration from the risk perspective, the following formula is used to calculate the total economic loss of risk for a particular risk scenario:

$$\tilde{Q}_s = \tilde{x}^T \sum_{t=1}^{T} \tilde{q}_s(t)$$

where $\tilde{Q}_s$ is the total economic loss of risk for the GPN configuration on risk scenario s, $\tilde{x}^T$ is the transpose of vector of fuzzy intended revenues of all nodes for a single time period, T is the number of time periods in the considered time horizon, $\tilde{q}_s(t)$ is the fuzzy inoperability vector of all nodes at time period t for risk scenario s.

This can be further aggregated for all scenarios as follows:

$$\tilde{Q} = \sum_{s=1}^{S} \tilde{p}_s \tilde{Q}_s$$

where $\tilde{Q}$ is the expected total economic loss of risk for the GPN configuration on all risk scenarios, S is the number of risk scenarios and $\tilde{p}_s$ is the fuzzy likelihood of risk scenario s.

4.10 Integrated GPN BSC evaluation

The following section introduces the procedure of GPN evaluation with the help of the BSC model, to include changes and extensions that have been made since the initial explanation in deliverable D2.2. Categories and concepts of the balanced scorecard evaluation framework, introduced in D2.2, were updated, now containing an additional category considering risk. Furthermore, the calculation method now contains fuzzy values, enabling the evaluation with values within a specific fuzzy range.

Weighting and evaluating new business models with respect to the related global production networks must consider a number of different environmental factors and key performance indicators. Although there are a high number of these factors, it is possible to consider only specific parts of the total collection of factors and indicators or to give more evaluation impact to several situation-related indicators. However, for that purpose a flexible and clearly defined evaluation has to be possible, which also has to provide the chance to build up a customised evaluation calculation model.

In the following example, as in D2.2, two possible plant locations are considered, which are Poland and Spain. The illustrated environmental factor is the "industrial electricity price", understandably different in both countries. Two important aspects are explained in this chapter. Firstly the general evaluation model with the related balanced scorecard views, each with a specific and adjustable relevance to the overall score. Secondly the main aspect is to explain how the exemplary factor and it´s measure can be integrated into the calculation model.

4.10.1 Description of the calculation model

The model in worksheet 1 (Figure 4-22:) shows different levels which are split progressively. The topmost level is LEVEL 0, which describes the economic feasibility. The economic feasibility is the result of various indicators and factors, organized within the balanced scorecard. The relations between them are static and %-based. In a second step, the economic feasibility is divided into different Balanced Scorecard views (BSC views) on LEVEL 1. These categories are "financial", "internal", "customer", "innovation" and – as mentioned above – the additional category "risk", which the user can weight with different percentages, depending on individual preferences. After that the single BSC views are split into Key Performance Indicator (KPI) sections on LEVEL 2. Again, these are categories to describe the upper level in a more detailed way. For example, the BSC view "financial" is divided into "cost", "revenue" and "growth", which are also weighted by different shares defined by the user. With the aid of LEVEL 3 the KPIs are made measureable. Therefore the user determines Performance Indicators (PI) and External Factors (EF) which relate to the corporation's business. The PIs are also imbued with specific weightings.

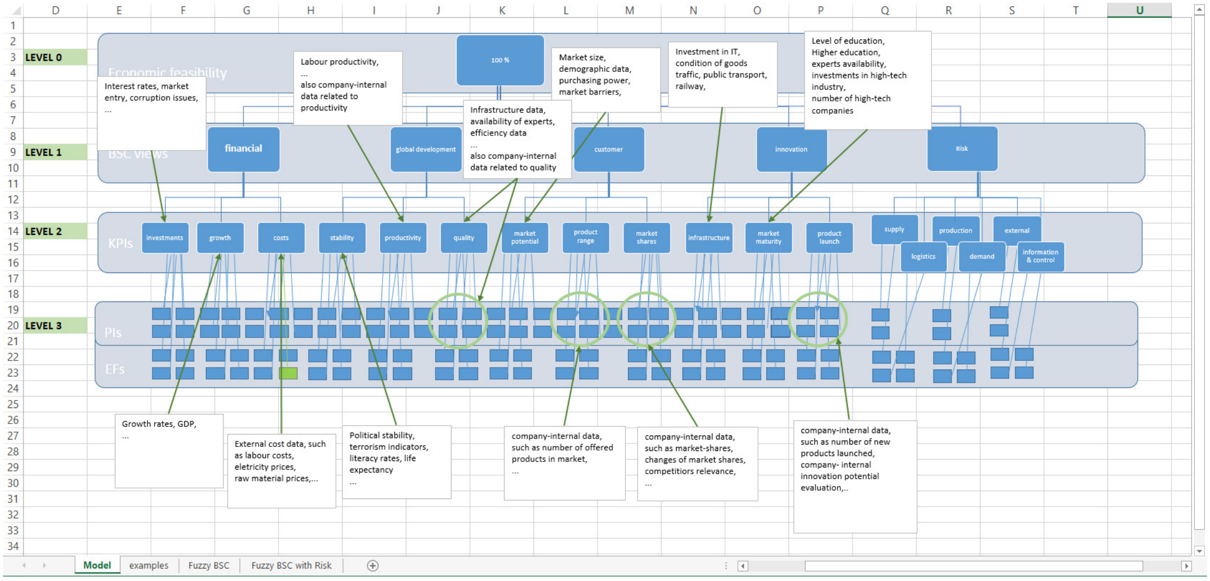
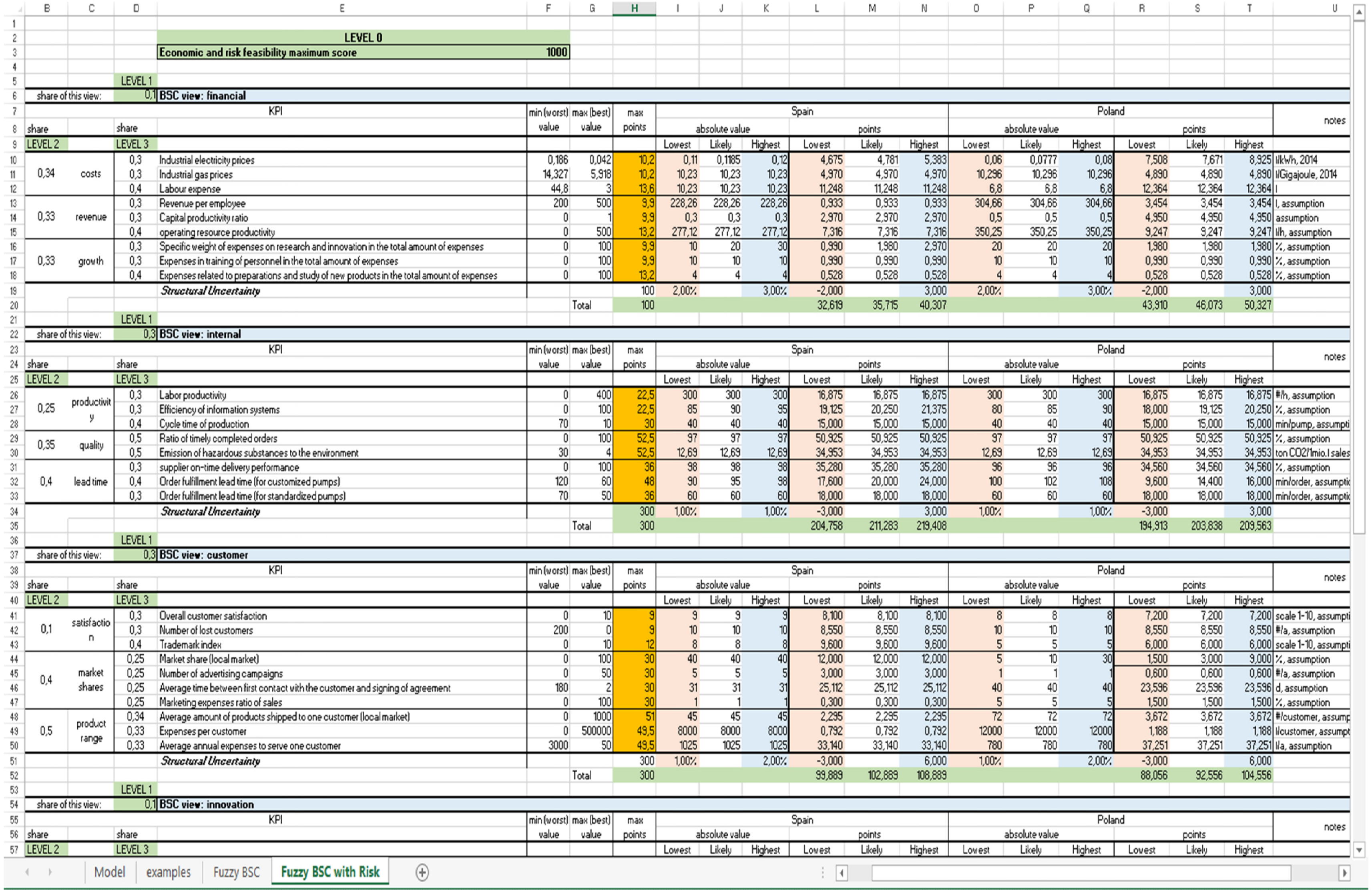


Figure 4-22: Worksheet 1 model

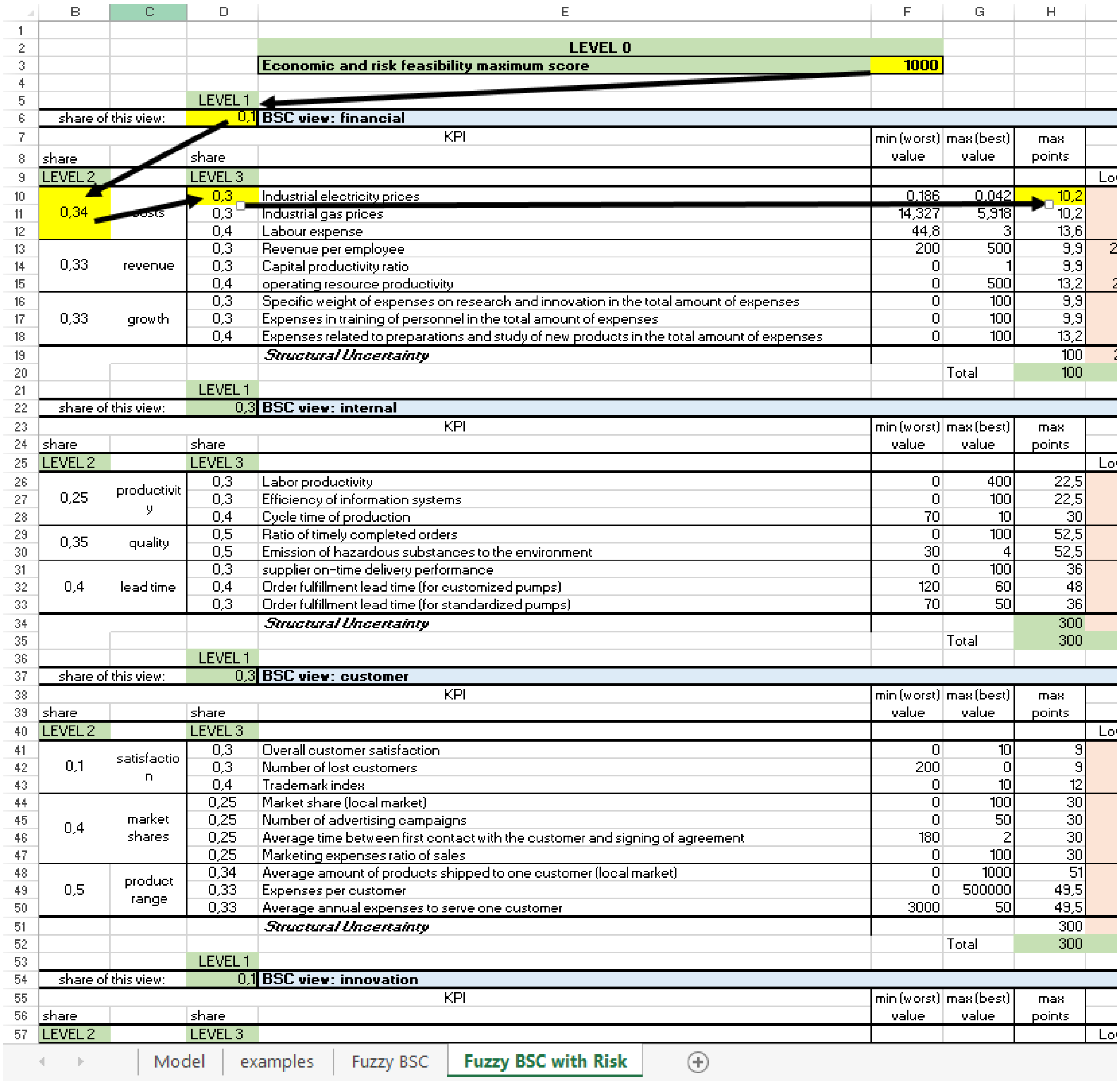
Explaining the coherences in worksheet 4 ("Fuzzy BSC with Risk") (Figure 4-23) in detail now, one can see that the highest achievable feasibility is 100% which equals 1000 points (cell F3) on LEVEL 0. The weightings of the BSC views on LEVEL 1 can be determined in cells D6, D22, D37, D54 and D56, whereas the weightings for the KPIs (LEVEL 2) are defined in cells B10:18, B26:33, B41:50, B58:63 and B71:82. Also, the definition of the shares of the different PIs on LEVEL 3 are done in cells D10:18, D26:33, D41:50, D58:63 and D71:D82. The achievable maximum score of each indicator, highlighted in orange in the following figure, is calculated by the multiplication of the weightings from LEVEL 0 to LEVEL 3.



	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1																				
2				LEVEL 0																
3				**Economic and risk feasibility maximum score**	1000															
4																				
5			LEVEL 1																	
6	share of this view:		0,1	**BSC view: financial**																
7				KPI	min (worst)	max (best)	max	Spain						Poland						notes
8	share		share		value	value	points	absolute value			points			absolute value			points			
9	LEVEL 2		LEVEL 3					Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	
10			0,3	Industrial electricity prices	0,186	0,042	10,2	0,11	0,1185	0,12	4,675	4,781	5,383	0,06	0,0777	0,08	7,508	7,671	8,925	l/kWh, 2014
11	0,34	costs	0,3	Industrial gas prices	14,327	5,918	10,2	10,23	10,23	10,23	4,970	4,970	4,970	10,296	10,296	10,296	4,890	4,890	4,890	l/Gigajoule, 2014
12			0,4	Labour expense	44,8	3	13,6	10,23	10,23	10,23	11,248	11,248	11,248	6,8	6,8	6,8	12,364	12,364	12,364	l
13			0,3	Revenue per employee	200	500	9,9	228,26	228,26	228,26	0,933	0,933	0,933	304,66	304,66	304,66	3,454	3,454	3,454	l, assumption
14	0,33	revenue	0,3	Capital productivity ratio	0	1	9,9	0,3	0,3	0,3	2,970	2,970	2,970	0,5	0,5	0,5	4,950	4,950	4,950	assumption
15			0,4	operating resource productivity	0	500	13,2	277,12	277,12	277,12	7,316	7,316	7,316	350,25	350,25	350,25	9,247	9,247	9,247	l/h, assumption
16			0,3	Specific weight of expenses on research and innovation in the total amount of expenses	0	100	9,9	10	20	30	0,990	1,980	2,970	20	20	20	1,980	1,980	1,980	%, assumption
17	0,33	growth	0,3	Expenses in training of personnel in the total amount of expenses	0	100	9,9	10	10	10	0,990	0,990	0,990	10	10	10	0,990	0,990	0,990	%, assumption
18			0,4	Expenses related to preparations and study of new products in the total amount of expenses	0	100	13,2	4	4	4	0,528	0,528	0,528	4	4	4	0,528	0,528	0,528	%, assumption
19				***Structural Uncertainty***			100	2,00%		3,00%	-2,000		3,000	2,00%		3,00%	-2,000		3,000	
20						Total	100				32,619	35,715	40,307				43,910	46,073	50,327	
21			LEVEL 1																	
22	share of this view:		0,3	**BSC view: internal**																
23				KPI	min (worst)	max (best)	max	Spain						Poland						notes
24	share		share		value	value	points	absolute value			points			absolute value			points			
25	LEVEL 2		LEVEL 3					Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	
26			0,3	Labor productivity	0	400	22,5	300	300	300	16,875	16,875	16,875	300	300	300	16,875	16,875	16,875	#/h, assumption
27	0,25	productivity	0,3	Efficiency of information systems	0	100	22,5	85	90	95	19,125	20,250	21,375	80	85	90	18,000	19,125	20,250	%, assumption
28			0,4	Cycle time of production	70	10	30	40	40	40	15,000	15,000	15,000	40	40	40	15,000	15,000	15,000	min/pump, assumpti
29	0,35	quality	0,5	Ratio of timely completed orders	0	100	52,5	97	97	97	50,925	50,925	50,925	97	97	97	50,925	50,925	50,925	%, assumption
30			0,5	Emission of hazardous substances to the environment	30	4	52,5	12,69	12,69	12,69	34,953	34,953	34,953	12,69	12,69	12,69	34,953	34,953	34,953	ton CO2/1mio.l sales
31			0,3	supplier on-time delivery performance	0	100	36	98	98	98	35,280	35,280	35,280	96	96	96	34,560	34,560	34,560	%, assumption
32	0,4	lead time	0,4	Order fulfillment lead time (for customized pumps)	120	60	48	90	95	98	17,600	20,000	24,000	100	102	108	9,600	14,400	16,000	min/order, assumpti
33			0,3	Order fulfillment lead time (for standardized pumps)	70	50	36	60	60	60	18,000	18,000	18,000	60	60	60	18,000	18,000	18,000	min/order, assumpti
34				***Structural Uncertainty***			300	1,00%		1,00%	-3,000		3,000	1,00%		1,00%	-3,000		3,000	
35						Total	300				204,758	211,283	219,408				194,913	203,838	209,563	
36			LEVEL 1																	
37	share of this view:		0,3	**BSC view: customer**																
38				KPI	min (worst)	max (best)	max	Spain						Poland						notes
39	share		share		value	value	points	absolute value			points			absolute value			points			
40	LEVEL 2		LEVEL 3					Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	
41			0,3	Overall customer satisfaction	0	10	9	9	9	9	8,100	8,100	8,100	8	8	8	7,200	7,200	7,200	scale 1-10, assumpti
42	0,1	satisfaction	0,3	Number of lost customers	200	0	9	10	10	10	8,550	8,550	8,550	10	10	10	8,550	8,550	8,550	#/a, assumption
43			0,4	Trademark index	0	10	12	8	8	8	9,600	9,600	9,600	5	5	5	6,000	6,000	6,000	scale 1-10, assumpti
44			0,25	Market share (local market)	0	100	30	40	40	40	12,000	12,000	12,000	5	10	30	1,500	3,000	9,000	%, assumption
45	0,4	market shares	0,25	Number of advertising campaigns	0	50	30	5	5	5	3,000	3,000	3,000	1	1	1	0,600	0,600	0,600	#/a, assumption
46			0,25	Average time between first contact with the customer and signing of agreement	180	2	30	31	31	31	25,112	25,112	25,112	40	40	40	23,596	23,596	23,596	d, assumption
47			0,25	Marketing expenses ratio of sales	0	100	30	1	1	1	0,300	0,300	0,300	5	5	5	1,500	1,500	1,500	%, assumption
48			0,34	Average amount of products shipped to one customer (local market)	0	1000	51	45	45	45	2,295	2,295	2,295	72	72	72	3,672	3,672	3,672	#/customer, assump
49	0,5	product range	0,33	Expenses per customer	0	500000	49,5	8000	8000	8000	0,792	0,792	0,792	12000	12000	12000	1,188	1,188	1,188	l/customer, assumpt
50			0,33	Average annual expenses to serve one customer	3000	50	49,5	1025	1025	1025	33,140	33,140	33,140	780	780	780	37,251	37,251	37,251	l/a, assumption
51				***Structural Uncertainty***			300	1,00%		2,00%	-3,000		6,000	1,00%		2,00%	-3,000		6,000	
52						Total	300				99,889	102,889	108,889				88,056	92,556	104,556	
53			LEVEL 1																	
54	share of this view:		0,1	**BSC view: innovation**																
55				KPI	min (worst)	max (best)	max	Spain						Poland						notes
56	share		share		value	value	points	absolute value			points			absolute value			points			
57	LEVEL 2		LEVEL 3					Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	

Figure 4-23: Weighting elements and maximum score per indicator

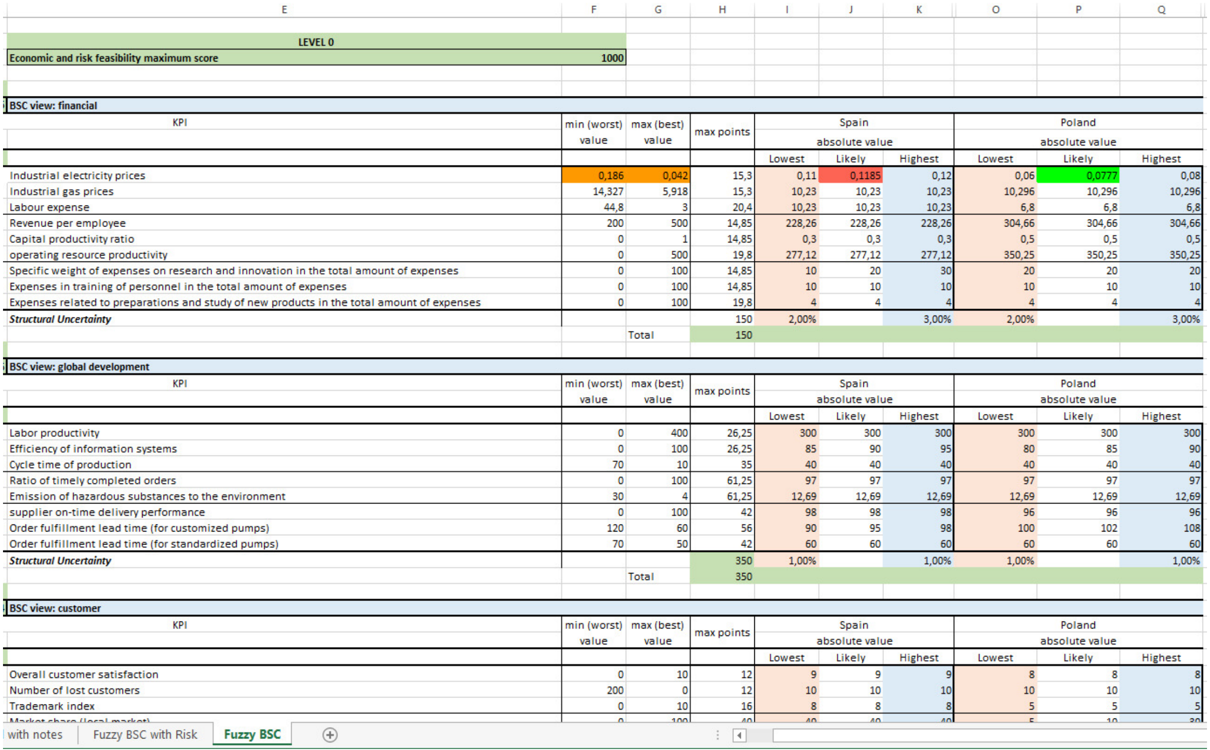
The maximum points are determined and explained as follows, using an example: The maximum points for the External Factor (EF) "Industrial electricity prices" in cell H10 are calculated by multiplying every single share on the different levels concerning this PI. This PI's own share is in cell D10, it belongs to the KPI costs the share of which is in cell B10 and is in the financial BSC view; the share of this view is in cell D6. Also, the maximum score of 1000 is in cell F3, multiplying all of these values will lead to the maximum points that this EF can possibly reach (see Figure 4-24).



	B	C	D	E	F	G	H
1							
2				LEVEL 0			
3				**Economic and risk feasibility maximum score**	1000		
4							
5			LEVEL 1				
6	share of this view:		0,1	**BSC view: financial**			
7				KPI	min (worst) value	max (best) value	max points
8	share		share				
9	LEVEL 2		LEVEL 3				
10	0,34	costs	0,3	Industrial electricity prices	0,186	0,042	10,2
11			0,3	Industrial gas prices	14,327	5,918	10,2
12			0,4	Labour expense	44,8	3	13,6
13	0,33	revenue	0,3	Revenue per employee	200	500	9,9
14			0,3	Capital productivity ratio	0	1	9,9
15			0,4	operating resource productivity	0	500	13,2
16	0,33	growth	0,3	Specific weight of expenses on research and innovation in the total amount of expenses	0	100	9,9
17			0,3	Expenses in training of personnel in the total amount of expenses	0	100	9,9
18			0,4	Expenses related to preparations and study of new products in the total amount of expenses	0	100	13,2
19				***Structural Uncertainty***			100
20						Total	100
21			LEVEL 1				
22	share of this view:		0,3	**BSC view: internal**			
23				KPI	min (worst) value	max (best) value	max points
24	share		share				
25	LEVEL 2		LEVEL 3				
26	0,25	productivity	0,3	Labor productivity	0	400	22,5
27			0,3	Efficiency of information systems	0	100	22,5
28			0,4	Cycle time of production	70	10	30
29	0,35	quality	0,5	Ratio of timely completed orders	0	100	52,5
30			0,5	Emission of hazardous substances to the environment	30	4	52,5
31	0,4	lead time	0,3	supplier on-time delivery performance	0	100	36
32			0,4	Order fulfillment lead time (for customized pumps)	120	60	48
33			0,3	Order fulfillment lead time (for standardized pumps)	70	50	36
34				***Structural Uncertainty***			300
35						Total	300
36			LEVEL 1				
37	share of this view:		0,3	**BSC view: customer**			
38				KPI	min (worst) value	max (best) value	max points
39	share		share				
40	LEVEL 2		LEVEL 3				
41	0,1	satisfaction	0,3	Overall customer satisfaction	0	10	9
42			0,3	Number of lost customers	200	0	9
43			0,4	Trademark index	0	10	12
44	0,4	market shares	0,25	Market share (local market)	0	100	30
45			0,25	Number of advertising campaigns	0	50	30
46			0,25	Average time between first contact with the customer and signing of agreement	180	2	30
47			0,25	Marketing expenses ratio of sales	0	100	30
48	0,5	product range	0,34	Average amount of products shipped to one customer (local market)	0	1000	51
49			0,33	Expenses per customer	0	500000	49,5
50			0,33	Average annual expenses to serve one customer	3000	50	49,5
51				***Structural Uncertainty***			300
52						Total	300
53			LEVEL 1				
54	share of this view:		0,1	**BSC view: innovation**			
55				KPI	min (worst) value	max (best) value	max points
56	share		share				
57	LEVEL 2		LEVEL 3				

Figure 4-24: Defining the weight of a PI

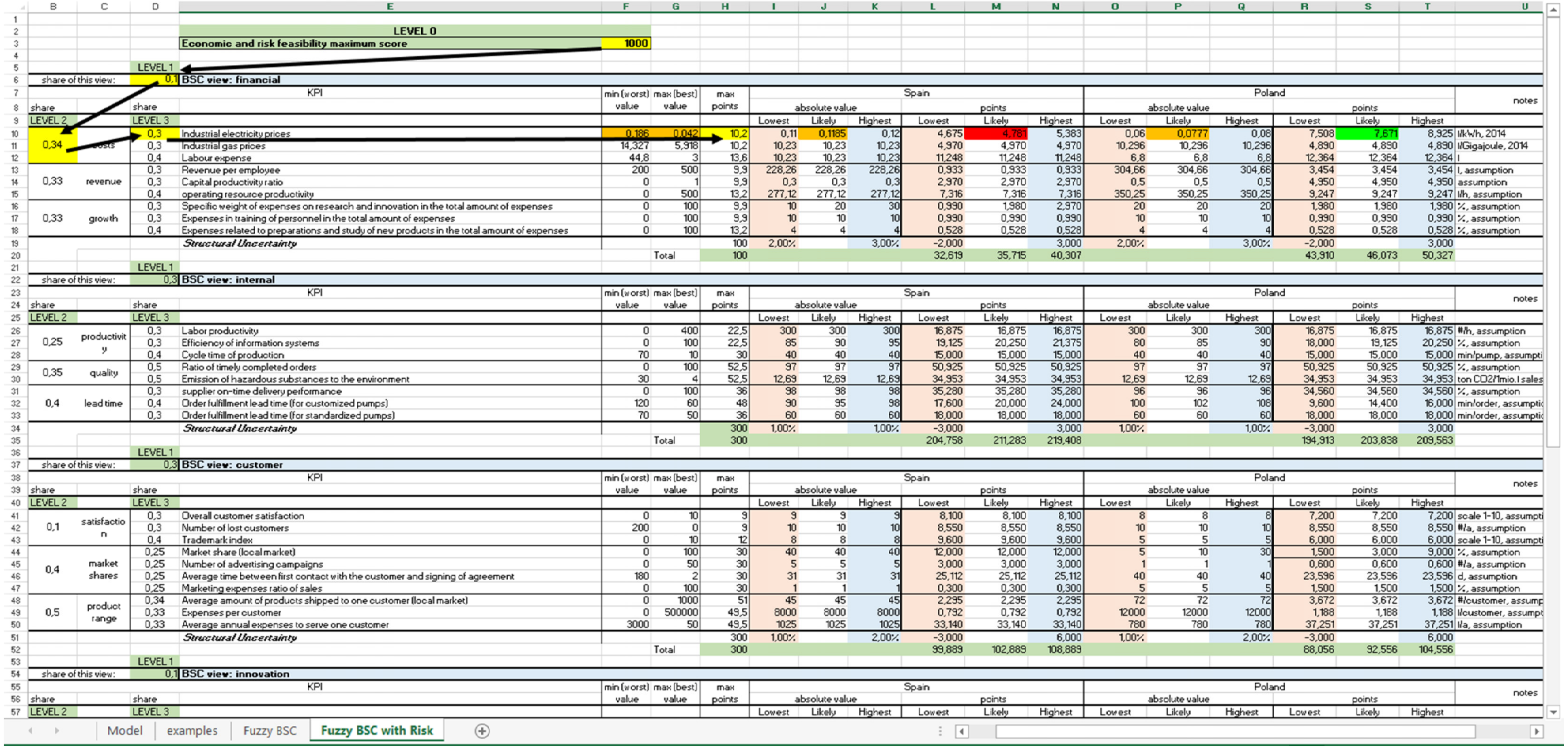
For every single EF "min (worst)", "max (best)" and "max points" values are determined. Depending on the EF, the "min (worst)" value is either high or low and so is the "max (best)" value. Explaining this using an example, one can see that the EF "Industrial electricity prices" in row 10 has a high "min (worst)" value (0,186) and a low "max (best)" value (0,042). This is due to the fact that it is a "the lower, the better" EF, which means that one can reach the maximum points by having the lowest electricity prices possible. The column U "notes" describes the metric, which is for the industrial electricity prices €/kWh, valid for 2014. The minimum value 0,186 therefore means 0,186 € or 18,6 cent per kWh electricity, the maximum value equals 4,2 cent per kWh electricity, see orange cells. The industrial electricity price per kWh for Spain is 11,85 cent per kWh, and thus higher (red), than the one in Poland (green), which equals 7,77 cent per kWh. This is shown in Figure 4-25.



E	F	G	H	I	J	K	O	P	Q
LEVEL 0									
Economic and risk feasibility maximum score	**1000**								
BSC view: financial									
KPI	min (worst) value	max (best) value	max points	Spain absolute value			Poland absolute value		
				Lowest	Likely	Highest	Lowest	Likely	Highest
Industrial electricity prices	0,186	0,042	15,3	0,11	0,1185	0,12	0,06	0,0777	0,08
Industrial gas prices	14,327	5,918	15,3	10,23	10,23	10,23	10,296	10,296	10,296
Labour expense	44,8	3	20,4	10,23	10,23	10,23	6,8	6,8	6,8
Revenue per employee	200	500	14,85	228,26	228,26	228,26	304,66	304,66	304,66
Capital productivity ratio	0	1	14,85	0,3	0,3	0,3	0,5	0,5	0,5
operating resource productivity	0	500	19,8	277,12	277,12	277,12	350,25	350,25	350,25
Specific weight of expenses on research and innovation in the total amount of expenses	0	100	14,85	10	20	30	20	20	20
Expenses in training of personnel in the total amount of expenses	0	100	14,85	10	10	10	10	10	10
Expenses related to preparations and study of new products in the total amount of expenses	0	100	19,8	4	4	4	4	4	4
Structural Uncertainty			150	2,00%		3,00%	2,00%		3,00%
		Total	150						
BSC view: global development									
KPI	min (worst) value	max (best) value	max points	Spain absolute value			Poland absolute value		
				Lowest	Likely	Highest	Lowest	Likely	Highest
Labor productivity	0	400	26,25	300	300	300	300	300	300
Efficiency of information systems	0	100	26,25	85	90	95	80	85	90
Cycle time of production	70	10	35	40	40	40	40	40	40
Ratio of timely completed orders	0	100	61,25	97	97	97	97	97	97
Emission of hazardous substances to the environment	30	4	61,25	12,69	12,69	12,69	12,69	12,69	12,69
supplier on-time delivery performance	0	100	42	98	98	98	96	96	96
Order fulfillment lead time (for customized pumps)	120	60	56	90	95	98	100	102	108
Order fulfillment lead time (for standardized pumps)	70	50	42	60	60	60	60	60	60
Structural Uncertainty			350	1,00%		1,00%	1,00%		1,00%
		Total	350						
BSC view: customer									
KPI	min (worst) value	max (best) value	max points	Spain absolute value			Poland absolute value		
				Lowest	Likely	Highest	Lowest	Likely	Highest
Overall customer satisfaction	0	10	12	9	9	9	8	8	8
Number of lost customers	200	0	12	10	10	10	10	10	10
Trademark index	0	10	16	8	8	8	5	5	5

Figure 4-25: Values per indicator

On the other hand, there are PIs or EFs existing which are classified into the "the higher, the better"-category. An example fo this is the PI "Efficiency in information systems" in row 27. Here, it is the other way around: One can reach the maximum points if the availability rate of information systems is 100%. Thus, the "min (worst)" and "max (best)" values are the limits of the "absolute value". The "max points" are the maximum points the PI can achieve if the absolute value equals the best possible value within the limits.



	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1																				
2				LEVEL 0																
3				**Economic and risk feasibility maximum score**	1000															
4																				
5			LEVEL 1																	
6	share of this view:		0,1	**BSC view: financial**																
7				KPI	min (worst)	max (best)	max	Spain						Poland						notes
8	share		share		value	value	points	absolute value			points			absolute value			points			
9	LEVEL 2		LEVEL 3					Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	
10	0,34	costs	0,3	Industrial electricity prices	0,186	0,042	10,2	0,11	0,1185	0,12	4,675	4,781	5,383	0,06	0,0777	0,08	7,508	7,671	8,925	l/kWh, 2014
11			0,3	Industrial gas prices	14,327	5,918	10,2	10,23	10,23	10,23	4,970	4,970	4,970	10,296	10,296	10,296	4,890	4,890	4,890	l/Gigajoule, 2014
12			0,4	Labour expense	44,8	3	13,6	10,23	10,23	10,23	11,248	11,248	11,248	6,8	6,8	6,8	12,364	12,364	12,364	l
13	0,33	revenue	0,3	Revenue per employee	200	500	9,9	228,26	228,26	228,26	0,933	0,933	0,933	304,66	304,66	304,66	3,454	3,454	3,454	l, assumption
14			0,3	Capital productivity ratio	0	1	9,9	0,3	0,3	0,3	2,970	2,970	2,970	0,5	0,5	0,5	4,950	4,950	4,950	assumption
15			0,4	operating resource productivity	0	500	13,2	277,12	277,12	277,12	7,316	7,316	7,316	350,25	350,25	350,25	9,247	9,247	9,247	l/h, assumption
16	0,33	growth	0,3	Specific weight of expenses on research and innovation in the total amount of expenses	0	100	9,9	10	20	30	0,990	1,980	2,970	20	20	20	1,980	1,980	1,980	%, assumption
17			0,3	Expenses in training of personnel in the total amount of expenses	0	100	9,9	10	10	10	0,990	0,990	0,990	10	10	10	0,990	0,990	0,990	%, assumption
18			0,4	Expenses related to preparations and study of new products in the total amount of expenses	0	100	13,2	4	4	4	0,528	0,528	0,528	4	4	4	0,528	0,528	0,528	%, assumption
19				*Structural Uncertainty*			100	2,00%		3,00%	-2,000		3,000	2,00%		3,00%	-2,000		3,000	
20						Total	100				32,619	35,715	40,307				43,910	46,073	50,327	
21			LEVEL 1																	
22	share of this view:		0,3	**BSC view: internal**																
23				KPI	min (worst)	max (best)	max	Spain						Poland						notes
24	share		share		value	value	points	absolute value			points			absolute value			points			
25	LEVEL 2		LEVEL 3					Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	
26	0,25	productivity	0,3	Labor productivity	0	400	22,5	300	300	300	16,875	16,875	16,875	300	300	300	16,875	16,875	16,875	#/h, assumption
27			0,3	Efficiency of information systems	0	100	22,5	85	90	95	19,125	20,250	21,375	80	85	90	18,000	19,125	20,250	%, assumption
28			0,4	Cycle time of production	70	10	30	40	40	40	15,000	15,000	15,000	40	40	40	15,000	15,000	15,000	min/pump, assumpti
29	0,35	quality	0,5	Ratio of timely completed orders	0	100	52,5	97	97	97	50,925	50,925	50,925	97	97	97	50,925	50,925	50,925	%, assumption
30			0,5	Emission of hazardous substances to the environment	30	4	52,5	12,69	12,69	12,69	34,953	34,953	34,953	12,69	12,69	12,69	34,953	34,953	34,953	ton CO2/1mio.l sales
31	0,4	lead time	0,3	supplier on-time delivery performance	0	100	36	98	98	98	35,280	35,280	35,280	96	96	96	34,560	34,560	34,560	%, assumption
32			0,4	Order fulfillment lead time (for customized pumps)	120	60	48	90	95	98	17,600	20,000	24,000	100	102	108	9,600	14,400	16,000	min/order, assumptio
33			0,3	Order fulfillment lead time (for standardized pumps)	70	50	36	60	60	60	18,000	18,000	18,000	60	60	60	18,000	18,000	18,000	min/order, assumptio
34				*Structural Uncertainty*			300	1,00%		1,00%	-3,000		3,000	1,00%		1,00%	-3,000		3,000	
35						Total	300				204,758	211,283	219,408				194,913	203,838	209,563	
36			LEVEL 1																	
37	share of this view:		0,3	**BSC view: customer**																
38				KPI	min (worst)	max (best)	max	Spain						Poland						notes
39	share		share		value	value	points	absolute value			points			absolute value			points			
40	LEVEL 2		LEVEL 3					Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	
41	0,1	satisfaction	0,3	Overall customer satisfaction	0	10	9	9	9	9	8,100	8,100	8,100	8	8	8	7,200	7,200	7,200	scale 1-10, assumpti
42			0,3	Number of lost customers	200	0	9	10	10	10	8,550	8,550	8,550	10	10	10	8,550	8,550	8,550	#/a, assumption
43			0,4	Trademark index	0	10	12	8	8	8	9,600	9,600	9,600	5	5	5	6,000	6,000	6,000	scale 1-10, assumpti
44	0,4	market shares	0,25	Market share (local market)	0	100	30	40	40	40	12,000	12,000	12,000	5	10	30	1,500	3,000	9,000	%, assumption
45			0,25	Number of advertising campaigns	0	50	30	5	5	5	3,000	3,000	3,000	1	1	1	0,600	0,600	0,600	#/a, assumption
46			0,25	Average time between first contact with the customer and signing of agreement	180	2	30	31	31	31	25,112	25,112	25,112	40	40	40	23,596	23,596	23,596	d, assumption
47			0,25	Marketing expenses ratio of sales	0	100	30	1	1	1	0,300	0,300	0,300	5	5	5	1,500	1,500	1,500	%, assumption
48	0,5	product range	0,34	Average amount of products shipped to one customer (local market)	0	1000	51	45	45	45	2,295	2,295	2,295	72	72	72	3,672	3,672	3,672	#/customer, assump
49			0,33	Expenses per customer	0	500000	49,5	8000	8000	8000	0,792	0,792	0,792	12000	12000	12000	1,188	1,188	1,188	l/customer, assumpt
50			0,33	Average annual expenses to serve one customer	3000	50	49,5	1025	1025	1025	33,140	33,140	33,140	780	780	780	37,251	37,251	37,251	l/a, assumption
51				*Structural Uncertainty*			300	1,00%		2,00%	-3,000		6,000	1,00%		2,00%	-3,000		6,000	
52						Total	300				99,889	102,889	108,889				88,056	92,556	104,556	
53			LEVEL 1																	
54	share of this view:		0,1	**BSC view: innovation**																
55				KPI	min (worst)	max (best)	max	Spain						Poland						notes
56	share		share		value	value	points	absolute value			points			absolute value			points			
57	LEVEL 2		LEVEL 3					Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	Lowest	Likely	Highest	

Figure 4-26: Results per indicator

Finally, the calculation of the "points" of the PI in columns M and S depends on the absolute value of the PI and the limits of the PI (min and max value). If it is a PI of the "the higher, the better"-category, the points are calculated in proportion to the limits; if it is a "the lower, the better"-PI the calculation is in inverse proportion (see calculation formula in cells M10 and M27 for more details). In the example of the industrial electricity prices, it is obviously a higher PI score for Poland, as they have lower electricity prices. As the maximum of achievable points equals 10,2 points, the specific values for both countries have to be calculated (see Figure 4-26). As a result, Spain reaches 4,781 of maximum 10,2 points. Poland has a higher score by achieving 7,671 of maximum 10,2 points (see Figure 4-27).

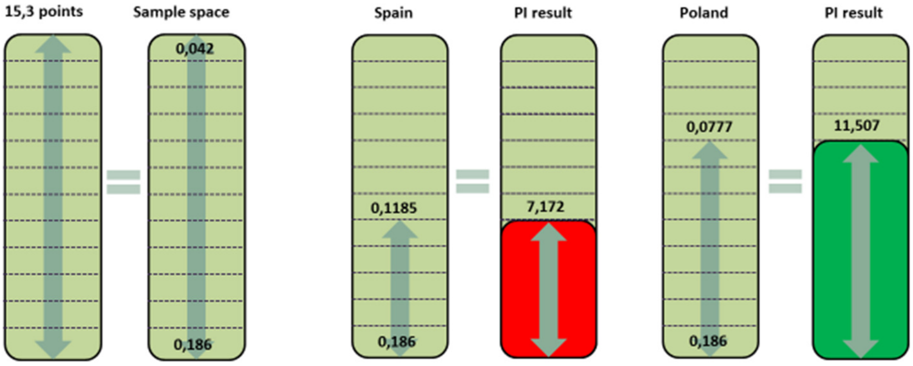


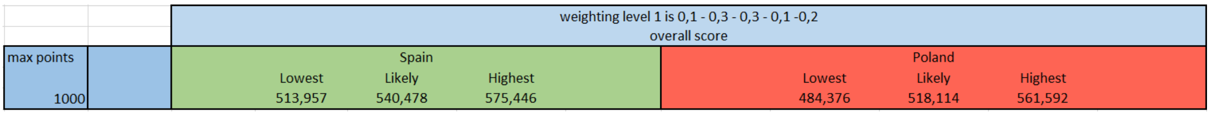
Figure 4-27: Matching maximum points to sample space and resulting score per indicator

If this calculation is done, determining the overall score is the next and final step by summing all single points of the PIs (in columns M and S respectively, for the "likely" case. The calculation of the "lowest" and "highest" case is done equally).

Now, the two overall scores can be compared, leading to a reasonable decision. By changing the values of the shares, the user can define how relevant the category/sub-category/level is; of course this will lead to a different outcome in the overall score.

Interpretation of scenario 1 (see Figure 4-28)

Here, the GPN with the plant chosen in Spain achieves the higher score. The weighing of the level 1 categories, which are the balanced scorecard views, is 10% financial, 30% internal, 30% customer, 10% innovation and 20% risk perspective. Due to that weighing in level 1, the GPN with Spain as the plants location has the better overall score.

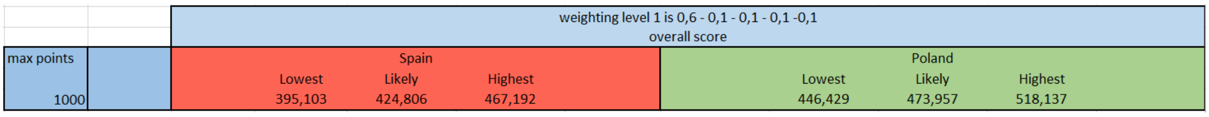


		weighting level 1 is 0,1 - 0,3 - 0,3 - 0,1 -0,2 overall score					
max points			Spain			Poland	
		Lowest	Likely	Highest	Lowest	Likely	Highest
1000		513,957	540,478	575,446	484,376	518,114	561,592

Figure 4-28: Results scenario 1

Interpretation of scenario 2 (see Figure 4-29)

The GPN with the plant chosen in Poland now achieves the higher score. The weighing of the level 1 categories, which are the balanced scorecard views, is 60% financial, 10% internal, 10% customer, 10% innovation and 10% risk perspective. Due to that weighing in level 1 with a strong focus of 70% on the financial view, the GPN with Poland as the plants location has the better overall score.



		weighting level 1 is 0,6 - 0,1 - 0,1 - 0,1 -0,1 overall score					
max points		Spain			Poland		
		Lowest	Likely	Highest	Lowest	Likely	Highest
1000		395,103	424,806	467,192	446,429	473,957	518,137

Figure 4-29 Results scenario 2

4.10.2 Approach for evaluation of GPN

The previous subsection both illustrated and calculated the evaluation of one node within a global production network in terms of one specific factor and how this affects the overall score. In a further step a complete GPN can be evaluated regarding a what-if comparison, as shown in the example. The evaluation is analogous to the evaluation within the excel tool and follows the ceteris paribus view on the whole GPN.

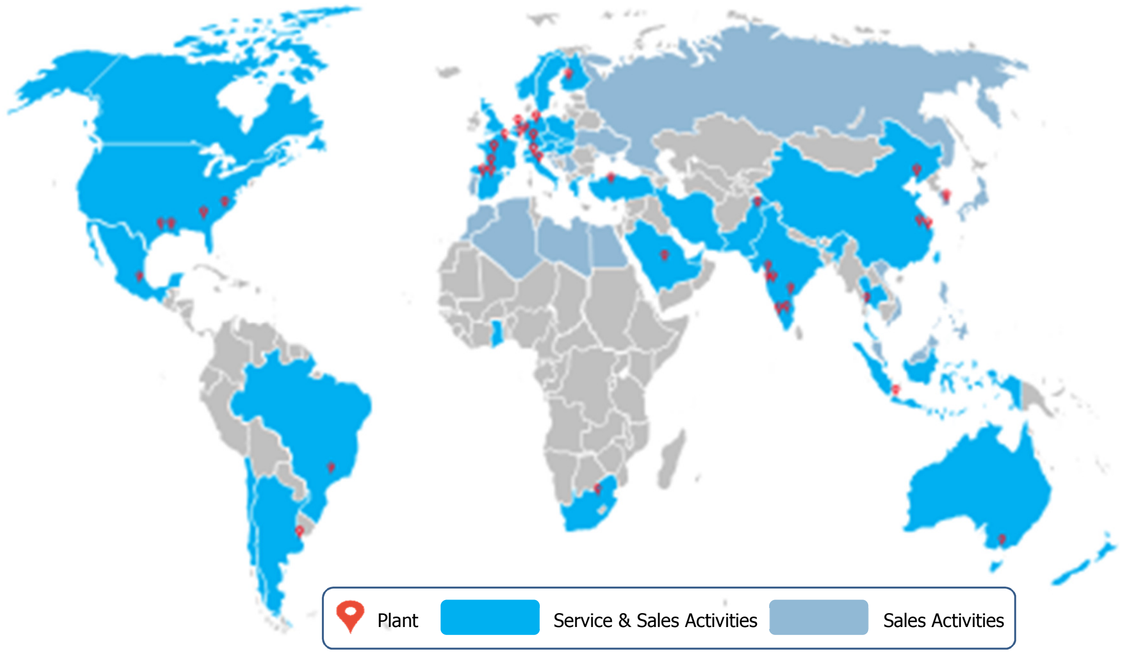


Figure 4-30: Global production network based on KSB

Figure 4-30 shows the global production network of the end-user KSB, illustrated with the help of the public available network data. Grey coloured countries have no KSB activity at all, light blue coloured countries have sales activities, whereas the blue coloured countries have both sales and services activities of KSB. Service means that at least one centre for service activities (repair, maintain, etc.) is located within the country. The red icons symbolise the manufacturing sites of KSB.

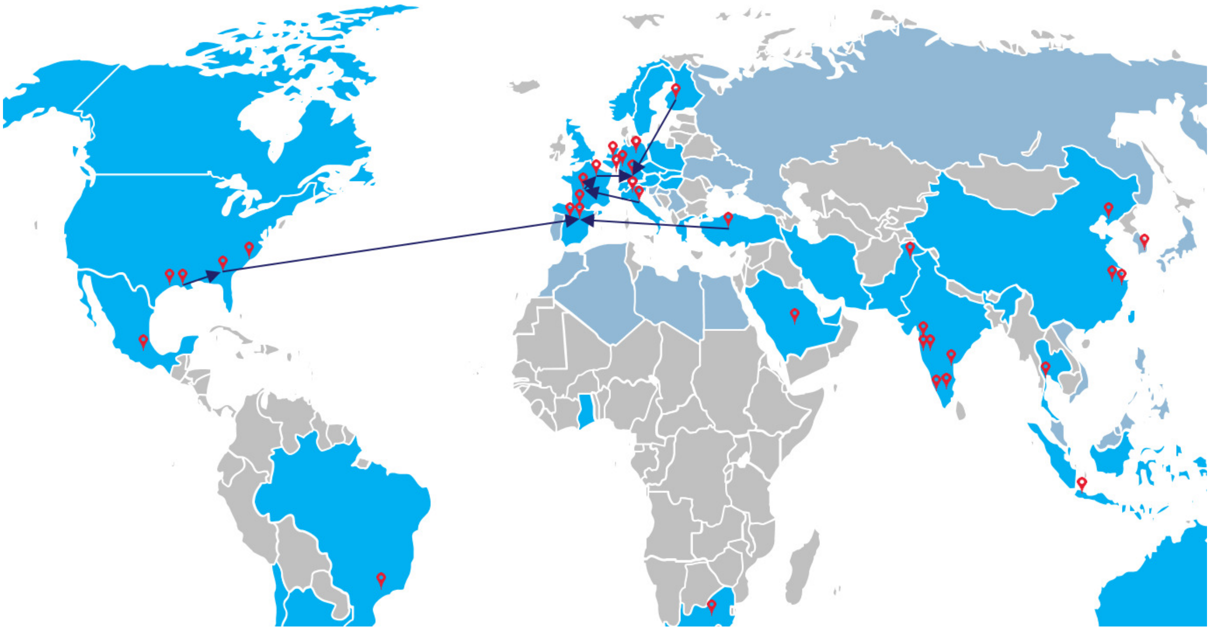


Figure 4-31: Exemplary GPN configuration A

An example of a KSB global production network is shown in

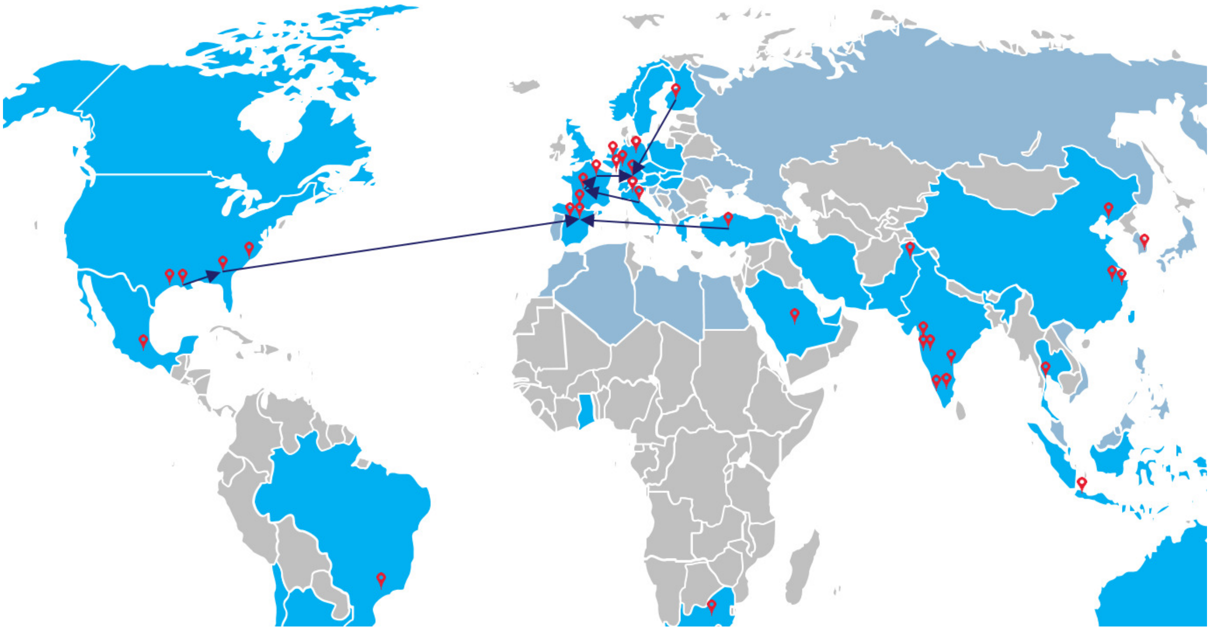


Figure 4-31. A product is manufactured in the plant in Germany, and that requires different components from several other plants. The supplying plants are located in Europe and northern America.

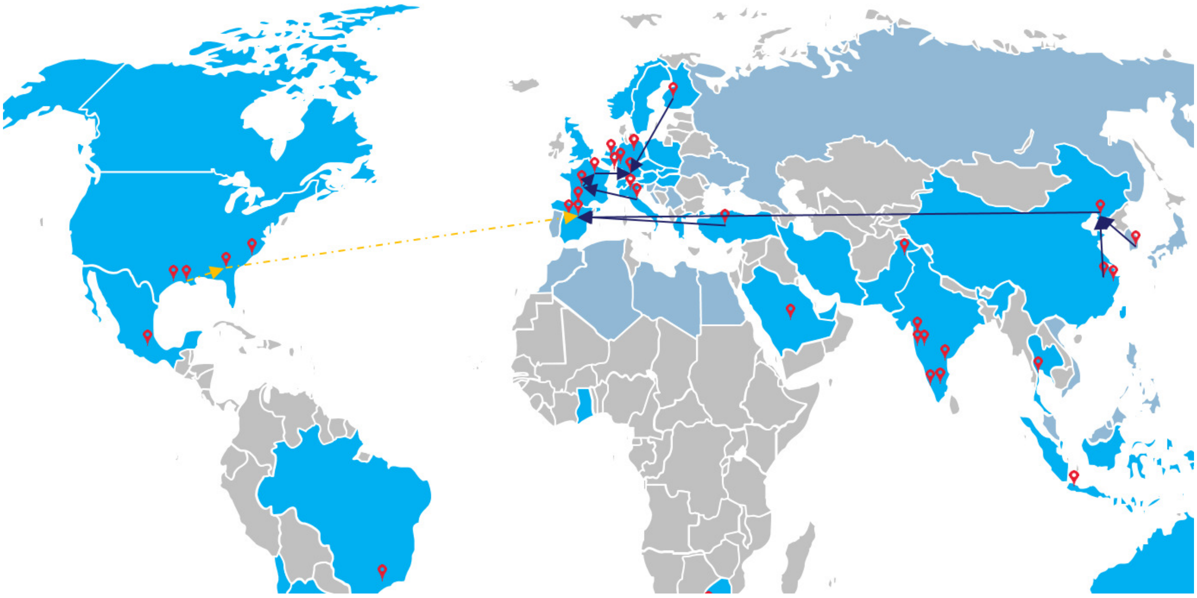


Figure 4-32: Exemplary GPN configuration B

Now the decision maker could think of sourcing some specific components from another plant and by that a different configuration would be applied. In the abovementioned example the parts that were originally sourced from northern America would now be supplied by an Asian plant, see Figure 4-32.

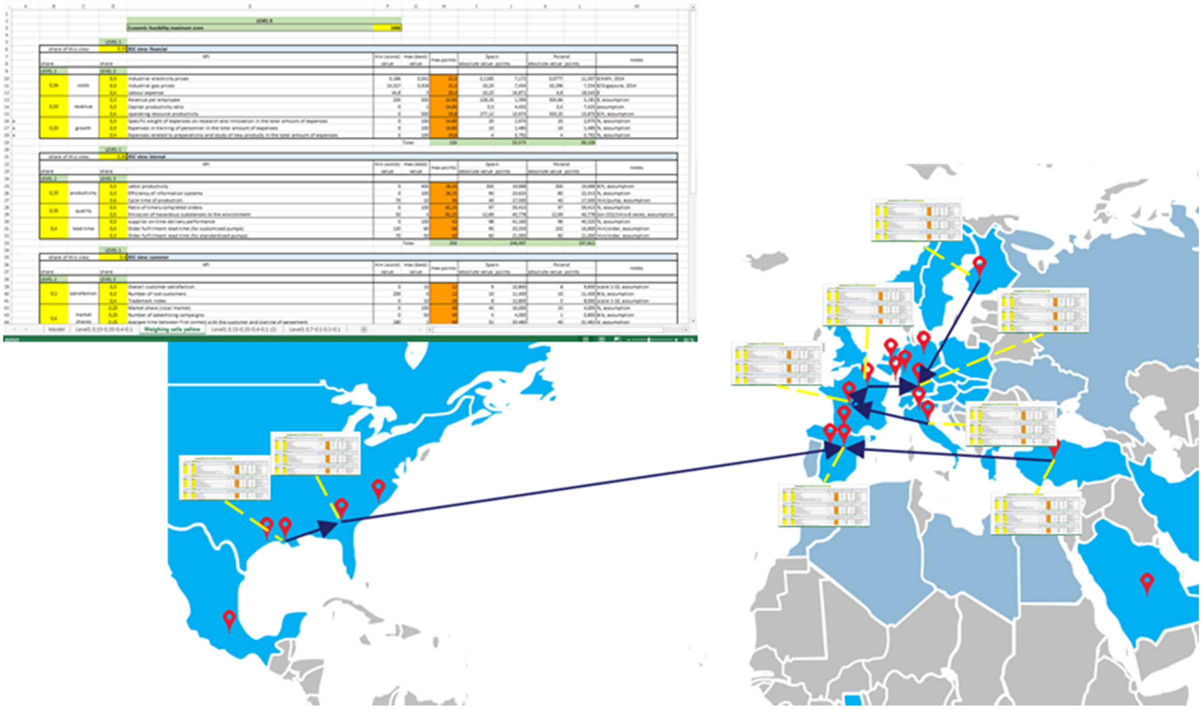


Figure 4-33: Evaluation of network configuration A

To compare the new generated network configuration with the alternative one, the entire network is evaluated. This evaluation is made in a similar way to that described in subchapter 4.10.1, whereas in the case of an entire global production network all of the nodes are considered for the evaluation, see

Figure 4-33 and Figure 4-34. Following the ceteris paribus principle a network configuration achieves an overall score, which is weighted to the nodes relevance in the network, e.g. the share that a component part of a certain node has for the finished product. Comparing to an alternative network configuration, the overall score will be different. So, the overall score is the sum of the weighted single scores related to the value relevance in the network.

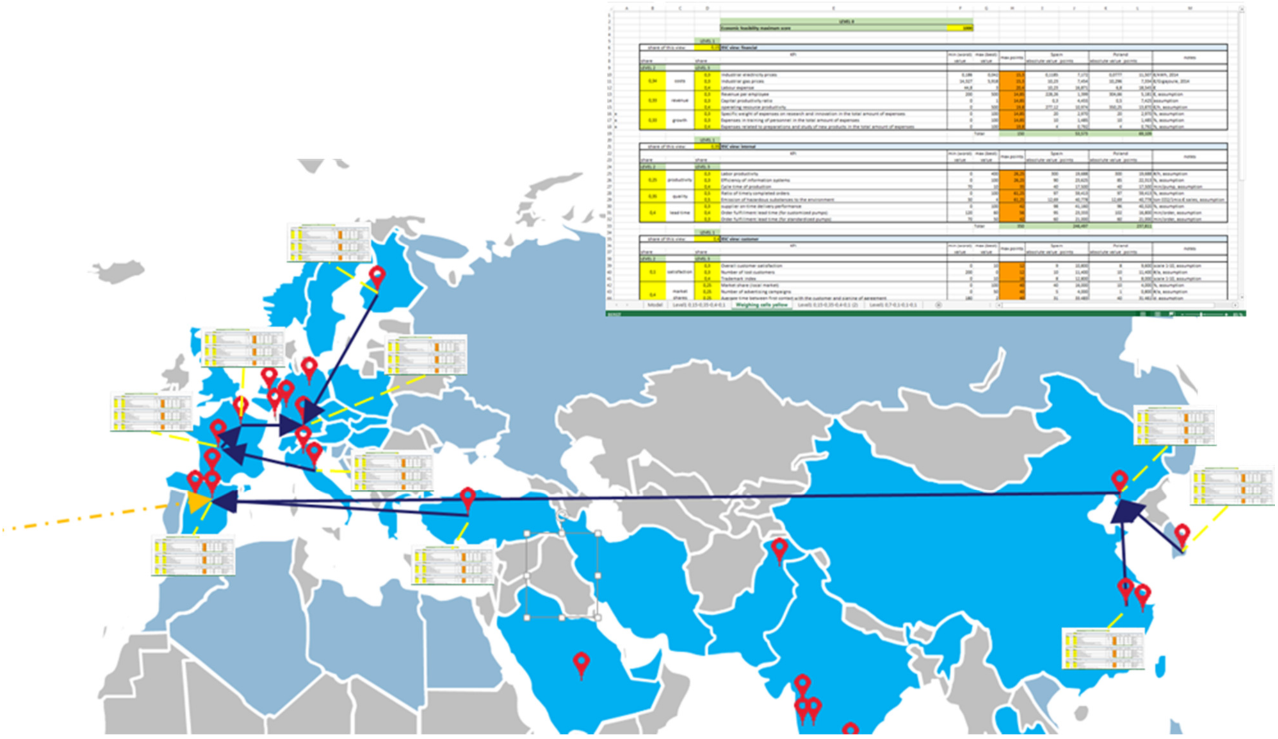


Figure 4-34: Evaluation of network configuration B

In summary it can be stated that together with the risk evaluation approaches, basically explained and illustrated in D2.1, two other figures will be obtained for each network configuration. Additionally to the illustrated strategic value figure, one economic and one risk figure for each configuration is calculated, as shown in chapter 4.3 for the profitability and in chapter 4.4 for risk.

5 Generic GPN business rules

5.1 Ruleset

The framework of this ruleset provides different categories of rules, which have been analysed for the requirements within FLEXINET and are provided in addition to the outcome in D2.2. For instance, the business rules considering different external factors can be applied on a GPN and provide the user decision support while selecting target markets or supplier, as the possible amount of actors will decrease when rules are applied. The rules shown in this section will be implemented within the business rules authoring application, programmed by WP5, and act as constraints within the business modelling in the strategic business model evaluator. Thus, rules can relate to different categories, which are e.g. related to target markets, supplier or production sites. A generic business rules set has the following:

- Market-related (target market)
- Logistic-related (supplier)
- Production-related (production site
- *Product-related (allowed components)*
- Risk-related rules (risk factor)
- Business modelling rules (Canvas Rules)
- Calculation-related rules (weighting-related rules/BSC)

also related to performance indicators and external factors

The rules related especially to target markets, production sites and supplier provide the user decision support in terms of selecting the "right" related markets, production sites or suppliers. In order to provide a user-aligned choice of these actors, different matching levels were developed. The basic level is concerned with mandatory requirements, e.g. that a supplier is simply able to supply a specific part. Acceptable is the next upper level, e.g. containing specific certificate requirements. Preferred is the last level, e.g. fulfilling performance indicator-related values, such as delivery on time. By applying this different level of matching the user retrieves worthy decision support for the needed choices that have to be done for the GPN configuration (see Table 5-1).

Target market	Production site	Supplier
Target market (mandatory requirements)	**Production site** (mandatory requirements)	**Supplier** (mandatory requirements)
Acceptable target market	**Acceptable production site**	**Acceptable supplier**
Preferred target market	**Preferred production site**	**Preferred supplier**

Table 5-1: Key concepts within business rules

5.1.1 Rules on target markets

The business rules related to target markets (see Table 5-2) enable the user to express different level of requirements in terms of markets, which the business model aims at supplying with the product/service output of the business model. Mandatory requirements, acceptable and preferred characteristics can be stated for the target markets.

Target Market
x is a target market.
x is an acceptable target market.
x is a preferred target market.
A target market is a country with an average income exceeds x.
A target market is a country with a Global Innovation Index in excess of x.
A target market is a country with a Global Innovation Index in below x.
A target market is a country with a Political Stability in excess of x.
A target market is a country with a Political Stability Index in excess of x.
An acceptable target market is a country with a Corruption Perceptions Index in excess of x.
An acceptable target market is a country with a Corruption Perceptions Index below x.
An acceptable target market is a country with the existence of child labour.
An acceptable target market is a country with a World Risk Index below x.
A preferred target market is a country if the regulations by law in terms of CO2 emission does not exceed x gram per ton of product y for production sites.
A preferred target market is a country with a Government expenditure on education, total in excess of x.
A preferred target market is a market with an average growth rate (GDP) of x % within the last y years.
A preferred target market is a market with a GDP per capita of x % within the last y years.
A preferred target market is a market with a GDP per capita of x % within the last y years and with an average growth rate (GDP) of x % within the last y years.

Table 5-2: Rules related to target markets

5.1.2 Rules on supplier

The business rules related to supplier (see Table 5-3) enable the user to express different level of requirements in terms of supplying companies. Mandatory requirements, acceptable and preferred characteristics can be stated. With the help of these constraints, the user gets decision support for the necessary choices that have to be made while configuring a GPN.

Supplier
x is a supplier.
x is an acceptable supplier.
x is a preferred supplier.
A supplier is a supplier with an invest in the reduction of CO2 emission below x in the next y years.
A preferred supplier is a supplier with a warranty in lead time of x days.
A preferred supplier is a supplier which costs of logistic do not exceed x €.
An acceptable supplier is a supplier with a delivery reliability less than y %.
An preferred supplier is a supplier with a forecasted average delivery time in excess of x for product y.
If the demand for product x is satisfied by supplier y, product x must not be supplied by another supplier.

Table 5-3: Rules related to supplier

5.1.3 Rules on production sites

The business rules related to production sites (see Table 5-4) enable the user to express different level of requirements in terms of their own sites within the global production network. Mandatory requirements, acceptable and preferred characteristics can also be stated here.

Production Site
x is a production site.

x is an acceptable production site.
x is a preferred production site.
An acceptable production site is a production site with an invest in reduction of CO2 emission below x in the next y years.
A acceptable production site is a production site with a free production capacity of x that underruns or equals the needed amount of free production capacity of y.
An efficient product is a product with an energy class in excess of x.
An unprofitable product is a product with a scrap rate in excess of x %.
An unprofitable production site is a production site with an overall scrap rate equals to or in excess of x %.
A bad production site is a production site with a scrap rate for product x in excess of y %.
If there is a production site producing good x with a free capacity of y within the range of z kilometres, opening a new production site producing good x is prohibited.
If there is a production site producing good x with a free capacity of y within the range of z kilometres, production site w must not produce good x.
If the demand for product x is satisfied by the production program in production site y, product x must not be produced in another production site.

Table 5-4: Rules related to production sites

5.2 Product-related rules

The following rules are related to the restrictions that involve the products (see Table 5-5). A list of generic rules are provided here. The customisation of these rules will continue in WP2 with the aim of providing a customised list for each end user, to be documented in D2.4.

Product related rules
It is necessary that the <product> conforms to the maximum energy consumption legislations of a <country>. + List of allowed energy consumption, +List of countries in the market
It is necessary that the <product> does not violate any existing patents
It is necessary that the <product> is composed only by permitted components for the product's use case (e.g. pump used in nutrition production). + List of non-allowed components

It is necessary that <service personal> is available in the <market> for the specific <product>
It is necessary that personnel is available for conducting <trainings> for a specific <product>
It is necessary that the <product> can be supplied in compliance with the offered <supply strategy>. + List of supply strategies (e.g. just-in-time, in sequence, from stock, by order)
It is necessary that the <product> meets a defined <quality level>
It is necessary that a <product component> meets a defined <quality level>
It is necessary that <experienced personnel> is available for the design/manufacturing/programming/training of the <product>
It is necessary that a maximum <delivery time> between the <location of production> and final <destination> at <client> is not exceeded
It is necessary that a minimum <quantity> of the <product> is ordered

Table 5-5: Rules related to products

5.3 Rules considering risk

While the inoperability model provides a method to determine the expected level of risk in a GPN, the risks also need to be considered before a GPN is constructed. This is necessary in the process of building the potential business model and the alternative GPN configurations and it is supposed to provide a rough initial estimate of the risk. For this purpose, we introduce an approach to consider risks on a market, supplier and production level, similar to the generic rule set defined so far.

To consider risks at this level, the identified risk factors need to be quantified considering relevant external factors or performance indicators. We are going to assume that a single external factor or performance indicator can be used to measure each of the relevant risk factors, and call it the risk indicator. The risk indicator's value is used in the rule for the relevant risk factor as shown by the risk templates in Table 5-6.

Risk Rules Templates
An acceptable supplier is a supplier with **[Risk indicator]** above/below x.
A preferred supplier is a supplier with **[Risk indicator]** above/below x.
An acceptable production site is a production site with **[Risk indicator]** above/below x.
A preferred production site is a production site with **[Risk indicator]** above/below x.
An acceptable market is a market with **[Risk indicator]** above/below x.

A preferred market is a market with **[Risk indicator]** above/below x.

Table 5-6: **Risk Rules Templates**

Some examples of these rules are shown in Table 5-7.

Risk Rules Examples
Risk Factor: Delayed Deliveries
An acceptable supplier is a supplier with **% On-time Delivery** above x.
A preferred supplier is a supplier with **% On-time Delivery** above x.
Risk Factor: Financial Instability of Supplier
An acceptable supplier is a supplier with **credit rating** above x.
A preferred supplier is a supplier with **credit rating** above x.
Risk Factor: Machine Modification Issues
An acceptable production site is a production site with **Engineering Change Order Cycle Time** below x.
A preferred production site is a production site with **Engineering Change Order Cycle Time** below x.
Risk Factor: Political Instability (see MapleCroft's Political Risk Index)
An acceptable market is a market with **Political Risk Index** below x.
A preferred market is a market with **Political Risk Index** below x.
Risk Factor: Import or Export Controls
An acceptable market is a market with **Average Applied MFN tariff** below x.
A preferred market is a market with **Average Applied MFN tariff** below x.

Table 5-7: **Risk Rules Examples**

Additionally, we are proposing rules which consider a specific GPN and interdependency among the GPN nodes.

We are introducing two new concepts: influential and robust nodes. A robust node is a node that has a low dependency on other nodes in the GPN configuration and, hence, can tolerate disruptions in the GPN. An influential node is a node that has significant influence on other nodes in the GPN (other nodes are dependent on the influential node) which means a disruption in the influential node will considerably affect the GPN. To define the relevant rules, we use the defuzzified interdependency values defined in Section 4.8. We consider the sum of all incoming and outgoing interdependency values for each node as shown in Figure 5-1: and compare them with the defined thresholds to determine the status of the node.

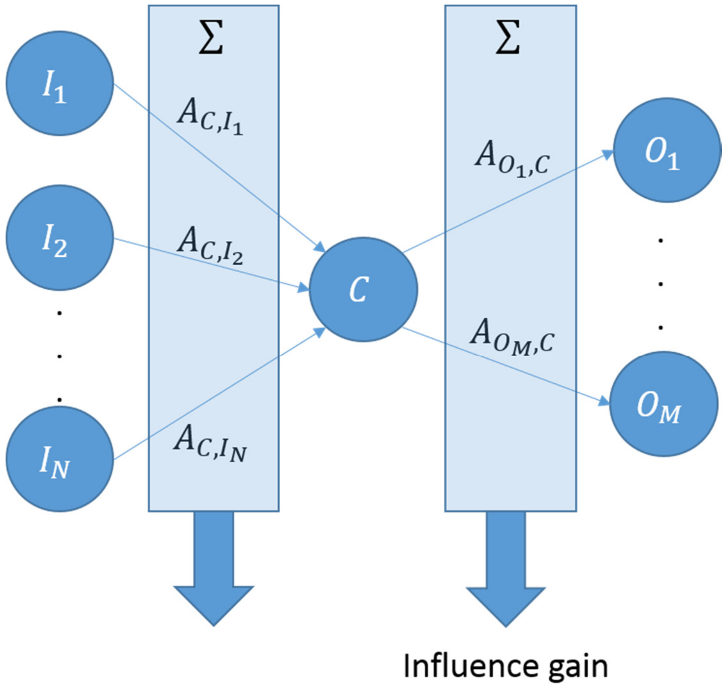


Figure 5-1: Incoming and outgoing dependencies of a node

The resulting rules are as shown in Table 5-8.

Rules for Influential and Robust nodes
If dependency index of **Node C** in **GPN Configuration Y** is below F then **Node C** is Robust in **GPN Configuration Y**.
If influence gain of **Node C** in **GPN Configuration Y** is above **Z** then **Node C F GPN Configuration Y**.

Table 5-8: **Rules for Influential and Robust nodes**

5.4 Business modelling rules

The relationship within the business model canvas framework, as shown in chapter 2.3 of this deliverable, also needs to be expressed in easy to read rule structure. The following set of business modelling rules describes the different dependencies between the business model building blocks. To customise the characteristics of a generic business model, changing these rules would be necessary. The following rules are proposed for the use within FLEXINET in Table 5-9.

Business modelling rules
A KeyActivity may require one or more KeyPartner
A KeyResource may require one or more KeyPartner
Each Key Activity requires at least one KeyResource
Each CustomerRelationship requires at least one KeyResource
Each ValueProposition is created by at least one KeyActivity
Each ValueProposition is created by at least one KeyResource
Each ValueProposition requires at least one CustomerRelationship
Each Value Proposition is delivered by at least one Channel
Each Channel requires at least one KeyResource
A CustomerRelationship has exactly one CustomerSegment
Each CustomerSegment requires one or more CustomerRelationship
Each Channel provides to one or more CustomerSegment
Each RevenueStream is generated by one or more CustomerSegment
Each RevenueStream is generated by one or more ValueProposition
Each KeyResource results in one or more CostStructure
Each RiskFactor applies to one or more KeyPartner
Each RiskFactor applies to one or more KeyResource
Each RiskFactor applies to one or more Channel
Each RiskFactor applies to one or more CustomerSegment

Table 5-9: **Business modelling rules (Canvas Rules)**

5.5 Calculation rules

The calculation model within the balanced scorecard framework contains various relationships, which can be described as business rules, defining the weighting values. For better understanding of the underlying calculation model, the relationships can be made easily interpretable in natural language description. The model itself is defined by the different levels, in detail expressed by the following facts in Table 5-10:

Explanatory calculation rules
The economic feasibility is the result of all balanced scorecard views.
The economic feasibility is a score within the values of 0 and 1000.
Each balanced scorecard view has a defined weighting within the level below the economic feasibility.
It is prohibited, that the sum of all balanced scorecard views exceeds 100 %.
It is obligatory, that each balanced scorecard view consists of more than one key performance indicators.
Each key performance indicator has a defined weighting within the level below the balanced scorecard views.
It is obligatory, that each key performance indicator consists of more than one performance indicators.
Each performance indicator has a defined weighting within the level below the key performance indicators.

Table 5-10: **Calculation rules explaining the calculation model**

As it may be necessary to change the weighting of specific indicators, there is also the possibility of changing values within the following quantifying expressions in Table 5-11:

Determining weightings rules
The “financial” view has a weighting of exactly 10%.
The “global development” view has a weighting of exactly 30%.
The “customer” view has a weighting of exactly 30%.
The “innovation” view has a weighting of exactly 10%.
The “risk” view has a weighting of exactly 20%.
The key performance indicator “costs” has a weighting of exactly 34%.
-Analogue to other key performance indicators on level 2-
The external factor “Industrial electricity prices” has a weighting of exactly 30%.
-Analogue to other external factors on level 3-

Table 5-11: Calculation rules determining views and indicators weightings

A complete set of these calculation rules, drilled down to the relevance of each specific external factor, describes one possible way of evaluating a business model and the related global production network.

6 Conclusion and next steps

6.1 Conclusion

Based on the earlier work within work package 2, namely the conceptual model for business model innovation and the rulebook, we have presented design specifications for business modelling in global production networks.

As a main achievement, the profitability model, helping the end-user to assess the profitability of a specific business model, has been presented. The user is supported in evaluating the profitability of a specific business model with different levels of granularity. Thus, the application of the profitability model within FLEXINET is possible at many different stages of the product development. A more estimative application is possible at the idea generation or rough planning stage, whereas the level of detail and accuracy increases by working on the detailed planning or realisation of a business model.

The evaluation of business models with respect to the corresponding global production network must also consider a number of different external factors and performance indicators. Therefore, in addition to the aforementioned quantitative evaluation of profitability, we also showed how to evaluate business models in a more qualitative way by assessing the strategic value. The normalisation of different indicators and factors and their utilisation within a user-customised balanced scorecard framework allows such an evaluation on a qualitative basis, resulting in the strategic value as an overall score. By drilling down to the different balanced scorecard views the user gets insight of the evaluation aspects and decision support to decide on new or changed business models.

The assessment of risk was done by the development of the novel fuzzy dynamic inoperability input output model. This model enables the determination of the output "inoperability" values for all nodes, considering the propagation of risk throughout a global production network. The resulting values for inoperability show the rate at which the actual level of operation differs from the planned activity level and acts as a measure of the risk impact on each node.

We also introduced the generic ruleset for business modelling in global production networks. The framework of the ruleset provides different categories of rules, which have been analysed for the requirements within FLEXINET. E.g. business rules considering different external factors can be applied on a GPN, acting as a constraint and providing user decision support.

6.2 Next steps

The next step within work package two is task 2.4, concerned with the design of business model scenarios for assessing the business model impact through the adoption of FLEXINET at a company level. As FLEXINET influences the transformation of organisations in a dynamic environment, in this case especially the underlying business model, the target is to simulate these influences, in terms of strategic opportunities and risks for innovative business models.

In particular the influence of change in the economic environment as described in task 2.1 on strategic questions as follows can be assessed and quantified by using the scenarios established in this task:

- Which products and services should companies offer to which markets?

- How many standards does a company have in their products and to what extent are products individualised for the customers?
- Where should companies manufacture different products and where does the customisation take place?

Diverse scenarios will be created in task 2.4 with respect to these strategic questions to assess and to quantify the business model impact of changing environmental factors. Change models described by (Linder & Cantrell, 2000) show how an organisation adapts in a dynamic environment. They describe the core logic for how a firm will change over time to remain profitable. These change models deliver basic scenarios which can be further detailed according to the strategic questions and the external factors. Thus, the outcome of task 2.4 are business model scenarios that assess and quantify the business model impact on company-level using the defined procedures of D2.3 based on the conceptual model for business model innovation (D2.1).

7 Annex A: References

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