www.irmbrjournal.com June 2014
International Review of Management and Business Research Vol. 3 Issue.2

Risk Management in Early Product Lifecycle Phases

JAN MACHAC
Department of Technologies and Measurement
University of West Bohemia, Pilsen, Czech Republic
Email: jmachac@ket.zcu.cz

FRANTISEK STEINER
Department of Technologies and Measurement
University of West Bohemia, Pilsen, Czech Republic

Abstract

A new product coming to the market usually brings certain uncertainty of its success. Especially, hidden failures and risks which might appear in the product service life could bring producers into difficulties costing them money. This might turn into a product phase out and loss of company reputation. Therefore, identification and treatment of risks in early phases of a product lifecycle are becoming more commonplaces nowadays. Since state-of-art companies that want to keep up with competitors, have to consider all actions which might prevent losses or customer's dissatisfaction. This paper deals with a new risk management procedure concerning the early phases of a product lifecycle. Proper risk identification in early phases should result in mitigation or removal of an impact that might cause considerable property, health or the environment losses in late phases of a product lifecycle. It is always very complicated to assess risks in an early phase of a project since almost no data is available. Therefore, this procedure has been developed to help to manage such risks. The procedure is focused on risk priorities according to customer's needs, requirements and it can be used for various products and industries.

Key Words: *Risk Management, Product Lifecycle, Voice of Customer, Conceive, Design, Risk Value*.

Introduction

Currently, risk management is an integral part of most of state-of-art production enterprises because running of enterprises usually goes with various kinds of risks. Therefore, it is necessary to develop and improve ways of implementation of a risk management system into enterprise processes. Risks are supposed to be managed across all levels of organization and considered in terms of finance, environment and occupational safety (Stark, 2011; McRoberts, 2005). As far as production enterprises are concerned, it is also necessary to apply risk management to produced products. Every product has its product lifecycle where it is needful to consider various influences which enter the product lifecycle and manage risks here (Bergejo, 2009; Ying-Kui*et al*., 2004). The product lifecycle and its managing have become a present standard and a part of the information structure of modern enterprises. Due to comprehensibility and definiteness, it consists of several phases. This helps to make risk management easier because it is feasible to manage risks for each phase separately. The issue of underdeveloped method for proper risk management of product lifecycle was touched by Zou and Lin-li (2010). This study deals with the phases of conceive and design that are considered to be the early phases of a product lifecycle. Managing risks at the beginning of a product lifecycle is very important because this action may be beneficial in the future phases and save a considerable amount of money, company's reputation or even human health.

Product Lifecycle Management

The product lifecycle is based on the principle of a biological cycle, i.e. the process from birth to death. This theory is the same for a product and it can also be understood as a process which is one of the other enterprise processes. In risk management, all participating subjects must understand the relationship between project management processes and the other enterprise processes. The product lifecycle is the natural framework for investigation of relationships and processes in the field of product management. It is described as a means of defining of the beginning and end of a product and its phases. The form of lifecycle definitions varies by industry areas but it is also various within the same industry for different organizations and businesses. In product lifecycle management, the risk approach changes in various stages. This depends on how much information is available and what extent of the project progress is. The typical product lifecycle description covering all phases is shown in Figure 1.

Figure 1.Product lifecycle phases.

The product lifecycle or PLM (Product Lifecycle Management) is a control process from conception through design and production to service and disposal. PLM includes people, data, processes, business systems and provides the main information flow for companies. Simultaneously, PLM systems help organizations in complying with increasing complexity and engineering tasks of new products development for global competitive markets (Guo & Zeng, 2010; Immonen & Saaksvuori, 2008).

Low-quality data in the process of a product origin means a considerable problem of higher costs (Wu et al., 2011; Porter & Rayner, 1992; Snieska *et al*., 2013; Dahlgaard *et al*, 1992; Modarress & Ansari, 1987, March, 1989). Number of components of all today's products and its shape complexity are still increasing. This trend is clearly seen in all industries. It is not an exception when the number of product components is not just in the tens of thousands but hundreds of thousands or even in six figures (automotive, marine, aviation and aerospace industry) (Gecevska & Stojanova, 2013; Comford*et al*., 2006). Therefore, it is necessary to prevent the risk of failures from the very beginning of the lifecycle of each product. The level of ease of changes in single phases is shown in Figure 2.

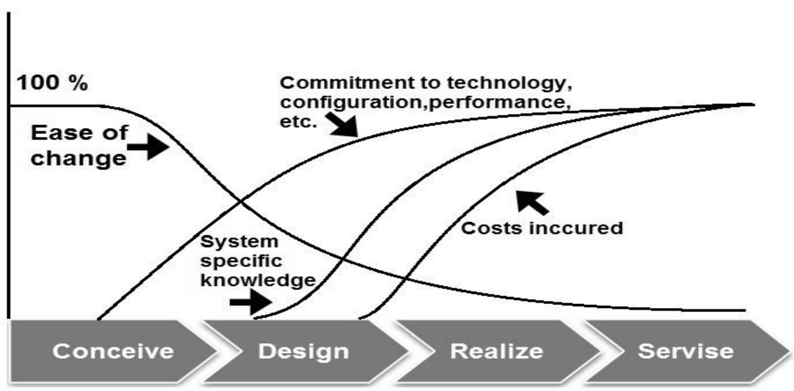

Figure 2. Ease of changes in single phases

Risk Management

Proper risk management process focuses on the identification and treatment of risks. The aim of risk management is to add the highest permanent value to all company activities. It contributes to better understanding of all possible advantages and disadvantages of all factors affecting the organization or project. It increases the likelihood of success and decreases the likelihood of failure as well as uncertainty in achieving of general objectives. The final output of the risk management process should be a decision about whether and how to manage risks. For an unacceptable level of risk, it may be required to stop the current process and accept countermeasures in order to reduce the risk level. If the risk is acceptable and the potential is considerable, development of a plan of preventive measures for its reduction usually follows. Residual risks which cannot be effectively decreased by countermeasures may be processed by using crisis plans [5]. Risk priority assessment is required to be carried out whether the risk is acceptable or not.

Risk management should be a continuous and ever-improving process integrated into the organization's strategy and its enforcement. It must encourage responsibility, measurement, performance and contributes to higher efficiency at all levels of the organization. Programs or plans should be naturally proactive and future aimed. This is a gradual, recurrent improvement process. Preferably, it is integrated into existing practices or other production and design processes.

Baseball Field Diagram

For the risk priority assessment, the basic principle of method from (Hsia *et al*., 2011) was adjusted and used. Risk value R is divided into five priority areas, from A to E, where A represents the area of the highest priority. Risks found in D and E priority areas may stay neglected or untreated. Risk value R combines the probability index - R_P and the impact index - R_I and its aim is to determine the priority height in the same priority area. With one index as horizontal axis and the other as the vertical axis, a diagram reminding of a sector of a baseball field can be drawn. Whose bottom left corner represents the lowest coordinates (0,0) and whose upper right corner is the largest coordinates (1,1) as seen in Figure 3.

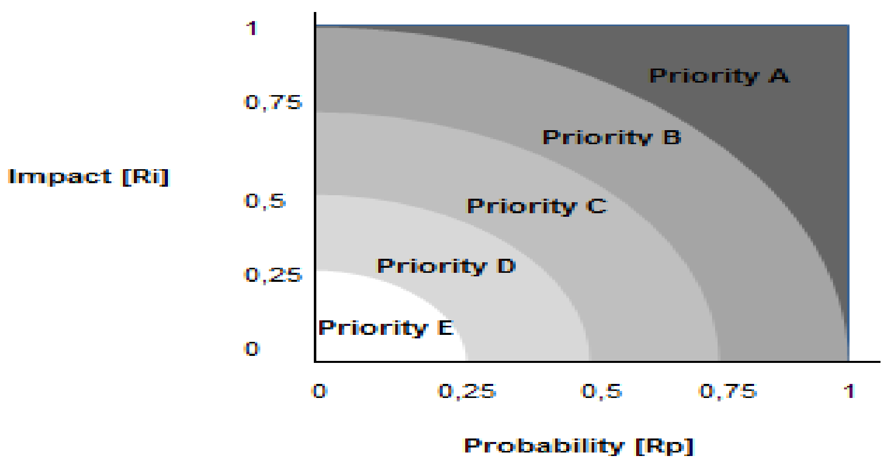

Figure 3. Baseball field diagram

There are five priority areas in the diagram. The priority area A represents risks of the highest priority and it is necessary to carry out immediate countermeasures. The area of B represents risks of the high priority.

It has the next highest priority for resources for management and control, and so on, down to the probability area E where risks may be neglected.

In this study, probability level is divided into five levels: very likely, likely, possible, unlikely and very unlikely. The relative description of probabilities is shown in Table 1. Further, the level of impacts of events is divided also into five levels: very serious, serious, moderate, minor and negligible. The exact criteria description depends on a certain product as seen in Table 2. The higher levels of both, the more serious issue may occur.

Table 1. Probability level

Level (μ_p)	Description	Probability [%]
5	Very likely	1 – 0,1
4	Likely	0,1 – 0,01
3	Possible	0,01 – 0,001
2	Unlikely	0,001 – 0,0001
1	Very unlikely	less than 0,0001

Probability Calculation

When risk probability is required to be calculated and no data from observation or usage is available, the Markov process method is used. The Markov process consists of state sets, a transition probability matrix, and an initial state matrix. A state is defined by the range of frequencies of a risk factor observed in past similar projects. The transition probability between states is computed in a Markov chain. The initial state matrix is defined as the occurrence frequency of risk factors that may occur in recent similar projects. Then, the probability of risk occurrence of a certain risk factor is obtained by multiplying the initial state probability with the transition probability [8]. When no relevant data based on recent similar projects is available. Then, an estimate provided by proper professionals might be used. But, past data based on frequency of risk factors is highly preferred.

Table 2. Impact level

Level (μ_I)	Description	Criterion
5	Very serious	Depends on the event
4	Serious	
3	Moderate	
2	Minor	
1	Negligible	

Impact Calculation

The impact of a risk factor can be determined from the past similar projects or can be estimated. The Analytic Hierarchy Process (AHP) model enables the quantification of risk factor impacts in decision-making under multiple criteria is appropriate for determining the importance level [NPD]. The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP [14] is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, subcriteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion [AHP].

Table 3. Example of a table with assessed risks (min. – max.)

Item	*Event*	*Probability level*	*Impact level*	*Probability index*	*Impact index*	*Risk value*
1-...	Risk	1-5	1-5	0-1	0-1	0-1,41

After identification of all risk events, it is needed to determine the probability R_P and impact R_I indices of a given event and the consequent risk value R as it is shown in Formula 1. Calculations of the probability and impact indices are described in Formulas 2 and 3.

$$R = \sqrt{{R_I}^2 + {R_P}^2} \quad (1)$$

Where,

$$R_P = \frac{\mu_P - min}{R_{FP}} \quad (2)$$

$$R_I = \frac{\mu_I - min}{R_{FI}} \quad (3)$$

From Formula 2, μ_P refers to the probability level. From Formula 3, μ_I refers to the impact level, min refers in both cases to the minimum of tables, set to 1. R_{FI} and R_{FP} refer to the full distance of table minus *1*, both values are *4* ($R_{FP} = R_{FI} = 4$). All counted indices and values are recorded in the table. An example is seen in Table 3.

Risks in the Phase of Conceive

At the beginning of each product's lifecycle is always the customer who expresses his needs and these needs must be heard. There is no universal voice of the customer (VOC), each is unique and very diverse. Customers have many different requirements. Even within a single purchasing unit may appear different requirements (Pol & Merlo, 2008; Ciegis *et al*, 2009; Hung, 2006). All these voices must be considered and balanced in order to develop a truly successful product. For a better understanding of customer needs, a discussion with him should be held where it is important to identify the basic needs of the customer. First, it is necessary to define requirements, answer questions of developers and then advice and criticise the actual product development process or evaluation of a prototype design, etc.

General requirements should be divided into more specific details - the customer should be urged to clarify and express thoroughly its demands until they make perfect sense. Such practices often lead engineers of highly technological products to fundamental findings that ease of use and durability are usually more important for the customer than the latest technology. Besides expressed needs of the customer, it is also needed to identify the unspoken ones. Needs considered to be a conjecture and therefore unmentioned, they can be identified through the preparation of the tree of functions. When all the needs of the customer are collected, it must be properly organized.

Voice of customer is usually the input for CTC. Critical to customer (CTC) are measurable standards of product performance that are essential for customers. Critical to Customer items are those which are particularly important for the customer, as defined through the process of assessing of the Voice of the Customer by methods from survey to interview to focus groups. CTC provides a simple method of prioritization and selection of appropriate input requirements for the whole process. CTC items are internally reflected in Critical to Quality (CTQ) criteria. Then, CTC and CTQ are inputs for further risk analysis as the Delphi method. The next input for the preliminary risk analysis of the entire product lifecycle is so-called Lessons Learned database. Recommendations based on experience, from which others can learn in order to improve their performance. It may be supplied by knowledge from DPM (Data

Product Management, ERP (Enterprise Resource Planning), CRM (Customer Relationship Management) and SCM (Supply Chain Management). It is necessary to consider whether a similar product was developed in the past and what risks occurred and how were treated. Then, the same countermeasures must be applied to the current product or eventually with improvements. As it was mentioned above, inputs for very first risk analyses should be CTC, CTQ and Lessons Learned database as it is shown in Figure 4.

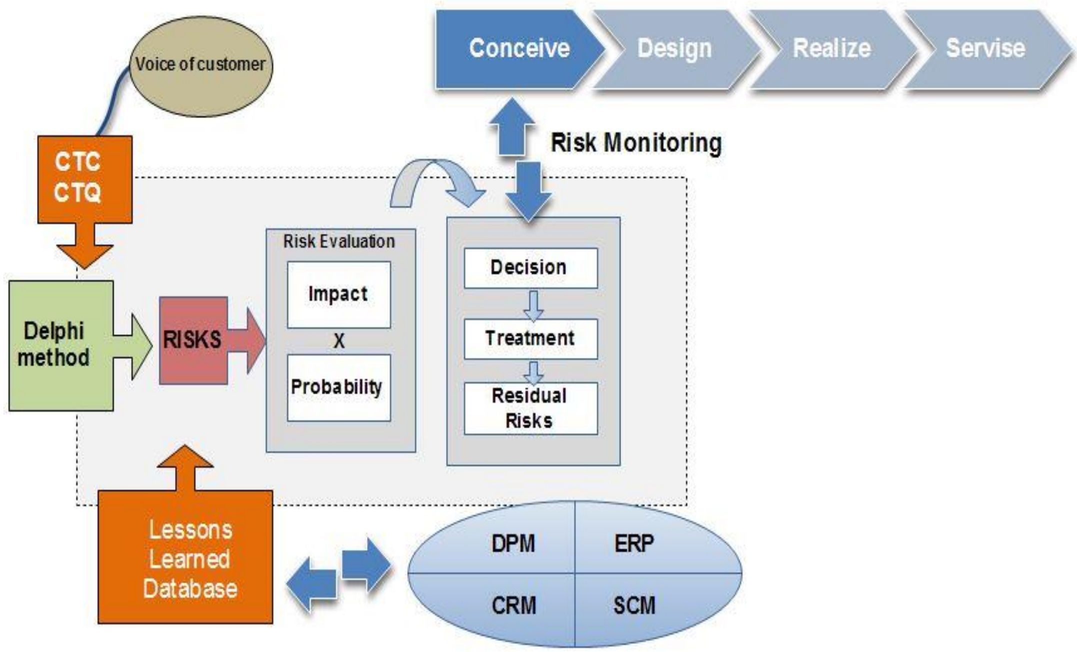

Figure 4

It is always difficult to assess risks when no or minimal data is provided. This makes the risk assessment in the initial product lifecycle phases difficult to be carried out. In spite of this fact, the risk analysis is important and integral part of a new product development. Therefore, the risk management procedure must be customized for each phase of the product lifecycle. The procedure for the conceive phase is shown in Figure 5. Every risk analyst starts with the risk identification. The means for proper risk identification may differ. It is recommended to use tools like Dephi, What If? or just a simple brainstorming. Next to these methods, there is the lessons learned database where it should be possible to get information about risks concerning previous similar products. All identified risks are structured in a table in the next step and possible effects are described. Risk estimation or measurement in early phases of product lifecycle is complicated. Since no real-time data is available, methods like the Analytic Hierarchical Process for impact and Markov chains for probability estimate are desired to be used. It can be also used a specific countermeasure or treatment for the lessons learned database.

Consequently the risk value is calculated in order to find out the priority from the baseball field diagram. If the priority requires treatment, the risk is reduced, avoided or transferred. If not, the risk is accepted. After treatment, all countermeasures must be verified and risks must be measured again in order to find whether there is no residual risk left. Subsequent risk monitoring is essential to be followed. The process of risk management in the conceive phase is shown in Figure 5.

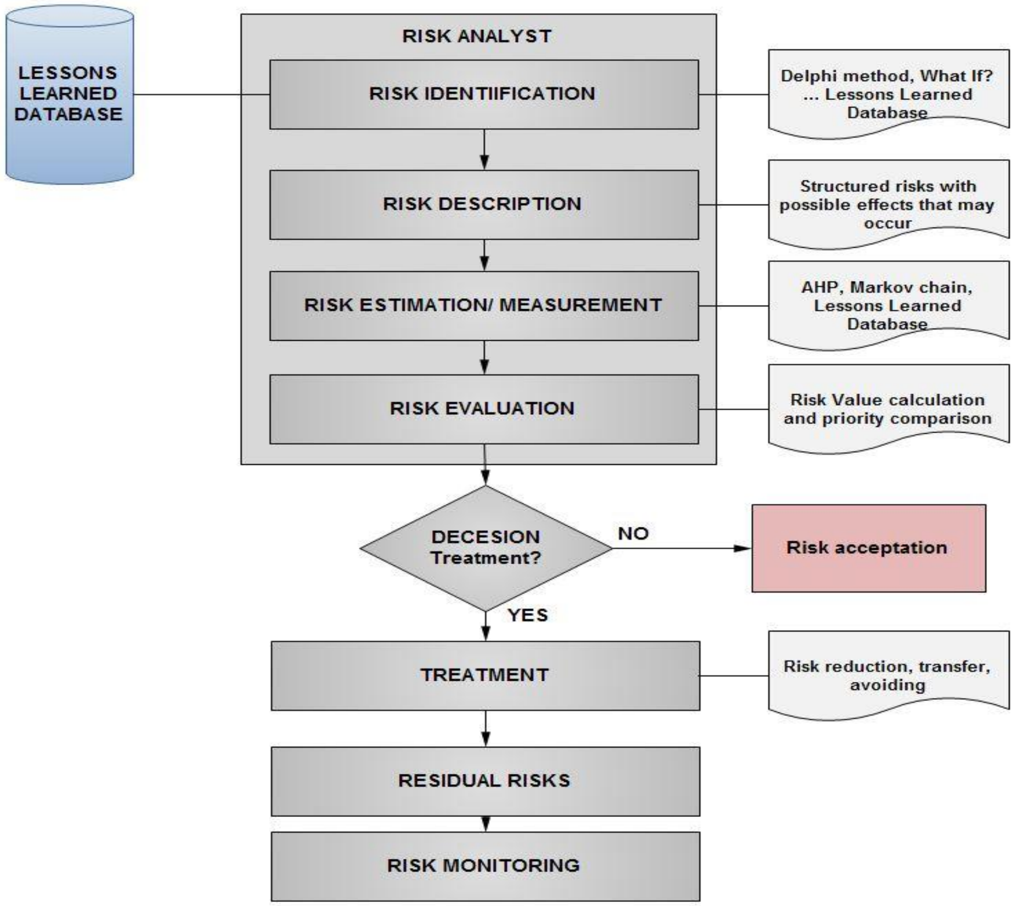

Figure 5

In this phase, it is not difficult to carry out any changes. In consequent product phases, the possibility and ease of any change goes down and a price of changes rapidly grows in time since the product is committed to a certain technology, configuration and performance. Therefore, it is needful to identify all risks in the first two phases when it is still possible to make changes and countermeasures with ease. Unidentified risks in the phases of realize and service may endanger the financial achievement of the whole product (Qi, 2008; Korecky & Trnkovsky, 2011).

Risks in the Phase of Design

A design risk assessment is the act of determination of potential risks in the design process, either in a detailed design, consequent analysis or simulation, validation and possible tool design (Markeset & Kumar, 2001; Grieves, 2005). It provides a broader evaluation of a design beyond just CTQs, and enables to eliminate possible failures and reduce the impact of potential failures. Thus, it is suitable to categorize risk factors into groups and manage risks for each group separately due to amount of risks (citace). The categories are marked as: R – resource, H – humans, P – process, T – technology and O – others. Scheme for the risk management of the phase of design is seen in Figure 6. Accepted risks and residual risks with accepted risk values from the conceive phase are transferred and evaluated in the phase of design again in order to verify their possible increase.

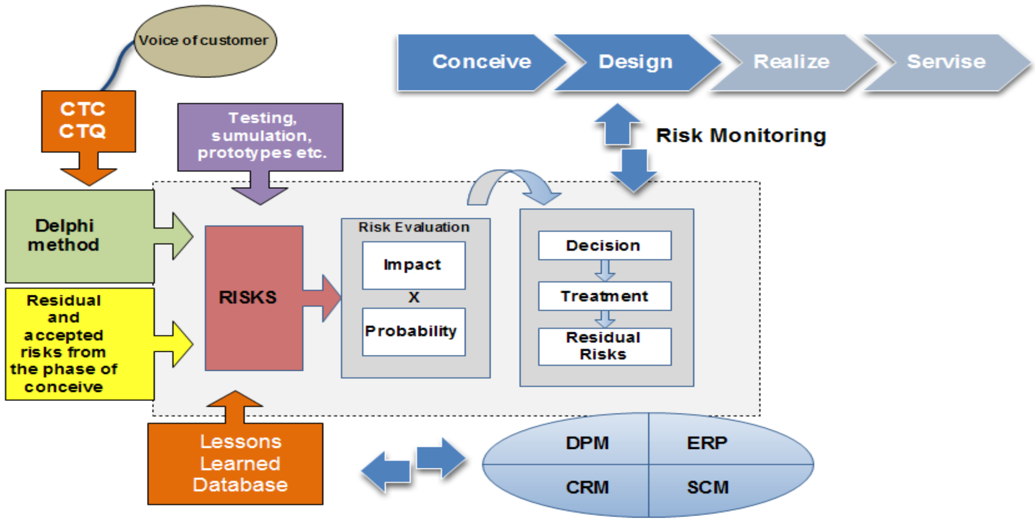

Figure 6

Making a prototype and simulations, this can considerably help in identification of new product risk aspects. Also, a simulation of treating the product and its placing into the working environment are important.

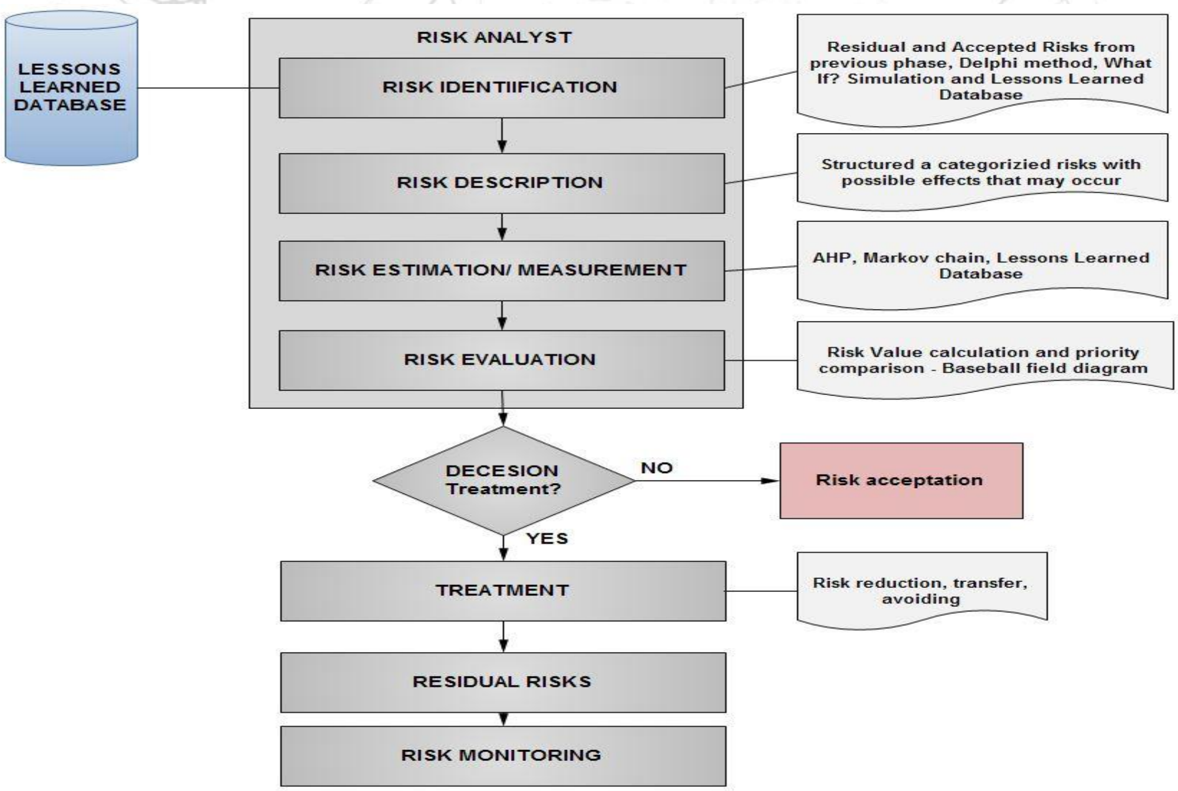

Figure 7

For the better understanding of customer's requirements, it is suitable to set an appointment with a customer and introduce the prototype. Then, it is possible to adjust it according to customer's needs. From the way of the customer's treating with the prototype, it is likely to observe other possible risks. A simple brainstorming with a customer is essential. Further, it is still necessary to follow CTQ, CTC and VOC as inputs for the Dephi method. In this phase, the knowledge management is easier to apply and the knowledge from DPM, ERP, CRM or SCM should be used in the Lessons Learned database to deliberate about risks from previous similar projects or from the past generally. The entire procedure of risk management in the phase of design is shown in Figure 7.

Risk Monitoring

When monitoring risks, faults, risk increases or countermeasures failures might be observed. When this happens, it is necessary to take an action against it immediately. Firstly, it is essential to find out whether this problem was observed in the past and what kind of countermeasure was used. If yes, the countermeasure has to be reviewed and improved or replaced. If no, the process of incident investigation has to be initiated.

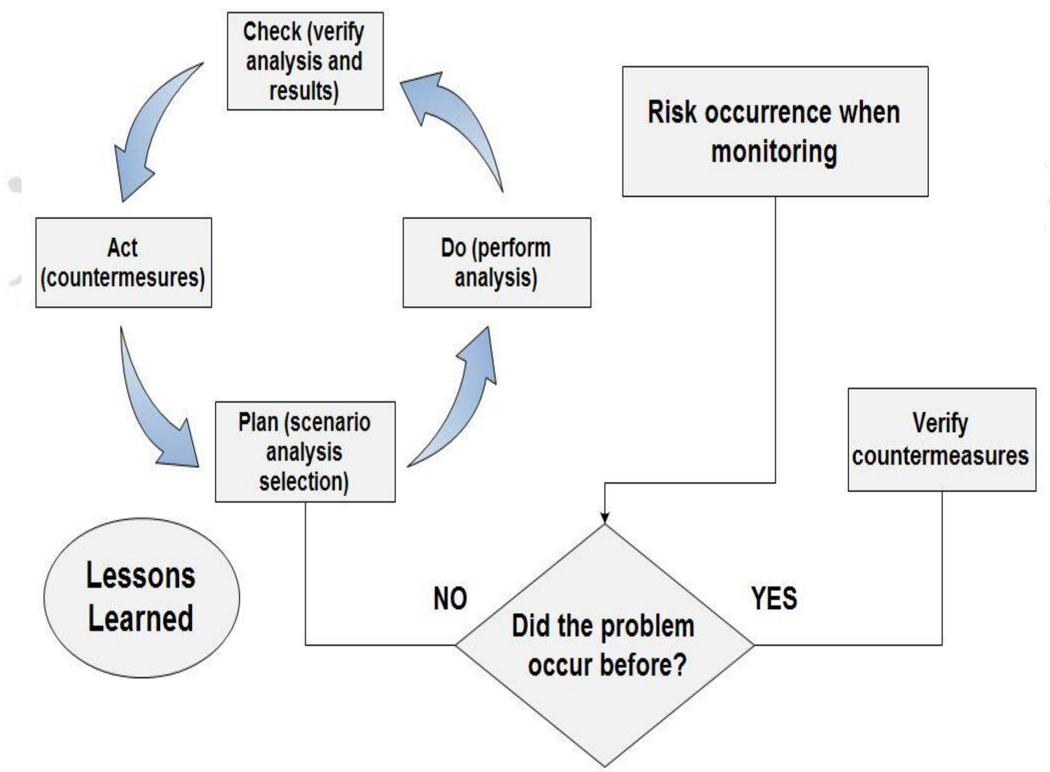

Figure 8

The investigation process is based on PDCA cycle, where P as Plan represents an analysis selection. The list of standard analysis for incident investigation is seen in Table 4. D as Do refers to analysis performance, C as Check where results of the selected analysis are verified and finally A as Act, here the countermeasure is implemented. This cycle is a continuous process. The fault or risk and countermeasures are consequently recorded to the Lessons Learned database. The whole process is shown in Figure 8.

Abbreviation	*Method name*
FTA	Fault Tree Analysis
ETA	Event Tree Analysis
CCA	Causes and Consequences Analysis
CIT	Critical Incident Technique
CRT	Current Reality Tree
MES	Multiple Events Sequencing
STEP	Sequentially Tied Events Plotting Procedure
SRAD	Schematic Report Analysis Diagram
TBA	Tripod Beta Analysis
CLD	Causal Loop Diagrams
RCA	Root Cause Analysis
RCFA	Root Cause Failure Analysis
ECFC	Events and Causal Factors Charting
SRP	Savannah River Plant Root Causes Analysis System
TR	TapRoot
ERCAP	Event Root Cause Analysis Procedure
HSYS	HSYS
ASSET	Assessment of Safety Significant Teams
SOL	Safety Through Organisational Learning
CTM	Causal Tree Method
SACA	Systematic Accident Cause Analysis
SCAT	Systematic Cause Analysis Technique
SS	Six Sigma
MORT	Management Oversight and Risk Tree
TOR	Technic of Operation
CA	Change analysis

Summary of Findings

Ever-increasing financial, time and qualitative demands force current companies and project teams to consider all possible risks and their consequences which might have fatal impacts. Right awareness, considering and consequent risk management at the beginning of the project can mean a multiple saving at its progression or the end. Risk management throughout the entire product lifecycle is slowly becoming a standard practice, but appropriate methods and procedures are not always used. This study offers a possible way how to treat risk in the first phases of the product lifecycle where is still possible to make significant changes without incurred costs that would considerably endanger the financial achievement. Identified risks can be used for a decision whether to continue the production of the product or make significant changes. Performing this analysis can result in mitigation of property, health or the environment losses. This case study enables a better view of the issue of risk management of the product lifecycle and shows a possible way of usage. Further research will be devoted to next product lifecycle phases in order to create a unique methodology.

References

Bergsjö, Dag. (2009). Product Lifecycle Management. Gothenburg: Chalmers University of Technology

Ciegis, R., Ramanauskiene J., &Startiene, G. (2009) Theoretical Reasoning of the use of Indicators and Indices for Sustainable Development Assessment.*InzinerineEkonomika-Engineering Economics*(3), 33-39.

Cornford, S.L., Feather M.S. & Hicks. K.A. (2006).DDP a tool for life-cycle risk management.*Aerospace and Electronic Systems Magazine*, 21, 13 - 22.

Dahlgaard, J. J., Kristensen, K., & Kanji, G. K. (1992).Quality Costs and Total Quality Management.*Total Quality Management*, 3, 211-221. http://dx.doi.org/10.1080/09544129200000029

Gecevska, V.; Stojanova, T. &Jovanovski, B.(2013).Product Lifecycle Management Tools, *Annals of Faculty Engineering Hunedoara*,Vol.1, 219-222.

Grieves, M. (2005). Product Lifecycle Management: Driving the Next Generation of Lean Thinking, McGraw-Hill

Guo, Q., & L. Zeng.(2010). Analysis on risk management based on the method of FMEA of EPC general contractor projects.*Management and Service Science (MASS), International Conference*, 1 - 4.

Harvard Business School. (2010). Improving Business Processes: Expert Solutions to Everyday Challenges. Boston, MA: Harvard Business School Publishing.

Hung, R. Y.Y. (2006). Business Process Management as Competitive Advantage: A Review and Empirical Study. *Total Quality Management*, 17(1), 21-40. http://dx.doi.org/10.1080/14783360500249836

Hsia, T.C., Chen, S.C., Tsai, R.K. & Huang, S.C..(2011). Using Systematic Innovation Process (TRIZ Method) to Improve the Manufacturing Technology of Platelet Agitators, *21st International Conference on Flexible Automation and Intelligent Manufacturing: FAIM 2011*, Taiwan, 5.

Immonen A.&Saaksvuori A..(2008) Product Lifecycle Management, Berlin, Springer.

Korecký, M. &Trkovský.V.(2011). Management rizikprojektů: se zaměřenímnaprojekty v průmyslovýchpodnicích. Praha: Grada Publishing.

Machac, J.; Steiner F.(2012): Řízenírizik v etapěvývojetechnologickéhoprocesu, *Electroscope*, 2(5).

Machac, J., Steiner, F. (2013). Risk Management Methodology Covering the Entire Product Lifecycle. *Advances in Suistainble and Competitive Manufacturing Systems*. Heidelberg: Springer, 59-64.

Markeset, T., Kumar U.(2001). R&M and Risk-Analysis Tools in Product Design to Reduce Life-Cycle Cost and Improve Attractiveness, *PROCEEDINGS Annual RELIABILITY and MAINTAINABILITY Symposium: IEEE*., 1-7.

Marsh, J. (1989). Process Modelling for Quality Improvement.Proceedings of the Second International Conference on *Total Quality Management*, 111.

McRoberts, S. (2005).Risk management ofproductsafety. *ProductSafetyEngineering, 2005 IEEE Symposium*, 65 - 71. DOI: 10.1109/PSES.2005.1529524.

Modarress, B., & Ansari, A. (1987).Two New Dimensions in the Cost of Ouality.*International Journal of Quality & Reliability Management*, 4(4), 9-19. http://dx.doi.org/10.1108/eb002886

Pol, G., Merlo, C., Legardeur, J. (2008). Implementation of collaborative design processes into PLM systems, *International Journal of Product Lifecycle Management*, Inder-science, Vol.3, 279-294.

Porter, L. J., & Rayner, P. (1992).Quality Costing for Total Quality Management.*Institutional Journal of Production Economics*, 27(1), 69-81. http://dx.doi.org/10.1016/0925-5273(92)90127-S

Qi. B. K.(2008) Engineering Project Management. Thirdedition. Dalian: Dalian University of Technology Press ,2, 6-7.

Snieska, V., Daunoriene A. &Zekeviciene, A. (2013). Hidden Costs in the Evaluation of Quality Failure Costs. *InzinerineEkonomika-Engineering Economics*, 24(3), 176-186. http://dx.doi.org/10.5755/j01.ee.24.3.1186

Stark, J.(2011). Product Lifecycle Management: 21st Century Paradigm for Product Realisation, London: Springer

Wu, H. Y, Chien, F. L., Lin, Y. J., & Yang, S. F. (2011). Analysis of Critical Factors Affecting the Quality cost of Process Management of Six Sigma Project Based on BSC. *International Research Journal of Finance and Economics*, 71, 93-104.

Ying-Kui, G. & Hong-Zhong H.(2004). An integrated product and process development model supporting entire lifecycle. *Computer Supported Cooperative Work in Design*, 2, 558 - 562.

[5] A Risk Management Standard. London : AIRMIC, 2002. 14 s

Acknowledgement

This research has been supported by the European Regional Development Fund and the Ministry of Education, Youth and Sports of the Czech Republic under the Regional Innovation Centre for Electrical Engineering (RICE), project No. CZ.1.05/2.1.00/03.0094.