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FACULTY OF INFORMATION TECHNOLOGY  
DEPARTMENT OF INFORMATION SYSTEMS

## A TOOL FOR PRODUCT PORTFOLIO ADMINISTRATION OF THE COMPANY

DIPLOMOVÁ PRÁCE

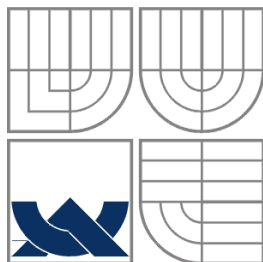
MASTER'S THESIS

AUTOR PRÁCE

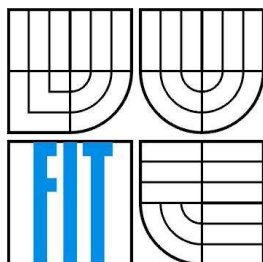
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## NÁSTROJ PRO SLEDOVÁNÍ PRODUKTOVÉHO PORTFOLIA SPOLEČNOSTI

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## **Abstrakt**

Práce je zaměřena na klíčový business proces ve výrobních společnostech a to na vývoj nových produktů. Jejím cílem bylo vytvoření nástroje na odhad rizika výroby nového produktu. Na uskutečnění cíle bylo nutné zjistit možnosti podpory rozhodování. Jako nejlepší nástroj, vhodný pro rozhodování vývoje nových produktů se ukázala Bayesovská síť. Práce vysvětluje návrh Bayesovské sítě pro potřeby odhadu rizika vývoje produktu a ukazuje způsob jak generovat pravděpodobnosti v síti, tak aby výsledné odhady rizik byly co nejpřesnější. Na základě těchto teoretických znalostí je pak vybudován program, který počítá rizika vývoje nových produktů a vyhodnocuje je.

## **Abstract**

This paper concerns about key business process in the production companies, namely, the new product development. The object of this thesis has been to create a tool to estimate the risk of the new product development. To reach this goal, current tools used to deciding the risk must have been explored. As the best tool, appropriate for assessing the risk of new product development has proved the Bayesian Network. This paper explains the construction of the Bayesian network and shows the way how to generate the probabilities in the network to be accurate for the risk estimation. Based on this theoretical knowledge has been built an information system, which estimates the risk of the new products and administer the risks.

## **Klíčová slova**

Vývoj nových produktů v společnosti, riziko vývoje nových produktů, rozhodování v nejistotě, Bayesovské sítě, podmíněné a prioritní pravděpodobnosti, reengineering podnikových procesů

## **Keywords**

New Product Development, new product development risk, uncertain reasoning, Bayesian network, conditional and prior probabilities, business process reengineering

## **Citace**

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# **A tool for product portfolio administration of the company**

## **Declaration**

I hereby declare that this thesis is my own work that has been created under the supervision of Ing. Šárka Květoňová, Ph.D. Where other sources of information have been used, they have been duly acknowledged.

.....  
Miroslav Koreň  
4.4.2011

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# 1 Introduction

To administer in these days the product portfolio, it is required to have a powerful tool which corresponds with business processes in the company. Competitors on the market constantly improve business processes with the help of new technologies. To be competitive means to follow this trend and apply new methodologies and technologies into all processes. One of the crucial processes to keep company competitive presents new product development. This process is playing an essential role in one company called SKB. Indeed, SKB has fought every year against a growing number of competitors and lost customers due to ineffective estimation of new product development risks. This serious situation resulted in the need to develop a tool which would analyze the risks of new product development process. This paper will address development of such tool, and will utilize the reasoning of the Bayesian Network.

After this slight introduction follows in this paper the second chapter which provides information about the way how to improve business process in a company, if it is better to proceed in slight changes or rebuilt process from scratch. Third passage focuses on process of new product development and assesses current new product development risk analysis. Based on the results of the evaluation is Bayesian Network chosen as a possible tool for analyzing risks of new product development in the company. However, Bayesian network needs some improvement to fit to the matter of new product development risk assessment, which is described at the end of second chapter.

Construction of Bayesian network is undoubtedly a difficult task, especially in the case of new product development. Chapter 4 describes construction of the new product development risk network for purposes of SKB Company. It informs the reader, why those particular nodes of the network were chosen and the meaning of each node is provided as well as the explanation of the nodes' states. In addition, on the case study is clarified, how are the risks in the network recounted.

Finding the right composition of the Bayesian network is not the only one important task to get the correct risk estimations. At least equally important is to decide probabilities in the network. The probabilities determine importance of each state of the node. Moreover, the probabilities influence relationship between the nodes. The chapter 5 gives the instructions about generation of probabilities for each kind of node in the network. It is important to have opinion about generation of probabilities as well as about construction of the network, because these theoretical principles have been applied in the developed software for assessing the risk of new product development.

The developed software for assessing the risk is indicated in the chapter 6. Firstly, this part introduces the changes against the provided theory, when the new way of estimating prior probabilities in the network is proposed to make the estimations more accurate. Secondly, the software for assessing the risk of the new product development is introduced, the architecture of the software is described and the description of the software is made. The final part ends with the summary of the software and brings the possible extensions of the system.

Last but not least, the opinions and experiences collected during the work on this project have been placed in the conclusion part. In addition, in Appendix to this paper are figured some screenshots of the developed software.

## 2 Business Process Management

Recently, more and more companies faced the problem of effective management of business processes. Ideas about how to define and manage processes, however, differ fundamentally. This is mostly due to the lack of knowledge about business process management. Then it is certainly difficult to set targets to be achieved [28].

According to [24], business process management can be defined as

„The achievement of an organization’s objectives through the improvement, management and control of essential business processes. BPM is

- more than just software
- more than just improving and reengineering processes of company processes – it also deals with the managerial issues
- not just hype – it is an integral part of management
- more than just modeling – it is also about the implementation and execution of these processes, which requires analysis “.

A precondition for making sufficient process management model is the knowledge of corporate strategy [28]. Within that knowledge, it is possible to make changes to process infrastructure. Before making process model, it is necessary to further define the scope of the process model. This means to determine which areas will be included in the model. After defining the scope of the model and its external requirements, the creation of the model is possible. Basement for model are material flows in company, which create natural processes. Above them we define the highest level, namely, key business processes. Key business processes usually cover numerous functional areas of business and they are tied to business strategy. Usually, in the company, there are only few key business processes. To the category of key business processes falls also “new product development”, which is the main topic of this thesis. The SKB Company has decided to rebuild this key business process.

Generally, two ways to rebuild company business processes exist [29]. The first of them, continuous improvement of processes, is the path that many companies in these days run on. This cyclic process depicts the figure 2.1.

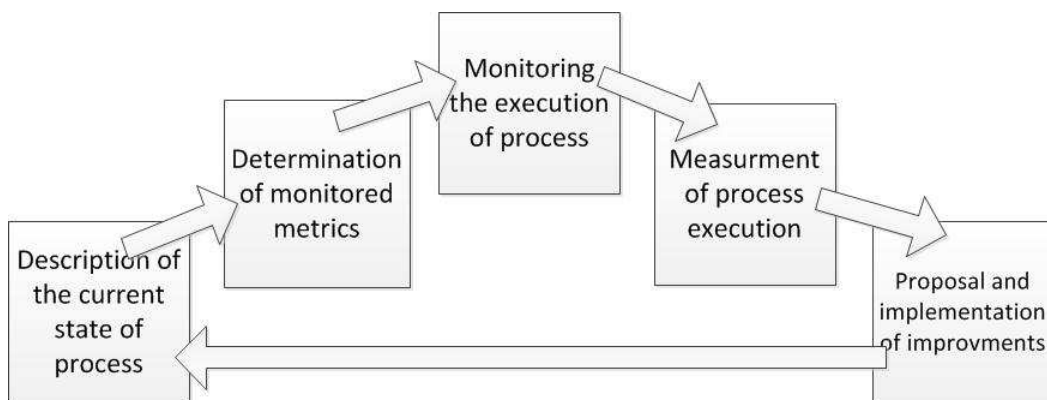


Figure 2.1: Continuous improvement of business processes in company (repainted from [29]).



The second possibility presents the “Business Process Reengineering” (BPR), which appeared in the early 90s. BPR is a completely different approach to the continuous process improvement. In its extreme form, BPR considers the current process as completely unsatisfactory. BPR is illustrated in the figure 2.2.

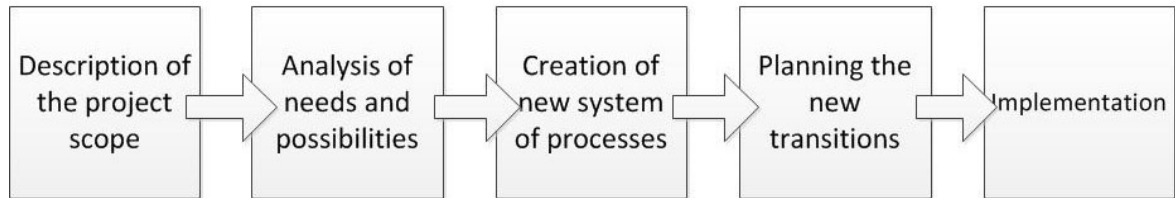


Figure 2.2: Business process Reengineering – BPR (repainted from [29]).

BPR begins with a definition of scope and the main goals of reengineering and continue with proper analysis (analysis of employees, competitors, customer needs etc.). After such proper analysis is possible to develop a vision of future processes and think about interdependencies between the processes. Then, based on the new scheme of processes, it is necessary to plan the actions towards deployment of the new processes. These actions aim to overcome the gap between current state of process and vision of its future state. Finally, implementation of process follows. Comparison between the BPR approach and continuous improvement sums up the table 2.1.

|                      | Continuous improvement | BPR                      |
|----------------------|------------------------|--------------------------|
| level of changes     | gradual                | radical                  |
| access point         | existing process       | starting from scratch    |
| frequency of changes | single / successive    | single                   |
| time needed          | short                  | long                     |
| typical range        | limited                | interdisciplinary        |
| Riskiness            | medium                 | high                     |
| primary tool         | statistical management | information technologies |
| type of change       | cultural               | structural               |

Table 2.1: Comparison of BPR with gradual improvement (drafted from [29]).

Information technologies play the key role in necessary changes. They break down the old rules and enable to replace them. The key role of information technologies leads to the impression that information technologies are the only cause of reengineering revolution. This impression does not reflect the reality, because technology is only a necessary part reengineering changes.

The management of SKB has decided to make a continuous improvement of the key process “new product development”. Except for the structural changes the company has already made, the SKB requires a software for assessing the new product development risk. The estimation of product development risk is available in some ERP systems, for instance in SAP. Mostly, such risk estimation in the companies are not done by some specialized software but with usage of some mathematical

methods. The summary of the methods that have been used in the new product risk development estimation so far, is provided in the next chapter.

## **3 New product development as a business process of a company**

SKB Company is engaged in the manufacture of steering wheels and polyurethane products for the automotive industry, as well as for other industry segments. As many other companies decided to rebuild company processes. One of the crucial processes to keep SKB being competitive is the development of new products. In response to a competitive business environment, new product development (NPD) plays an essential role in the success of many companies. By nature, it is relatively risky activity and process with high uncertainty. Managing the risks of any NPD project is therefore becoming important. In SKB, risk handling of NPD projects, have been dealt with so far, by using informal and unsystematic methods. Mostly it has been based on management perceptions. Even though the company's management has, on numerous occasions, defined the risks correctly, sometimes a fluke occurs. New product development was costly, and sometimes did not attain expected success. Given the past experiences, company management now demands the evaluation of potential project risks, prior to the implementation of NPD projects.

Determining the projects with higher probability of failure, company's management can consider them before making substantial investments in NPD projects.

### **3.1 Existing NPD project risk analysis**

Unfortunately, not much has been written about NPD risks in so far. Although some studies have been made, risk-based NPD evaluation is vague in many areas. According [2] to existing studies in NPD, the existing studies do not provide sufficient in-depth investigation of this area.

In the next few lines advantages and disadvantages of decision methods and techniques will be summed up, as identified for NPD risk analysis.

#### **3.1.1 Behavioral Model**

Behavioral model analysis reproduces the required behavior of the original analyzed system, such as there is a one-to-one correspondence between the behavior of the original system and the simulated system. That namely implies that the model uniquely predicts future system states from past systems states [1]. However, as in [2] the authors imply, behavioral model can neither analyze uncertainties quantitatively, nor accommodate complex decision making.

#### **3.1.2 FMEA**

Failure Mode and Effect Analysis (FMEA) is in [3] defined as "an engineering technique used to define, identify, and eliminate known and/or potential problems, errors from the system, design or process before they reach the customer". According to the information summed up in [2], "FMEA exists in many applications and modifications, but as the scoring method can only indicate the average of performance in a single score and cannot present the true diverse nature of an assessment. On the other hand, a human's judgment, e.g., the human's knowledge on the distribution of different risk states, cannot be modeled by just a precise number by pre-aggregating various types of

information. Therefore, FMEA can only be used as a tool for initial assessment or a rough assessment categorization tool.”

### 3.1.3 Fuzzy TOPSIS

Fuzzy TOPSIS [4] is a method for analyzing decision making in NPD based on TOPSIS technique. TOPSIS is one of the best grading methods of multi criteria decision making (MCDM) that is taken place in compromising. According to this technique, the best alternative would be the one that is nearest to the positive-ideal solution and farthest from the negative ideal solution [5]. However, fuzzy TOPSIS require strict hierarchy, whereas NPD is a complex problem hardly modeled in strict hierarchy [2].

### 3.1.4 AHP

Due to [2] Analytic Hierarchy Process (AHP) has been used in NPD risk analysis as well. AHP is based on assumption that a problem can be constructed in strict hierarchy, where the elements on the same level do not influence each other. This assumption however, hardly corresponds with reality, where the dependency between elements is really complicated.

To solve AHP independency problem, author of AHP proposed Analytic Network Process (ANP). ANP can handle more complicated relationships and has already been used in NPD analysis [2]. Despite slight success in ANP, some limitations still exist. Relationships given by weights between elements (generated with pair-wise comparisons) cannot quantify or demonstrate influences among those elements. Moreover, as NPD lives in uncertain environment, sometimes update of results is needed due to the changes of information. Unfortunately for ANP, these changes are inconvenient.

### 3.1.5 Bayesian Network

Another way to analyze risk of NPD is Bayesian Network (BN). Bayesian Network is a probabilistic graphical model represented via directed acyclic graph (DAG). BN consists of nodes labeled by random variables<sup>1</sup> connected with edges. Each edge connecting two variables means conditional dependence between these variables. Dependence is expressed with conditional probability table (CPT)<sup>2</sup>. For example, a Bayesian network could represent the probabilistic relationships between diseases and symptoms. Given symptoms, the network can be used to compute the probabilities of the presence of various diseases. Another network, can compute probability of wet grass according to various conditions, as shown in Fig. 3.1.

Comparing Bayesian Network to tools mentioned before, BN is a tool for reasoning with probability. It can deal with problems which can be modeled in network structure. Contrary to previous tools, Bayesian Network can conveniently update prior judgments when new evidence becomes available [2].

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<sup>1</sup> In the following text will the expressions variable and node represent the same idea.

<sup>2</sup> Examples of conditional probability table are displayed in the figure 3.1. Note that the probabilities of each row sum up to 1. The nodes without parents include the prior probability, which reflects our belief about the variable [11].

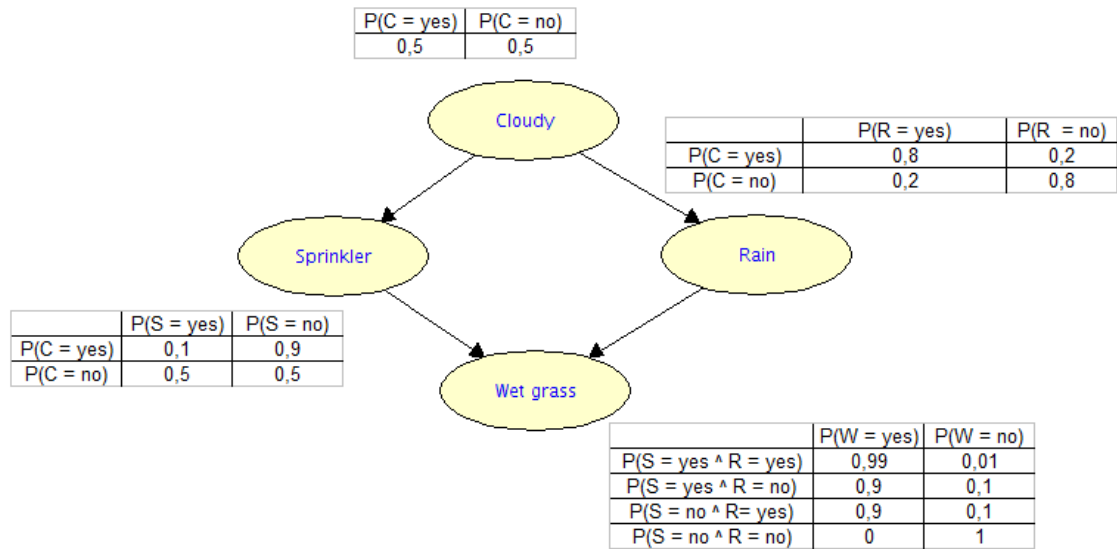


Fig. 3.1: Example of Bayesian Network with figured distribution of conditional and prior probabilities (C – cloudy, R – rain, S – sprinkler, W – wet grass, picture redrawn from [7]).

### 3.1.6 Conclusion

The reasons mentioned above persuaded authors of [2] to apply Bayesian Network in “New Product Development” analysis. For SKB Company, were these reasons conclusive enough to follow the study [2] and develop system assessing new product development risks based on the reasoning of Bayesian Network.

## 3.2 Assessing Bayesian Network as a tool for NPD analysis

Construction of Bayesian Network consists obviously from 2 difficult tasks. In applications, where BN was used to predict NPD risk, only the generation of structure of BN was described properly. To generation of conditional probabilities has been paid only little attention [2].

### 3.2.1 Generation of conditional probabilities in BN

Complete CPT for a binary variable with  $n$  binary predecessors in a BN requires  $2^n$  independent parameters<sup>1</sup>. Hence the number of parameters in a CPT grows exponentially with the number of parents. An assumption of causal independence among the parent nodes that affect the child node greatly reduces the number of required parameters. The Noisy-OR model [25] makes this assumption

<sup>1</sup>This statement confirms the distribution of conditional probabilities for the node wet grass in the figure 3.1. The variable wet grass has 2 parents, both parents are binary variables. Indeed, the number of values, which must be filled in the CPT for the node wet grass, meet  $2^2 = 4$ .

and provides a logarithmic reduction in the number of parameters required relative to the CPT. However, this advantages convert into disadvantage in NPD risk analysis. As mentioned before, assumption of independence of node parents does not fit much to reality of NPD. Moreover, Noisy-OR assumes that the states of variables are only binary.

Given these problems, in [6] Das introduced new approach how to generate conditional probabilities in BN. Das proposed definition of ‘compatible’ which released the assumptions of independence and the restriction to the binary that could reduce the burden of computation[2]. However, accordingly [2], in NPD environment, where every combination of parents is possible, the definition of ‘convenient’ is not much practical. Even more, Das approach uses direct estimation of conditional probabilities, which may involve subjectivity and biases. Such subjectivity can be decreased using pair-wise comparison to generate conditional probabilities. This method, according to [2], mentioned Monti and Carenini in [27]. In pair-wise comparison just two states of variable are compared instead of all states of variable. Unfortunately, Monti and Carenini were using pair-wise method only for nodes with single parent, whereas nodes in Bayesian Network can have more than one parent.

### **3.2.2 Conclusion**

To conclude, Bayesian Network has some advantages when compared to other above mentioned tools, but need some improvements. What needs to be improved is generation of conditional probabilities. Authors of [2] decided to develop own methodology for generating conditional probabilities. In addition, they put effort into investigation of critical risk factors of NPD.

## 4 Constructing a NPD project risk network

To acquaint the reader with the Bayesian Network more in detail, following chapter deals with the proper explanation of this tool. On the example from the figure 3.1 explains the calculation of the risks in BN. Moreover, the theoretic base is provided to this calculation.

### 4.1 Counting probabilities in Bayesian Networks

As stated previously, constructing BN consists of two parts, qualitative and quantitative. Qualitative includes generation of nodes and edges between the nodes. The nodes represent the variables of interest with uncertainty, expressed in probability. The directed arcs pointing from a parent node to a child node represents the casual and conditional dependency. The nodes without parents are called root nodes. Quantitative part addresses the relationship among a node and its parents. The relationship is expressed by the probability of the states of some node, conditioned on the different combinations of its parent's states [2]. Such probability can be expressed in mentioned CPT tables. After the structure of BN is decided and the conditional probabilities are generated, BN can be constructed. When new evidence is revealed that determines the prior probability of the states of root nodes, the inference (4.1.3) can be performed. Probability inference recounts marginal probabilities. Marginal probability means probability of the state of node over all possible values of node's parents. It is determined from joint distribution (4.1.2).

In chapter 3, figure 3.1 captures the situation, in which the grass on the garden can appear. Given the prior and conditional probabilities from 3.1, the marginal probabilities of nodes in BN were recounted and are shown in figure 4.1.

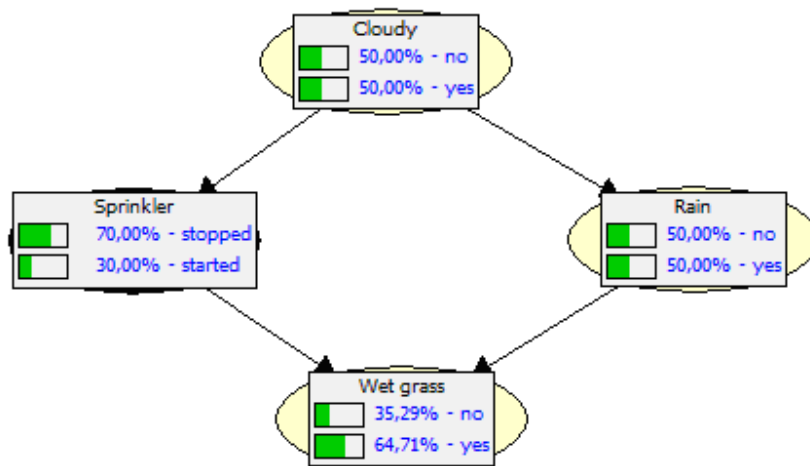


Fig. 4.1: Bayesian network with marginal probabilities.

### 4.1.1 Case study of building Bayesian Network

This section addresses how the network in the figure 3.1 was built and why the CPT's were filled as depicted in the figure. To simplify the situation, consider that the grass can be wet only if it is raining or the sprinkler is on. Then the probability of the wet grass depends on the fact that the sprinkler had been turned on or it had been raining. In addition, sometimes it is cloudy and sometimes the sun is shining. The probability of rain is higher when it is cloudy, compared to when it is sunny weather. Similarly, the probability of turning on the sprinkler is higher on a sunny day. The probability of turning on the sprinkler, is the same as the probability of rain, both are conditional on cloudy weather. If it is cloudy, it is more probable that it will start raining, whereas if it is not, then the probability that the sprinkler will be started is higher. In the figure 3.1 every node has specified the distribution of conditional probabilities<sup>1</sup>. The states of the mentioned variables are discrete, therefore the distribution is viewed in the given tables. Table involves the probabilities of all states of variable given all combinations of parent nodes. For example probability of wet grass given the fact that sprinkler had been started and it had not been raining before:  $P(W = \text{yes} \mid S = \text{yes}, R = \text{no}) = 0.9$ . Probability of the cloudy weather is prior probability<sup>2</sup>. The node "cloudy weather" does not have in the network parents and the distribution of prior probabilities for this node is set just according to the experiences we gained from weather observation. The observation tells that rainy weather is same probable as it is not raining. For that reason is the prior probability of the node "cloudy weather" set to 50% (0.5).

After the CPT's of all nodes are filled, various probabilities can be counted from BN. For example, for the "wet grass" case can be useful to count the probability of previous rain, when the grass is wet. Same as the probability that the sprinkler was turned on, can be recounted and both probabilities can be compared.

Furthermore, Bayesian network is convenient for changes. It can successfully combine new evidence with existing knowledge. This is possible because BN implements Bayes' theorem.

### 4.1.2 Bayes' theorem

Mathematically, this rule is presented as:

$$P(H \mid E, c) = \frac{P(H \mid c) * P(E \mid H, c)}{P(E \mid c)}$$

Equation 4.1: Bayes' rule used in Bayesian Network ([7]).

The equation above means that our assumption about the hypothesis H is actualized given the new evidence E in background context c.  $P(H \mid E, c)$  is posterior probability of hypothesis H taking effect of new evidence E on context c into account.  $P(H \mid c)$  means prior probability of H in the context without taking information about E into account. Probability  $P(H \mid E, c)$  called likelihood is

---

<sup>1</sup>Conditional probability is a type of probability, which is conditioned on other known factors. For two events A and B, with  $P(B) > 0$ , the conditional probability of A given B is  $P(A \mid B) = P(A \cap B) / P(B)$ .

<sup>2</sup> Prior probability is according to [11] the probability that an event will reflect established beliefs before the arrival of new evidence or information. Prior probabilities are the original probabilities of an outcome, which be will updated with new information to create posterior probabilities.



probability of new information provided the H and context c are true. Normalizing factor  $P(E | c)$  is independent of H and normalizes the value of posterior probability [7].

With the usage of Bayes' theorem, the probability of started sprinkler given the wet grass can be rewritten in the following way:

$$P(S = 1 | W = 1) = \frac{P(S = 1) * P(W = 1 | S = 1)}{P(W = 1)} = \frac{P(S = 1, W = 1)}{P(W = 1)}$$

Equation 4.2: Probability of started sprinkler given the wet grass ([7]).

### 4.1.3 Joint probability

Joint probability expresses how likely it is that two (or more) events happen at the same time. The numerator in the equation 4.2 is an example of such joint probability. With the help of chain rule<sup>1</sup> is possible to deduce the joint probability  $P_N$  for our network like:

$$P_N(C, S, R, W) = P(C) * P(S | C) * P(R | C, S) * P(W | C, S, R)$$

Equation 4.3: Joint probability ([7]).

The simplest rule of conditional independence for Bayesian Network says that the node is independent from its ancestors with given parents. In other words, conditional independence is expressed with the absence of possible oriented edges. In our case, "Rain" is independent from "Sprinkler" given its parent "Cloudy weather" and "Wet grass" is independent from "Cloudy weather" given its parents "Sprinkler" and "Rain". Applying the conditional independence into equation 4.3, the equation can be reduced into:

$$P_N(C, S, R, W) = P(C) * P(S | C) * P(R | C) * P(W | S, R)$$

Equation 4.4: Applying conditional independence ([7]).

### 4.1.4 Probability inference

Probability inference is one of the basic tasks the Bayesian Networks are used for. In the example we found out that the grass is wet. The case takes into account just 2 possibilities why the grass can be wet. Either it had been raining before or the sprinkler had been started. One of the interesting challenges is to explore what is more probable, if the wet grass is caused by sprinkler or by previous rain. With the help of Bayes' rule and joint probability the posterior probabilities of both reasons of wet grass can be figured up.

---

<sup>1</sup> Chain rule is used for decomposing a probability distribution into a product of conditional distributions according the structure of the network [25].

For Sprinkler:

$$\begin{aligned}
P(S = 1 | W = 1) &= \frac{P(S = 1) * P(W = 1 | S = 1)}{P(W = 1)} = \\
&= \frac{P(S = 1, W = 1)}{P(W = 1)} = \frac{\sum_{c,r} P(C = c, S = 1, R = r, W = 1)}{\sum_{c,s,r} P(C = c, S = s, R = r, W = 1)} = \\
&= \frac{\sum_{c,r} P(C = c) * P(S = 1 | C = c) * P(R = r | C = c) * P(W = 1 | S = 1, R = r)}{\sum_{c,s,r} P(C = c) * P(S = s | C = c) * P(R = r | C = c) * P(W = 1 | S = s, R = r)} = \\
&= \frac{0,2781}{0,6471} = 0,4298
\end{aligned}$$

Equation 4.5: Probability of started sprinkler given wet grass ([7]).

For Rain:

$$P(R = 1 | W = 1) = \frac{P(R = 1) * P(W = 1 | R = 1)}{P(W = 1)} = \frac{P(R = 1, W = 1)}{P(W = 1)} = \frac{0,4581}{0,6471} = 0,7079$$

Equation 4.6: Probability of previous rain given wet grass ([7]).

According the probabilities inserted into CPT's and the previous equations, the assumption can be made that the rain caused the wet grass with higher probability then sprinkler. The ratio of the probabilities is  $0,7079 / 0,4298 = 1,647$ . Rain is 1,6x more probable cause of wet grass then sprinkler.

## 4.1.5 Conclusion

To sum up, this example showed how the Bayesian network can be built, how the probabilities can be generated or how to recalculate the network, given new evidence. With this knowledge, the construction of NPD project risk is possible.

## 4.2 NPD risk network

NPD project's risk is in [2] defined as the probability that the NPD project cannot be executed within the expected duration. Products with high NPD risk are rather not selected for production. As the critical aspects for the NPD project selection are generally taken market fitness, technical competencies, financial issues and operational uncertainties. Among all these uncertain aspects will be in this work highlighted technical impact on the NPD projects. Indeed, in conjunction with [2] just technical aspect brings most challenges in NPD. Project technical fitness can be examined in terms of product design, manufacturability, product quality and supplier stability. Actually, NPD execution process can be categorized into three major steps starting with concept development and prototype

development, continue with manufacturing start-up and technical service [2]. Throughout the various stages of this process a lot of uncertainties can be found and all can cause the NPD project risk. For instance, using new or advanced technologies could result into changed product performance. New technologies, same as experiences of the workers and many other factors influence research and development risk. The capability of incorporating new technologies into mass production presents production reliability. The bigger the production reliability, the smaller is the risk of NPD. In addition, the product alone, determines how risky the production will be. Complexity of product and its production, impact product reliability and subsequently NPD risk. Last but not least, having reliable supply of materials and components needed for production leads to the lower risk in production. Generalization of all the factors that affect NPD risk is provided in [2]. According this study NPD risk can be classified into 4 main classes, namely, research and development risk (RADR), production risk (PROR), product reliability risk (PRRR) and supply risk (SUPR). These sub-risks are inserted into the NPD project risk Bayesian network as non-root nodes and all those create parents for NPD risk node. This Bayesian network is figured below and will be discussed in following sections more specifically.

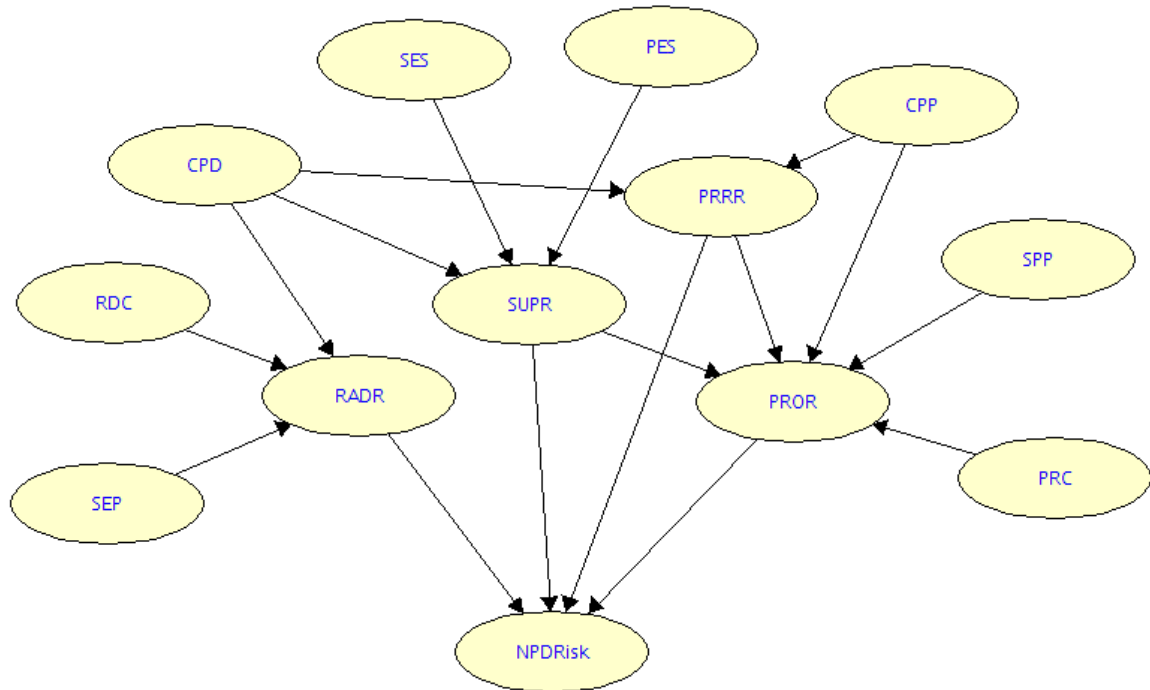


Fig. 4.2: NPD project risk network (redrawn from [2]).

### 4.2.1 Similarity of the existing product (SEP)

SEP is presented like the measure of similarity to which the new product design will be corresponding to the existing products. The similarity is related to product structure, materials used for production of such product, functional mechanism, etc. Similarity of the existing product in the network of NPD project risk impacts already stated research and development risk. The higher the SEP, the lower the RADR is.

### **4.2.2 Research and Development capability (RDC)**

Level of experience, knowledge, competence of the R&D engineers in company can determine research and development capability. As stated in [2], RDC is the measure of the extent to evaluate the company's potential to articulate successful research and development capabilities. If the developers of the company are able to provide parts, technology, procedures for some innovative product, this capability is high. High RDC significantly decreases RADR and subsequently NPD risk.

### **4.2.3 Complexity of the product design (CPD)**

Variety of accessories, from which the product can consist, different material, maturity of product technologies makes from the CPD important measure. Usually more components and smaller size cause higher complexity risk. CPD influences RADR, because development of more complex product can bring the need of additional research or development. Product made from rare or expensive accessories, can result in difficulties with suppliers. Such problems can lead to high SUPR. Furthermore, higher complexity increases the extent of PRRR.

### **4.2.4 Similarity of the existing supply (SES)**

Obviously, only the brand new companies construct their products from scratch. Most of the companies, established on the market, use the similarity of new proposed product with the existing products. Such similarity allows using common materials and outsourced components from the current supplier. Usage of current suppliers or the necessity to gain new suppliers, creates the measure called similarity of the existing supply (SES). On one hand, usage of current suppliers increases the value of SES. On the contrary, the need for new supply decreases the SES. Of course, SES notably influences SUPR.

### **4.2.5 Supplier performance (PES)**

The measure to which the suppliers are reliable, with acceptable performance is defined like supplier performance (PES). There exist many methodologies on how to evaluate supplier performance [8]. Accordingly, price, quality, innovation, delivery, account management, service performance play a key role in assessing suppliers. Apparently, high supplier performance makes SUPR lower and vice versa.

### **4.2.6 Complexity of the production process (CPP)**

Production process means transformation of necessary inputs into the product that meets the needs and wants of customers. Complexity of this transformation from the technical viewpoint depends on ease of assembly, degree of automation, precision requirements of the product that should be constructed and many other factors. CPP directly influence production risk and product reliability risk in the network of NPD. PROR same as PRRR proportionally increase with the enlargement of CPP.

### **4.2.7 Similarity of the production process (SPP)**

Production processes differ from one product to another and depends on how the product is manufactured. Production can be utilized on the same level of automation for 2 products, same level

of tools used or same workers with experiences included. The higher similarity and commonality cause lower production risk in both quality and productivity aspects [2].

#### **4.2.8 Production capability (PRC)**

In accordance with business dictionary [9], production capability is defined as a volume of products that can be generated by a production plant in a given period by using current resources. How to evaluate production capability? There exists plenty of methods that companies use to assess production, beginning with simple AHP [10] to methods constructed directly on the type of production. Machine precision, production process capability, competence of the production operators and engineers, effectiveness of quality assurance system, efficiency of maintenance play important role in assessing PRC as reported by [2].

#### **4.2.9 Research and development risk (RADR)**

Research and development risk is defined in [2] as: “the likelihood that product specifications cannot be fulfilled within the expected schedule”. Fulfilling the specification means in case of NPD provide sufficient materials, technology and knowledge before production. Development of some product can bring challenges to apply advanced technology into the product. The likelihood the company can deal with such challenge is the mentioned research and development capability (4.2.2). Production can be understood as building some functional blocks together. If the blocks are common, the experience gained in the past may be helpful. Here, similarity of the existing products (4.2.1) with the new product decreases RADR significantly. Last but not least, complexity of the product design (4.2.3) determines how much effort should be put in research and development.

#### **4.2.10 Supply risk (SUPR)**

Business dictionary [9] defines supply risk as probability of loss occurring from unavailability of the necessary raw material(s) within the expected schedule. According to [2], list of the reliable suppliers should exist, as they could bear the responsibility of the quality and availability of some critical components, so management of supplier performance (4.2.5) is one critical factor influencing SUPR. As it was mentioned in 4.2.4, if similarity of existing product and the new product is high, company should already have the records of the required suppliers. Therefore, stable supply of materials is easier to be achieved. Product complexity (4.2.3) makes the product more dependent from the suppliers and subsequently more risky, because higher difficulties in searching for the suitable components may appear.

#### **4.2.11 Product reliability risk (PRRR)**

As defined in [2], “product reliability risk is the likelihood that a stable production process and an expected product performance in its service lifetime can not be fulfilled.” The low complexity of production process provides assumption for stable production. On the other hand, the expected product performance can be achieved due to the low complexity of product design. Therefore, in the Bayesian Network are modeled the nodes “complexity of product design” and “complexity of production process” as the parents which influence the child node “product reliability risk”. The paper

[2] prefers the multiphase development approach and employing modular design of a product to achieve product's reliability.

#### 4.2.12 Production risk (PROR)

The paper [2] provides also the definition of production risk. "Production risk is the likelihood that the production requirements cannot be met within the expected schedule." Low similarity of production process (SPP) same as high production complexity make the production risky. In addition, production capabilities (PRC), supply risk (SUPR) and production reliability (PRRR) significantly influence the production in the company.

#### 4.2.13 Considering node states in the network

Construction of the Bayesian Network forces implementer to think not only about nodes of the network, but also about the states, in which the node can appear. As the reader will see in the next chapter, choice of the right states of the node in the network has enormous impact on generation of conditional probabilities in the network. Given the past experiences, for the purposes of SKB NPD risk network were chosen only binary states of all nodes. This decision was supported also after the discussion with the company. Section 3.2.1 talked about generation of probabilities in BN, where was stated the following fact: „Complete CPT for a binary variable with  $n$  binary predecessors in a BN requires  $2^n$  independent parameters“. For instance, for the node PRRR with 5 parents it means generation of 32 values if all parents' values are binary. Such example of completed CPT is placed in the figure 4.3. Generation of so many values represents certainly difficult task. If one of the parents, for example CPP would have 3 states, generation of 48 would be even more difficult.

| spp  | Low |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | High |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| cpp  | Low |      |      |      |      |      |      |      | High |      |      |      |      |      |      |      | Low  |      |      |      |      |      |      |      | High |      |      |      |      |      |      |      |
| prc  | Low |      |      |      | High |      |      |      | Low  |      |      |      | High |      |      |      | Low  |      |      |      | High |      |      |      | Low  |      |      |      | High |      |      |      |
| supr | Low |      | High |      | Low  |      | High |      | Low  |      | High |      | Low  |      | High |      | Low  |      | High |      | Low  |      | High |      | Low  |      | High |      | Low  |      | High |      |
| prrr | Low | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High | Low  | High |
| Low  | 0,5 | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  |      |
| High | 0,5 | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  | 0,5  |      |

Fig. 4.3: Completing CPT of the node PROR with all binary parents (the 0.5-values present just the starting state of the table, when any evidence is set yet).

Nevertheless, let's consider the situation, in which the node CPP has 3 values. Logically, we can consider CPP like 3 states variable with the states high, low and medium. Expert wants to put into the network prior probability of CPP. He decides to put same probability to the states low and high and a bit higher probability to the state medium as in the figure 4.4.

|        |      |
|--------|------|
| Low    | 0,25 |
| Medium | 0,5  |
| High   | 0,25 |

Fig. 4.4: Completing CPT of the node CPP as ternary variable.

The same situation is possible to express with two states only like shows the figure 4.5. However, it is possible only with usage of some abstraction. This idea can be misleading, but dramatically decreases the number of values, which should be included into the CPT's of the nodes. For the mentioned reasons was decided to assume that all states of the nodes are binary.

|      |     |
|------|-----|
| Low  | 0,5 |
| High | 0,5 |

Fig. 4.5: Completing CPT of the node CPP as binary variable.

To sum up this solution, the nodes SEP, SES, SPP acquire in BN for SKB Company values high similarity and low similarity. Similarly, CPP, CPD can appear in states low complexity and high complexity, PRC and RDC in states called high capability and low capability and PES can achieve high performance or low performance. In, addition all the risk nodes in the network can acquire value of high risk or low risk.

## 5 Determining probabilities in NPD project risk network

Discussion in section 3.2 has revealed the problems with generating conditional probabilities in Bayesian network. Although new approach using pair-wise comparison was introduced, such method was proposed only for nodes with single parent. However, Bayesian network of NPD risk includes just the nodes with multiple parents. This problem tried to overcome the authors of [2] by creating new methodology for generating conditional probabilities for all kinds of nodes (nodes with a single parent, nodes with multiple parents). In this chapter will be discussed the generation of prior and conditional probabilities in the Bayesian network of NPD risk.

### 5.1 Generation of prior probabilities

Prior probabilities have been discussed already, to remind the reader, prior probability is defined in [11] like “The probability that an event will reflect established beliefs about the event before the arrival of new evidence or information”. Prior probabilities are the original probabilities of an outcome, which will be updated with new information to create posterior probabilities. Prior probabilities are in the Bayesian network estimated for the nodes without parents. Generated NPD risk network provides 8 nodes without parent.

Specification of prior probabilities means to find the probability for each state of the node. For instance, for the node SES, we have to specify probability of low similarity and high similarity of new product comparing to already produced product. Such probability is specified obviously by experts, with the usage of their knowledge and experiences. According to [2], such specification can be feasible only when the number of states is small. With the increase of states of a node, this method can involve biases and inaccuracies. One solution brings stated pair-wise comparison of the states. Since there are only two instead of  $n$  states considered at one time, it should be easier to provide more exact judgments<sup>1</sup>.

|       | $S_1$    | $S_2$    | ... | $S_n$    | $\omega$   |
|-------|----------|----------|-----|----------|------------|
| $S_1$ | $a_{11}$ | $a_{12}$ | ... | $a_{1n}$ | $\omega_1$ |
| $S_2$ | $a_{21}$ | $a_{22}$ | ... | $a_{2n}$ | $\omega_2$ |
| ...   | ...      | ...      | ... | ...      | ...        |
| $S_n$ | $a_{n1}$ | $a_{n2}$ | ... | $a_{nn}$ | $\omega_n$ |

Table 5.1: Generation of prior probabilities using pair-wise comparison for a node in BN.

<sup>1</sup> The pair-wise comparison is effective for the nodes with many states. As stated in the section 4.2.13, the nodes without parents in the NPD risk network have just 2 states to decrease the amount of estimations in the network. For the nodes with only 2 states, it is useless to do the pair-wise comparison, because the pair-wise comparison matrix includes only 4 comparisons, where the values at the diagonal are set to 1. Moreover, the rest two values are reversed to each other. Therefore just one comparison must be provided to the matrix and the final probability division is the same as the one inserted comparison. However, in the chapter 6 will be introduced the technique for estimating the prior probabilities based on pair-wise comparison. Therefore, the pair-wise comparison is explained in this section.



In the matrix 5.1, the “ $S_i$ ” presents a state “ $i$ ” of a node, the “ $a_{ij}$ ” presents the pair-wise comparison of the states “ $S_i$ ” and “ $S_j$ ”, and last but not least, “ $\omega_i$ ” is the counted weight of the state “ $i$ ” of a node. For instance, for the node SES, the matrix would include just two states, namely, the low and high similarity with 4 pair-wise comparisons. The matrix would result in the weight for low and high similarity. How to specify “ $a_{ij}$ ” in the pair-wise comparison? The “ $a_{ij}$ ” can be specified by question like: „comparing the state  $S_i$  and  $S_j$ , which one is more likely and how much more likely?“ In such table comparing “ $S_i$ ” and “ $S_j$ ” with the same index return automatically the result 1. Given this fact, there are  $n*(n - 1)$  comparisons of the states. In addition, almost half of the table involves inversed values, which are possible to recount by equation 5.1.

$$\frac{S_i}{S_j} = 1 - \frac{S_j}{S_i}$$

Equation 5.1: The way how to recount second half of the matrix ([2]).

For simplification, it can be better to provide just  $(n - 1)$  inter-related comparisons rather than all the  $n*(n-1)$  comparisons [2]. Although it can be useful to insert more comparisons for checking consistency, decreasing the number of judgments plays more important role. Relative priorities of all “ $S_i$ ” states in pair-wise comparison can be generated by maximum eigenvector like in AHP [12].

## 5.2 Generation of probabilities for a single parent node

Bayesian Network of “New Product Development Risk” does not contain such situation, where the child has only one parent. Nevertheless, explaining generation of probabilities for a single parent node will be useful in the next chapter. In the situation where a node has one parent, we need to generate conditional probabilities, which show dependence between the nodes, namely, between the parent and the child node as in the figure 5.1.

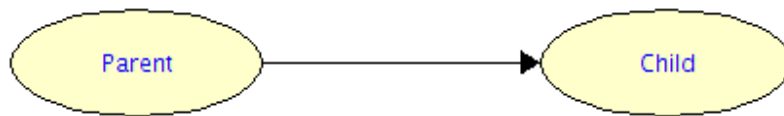


Figure 5.1: Parent-child relationship in Bayesian Network.

The node “Parent”, same as the node “Child” can occur respectively in  $n$  and  $m$  states, which can be represented as  $S_{p1}, \dots, S_{pn}$  and  $S_{c1}, \dots, S_{cm}$ . Example in the figure 5.2 shows states of the nodes. How to estimate probabilities of each state of the node “Child” conditional on each state of the node “Parent”? Such conditional probability is marked as  $P(S_{cm}|S_{pn})$  and can be estimated by expert directly or as mentioned in 3.2.1 with pair-wise comparison. As the pair-wise comparison provides more reliable estimation according to [27], this method will be used in this case also.

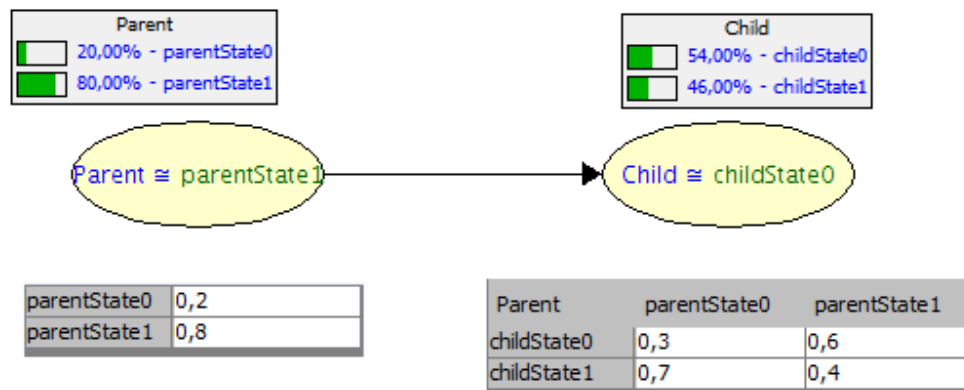


Figure 5.2: Parent-child relationship with visible CPT-tables and marginal probabilities of the nodes.

Considering the relationship from the figure 5.2, the pair-wise comparison can be done as in the table 5.2. The states of the node “Child” are compared given the evidence about state of the node “Parent”.

| Parent is in state0 | childState0 | childState1 | $\omega$   |
|---------------------|-------------|-------------|------------|
| childState0         | 1           | $a_{01}$    | $\omega_1$ |
| childState1         | $a_{10}$    | 1           | $\omega_2$ |

Table 5.2: Generation of conditional probabilities with usage of pair-wise comparison.

The values in the above table ( $a_{01}$ ,  $a_{10}$ ) can be specified by similar questions as in the section 5.1 „If the node “Parent” is in state0, comparing the states of the node “Child” childState0 and childState1, which one is more likely and how much more likely? “ The weights of the states are generated by maximum eigenvector, same as in the section 5.1.

After filling the tables for all states of the parent, all conditional probabilities can be displayed in summarizing table. For instance, the example of summarizing table presents the table 5.3.

|             | parentState0  | parentState1  | $\omega$   |
|-------------|---------------|---------------|------------|
| childState0 | $\omega_{00}$ | $\omega_{01}$ | $\omega_1$ |
| childState1 | $\omega_{10}$ | $\omega_{11}$ | $\omega_2$ |

Table 5.3: Summary of conditional probabilities from figure 5.1

## 5.3 Generation of probabilities for a multiple parent node

In the section 4.2.13 was explained, why it is more effective to have less states of the nodes. Indeed, if the node “N” has n-states and k-parents and every parent node has own m-states, the expert must

estimate the probability of each state of the node “N” conditional on the combination of the states of its parents. Such situation is visible in the figure 5.3.

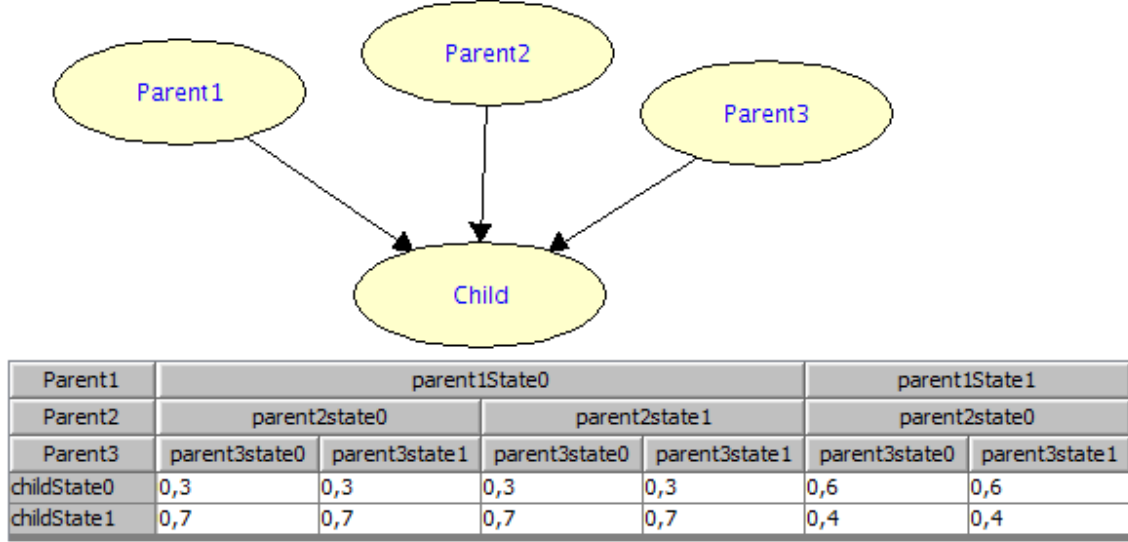


Figure 5.3: Estimation of probabilities for multi-parent node.

However, the direct estimation is hardly feasible. In the previous chapter was stated that generation of probabilities for nodes with single parent will be used later. What about to look at the problem of generating probabilities for a multiple parent node separately? It means to distribute the problem in such a way so that we generate probability of a node conditional on each of its parent. Then we can combine those conditional probabilities to get the node’s probability conditional on all of its parents. The question is how to do such combination.

According to [2], such combination is possible. When a node “A” in Bayesian network has two parents “B” and “C”, its probability conditional on B and C can be approximated by  $P(A|B,C) = \alpha(A|B)P(A|C)$ . In this equation “ $\alpha$ ” is a normalization factor to ensure  $\sum_{a \in A} P(a|B,C) = 1$ . Such equation can be rewritten to general form displayed in the equation 5.2.

$$P(A | X_1, X_2, \dots, X_n) = \alpha P(A | X_1) P(A | X_2) \dots P(A | X_n)$$

Equation 5.2: Decomposing of conditional probability for node with multiple parents on more probabilities conditional on only one parent.

Estimation of  $P(a | X_i)$  is much easier than estimation of all product  $P(a | X_1, X_2, \dots, X_n)$ . Then, using the decomposition will lead to more reliable estimation.

## 5.4 Conclusion

This chapter informed the reader about generation of probabilities in Bayesian network. After having the structure of Bayesian network and generated probabilities, Bayesian network provides marginal probabilities of all states of each node as in the picture 5.4. Of course, the marginal probabilities can be recounted in the light of new evidence as shown in example in the figure 5.5. In that figure, the new evidence about the nodes “Complexity of product design” (CPD) and “Similarity of existing supply” (SES) decreases the risk of the new product development.

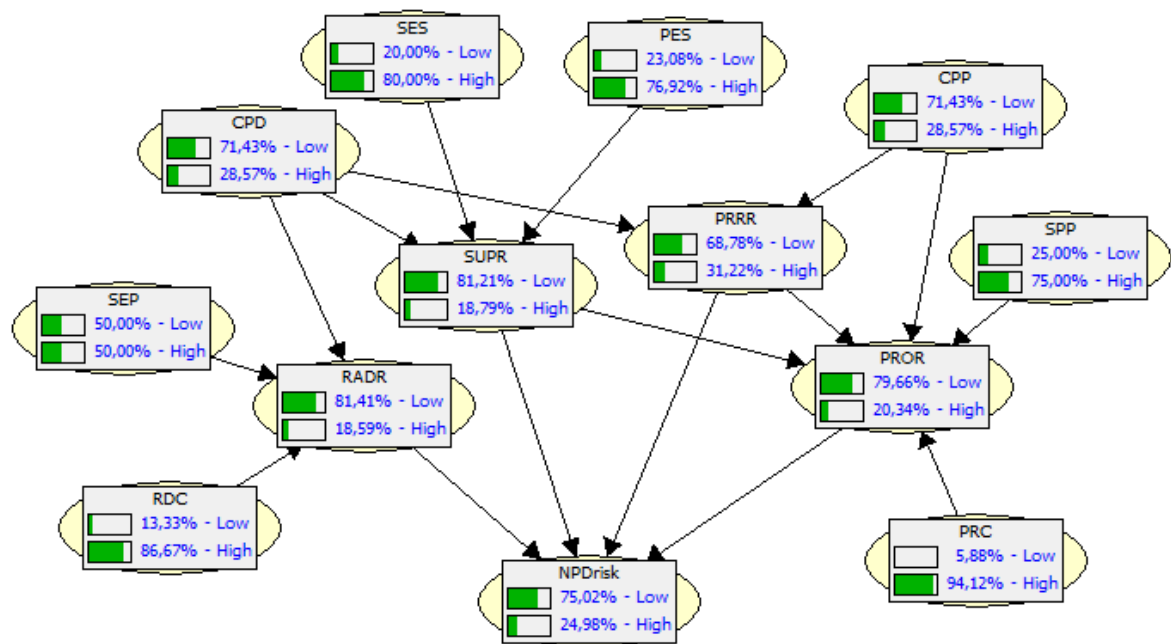


Figure 5.4: Counted marginal probabilities in the Bayesian network of new product development risk.

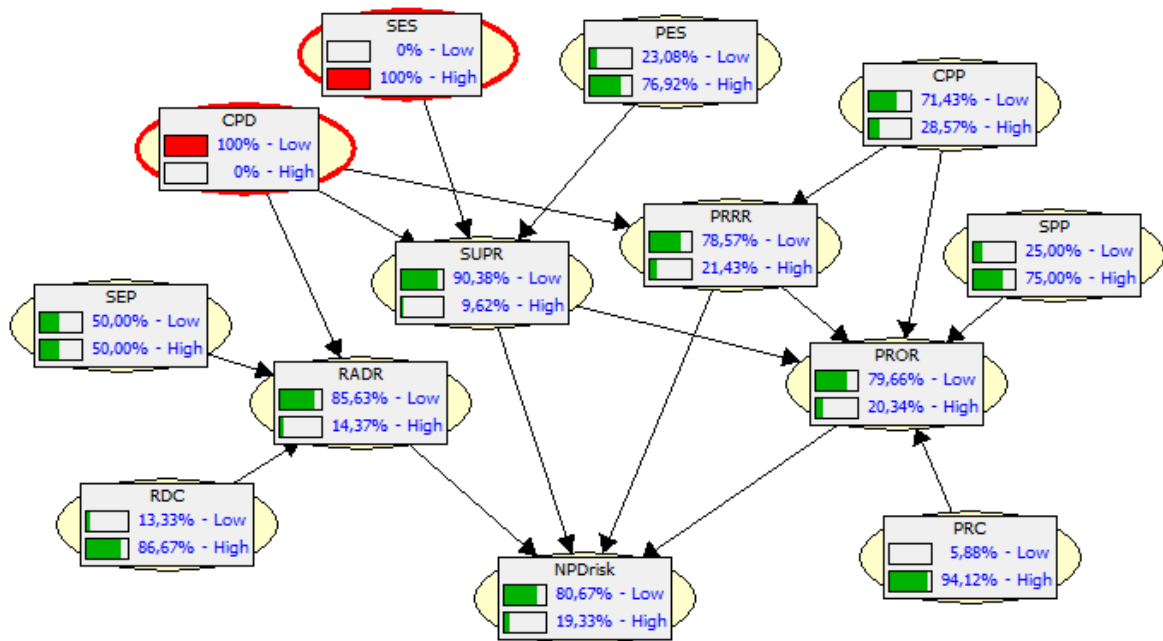


Figure 5.5: BN of the new product development risk with new evidence about the nodes SES and CPD.

## 6 Proposal of a tool for assessing new product development risk

To sum up the concept introduced in the previous chapters, SKB Company decided to create a tool, which measures the risk of new product development. In the previous parts of this paper, Bayesian network was discussed as possible tool, which can determine the risk of new product development. After some improvements in generating probabilities, BN is really a sufficient tool to do such risk analysis. How to implement such BN as an information system, which could be used by company experts?

This chapter provides the information about the developed tool for assessing new product development risk. At first, the new concept of estimating prior probabilities is described. Even though the description of this concept is theoretical, it is included in this practical part. It is because the concept is my own solution of the problem of generating prior probabilities. However, the concept is based on the theory from the previous chapters. The following parts of the chapter presents the developed web application for assessing new product development risk.

### 6.1 Estimation of prior probabilities in the tool

According to the theory about new product development risk network, if user wants to get marginal probabilities of NPD risk, he must provide to the network prior and conditional probabilities. Prior probabilities should be gained with pair-wise comparison of the node's states as stated in the section 5.1. For the user it means to answer on the type of question: "Comparing the states  $S_1$  and  $S_2$  of the node, which one is more likely to occur and how much more likely?". For instance for the node similarity of the existing supply (SES) it means to answer on the question about some new product: "Comparing the states low and high similarity of the node SES, which one is more likely and how much more likely?". To answer such question can be really difficult. Because of that, after discussion with SKB management, it was decided to adapt estimation of prior probabilities. To each node with prior probabilities is defined a set of questions. These questions are editable and can be deleted, updated or added by user. In the estimation of prior probabilities, user answers these questions and prior probability division is counted, from the answers. According to the proposal, the questions must be constructed in a way, so that they can be answered with either yes or no.

With the usage of questions, the pair-wise comparison is not done with the node's states, but with the questions belonging to the node, as in the table 6.1. In such case, the user has to estimate, based on his knowledge and experiences, the ratio between each two questions. When the user inserts some new question, belonging to the node, then he must provide also the ratio between the new question and the rest of the questions.

The pair-wise comparison is the system from Saaty's AHP [12]. The principal Eigen value is obtained from the matrix as the largest Eigen value. The explanation, how are the Eigen vectors and Eigen values counted provides the paper [26]. The table 6.2 displays the Eigen values and Eigen vectors for the matrix from the table 6.1. As shown in the table 6.2, the highest Eigen value is 4.999999. The highest Eigen value belongs to the Eigen vector [0.801784, 0.178174, 0.534522, 0.089087, 0.178174]. After normalizing that Eigen vector, the principal Eigen vector is approximately

[0.45, 0.1, 0.3, 0.05, 0.1], what corresponds with the weights in the table 6.1. The weight of the question in the table presents the importance, how much the question influences the probability division in the node. For instance, if the weight of some question is 50%, it means that the question is same important as the rest of the questions. With the pair-wise comparison for all nodes, the weight of each question is counted.

|   | Will steering wheel include standard contact system for radio control? | Will steering implement standard contact system for cruise control? | Is the signal in steering wheel transmitted wirelessly with standard electronics? | Is the signal in steering wheel transmitted by wire with standard system? | Will steering wheel include standard implementation of airbag? |
|---|--|---|---|---|--|
| Will steering wheel include standard contact system for radio control?            | 9/2  | 9   | 3/2   | 9/2   | 1  |
| Will steering implement standard contact system for cruise control?               | 1  | 2   | 1/3   | 1   | 2/9  |
| Is the signal in steering wheel transmitted wirelessly with standard electronics? | 3  | 6   | 1   | 3   | 2/3  |
| Is the signal in steering wheel transmitted by wire with standard system?         | 1/2  | 1   | 1/6   | 1/2   | 1/9  |
| Will steering wheel include standard implementation of airbag?                    |  |   |   |   | 2/9  |
| Weight of each question:  | 10%  | 5%  | 30%   | 10%   | 45%  |

Table 6.1: Example of the pair-wise comparison between questions for the node SEP (Similarity of the existing product).

|                |          |           |              |              |           |
|----------------|----------|-----------|--------------|--------------|-----------|
| Eigen values:  | 4,999999 | 0.000001  | 1.035903E-07 | 0.0          | 0.0       |
| Eigen vectors: | 0.801784 | -2.323461 | -1.887885    | 6.212936E-09 | 0.0       |
|                | 0.178174 | -0.064511 | 0.125823     | 0.617567     | -0.379801 |
|                | 0.534522 | -1.415258 | -0.043621    | 6.212941E-11 | 0.0       |
|                | 0.089087 | 0.558550  | 0.091212     | -0.617567    | 1.086908  |
|                | 0.178174 | -0.064511 | 0.125823     | 0.617567     | -1.794014 |

Table 6.2: Counting Eigen values and Eigen vectors from pair-wise comparison matrix.

However, the task is to generate prior probabilities of the node's states. For instance, for the node SEP, the distribution between high similarity and low similarity must be found. So far, we have obtained with the pair-wise comparison only the weights of the questions. To change the answers of questions to prior probabilities, each question has defined the parameter "effect on the node". This

parameter means if the positive answer to that question increases or decreases the risk of new product development. If the positive answer decreases the risk, this parameter is set to positive. Otherwise it is negative. To explain it more properly, let's consider the node SEP. According to the SKB Company, SEP can be measured as the extent of usage standard construction elements of a steering wheel. In such cases, user can create for instance question, concerning about airbag: "Is in the new product standard implementation of airbag?". The effect of such question is significantly positive, because usage of standard implementation of airbag decreases research and development risk and subsequently the risk of new product development. Effect of all questions in the table 6.1 is set as positive, because positive answers to those questions decrease the risk of new product development.

Imagine the following situation. User wants to estimate prior probabilities of the node SEP. To the node SEP are defined questions as in the table 6.1 and the pair-wise comparison values are also the same. User answers the questions as visible in the table 6.3.

| Order | Question   | Weight of the question | Effect on the node | Answer YES                          | Answer NO                           |
|-------|--|------------------------|--------------------|-------------------------------------|-------------------------------------|
| 1     | Will steering wheel include standard implementation of airbag?         | 45%                    | positive           | <input checked="" type="checkbox"/> |                                     |
| 2     | Is the signal in wheel transmitted by wire with standard system?       | 10%                    | positive           | <input checked="" type="checkbox"/> |                                     |
| 3     | Is signal in wheel transmitted wirelessly with standard electronics?   | 30%                    | positive           |                                     | <input checked="" type="checkbox"/> |
| 4     | Will steering implement standard contact system for cruise control?    | 5%                     | positive           |                                     | <input checked="" type="checkbox"/> |
| 5     | Will steering wheel include standard contact system for radio control? | 10%                    | positive           | <input checked="" type="checkbox"/> |                                     |

Table 6.3: The example of answering the questions for the node SEP.

Node SEP (Similarity of the existing product) has defined according the section 4.2.13 two states, namely, low and high similarity. As mentioned before, if the effect of question is set to positive, positive answer to such question decreases the risk. In case of the node SEP, positive effect of question combined with positive answer to that question causes higher similarity. Indeed, consider the questions and answers in the table 6.3. First, second and fifth answer increases the similarity. On the other hand, negative answers 3) and 4) decreases similarity of new product with the existing products. Prior probability of low and high similarity is then counted as in the table 6.4<sup>1</sup>.

According the results from the table 6.4, high similarity is more probable than low similarity with the existing products. Subsequently as the similarity is higher, the RADR (Research and Development risk) will be lower and also NPD risk can decrease.

This estimation is made for every node without parents. Every node without parent has defined its own set of questions, which can be updated. When user answers the questions of the node, automatically get the prior probabilities.

<sup>1</sup> Somebody could ask here, if it is not easier to implement the questions as the states of the nodes. Such implementation would simplify this calculation. On the other hand, it is much simpler to have just two states of the node for the reason stated in the section 4.2.13.



| Order | Question   | Weight of the question | Answer YES                          | Answer NO                           | High Similarity | Low Similarity |
|-------|--|------------------------|-------------------------------------|-------------------------------------|-----------------|----------------|
| 1     | Will steering wheel include standard implementation of airbag?         | 45%                    | <input checked="" type="checkbox"/> |                                     | 0.45            |                |
| 2     | Is the signal in wheel transmitted by wire with standard system?       | 10%                    | <input checked="" type="checkbox"/> |                                     | 0.1             |                |
| 3     | Is signal in wheel transmitted wirelessly with standard electronics?   | 30%                    |                                     | <input checked="" type="checkbox"/> |                 | 0.3            |
| 4     | Will steering implement standard contact system for cruise control?    | 5%                     |                                     | <input checked="" type="checkbox"/> |                 | 0.05           |
| 5     | Will steering wheel include standard contact system for radio control? | 10%                    | <input checked="" type="checkbox"/> |                                     | 0.1             |                |
|       |  |                        |                                     |                                     | 65%             | 35%            |

Table 6.4: Division between low and high similarity for node SEP.

## 6.2 Tool as a web application

SKB is the production company with scope in many parts of Czech Republic and also abroad. Its managers travel around Europe to gain new orders for steering wheels. In such situation, it seems that the best solution would be implementing the software for estimating NPD risk as a web service. The system would be then available from every place with internet connection.

Taking into consideration the preceding factors, the building platform selected for this web application was the Java 2 Enterprise Edition (J2EE). J2EE is suitable for running and developing enterprise application, because it allows basing the application on standardized modular components. To these components is provided complete set of services. Moreover, this platform handles many details of application behavior automatically, without complex programming [13]. Last but not least, the J2EE takes advantage of many features of the Java 2 Platform, Standard Edition (J2SE).

To simplify the integration of user interface with the application, JavaServer Faces (JSF) is used. JSF is a Java-based web application framework that establishes the standard for building server-side user interfaces [14]. In addition, the Richfaces project is included into this web development. The RichFaces project is an advanced UI component framework for easily integrating Ajax capabilities into business applications using JSF [15]. To sum up, J2EE combined with JSF and Richfaces presents powerful tool for developing enterprise applications.

The need for saving big amount of values in product estimations led to the necessity to include some useful persistent storage to the software. Considering the speed, price and robustness, Mysql sounded like a good choice. Mysql is the world's most popular open source database, fast, reliable and of course available for free [16]. Another tool used in the NPD risk tool was object-relational mapping provided by Hibernate. Hibernate facilitates the storage and retrieval of Java domain objects via mentioned object-relational mapping [17]. To expand, Hibernate is a framework for mapping object-oriented domain model to a traditional relational database.

Implementation of Bayesian network is made using Weka API. Weka is a collection of machine learning algorithms for data mining tasks [18]. It provides API in Java for Bayesian Network. One of the advantages of implementing Bayesian Network in Weka consists in the usage of the BayesNet Interchange Format (BIF) [19]. BIF is a XML-based format, which defines Bayesian

Network. Part of the BN definition in BIF format is placed in the Appendix A, in the figure 9. BIF is also output from SamIam [23], which is the tool for modeling and reasoning with Bayesian networks. This property enabled modeling of NPD risk network in SamIam tool and subsequent usage the BIF output in our tool. In addition, Weka API includes library for counting Eigen vectors and Eigen Values, what is useful in the mentioned pair-wise comparison.

In addition to all the foregoing, the graphs and charts for displaying the risks distribution are rendered by FusionCharts [22], which is the open-source component for creating a Flash charts in the web applications.

## **6.3 Architecture of the tool**

To propose the architecture of the tool, the software is build on the mentioned J2EE architecture [20], which includes the client tier, middle tier and enterprise data tier. Client tier is in the tool represented by the web components joined in the xhtml pages. Middle tier is created by the enterprise beans, which with the help of other functional classes encapsulates the business logic of the application. Last but not least, the data tier in the application, created by the relational database, is accessed by Hibernate DAO objects [21]. In the Appendix A, in the figure 8 is displayed the conceptual diagram of classes which create the data tier.

## **6.4 Users in the system**

From the company came the request for multi-user system. Generally, the system is available in 2 roles, namely, manager and administrator. For a regular manager of the company, it is possible to create a new product in the system and assess the risk of its development according to the answers he inputs into the system. In addition, the system allows the company manager to save unfinished product and load it when necessary.

The user role admin is responsible for generation of questions and its weights in pair-wise comparison. Moreover, admin can browse the estimations of already saved products and edit user accounts. All roles and its functions in the system are displayed in the use case diagram in the figure 6.1.

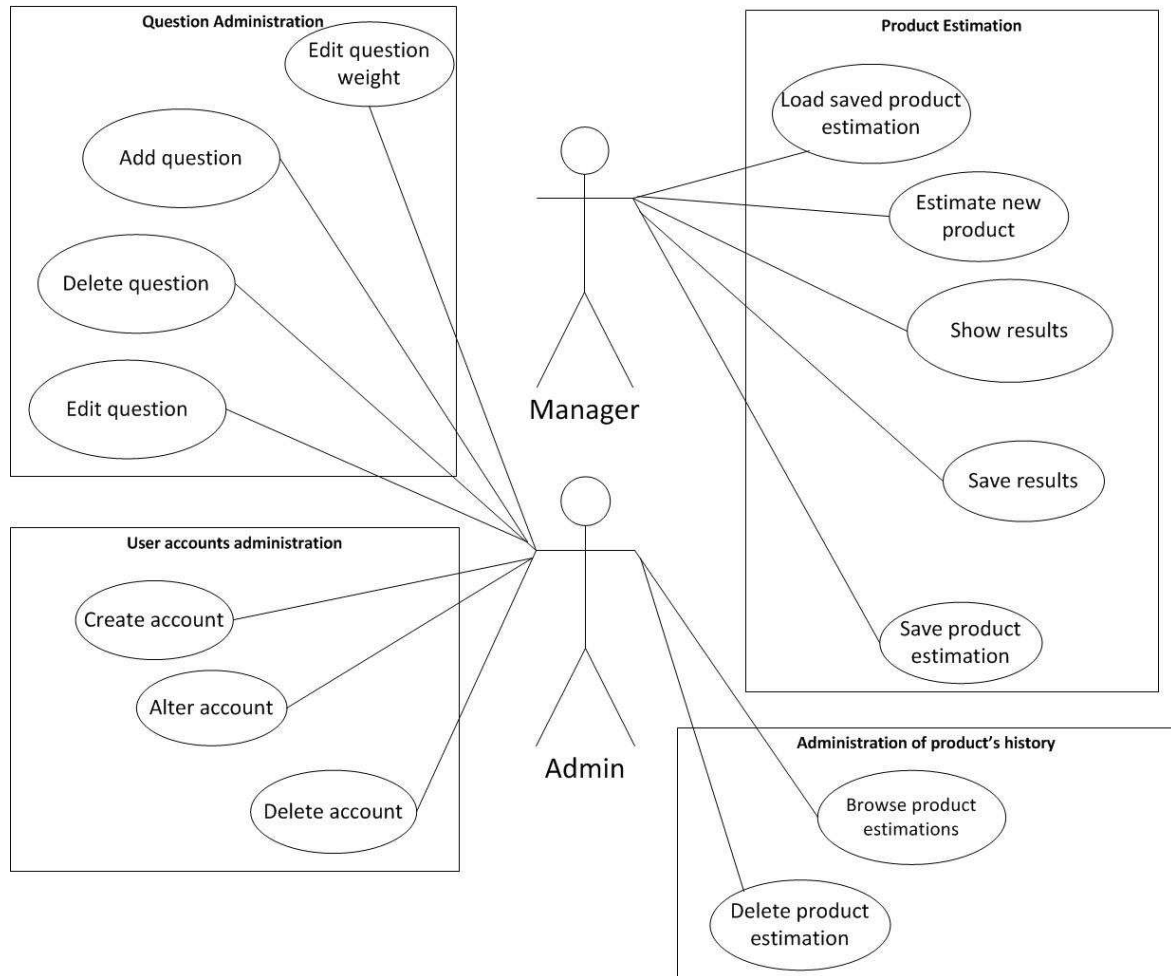


Figure 6.1: Use case diagram of the developed tool that assesses new product development risk.

## 6.5 Work with the tool

Current section would like to inform the reader about the usage of the developed tool. Functionality, depicted in the use case diagram from the figure 6.1, will be described more properly. To provide the reader a preview of the tool, some screenshots describing the system have been placed in the Appendix A.

### 6.5.1 Administration of the questions in the system

Administrator is after the logging in the system redirected to the administration of questions. The screenshot of this administration is placed in the Appendix A in the figure 1. The admin can see the defined questions and the pair-wise comparison between the questions in the nodes, which do not have parents. Every node is available in a tab panel as in the picture 6.2.

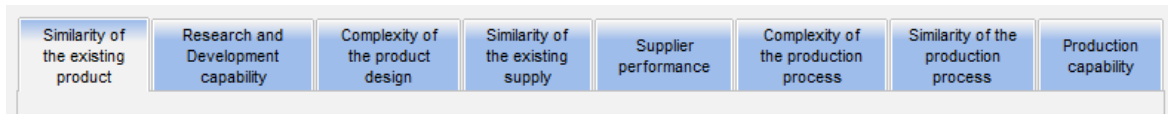


Figure 6.2: Tab panel for changing the node.

After click on each tab, questions and pair-wise comparison for every node appear. Questions panel covers the questions inserted to the system by administrator. Admin has 3 possibilities how to change this panel. Upon clicking on the actions in each row can redefine or delete the question. When user decides to alter question, he can redefine question text, reason of the question and question effect. The meaning of the question effect has been already stated in the section 6.1. When the admin wants to define reason, why he inserted the question to the system, he can define for question the parameter “reason of the question”.

The other possibility in the question administration is the cancellation of the question. This cancellation of the question does not mean complete vanity from the system. When the system was proposed, the opinion about the question administration was that user won’t change or delete questions often. This opinion results from the basics of the Bayesian network. Generally, when user wants to compare some products, he should compare it in the same environment. It means that products are comparable only when the questions are the same for both of them. However, estimating probability is certainly difficult task and the possibility of changing questions provides the user the way to find optimal questions and subsequently optimal weight of importance for each question. In such situation a question cannot be deleted completely from the system, because some products could be already estimated with this question. Solution to this problem is that to the question, after its cancellation in the user interface, is set the flag ‘canceled’. Then following product estimations are done without this question, but in the “product estimation history”-panel the question still occurs. Panel of questions is displayed in the figure 6.3

Under the table of questions is placed the button “add question”. When admin wants to add question to the panel, he needs to set a question text, question effect and also fill pair-wise comparison with other questions. By default the pair-wise comparison is set to 1:1 relationship as depicted in the figure 6.4. If the administrator would click the “add question” button and would not change the default 1:1 relationships, the new question that is inserted to the system would have the same weight as the other questions already placed in the system.

After filling the questions and its pair-wise comparisons, the weight of all inserted questions is shown in the column called question weight. In addition, the division of the weights between the questions is displayed clearly also in the pie chart at the bottom of user interface. However, sometimes may appear the need for changing the weight ratios between the questions. For that reason the system involves the functionality for changing the pair-wise comparison. This is possible in the pair-wise comparison table as depicted in the figure 6.5. Whole panel of the questions administration is visible in Appendix A in the figure 1 and 2.

| Similarity of the existing product                                | Research and Development capability   | Complexity of the product design | Similarity of the existing supply | Supplier performance | Complexity of the production process |
|---|---|----------------------------------|-----------------------------------|----------------------|--------------------------------------|
| <b>Questions to the node - Similarity of the existing product</b> |   |                                  |                                   |                      |                                      |
| Order   | Question text ↕   | Question effect                  | Question weight                   | Actions              |                                      |
| 1   | Will steering wheel include standard implementation of airbag?              | positive                         | <div><div></div></div> 45.00%     |                      |                                      |
| 2   | Is the signal in wheel transmitted by wire with standard system?            | positive                         | <div><div></div></div> 10.00%     |                      |                                      |
| 3   | Is the signal in steering wheel transmitted wirelessly with standard electr | positive                         | <div><div></div></div> 30.00%     |                      |                                      |
| 4   | Will steering implement standard contact system for cruise control?         | positive                         | <div><div></div></div> 5.00%      |                      |                                      |
| 5   | Will steering wheel include standard contact system for radio control?      | positive                         | <div><div></div></div> 10.00%     |                      |                                      |
| <div>Add question</div>   |   |                                  |                                   |                      |                                      |

Figure 6.3: Questions panel.

Add question to the questions table

Question text:

Question effect: negative

| Question text 2 ↕   | Weight 2 ↕     | Weight of the new question ↕ |  |
|---|----------------|------------------------------|--|
| Will steering wheel include standard implementation of airbag?                    | <span>1</span> | <span>1</span>               |  |
| Is the signal in wheel transmitted by wire with standard system?                  | <span>1</span> | <span>1</span>               |  |
| Is the signal in steering wheel transmitted wirelessly with standard electronics? | <span>1</span> | <span>1</span>               |  |
| Will steering implement standard contact system for cruise control?               | <span>1</span> | <span>1</span>               |  |
| Will steering wheel include standard contact system for radio control?            | <span>1</span> | <span>1</span>               |  |

Add question

Figure 6.4: Panel for adding a question.

| Pair-wise comparison of the questions in the node - Similarity of the existing product |   |  |            |            |         |
|--|---|--|------------|------------|---------|
| Order  | Question text 1 ↕   | Question text 2 ↕  | Weight 1 ↕ | Weight 2 ↕ | Actions |
| 1  | Is the signal in wheel transmitted by wire with standard system?                  | Will steering wheel include standard implementation of airbag?               | 2          | 9          |         |
| 2  | Is the signal in steering wheel transmitted wirelessly with standard electronics? | Will steering wheel include standard implementation of airbag?               | 2          | 3          |         |
| 3  | Is the signal in steering wheel transmitted wirelessly with standard electronics? | Is the signal in wheel transmitted by wire with standard system?             | 3          | 1          |         |
| 4  | Will steering implement standard contact system for cruise control?               | Will steering wheel include standard implementation of airbag?               | 1          | 9          |         |
| 5  | Will steering implement standard contact system for cruise control?               | Is the signal in wheel transmitted by wire with standard system?             | 1          | 2          |         |
| 6  | Will steering implement standard contact system for cruise control?               | Is the signal in steering wheel transmitted wirelessly with standard electro | 1          | 6          |         |

Figure 6.5: Pair-wise comparison of the questions.

When the questions are put in the system properly, estimation of the new product development risk can start already.

## 6.5.2 Risk estimation in the tool

For the product risk estimation in the tool is responsible the user in role manager. After the logging to the system, the manager has to choose if to load some previous unfinished product or start estimating some new product. If the manager decides to load some unfinished product, he can choose from previous products he saved before. However, the system offers him only the products belonging to him, not to the other users. If there are any available, user has to start estimating some new product. Nevertheless, during the estimation process user can save the answers he provides to the system if he does not want to finish estimation in that time. This functionality was discussed by the company management, because such loading and saving project can bring some complications. As the reader could see in the chapter about generating probabilities, user which wants to assess product development risk has to insert into the system a big amount of values. Specifically, for every node without parent it is 2 values, for node with two parents 4 values, for node with 3 parents 8 values, for node with 4 parents 16 values and for node with 5 parents 32 values. Whole sum is displayed in table 6.5.

|            |           |
|------------|-----------|
| SEP        | 2         |
| RDC        | 2         |
| CPD        | 2         |
| SES        | 2         |
| PES        | 2         |
| CPP        | 2         |
| SPP        | 2         |
| PRC        | 2         |
| RADR       | 8         |
| SUPR       | 8         |
| PRRR       | 4         |
| PROR       | 32        |
| NPDRisk    | 16        |
|            |           |
| <b>Sum</b> | <b>84</b> |

Table 6.5: Number of probabilities, which must be filled in BN of new product development risk.

Moreover, with the estimation of the prior probabilities as mentioned in the section 6.1, the manager has to put even more values. The reason is that to each node are linked usually more than two questions to answer. However, filling more than 84 values spends definitely some time and for that reason could be useful to save the project in the middle of filling the values and load it whenever manager wants. On the other hand, such functionality can lead into its misusing and subsequently not reliable estimation. To explain it more, for instance manager wants to assess the risk of a product which is similar to some product already saved. What he can do is that he can load some already saved product, change few values according the new product and get the risk of the new product. However, such estimation is not correct, because the evidence and probabilities about the new product are influenced from the old product. Correctly, all estimation should be independent to get right results. This problem was in the system solved in the following way. Manager can load only the

product which has not been processed yet. In such product, manager answered some questions already, but whole product estimation has not been saved yet.

After the load of some product from history or beginning with the new product, it is possible to start filling answers and the probabilities. The indication of filling answers is depicted in the figure 6.6. The manager can choose just from the answers yes and no, as mentioned in the section 6.1. Moreover, he can fill also the reason of the answer.

| Insert answers about the product press save evidence |   |                 |   |   |
|--|---|-----------------|---|---|
| Order  | Question text ↓   | Question effect | Answer  | Reason of the answer                              |
| 1  | Will steering wheel include standard implementation of airbag?                    | positive        | <input checked="" type="radio"/> no <input type="radio"/> yes |   |
| 2  | Is the signal in wheel transmitted by wire with standard system?                  | positive        | <input checked="" type="radio"/> no <input type="radio"/> yes | standard system included                          |
| 3  | Is the signal in steering wheel transmitted wirelessly with standard electronics? | positive        | <input type="radio"/> no <input checked="" type="radio"/> yes | Yes, the signal is transmitted with usage of star |
| 4  | Will steering implement standard contact system for cruise control?               | positive        | <input type="radio"/> no <input checked="" type="radio"/> yes | standard contact system is included               |
| 5  | Will steering wheel include standard contact system for radio control?            | positive        | <input checked="" type="radio"/> no <input type="radio"/> yes | not yet for radio control                         |

Figure 6.6: Pair-wise comparison of the questions.

When the answers are filled, it is possible to move this information from questions to the network with the button “save evidence”. Once the user has clicked on the button, the probability of the current node is recounted between the node’s states as in the instructions in the section 6.1. For instance for the answers from the picture 6.6 is the probability divided between the high similarity and low similarity of the existing product and it is divided as in the chart from the figure 6.7.

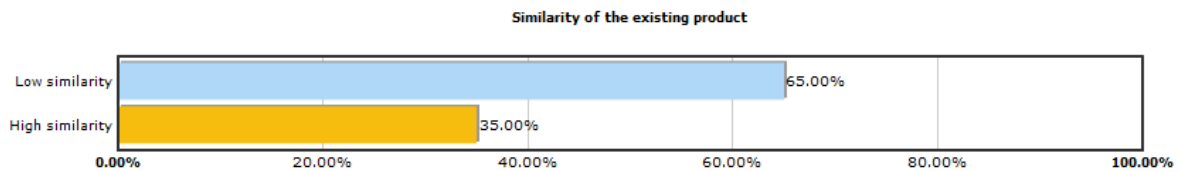


Figure 6.7: Marginal probabilities for the node according the answers the manager put into the system.

The previous lines concerned about the estimation of prior probabilities. For the estimation of conditional probabilities is in the tool applied the methodology described in the section 5.3. To refresh the reader’s memory, computing the conditional probability differs according the number of parents the node has. However, generation of conditional probabilities for multiple parent nodes can be turned into the simple problem of generating probabilities for single parent node according the theory in the section 5.3. As in the BN for the new product development risk are only the nodes with multiple parent nodes, the generation of conditional probabilities for every node is done by combination of probabilities conditional on each of its parents. Such estimation is more reliable not only according the theory in the 5.3 but also according the experiences collected among developing the tool. Namely, first version of the tool was developed with the direct estimation of the probabilities for multiple parent nodes and the company managers were complaining that it is difficult to decide

such probabilities. The example of the conditional probabilities estimation in the tool is depicted in the figure 6.8, where the manager set the probabilities for the node “Supplier risk”. In that case, the ratio is set between low supplier’s risk and high supplier’s risk.

| Order | Question text ↕  | State 1           | Weight o | Weight c | State 2            |
|-------|--|-------------------|----------|----------|--------------------|
| 1     | If the complexity of the product design is low, which following state is more likely and how much more likely?   | low supplier risk | 4 ▾      | 3 ▾      | high supplier risk |
| 2     | If the complexity of the product design is high, which following state is more likely and how much more likely?  | low supplier risk | 5 ▾      | 6 ▾      | high supplier risk |
| 3     | If the similarity of the existing supply is low, which following state is more likely and how much more likely?  | low supplier risk | 7 ▾      | 8 ▾      | high supplier risk |
| 4     | If the similarity of the existing supply is high, which following state is more likely and how much more likely? | low supplier risk | 9 ▾      | 8 ▾      | high supplier risk |
| 5     | If the supplier performance is low, which following state is more likely and how much more likely?               | low supplier risk | 8 ▾      | 9 ▾      | high supplier risk |
| 6     | If the supplier performance is high, which following state is more likely and how much more likely?              | low supplier risk | 8 ▾      | 7 ▾      | high supplier risk |

Figure 6.8: Setting conditional probabilities in the tool in more reliable way.

Given the values in the figure 6.8, the marginal probabilities are recounted when the user click the button “save evidence”. After the click, the graph with the marginal probabilities appears as visible in the figure 6.9. The important note here is that the counted marginal probabilities of some node depends on the already set evidences from the other nodes. The network is interactive and it recounts its marginal probabilities every time the button “save evidence” pressed. We could say that the evidence spreads through the network.

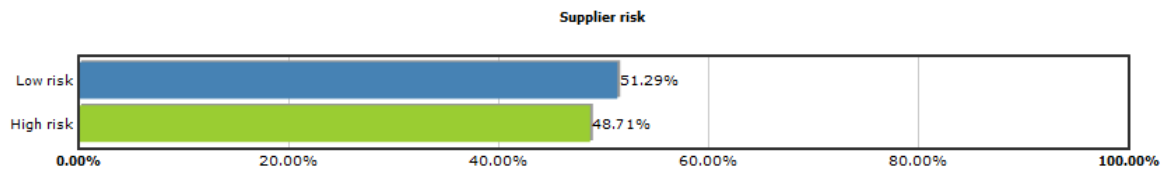


Figure 6.9: Margin probability division for the node Supplier risk.

The prior probabilities in the network same as the conditional probabilities, both are on the load of the tool set to the probability 50%. When the manager press the button save evidence for some node in the network, the rest of the nodes have still the probabilities set to 50%. Such estimation is not accurate. If the user decides in that moment to save the product evidence<sup>1</sup>, the tool warns him that the evidence has not been set completely so far. In this case, the user can browse the marginal probabilities, he has saved already, but he is not able to save all product estimation. This is possible, when the manager saves the evidence of all nodes. The panel for saving the product estimation is visible in Appendix A in the image number 7. Once the manager has saved the product, he can start estimating the other one or he can log out.

To conclude, the section 6.5.2 informed the reader about the risk estimation in the tool. It was described how to put the answers to fill the prior probabilities and how to set conditional probabilities in the system.

<sup>1</sup> The manager can save the product estimation calling the main menu of the application and pressing Show->Show results and save product estimation



### 6.5.3 Administration of the history of products

To have all product estimations together at the same place, the administration of the estimated products has been implemented to the tool. This administration is available from the main menu of the application when the user is logged in as the administrator. As rendered in the picture 6.10, the administrator can browse the history of product's estimations. In addition, with the usage of the "actions" buttons, he can display every estimated product separately or delete the product estimation.





| Show.. Tools <span>english   český</span> |                         |                                 |                      |   |  |
|---|-------------------------|---------------------------------|----------------------|---|--|
| Order                                     | Product name ↕          | Time of the product insertion ↕ | Responsible worker ↕ | Actions   |  |
| 1   | Steering wheel num.1244 | 2011-05-06 00:00:00.0           | Sýkora               |   |  |
| 2   | Steering wheel num.1241 | 2011-05-07 16:50:55.0           | Sýkora               |   |  |

Figure 6.10: Product estimation history.

Once the user has clicked the "show product" button, the same fields as in the product risk estimation appear, only the user is not able to edit entered values. In the figure 6.11 the reader can see the example of saved product estimation. As shown there, the first question has had the state set to question deleted. This property has been discussed already. It means that some manager entered the product estimation, when the question was still active. But then it was decided that this question is not suitable more, so it was deleted from the question administration. The property named "state of the question" aware the user to be careful, because the estimation can not be done with the current questions.

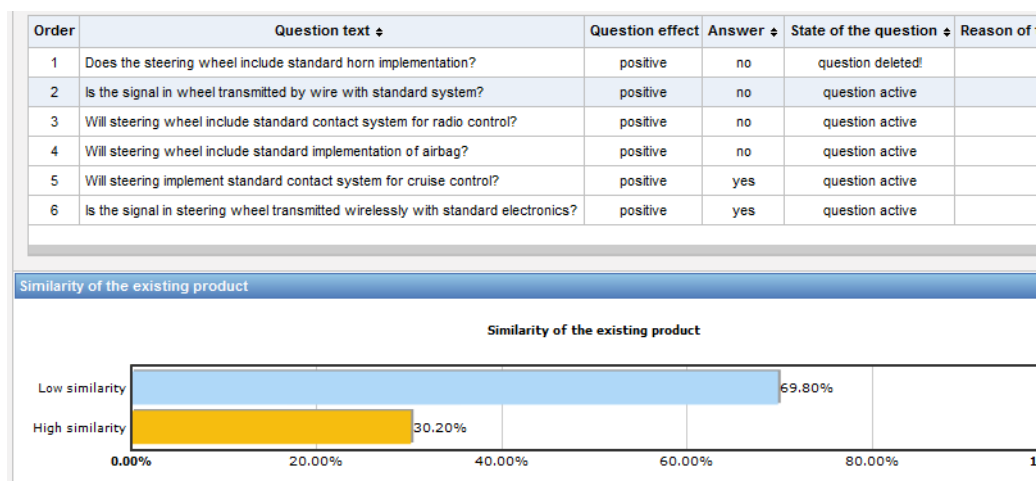
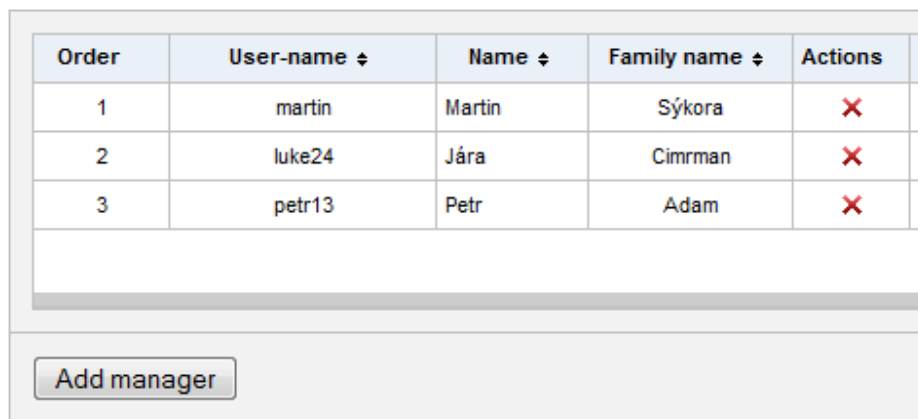


Figure 6.11: History of the answers entered by user for the node SEP into the system.

To provide the reader an idea about whole administration of the product history, in the Appendix A, there is screenshot of this administration in the figure 3.

#### 6.5.4 Administration of the user accounts

As stated before, there are 2 user roles in the tool. The administrator is able to administer not only “questions panel” and the history of the estimated product, but also he can administer user accounts. Generally, there is just one administrator in the tool with the abilities to manage user accounts. Namely, according the needs of the company, in the system was created one admin, which has the law to create and delete managers, which estimate the risk of the new product development. Administration of the managers’ accounts is available in the main menu of the application. A little preview is provided in the figure 6.8 and also in the appendix A.



| Order | User-name ↕ | Name ↕ | Family name ↕ | Actions |
|-------|-------------|--------|---------------|---------|
| 1     | martin      | Martin | Sýkora        | X       |
| 2     | luke24      | Jára   | Cimrman       | X       |
| 3     | petr13      | Petr   | Adam          | X       |

Add manager

Figure 6.8: Administration of the user accounts in the tool.

### 6.6 Other features of the tool

This part describes some interesting features of the developed software, which can be hardly noticed from the user interface of the tool or from the previous chapters. As stated before, the developed tool is a multi-user system. The user logs in the system and is redirected to the page appropriate to his role. Specifically, a user in the role manager is redirected to the panel, which includes the estimation of the product risk. On the other hand, the administrator is redirected to the question administration at the beginning.

All working places of the system are placed in the protected area available only after user logs into the system. Communication with this protected area is provided by the HTTPS protocol so that the data are transmitted encrypted. Users, which wants to work with the system has to not only log in the system but also obtain the certificate of the web site.

Another important functionality implemented in the system is the possibility to switch the language of the application between English and Czech. The need for a multi-language application rose during the development of the tool. The SKB Company preferred to localize the application in

Czech language which was in contrast with the language of this thesis. If the user is confused and can't understand the tool properly, he still can use the help function available from the main-menu.

## 6.7 The tool summary and its possible future extensions

Here is the place to assess the developed tool and suggest some future additions to the software. At first, the architecture used in the development of the tool provides relatively good environment for implementing a future extensions to the tool. However, the reached level of the application enables the risk estimation of the new product development in the sufficient extent. In contrary, the field of this tool, the risk estimation, it is so wide that the tool can hardly cover everything. What sounds reasonably, is the future connection of the tool with the current company system. This would add the possibility to compare already developed product with its previous risk estimation. With such comparison, the company could measure how accurate is the system and if its estimates are reliable. According [2], there is a possibility to check the consistency of the pair-wise comparison in the generation of the probabilities. Such tool would inform the user if the inserted values in the pair-wise comparison are consistent. The consistency can be checked by the consistency ratio defined in the equation 6.1.

$$CR = \frac{CI}{RI}$$

Equation 6.1: The way how to recount the consistency of the pair-wise comparison ([2]).

In the equation 6.1 is CI defined as  $(\lambda_{\max} - n)/(n - 1)$ , where  $\lambda_{\max}$  is the maximum Eigen value corresponding to the maximum Eigen vector and n is a number of values in the pair-wise comparison. The explanation to the Eigen vector and Eigen value was given in the chapter 6.1. RI is the random consistency index, which can be obtained from the table 6.6.

| n  | 1 | 2 | 3    | 4    | 5    | 6    | 7    | 8    | 9    |
|----|---|---|------|------|------|------|------|------|------|
| RI | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 |

Table 6.6: Random consistency index used for counting the consistency index in pair-wise comparison (picture drafted from [2]).

Implementation of the consistency index to the developed system could aware the user of the system to reassess the values inserted in the system.

However, the software has been already tested by the SKB Company and so far has provided sufficient risk estimations. The manager of the SKB has tried to estimate the risk of the products in the tool, which has been produced already. The reason of such test was to find out, if the results of the estimation really correspond with the experiences gained from the previous development of those products. At the end the manager declares that these estimations correspond with opinions the company have gathered during the development of those products. Maybe you are asking, what does

it mean that the estimates correspond with opinions the company have about those products? It is hard to interpret the value of the risk obtained from the system. If the manager gets the 80 % risk of the product development, he can think that it is relatively hard to produce that product. But with this risk number only, it is difficult to decide if to start producing this product or not. The advantage of the tool is in choosing the better product. When the manager has to choose between two products which one to start producing, he must compare them. If the manager puts this two products into this tool for estimating the new product development risk and gets the risks for one of them 80% and for the second 70%, he can say that he wants to start producing the second product, because it has lower risk of its development. The manager in the SKB has used the same method. He has put into the system information about already developed products and got the risk for each of them. The order of the products risks has corresponded with the order, how difficult it was to develop those products. For that reason the manager could say that the tool has made proper estimations so far.

The other possible improvement of the system would make from the software really universal tool for assessing risk. The current system loads the Bayesian network from the xml file, where the structure of the network cannot change. The example of the xml file is placed in the Appendix A. It would be really interesting, if the system would be able to load the Bayesian network with any structure. Such improvement would allow the user of the system to model any problem and he would be able to estimate not only the risk of new product development. However, this improvement would require much more time than has been provided for this thesis.

## 7 Conclusion

To conclude, it was not easy to get the project to its current stage. From the general topic named “the tool for administering the product portfolio” has developed in few months the software capable to assess risk of the new product development in the company. The problem of assessing the risk of a new product was chosen for one important reason. When there was a discussion, regarding the type of software, used for administration of the product portfolio, one company asked for help with the risk estimation of the new product.

Risk estimation has been so interesting that I focused on this problem. Of course, some research has been made afterwards, how to deal with this topic. The materials founded for the risk estimation of the new product development have differed in their quality significantly. The most convincing source [2] persuaded me to implement the risk estimation by the tool called Bayesian Network. The paper informed about the advantages of using Bayesian network comparing to other tools. Moreover, it provided improvements in generating the probabilities in the network to make the estimation more proper. However, the paper suggested how to assess the new product development risk, not how to build a tool for assessing the risk. In addition, the developed software should have been accommodated to the conditions of the SKB Company. To go step by step, after the Bayesian network (BN) was offered to the company as a possible tool for assessing NPD risk, the process of testing BN started. With the help of the software SamIam [23] the company tried to estimate the product risks and decide if this BN is reliable tool for the estimations. Then the necessity to accommodate the network appeared, because the nodes in the network were too general. For that reason was the concept proposed by [2] edited slightly and the system of questions described in the chapter 6.1 has been added. The questions make the node more specific. The manager can set the probability division more precisely, because he answers the questions, which has been created by somebody from the company. The creator of the questions knows, how works the process of the new product development in the company. At that moment he can fit the network for the company purposes.

Later, when the concept of the software was known, phase of programming the software started. At first, the appropriate technologies were chosen. This was followed by programming the software. This phase revealed some defect, which had to be corrected. One of the biggest defects appeared in the proposal of estimating conditional probabilities. Direct estimation of the conditional probabilities, implemented before had been unsuitable. When the software has been developed already, we realized that the direct estimation generated huge amount of questions, which could be hardly answered in reasonable time. This approach must have been reworked, what is explained in the part 6.5.2 of this paper. Other complication became, when the necessity to test the correctness of the results revealed. Big amount of the equations counted inside the software were tested with difficulties. Here the management of the company helped me. They have tested the tool with the products and compared the results with the SamIam outputs. However, the software SamIam allows just the direct estimations, so some equations had to be counted by hand also.

Here, somebody could ask, why it was developed the software with the same functionality as the SamIam provides. Although both the SamIam and my tool estimate probability of some problem described by Bayesian network, they are totally incomparable. My tool concerns just with the NPD risk network. It is available as a web application and fits to the needs of the SKB Company. It

provides the interface, which lead the user step by step to get the final risk of the new product development. In addition, user can administer the history of the estimated products and administer the users in the system. The concept of generating prior probabilities through the questions makes from the software universal tool for reasoning the risk of new product development in any part of industry. Nevertheless, the software can be still improved in some ways.

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# Appendix

Appendix A. Screenshots of the developed software for the SKB Company

Appendix B. DVD with the source code of the system

# Appendix A

Screenshots of the tool for assessing new product development risk:

Show...

Tools

english

česky

Similarity of the existing product

Research and Development capability

Complexity of the product design

Similarity of the existing supply

Supplier performance

Complexity of the production process

Similarity of the production process

Production capability

Questions to the node - Similarity of the existing product

| Order | Question text 1  | Question effect | Question weight | Actions | Reason of the question |
|-------|--|-----------------|-----------------|---------|------------------------|
| 1     | Konecna ra CAM - konecna bez znehy driver?                         | positive        | 20.00%          |         |                        |
| 2     | Širokáni signálu - užiti standardizovaného širínání?               | positive        | 15.00%          |         |                        |
| 3     | První signálu vzduchem - možná implementace standardu elektroniky? | positive        | 15.00%          |         |                        |
| 4     | První signálu drátem - normalizovaný konektorový systém?           | positive        | 5.00%           |         |                        |
| 5     | Zbírání kružek - existující kontaktní systém?                      | positive        | 3.00%           |         |                        |

Add question

Pair-wise comparison of the questions in the node - Similarity of the existing product

| Order | Question text 1  | Question text 2                                    | Weight 1 | Weight 2 | Actions |
|-------|--|--|----------|----------|---------|
| 1     | Forma - bez nároku na změnu standardní konstrukce?                 | Ovládací páčba - standardizovaná?                  | 1        | 1        |         |
| 2     | Drážkování - standardizované existující nástroje?                  | Holkačka - existující kontaktní systém?            | 3        | 2        |         |
| 3     | Forma - bez nároku na změnu standardní konstrukce?                 | Holkačka - existující kontaktní systém?            | 1        | 2        |         |
| 4     | Ovládací páčba - standardizovaná?                                  | Holkačka - existující kontaktní systém?            | 1        | 2        |         |
| 5     | Drážkování - standardizované existující nástroje?                  | Forma - bez nároku na změnu standardní konstrukce? | 3        | 1        |         |
| 6     | Drážkování - standardizované existující nástroje?                  | Ovládací páčba - standardizovaná?                  | 3        | 1        |         |
| 7     | Ovládací přípravy - užiti existujících nástrojů na kování volantu? | Holkačka - existující kontaktní systém?            | 1        | 1        |         |
| 8     | Ovládací přípravy - užiti existujících nástrojů na kování volantu? | Drážkování - standardizované existující nástroje?  | 2        | 3        |         |
| 9     | Ovládací přípravy - užiti existujících nástrojů na kování volantu? | Forma - bez nároku na změnu standardní konstrukce? | 2        | 1        |         |
| 10    | Ovládací přípravy - užiti existujících nástrojů na kování volantu? | Ovládací páčba - standardizovaná?                  | 2        | 1        |         |

Figure 1: Administration of questions and weights between questions.

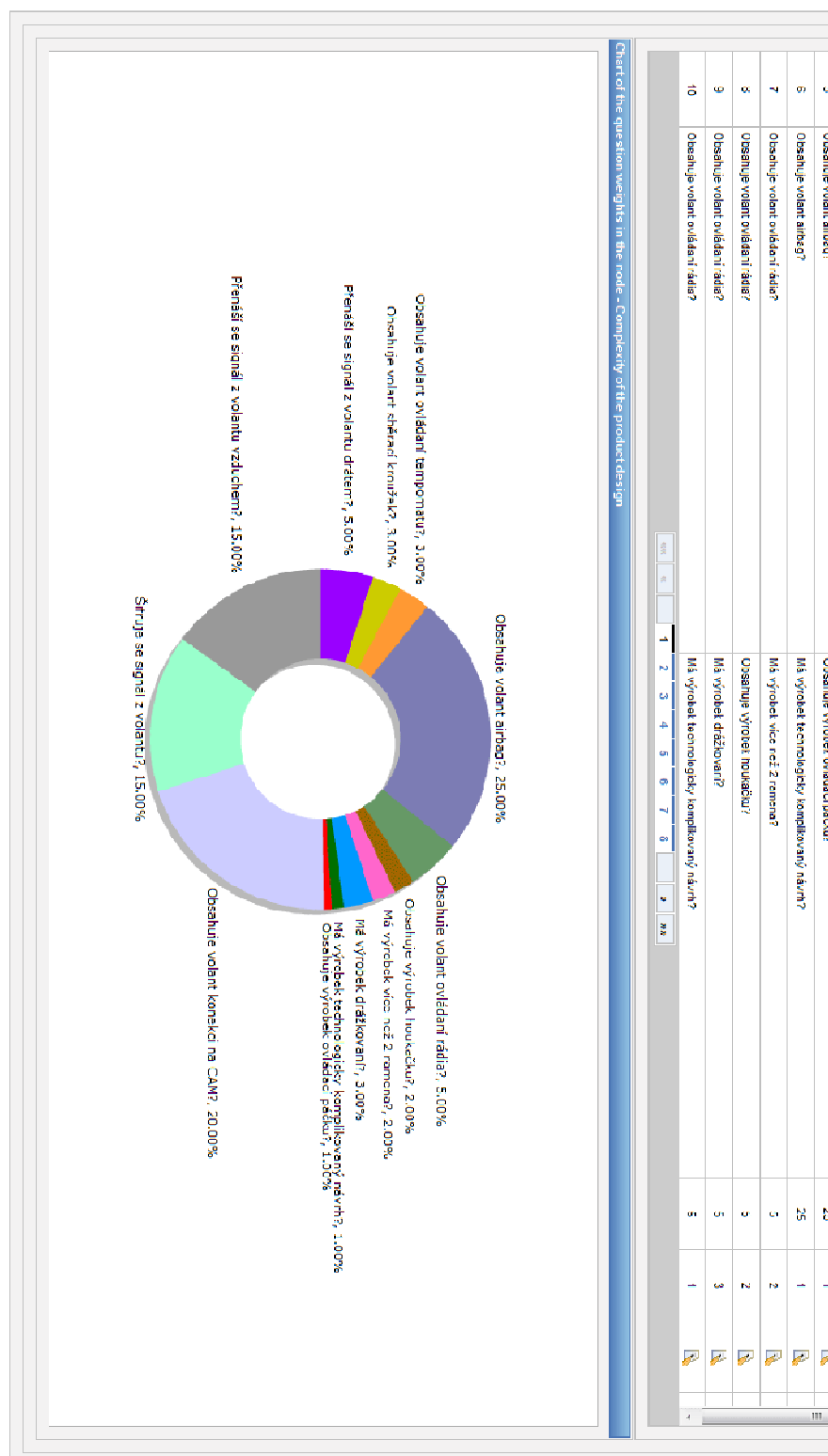


Figure 2: Pie chart of weights of each question generated by pair-wise comparison in the developed software.

Show.. Tools

english | český

Product's estimations:















| Order | Product name ↕      | Time of the product insertion ↕ | Responsible worker ↕ | Actions   |  |
|-------|---------------------|---------------------------------|----------------------|---|--|
| 1     | Volant 175294565002 | 2011-05-18 00:00:00.0           | Sýkora               |   |  |
| 2     | Volant 175500401005 | 2011-05-22 22:11:27.0           | Sýkora               |   |  |
| 3     | Volant 175500099002 | 2011-05-22 15:07:51.0           | Sýkora               |   |  |
| 4     | Volant 175350021003 | 2011-05-22 15:39:47.0           | Sýkora               |   |  |
| 5     | Volant 175300021001 | 2011-05-22 17:26:59.0           | Sýkora               |   |  |
| 6     | Volant 175200077001 | 2011-05-22 17:43:07.0           | Sýkora               |   |  |

Figure 3: History of estimated products.

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Managers:

| Order | User-name ↕ | Name ↕ | Family name ↕ | Actions   |  |
|-------|-------------|--------|---------------|---|--|
| 1     | kamil       | Kamil  | Knopp         |  |  |
| 2     | petr        | Petr   | Sýkora        |  |  |
|       |             |        |               |   |  |

Add manager

Figure 4: Administration of managers.



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Similarity of the existing product

Research and Development capability

Complexity of the product design

Similarity of the existing supply

Supplier performance

Complexity of the production process

Similarity of the production process

Production capability

Production risk

Supplier risk

Product reliability risk

Research and development risk

New product development risk

Information about the product

Product name: Volant 17520077001

Description:

Edit product info

Set product probabilities a press save

| Order | Question text ▼  | State 1                          | Weight of the state 1 | Weight of the state 2 | State 2                           |
|-------|--|----------------------------------|-----------------------|-----------------------|-----------------------------------|
| 1     | If the supplier risk is low, which following state is more likely and how much more likely?                  | low new product development risk | 2 ▼                   | 1 ▼                   | high new product development risk |
| 2     | If the supplier risk is high, which following state is more likely and how much more likely?                 | low new product development risk | 1 ▼                   | 2 ▼                   | high new product development risk |
| 3     | If the research and development risk is low, which following state is more likely and how much more likely?  | low new product development risk | 3 ▼                   | 1 ▼                   | high new product development risk |
| 4     | If the research and development risk is high, which following state is more likely and how much more likely? | low new product development risk | 1 ▼                   | 2 ▼                   | high new product development risk |
| 5     | If the production risk is low, which following state is more likely and how much more likely?                | low new product development risk | 3 ▼                   | 1 ▼                   | high new product development risk |
| 6     | If the production risk is high, which following state is more likely and how much more likely?               | low new product development risk | 1 ▼                   | 2 ▼                   | high new product development risk |
| 7     | If the product reliability risk is low, which following state is more likely and how much more likely?       | low new product development risk | 2 ▼                   | 1 ▼                   | high new product development risk |
| 8     | If the product reliability risk is high, which following state is more likely and how much more likely?      | low new product development risk | 1 ▼                   | 2 ▼                   | high new product development risk |

Save Evidence

New product development risk

New product development risk

Low risk

High risk

0.00%

20.00%

40.00%

60.00%

80.00%

100.00%

56.77%

43.23%

Figure 6: The risk estimation in the software, company manager answers the questions linked with some node of NPD risk network and get the marginal probability for that node according the answers.

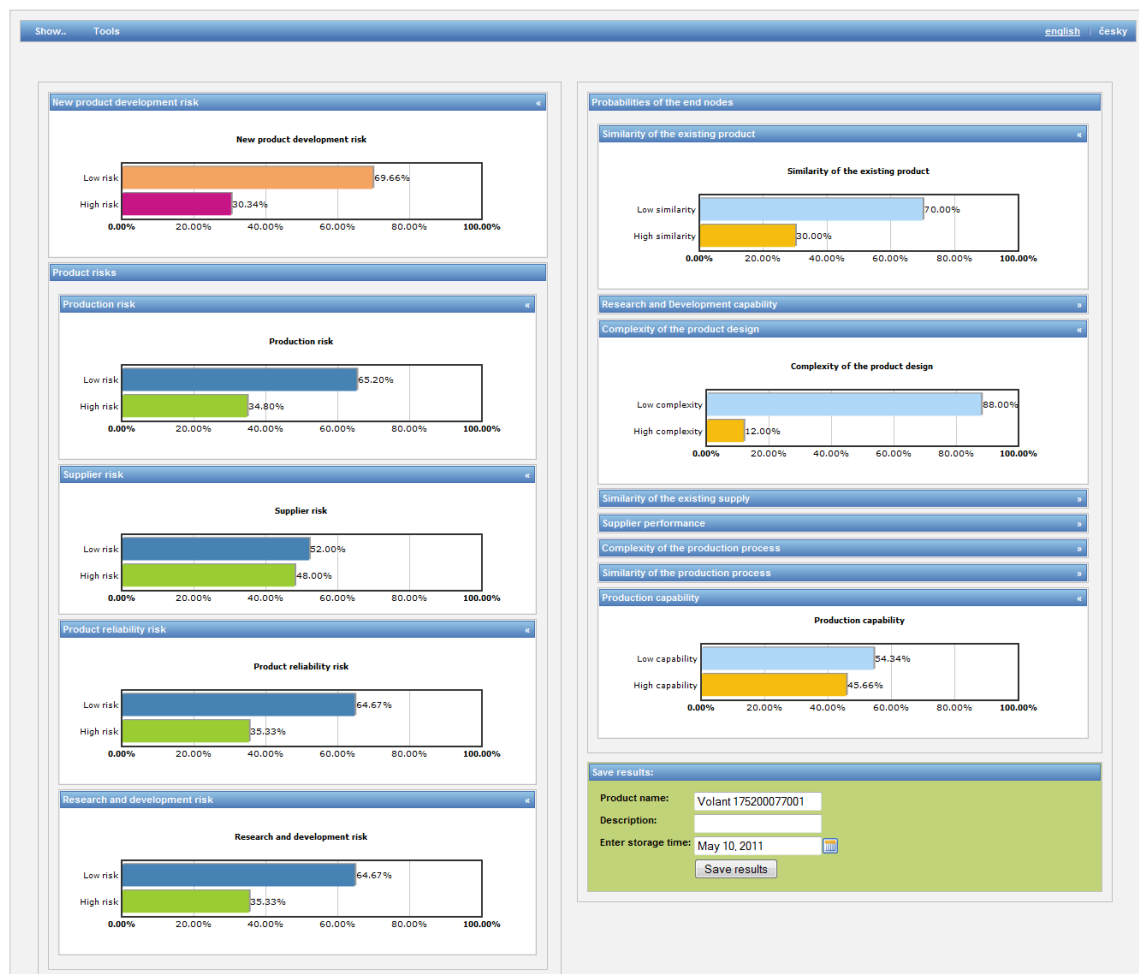


Figure 7: Panel with showed results of estimation with possibility to save risk estimation of product.



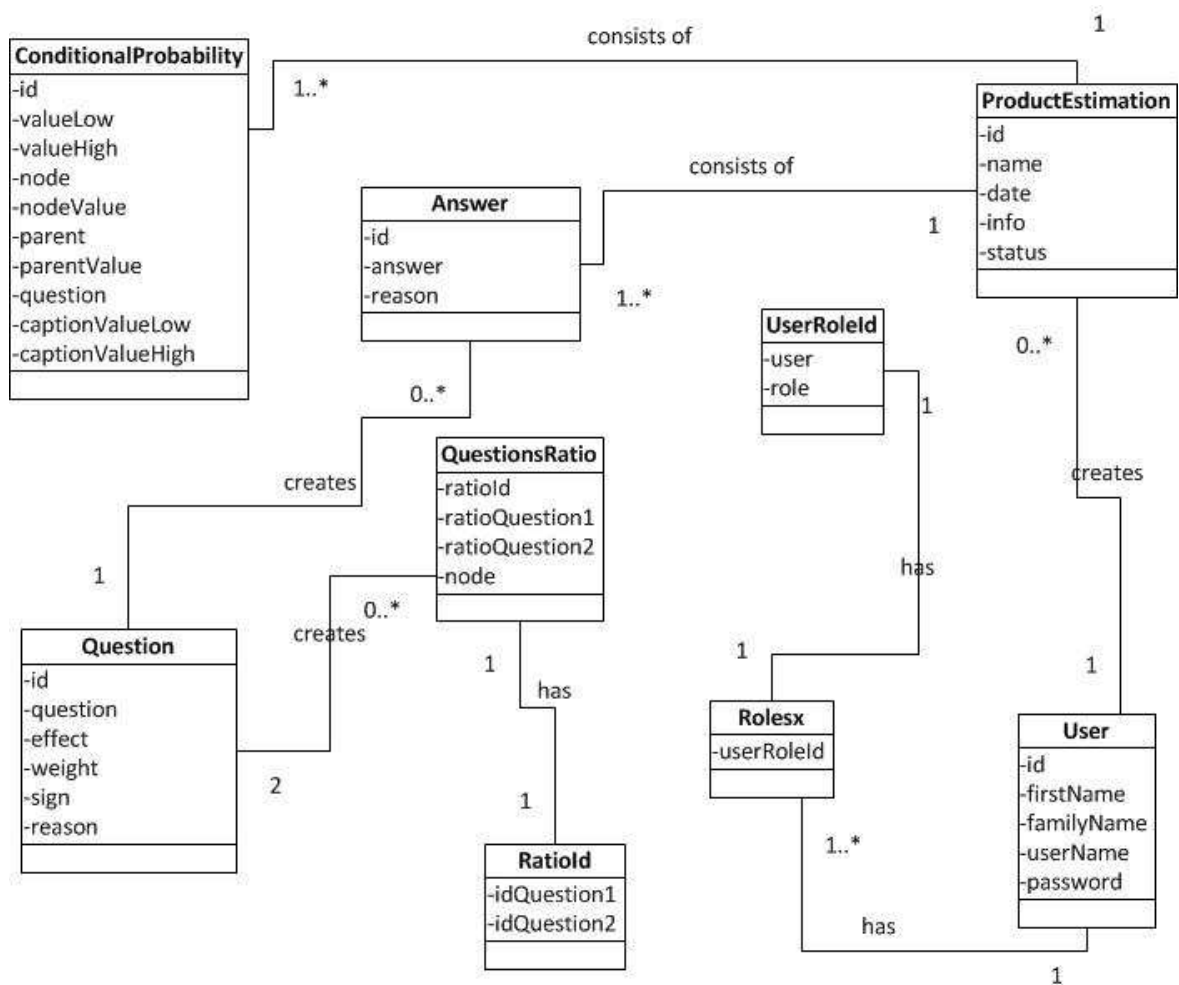


Figure 8: Conceptual diagram of the mapped classes.

```

<?xml version="1.0" encoding="US-ASCII"?>

<BIF VERSION="0.3">
<NETWORK>
  <NAME>BayesianNetwork</NAME>

  <VARIABLE TYPE="nature">
    <NAME>CPD</NAME>
    <OUTCOME>Low</OUTCOME>
    <OUTCOME>High</OUTCOME>
    <PROPERTY>position = (70, -299)</PROPERTY>
  </VARIABLE>

  <VARIABLE TYPE="nature">
    <NAME>NPDrisk</NAME>
    <OUTCOME>Low</OUTCOME>
    <OUTCOME>High</OUTCOME>
    <PROPERTY>position = (337, 5)</PROPERTY>
  </VARIABLE>

  <VARIABLE TYPE="nature">
    <NAME>SUPR</NAME>
    <OUTCOME>Low</OUTCOME>
    <OUTCOME>High</OUTCOME>
    <PROPERTY>position = (282, -220)</PROPERTY>
  </VARIABLE>
  .
  .
  .

  <DEFINITION>
    <FOR>SEP</FOR>
    <TABLE>0.5 0.5 </TABLE>
  </DEFINITION>

  <DEFINITION>
    <FOR>PES</FOR>
    <TABLE>0.5 0.5 </TABLE>
  </DEFINITION>

  <DEFINITION>
    <FOR>PRRR</FOR>
    <GIVEN>CPD</GIVEN>
    <GIVEN>CPP</GIVEN>
    <TABLE>0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 </TABLE>
  </DEFINITION>

  <DEFINITION>
    <FOR>RDC</FOR>
    <TABLE>0.5 0.5 </TABLE>
  </DEFINITION>

</NETWORK>
</BIF>

```

Figure 9: Part of the Bayesian Network definition in BIF format used in the software.