Dynamic Risk Assessment on Innovation Risks in the German Machinery and Plant Engineering Industry

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Abstract

For today's companies innovation becomes more and more the source of strategic differentiation or cost leadership. Challenging competition, frequent changes in their environments increases increase complexity in innovation management significantly. Therefore, deviations from companies' innovation objectives, commonly known as innovation risks, are also rising. They result from complex structures and can be modelled in risk nets. Theory and managers understand that risks are interrelated; nevertheless the portfolio of innovation risks manages the risks separately. This limits the understanding of the dynamic behavior in risk nets. Simulations based on statistical approaches are already approved und used for risk analysis identifying, valuating and aggregating the risks. The limitations of these methods can be overcome by using System Dynamics to gain new insights into the behavior of risk nets. In the research project cause-and-effect relations and the dynamics of innovation risks are investigated in the German machinery and plant engineering industry. With the support of the German Engineering Association and leading companies in the industry this research demonstrates the potential of System Dynamics for a holist holistic risk assessment of Innovation risk and develops a risk net of the main innovation risks in the industry.

Key words

Innovation risk, risk management, complexity, risk assessment, System Dynamics

1. The Problem of Innovation Risks

1.1 Isolated Perspective on Interconnected Innovation Risks

Today's competition is determined by less sustainable competitive advantages and increasing efforts to overcome this by innovation. They offer potential for differentiation and/or for cost reductions. The management of innovation, especially from a practitioner perspective, is still a challenge. Innovation at the right time and in budget is what drives the Innovation Management *(Gassmann 2006a, 2006b).* Additionally competition is becoming more global and innovation cycles are getting shorter to provide more customized products. Also the complexity and dynamics of technology escalate, reinforcing the challenge (*Howell, 2013*). Dealing with these challenges is leading into higher and interconnected innovation risks (see Fig. 1, *Warren, 2008),* which makes the innovation harder to manage *(Gassmann 2006a).*

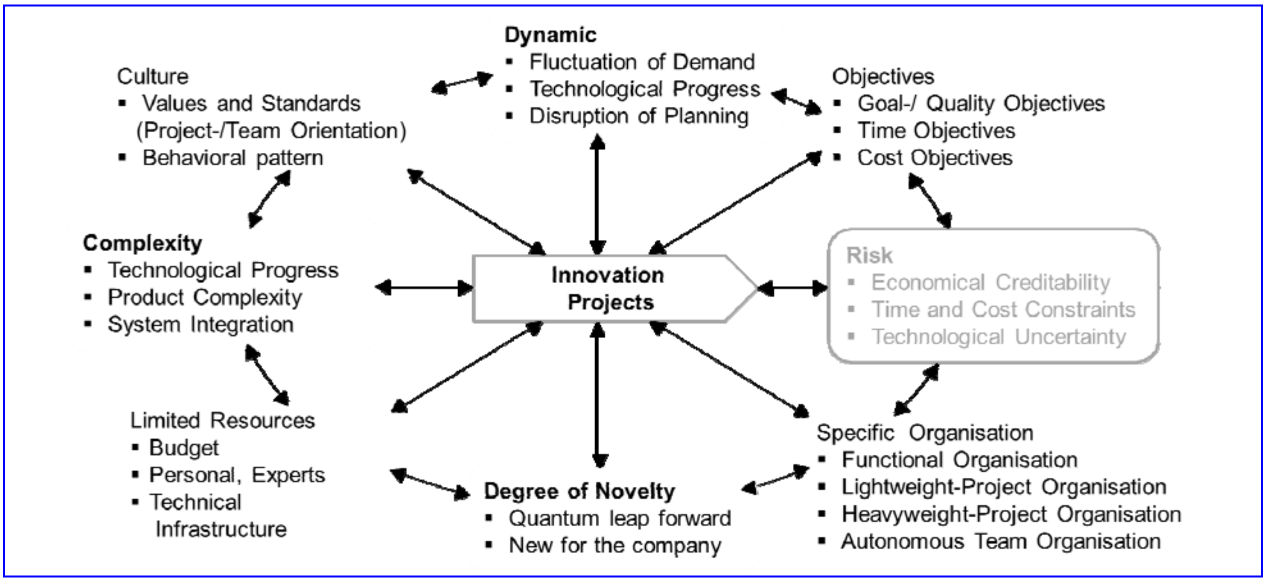

Fig. 1: Aspects and Interconnection of Innovation Risks (Gassmann 2006b S.9)

Due to this complexity the decision making process is determined by uncertainty *(Sinn, 1980; Diederichs, 2004; Romeike/Hager, 2009; Silvestri et al., 2010)*. This uncertainty results from a lack of understanding the behavior of the complex system innovation management. Therefore deviations from a perceived outcome are results. In business "risk" is the hypernym which determines these matters *(Romeike/ Hager, 2009; Silvestri et al., 2010; Gleißner 2011).*

Current research has shown that the incorporation of interconnected risks is still underdeveloped in the risk management process. Therefore the understanding of the "big risk picture" is poor, because it is composed by isolated risks or statistically identified correlations. To overcome these deficits a research project on risk systems and their behavior over time was initialized to develop a holistic perspective of risk systems or risk nets. In order to fulfill these challenge two further aspects will narrow the research. Every industry has its own regulations and its special risks, so there is a need to focus on a specific industry. In addition companies with limited resources are even more challenged to manage innovation. So the second focus in on small and medium sized companies (SME) in Germany. They most often rely on innovation, are market leader in their niches and family owned. Handling risk and innovation management is mainly resource constraint with an isolated perspective on every innovation project and every risk *(Pleitner, 1995; Marwede, 1983; Pichler et al., 2009; Tappe, 2009)*. For the research project the German machinery and plant engineering industry (MPI) was chosen. This branch is highly determined by a high density of SMEs acting in an increasing global environment and high investment volumes. Therefore an appropriate risk management approach covering all aspects is a success factor in this industry.

1.2 Machinery and Plant Engineering Industry

Within the German industry the machinery and plant engineering is one of the most important ones. The industry was in 2013 the largest industrial employer and also the second biggest industry in Germany. It consists out of more than 6,000 companies, whereby most of them (87%) are SMEs. Their business models are aligned to the development and production of machinery and plants in the Business-to-Business Sector (B2B). Therefore production is producing individualized equipment with high volumes in terms of investment. To stay competitive innovation and the underlying knowhow and the capabilities in Research & Development (R&D) are the most important success drivers of the industry. This is one reason, why the industry is beside the automotive industry, electrical engineering and the pharmaceutical/chemical industry one of the strongest industry in research. The further development in this core competence could also be seen in the hiring-rate of the R&D-staff. Using patents as an indicator of innovation underpins this argument, as the German MPI is leading in the number of engineering patent applications at the European Patent Office *(VDMA FuI, 2014; VDMA KZK, 2015)*.

1.3 Innovation Risk Categories & Characteristics

The main risks derived from the business model in the MPI are innovation risks. Having a closer look to the scientific literature dealing with Innovation, several risks categories have to be considered *(Heck, 2003 and Table 1).*

Author	Year	Risk Categories R&D
Moenaert and Souder	1990	Consumer Uncertainty, Competitive Uncertainty, Resource Uncertainty Technological Uncertainty
Smith and Reinertsen	1991	Market & Technical Risk
Voigt	1991	R&D-, Production- & Market Risk
Rinza	1994	Economical, Political, Social & Technical Risk
Gackstatter	1997	Cost, Economic, Liability, Order, Production, Serendipity, Sourcing, Technical & Time Risk
Kern and Schröder	1997	Commercial Uncertainty, Expense Uncertainty, Result Uncertainty, Time Uncertainty,
Reinhardt	1997	Commercial, Market & Technical Risk
Conroy and Soltan	1998	Commercial, Contractual, Financial, Organizational, Program, Strategic, Technical & Third-Party Risk
Branscomb et. al.	2000	Market & Technical Risk
Bürgel and Ackel-Zakour	2000	Economic, Market & Technical Risk
Pepels	2000	Cost, Commercial, Economization, Innovation, Serendipity, Technical &, Time Risk
Gassmann	2001	Legislation, Market & Technical Risk, Missing focus, Not-invented-here-Syndrome, Over engineering
Specht et al.	2002	Cost, Commercial, Technical & Time

Tab. 1: Weakness in the methods of risk analysis

In Addition current scientific papers deal with specific innovation risks. Some examples chosen out of a deep literature review shows the wide range of issues that are addressed *(Wilhite, 2006; Gnyawali/Park, 2009; Ma, 2010; Brophey Baregheh, 2013):*

- Management of technical risk process,
- Co-opetition as option for SMEs to overcome the commercial risks among others,
- Uncertainty in R&D learning or
- The development of the meaning of the four risk domains over time.

In practice a "risk-list" on things that have to be considered in the innovation management is offered by leading German risk experts *(RISKNET, 2015).* Merging the Risks discussed with a generic market model for innovation *(Porter, 1980; Gassmann, 2006b; Kotler et al., 2011)* the innovation risk seems to cover Multi-Causal-Dynamic-Risk-Net. Therefore a broad range of information on the factors and risks that affect the innovation risk is available. Also the System Dynamics literature covers a lot of research on innovation *(Milling, 1998; Maier, 1998; Sterman, 2000).* Nevertheless no specific research could be identified that assembles the total picture of causes and effects of innovation risks for the MPI so fare. To overcome this research gap the innovation risk will be discussed for the MPI from a system perspective.

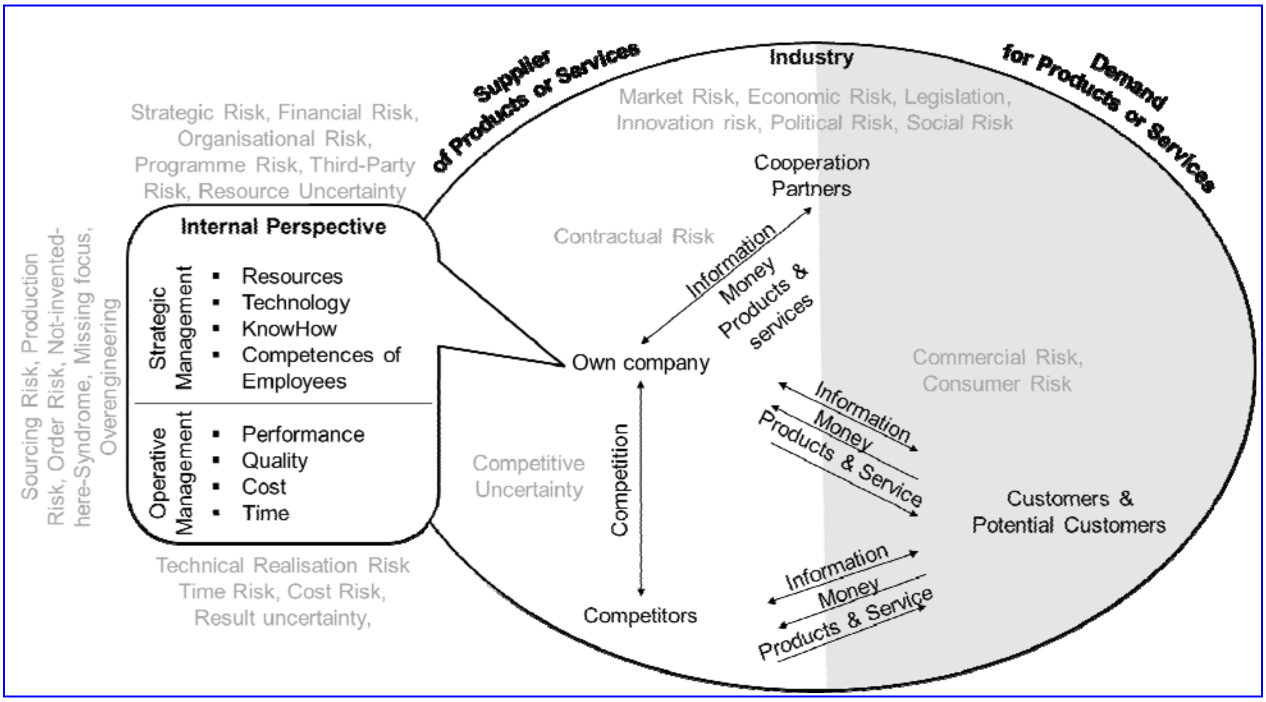

Fig. 2: Multi-Dimensions of Innovation Risks

2. Risk Management and Methodical Weaknesses

2.1 Standard Risk Management Process

In order to manage risk systematically there are standard processes recommended by many authors and non-governmental organizations (see figure 3). The classical risk management process is carried out along business segments, processes or risk classifications. The risk management process covers six steps, some authors use less steps by integrating some steps into one *(White, 1995; Diederichs, 2004; Romeike/Hager, 2009; Stiefl, 2010; Gleißner, 2011).*

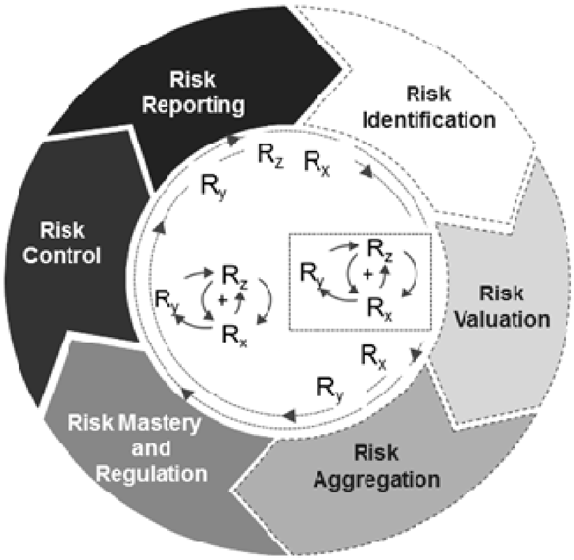

Fig. 3: Extended Risk management process *(based on IDW PS 360; White, 1995; Crouhy et al. 2006; Denk et al. 2008; Romeike/ Hager 2009; Stiefl 2010; Fraser/Simkins 2010; Gleißner 2011)*

The risk analysis sums up the risk identification, valuation and aggregation. The results out of these analyses effects subsequent activities. It is the most difficult and import step especially in the context of managing risk nets and their dynamics. Starting point is the risk identification. Some risks occur not only isolated; interrelations should be part of the analysis as well. Positive and negative feedback loops can take a decisively influence on a risk object and therefore the change in the meaning of the risk *(IDW PS 360; White, 1995; Tchankova, 2002; Denk et al., 2008; Romeike/Hager, 2009; Gleißner, 2011)*. Next step of the process is valuation covering the quantitative description of the risks. The common approach is to evaluate each risk regarding their probability of occurrence and the extent of potential loss, caused by the risk. The aggregation of the isolated risks into the total risk position follows and is compared with the risk bearing ability of a firm reflected in the equity of a company. The applied models and methods to aggregate risk base on distribution functions and their simulation (Monte Carlo simulation). Traditional approaches like damage classes, inquiry of maximum loss or values of expectation of loss are common practice *(Denk et al., 2008; Romeike/Hager, 2009; Gleißner, 2011).* The evaluation of cause and effect structures and their behavior is in the classic approaches not included but should be considered as well to improve risk aggregation. Single risks with a subordinated isolated meaning might develop to a relevant risk in combination with others or by accumulation *(IDW PS 340 3.2).* Such cause and effect relations and their development over time cannot be considered by the used standard methods. The risk assessment is the basis for risk mastery and regulation. In this step unbearable risks can be avoided and unavoidable risks are leveled to an acceptable standard. Finally risks are reported and controlled. The process is ruled by the risk policy of a company defining acceptable risk levels, methods, frequency and so on of the risk management process *(Gleißner, 2011).*

2.2 Applied Risk Assessment Methods

Having a critical review of the most used risk assessment methods they show some methodical weaknesses. There are many methods and instruments available, but the more advanced and time consuming they are, the less they are used in industry practice. Regarding the requirement to deal with system structures and dynamics the standard methods are assessed by the dimensions "Dynamic" and "Complicacy". Dynamic evaluates the methods' ability to cover the development over time. Complicacy gives an idea about the ability to incorporate explicit cause-and-effect-structures.

Method	Dynamic &	Complicacy =	Complexity
Ishikawa Diagram	Statically 🔴	Comprehensive risk number 🟢	Average 🟡
Risk- Check Lists	Statically 🔴	Comprehensive risk number 🟢	Average 🟡
Scenario Analysis	At this stage 🔴	Limited number of scenarios 🔴	Low 🔴
Sensitivity Analysis	No cause effects 🟡	Comprehensive scenarios 🟢	Average 🟡
Gaussian bell	Gaussian distr. 🔴	Comprehensive risk number 🟢	Average 🟡
Portfolio Analysis	Limited 🔴	cause effects / Feedback 🔴	Low 🔴
Stochastic	Limited 🟡	Comprehensive risk number 🟢	Average 🟡
Monte-Carlo	Random walk 🟡	Comprehensive simulations 🟢	Average 🟡
…			

Tab. 2: Weakness in the methods of risk analysis

Main criticism found within the literature analysis capture the validity of the statistical instruments and models used. Mathematical Models are limited models of the reality. They fulfil their requirements when their results not differ too much from those in the reality. These results are influenced by the purpose of the chosen function, the underlying assumptions and also the restrictions *(McNeil, 2005).* Therefore statistical models do not fulfill the requirements for a risk assessment in the following aspects *(McNeil, 2005; Gleißner/Romeike, 2008):*

- Risks don not necessarily underlie a normal distribution
- Random-walk is a movement which not necessarily corresponds to the reality
- Some assumptions are not meeting the reality like perfect markets as a simplification of the market model

Although auditors are aware of these facts the use of insufficient methods in the necessary annual risk audit for German companies is not prohibited. In fact in the audits the formal validity of the risk process is checked but not the appropriateness for the model and the methods *(Bieta/Milde, 2009)*. Therefore, it is necessary to catch up in managing dynamic risk nets and adding cause and effect relations into the risk management process. Figure 3 illustrate the extended version of risk management process.

3. Methodical Enhancements of Risk Assessment

3.1 Risk Assessment without Systems Thinking

Common understanding of risk in science and practice is defined as "Chance or Danger, arising from tasks and decisions, to deviate from set objectives." *(Romeike/Hager, 2009; Gleißner, 2011; Dietrichs, 2012).* Objectives are defined in the business planning process for all business functions with a defined ambit and time line *(Wild, 1982):*

- Objective: What? In which extent? When?
- Problem: Why?
- Premises: Conditions
- Actions: How?
- Resources: With what?
- Deadline: When?
- Owner of fulfilment: Who?
- Result: Outcome

Performance Management allows managers to quantify and measure different kinds of performances and objectives *(Warren, 2008)* in the context of the dimensions *(Gleich, 2011)* time, cost, quality, flexibility or satisfaction. Although these starting points seem to be appropriate for the evaluation of deviations, problems arise from the isolated and one-dimensional management of the dimensions with current risk assessment methods.

The problem of assessing the “set of objectives” and their deviations (risks) without Systems Thinking could be derived from the isolated treatment of the several planning details. Some risks occur not only isolated or by one cause, interrelations should be part of the analysis as well. Positive and negative feedback loops can take a decisively influence on a risk object and therefore the change in the meaning of the risk *(White, 1995; Tchankova, 2002; Merbecks et al., 2004; Denk et al., 2008; Romeike/Hager, 2009; Gleißner, 2011; IDW, 2011).* This view is relevant for the risk identification and priority setting.

In Addition risk assessment itself is problematic. This process covers the quantitative description of a risk. Common risk evaluations look at the probability of occurrence and the extent of loss which determines the decisive parameters of the function *(Denk et al., 2008; Romeike/Hager, 2009; Gleißner, 2011)*. Hence, the appropriateness of assessing risk two dimensional instead of keeping the real dimensions and quantify the deviation in monetary units seems to be doubtful. Also the rating of the total amount of all risks (risk aggregation) the models and methods used to quantify are mostly based on distribution functions and their simulation (Monte Carlo Simulation). Traditional approaches like the arrangement in damage classes, inquiry of maximum loss or values of expectation of loss are also common practice.

For closing the loop to the problem of risk assessment it can be concluded that there are lacks in the risk analysis by treating the risks one-dimensional, isolated and not in system-perspective:

1. Missing considerations of the development of each element over time.
2. The missing causalities between the risks.
3. The multidimensional perspective on performance.

The risk assessment as well as the actions derived from these step should be evaluated critical in terms on reliability, if dynamics of the overall system is not considered. To overcome this problem and incorporating multi-causal interconnections on the isolated risk perspective System Dynamics could close the gap *(Warren, 2006, Warren, 2008):*

Therefore a solution seems to the application of System Dynamics in the process of risk analysis which could close the gaps identified in Table 2.

Planning Perspective	System Dynamics Perspective
Objective: What? In which extent? When?	Expected Behavior of a System
Problem: Why?	Systems Behavior
Premises: Conditions	Endogenous / Exogenous factors
Actions: How?	Policies
Resources: With what?	Stocks & Flows / Causalities
Deadline: When?	Dynamics
Owner of fulfilment: Who?	Stocks
Result: Outcome	System Behavior

Tab. 3: Comparison of Perspectives on common planning requirements and SD-Models

3.2 Contribution of System Dynamics

For managers the use of simulation methods offers many advantages, such as (*Law, 2007; Romeike/Spitzner, 2013):*

- Observation in real systems are limited.
- Safety in terms of ethical acceptance or riskiness.
- Costs of real systems observations.
- Modification options are limited in real systems.
- Confidentiality of the results out of the behavior.
- Reproduction of results.

Confronted with complex relations among large numbers of variables, simulation methods can provide more insights than maybe other methods do *(Law and Kelton, 1991)*. The applications of simulations are considerable when availability of empiric data material is limited. This allows the development of deeper understanding for complex situations, which effects can also occur with time delays *(Davis et al., 2007).*

The System Dynamics approach is an appropriate simulation approach for risk assessments, especially as it can show the system structure and behavior over time *(Davis et al., 2007; Forrester, 1972; Sterman, 2000; Morecroft, 2007; Raffée/Bodo, 1979).* System Dynamic takes the complexity, feedback loops and the non-linearity of social systems into account (*Sterman, 2000*) and simulates the interaction of quantifiable and related variables on an aggregated overall system level *(Dooley, 2002).* Using these methodical advantages System Dynamics can offer an important contribution in each phase of the risk analysis process (Identification, Assessment and Aggregation): For the risk identification new insights are expected in the initial relevance evaluation depending on the risk structure. By the investigation of the risk nets there will be insights in the influencing factors and risks in risk-feedback-systems.

In the risk assessment and aggregation phase new insights could be gathered not only from a “random” perspective. The incorporation of time delays, non-linear interactions and feedback can contribute in the quantitative perspective. Even for complex risk nets, System Dynamics can create new findings. A lot of risks and risk nets are determined by missing empirical data or events with a low probability (black swans). This is a major weakness. Especially in this case, simulation approaches like System Dynamics are able to offer insights. By applying System Dynamics more insights can be expected in all phases of the risk management process.

3.3 Modelling Standard Risks with Standard Models

The incorporation of complexity in the process of risk assessment leads to the following research questions:

a) How is innovation risk in the machinery and plant engineering defined?
b) How does the structure of the relevant innovations risks look like?
c) How do they affect each other?
d) Does the relevance of single risks change as result from simulation of risk nets?

There is a lot of research available in the field of cause and effect of risks and also in the field of innovation. Current literature about the management of innovation risks discusses several risk categories and aspects that have to be considered. Also results from the practitioner side derived from workshops and interviews with consultants, auditors, the German Engineering Association and leading companies in the machinery and plant engineering industry confirmed in the main innovation risks in the industry. They arise from the supply and demand side and are determined by the subsystems customers, own company and competitors *(Kotler et al., 2011, Porter, 1980),* coopetition/ cooperation partners and suppliers *(Gassmann, 2006b and Fig. 1).* Extracted these findings in an internal and external perspective, following risks were included in the System Dynamics risk assessment model.

1. Technological Demand (Commercial Risk & Consumer Risk): This risk is driven by the suppliers of products and services and the requirements of the customers.
2. Plagiarism (Intellectual Property Rights IPR): Risks which refers to the relevant innovation risks in the MPI *(Gleich et al., 2007; VDMA PP, 2014).* Plagiarism is also determined as risk that affects the technology demand. Plagiarism can be derived from internal sources which are the technology state (protected by Intellectual Property Rights or unprotected Non-IPR)) and knowhow of the R&D-people.
3. Technical Realization of the Technology Demand (Technology Risk/ Risk of Innovation) which is mainly determined by knowhow (Internal and external) of Employees.

Overall all this perspectives in turn have to be linked with the operational view of Performance, Quality, Cost and Time. Following the approach of leading System Dynamics experts building models out of validated generic business *models (Brossel, 2004a; Bossel, 2004b; Warren, 2014)* a literature research about generic business architectures on innovation models, market models, knowledge management and project management in the System Dynamics literature was conducted. Based on the appropriateness for the research projects generic models in Tab. 4 are considered.

These standards models are the fundament of the holistic Innovation-Risk-Model. In a first step they are adjusted and extended for the machinery and plant industry. By a literature review on the specific innovation characteristics in the MPI initial adjustments were identified. For validation purposes interviews with risk experts in the MPI have been conducted where the Causal-Loop-Diagrams (CLD) were discussed and reviewed.

For the purpose of this paper the scope is limited to some aspects derived out of the holistic model. The MPIs business model is technology driven. Not fulfilling the appropriate specifications means finally a deviation where we again refer to risk. For getting more insights in how the objective will be achieved necessary resources and their interconnections will be modelled in detail.

Potential Standard Structures & Selected Structures (italic)
1. Technology Leadership: *Maier (1998);* Milling (1996) auf Basis von Bass (1969); Dillerup (1999); Milling (2002); Morecroft (2008); Warren (2008).
2. Price Competitiveness: *Maier (1998); Bossel (2004);* Milling (2002).
3. Quality: *Lyneis & Ford (2007); Rahmandada & Weiss (2009); Rahmandad & Hu (2010);* Ford & Sterman (1998); Lyneis et al. (2001); Love et al. (2002).
4. Time for Development: *Rodrigues & Williams (1998);* Lyneis et al. (2001); Love et al. (2002); Lyneis & Ford (2007); Richardson (2014).
5.1 Internal Capacity Expansion: *Lyneis & Ford (2007);* Ford & Sterman (1998); Rodrigues & Williams (1998); McGray & Clark (1999); Lyneis et al. (2001); Morecroft (2008).
5.2 External Capacity Expansion: *Ford & Sterman (1998)*
6. Technical Qualification: *McGray & Clark (1999); Lyneis & Ford (2007); Warren (2008***);** Lyneis et al. (2001); Rodrigues & Williams (1998).
7. Knowledge Transfer: *Georgantzas & Katsamakas (2008); Warren (2008);* McGray & Clark (1999); Luna-Reyes et al. (2008); Rahmandada & Weiss (2009).

Tab. 4: Modelling Standard Risk(s) with Standard Structures

Coming from the process of project management, first of all “innovation tasks” have to be defined by considering time limitations (time risk) and quality restrictions (quality risk). In order to close the technology gaps within a defined timeframe the policies are either purchasing the technology, development by cooperation’s (External Acquisition) or In-house development (Internal Acquisition).

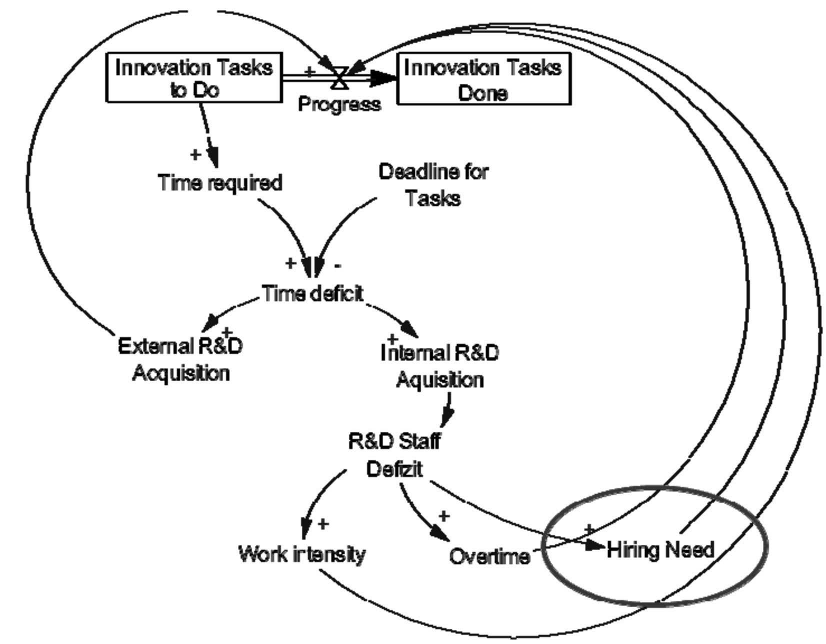

Fig. 4: Simplified Project Management Loops (*Ford & Stermann, 1998; Lyneis & Ford, 2007 extended by external R&D Acquisition VDMA FuI, 2014*)

For the MPI the In-house development is the preferred policy in order to keep the knowledge in the enterprise. Therefore the hiring cycle (Fig. 8: B4: Resource of In-house innovation) will be analyzed further. Risks are the result of a gap between planning and potential deviations. Hence the risk manager is confronted not only with the final stock of R&D-people. Also the In- and Outflows, which are finally the cause of deviation, have to be considered (Fig. 5). In the simulation model the capacity risk will be identified by the deviation of the base run (planning) and the Risk-Runs (varied in- and outflows as well as discussing different policies). So for example the shortage of skilled workers is one of the limiting factors choosing this innovation policy which is the restriction of In-house development.

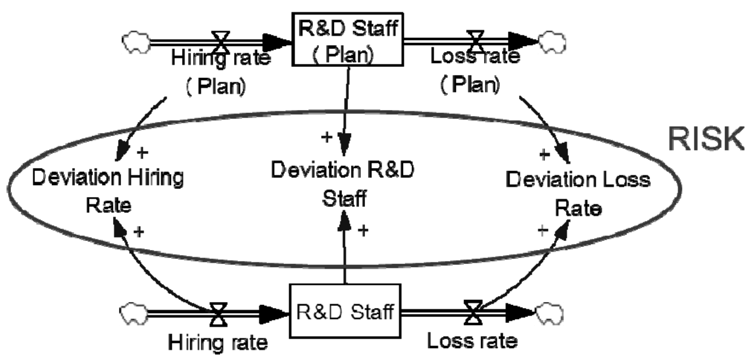

Fig. 5: R&D capacity risk

From an innovation perspective it is not only a risk on personnel capacity that has to be considered. It is also a knowledge risk which covers multidimensional aspects. Technology is defined as knowledge about scientific and technical impact coherence which could be used to solve technical problems. It is reflected in products, services or processes *(Brose, 1982).* Therefore knowledge management is identified in the innovation literature as important success factor *(Gassmann, 2006b*) which has to be included in the CLD as a potential risk.

There are several sources of Innovation knowledge. Coming from an Input-Output-perspective the main drivers of R&D activities can be identified by analyzing the investments within the R&D-Budget. In 2011 63% of the R&D-Budget in the industry was invested in R&D-Staff, 27% in equipment and 10% in other R&D items. These figures underpin the meaning of the R&D-staff as the main knowledge carrier. Within in this cycle the hiring rate is one of the most important risks identified. In the MPI 30% of the enterprises were affected by this issue which finally leads to the abandonment of innovation projects in the crisis 2008-2010. For comparison purposes other industries were affected only by 17% *(VDMA FuI, 2014).* Therefore it is not only the capability of hiring R&D staff, it is also the capability of promotion (Fig. 6) which at least influence the capacity again (Fig. : R2: Further Learning and link to personnel capacity). In the scope of functional and technical learning the spending covered 55.6% relating to the whole spending's for further learning in the MPI 2013 *(VDMA FuI, 2014).* Hence, learning has to be included in the workforce cycle in order to consider the risk of missing or insufficient promotion (Fig. 8: B5: Technical Qualification).

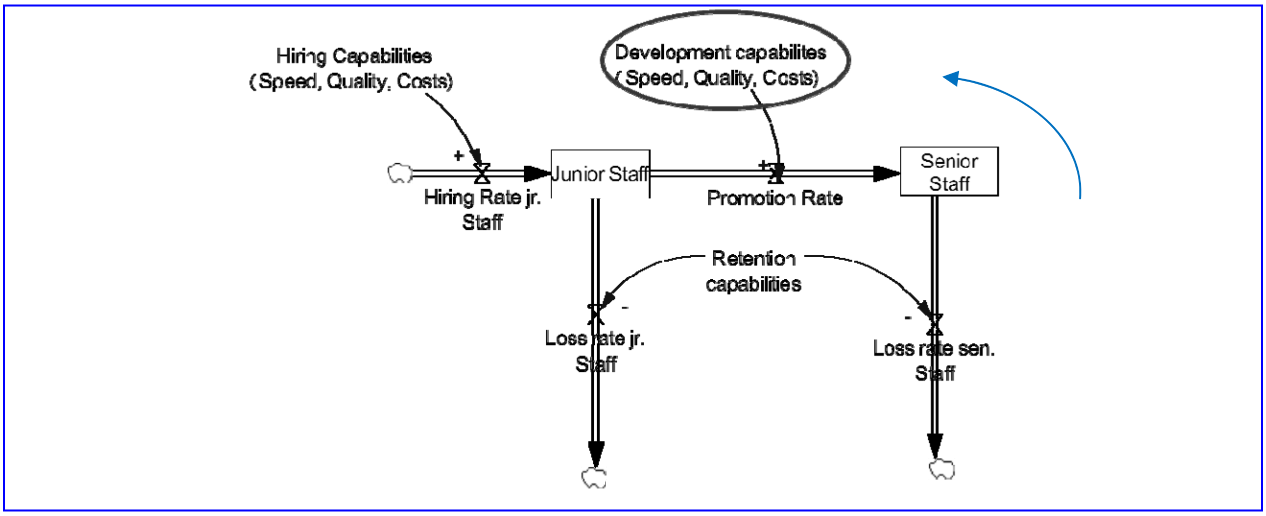

Fig. 6: Finding and developing the Staff (Dillerup 1998; Warren 2008)

Knowledge could also be gathered by buying technology from external partners (Cooperation/ Development Partners). From this point of view knowledge transfer could be defined as chance (positive deviation/ positive risk) (Fig. 8: B6: Knowledge Inflow by externals). But in the MPI it is seen the other way round and this is affecting the industry tremendously *(VDMA Produktpiraterie, 2014*).

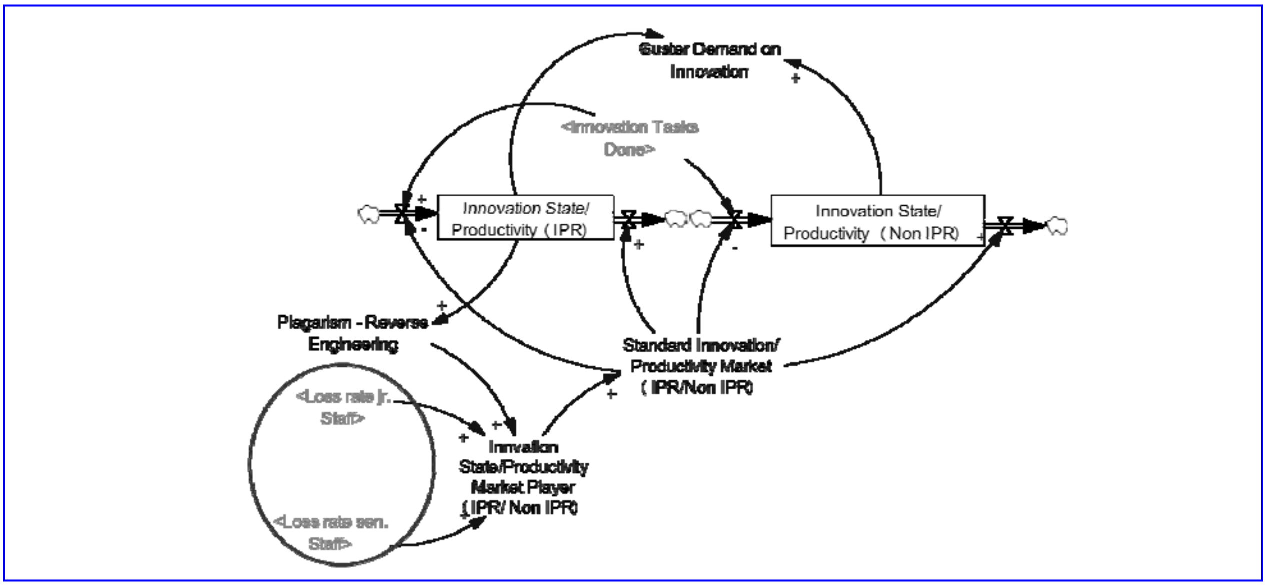

Fig. 7: The Risk of Losing Know How (Sterman, 2000; Dillerup, 1998; VDMA PP, 2014)

An aspect which is not considered in the generic models is the effect of the loss of R&D-capacity. The capital of an enterprise is the knowledge in the employee's head having emerged after long years of work *(Fritsch, 2013 citied by Haerdle, 2013).* Hence the loss is not only affecting the R&D-capacity it is also the loss of knowledge (Fig. 8: B7.3: knowledge outflow by ex-employees). There has been evidence that this is affecting the innovation success of the market player if they are able to acquire this knowledge *(VDMA Produktpiraterie 2014).* To overcome this problem intellectual property rights should keep the competitive advantage in the enterprise. Although 80% of technical Information is available in Patents (*Gassmann, 2006b, VDMA Produktpiraterie, 2014*) this is not a relevant figure for the MPI *(VDMA R&D, 2014).* One the one hand the patent application is quite expense on the other hand the technical solution is getting publicly accessible (*Haerdle, 2013*). This is one cause of product piracy which will finally influence the competitive advantage in defining the technology standards of the industry (Fig. 8: B7 loops). The risk of product piracy is linked to the market success of the enterprise's innovation which will finally influence the demand (see Fig. 7) which will close the loop to the innovation tasks (Fig. 4).

The final CLD of the Innovation-Risk derived from literature and validated with experts is shown in Fig. 8. Due to the fact that risk is measured by losses the cost perspective has to be included. With regard to table 5 the final model structure shows following Loops and Risk Factors:

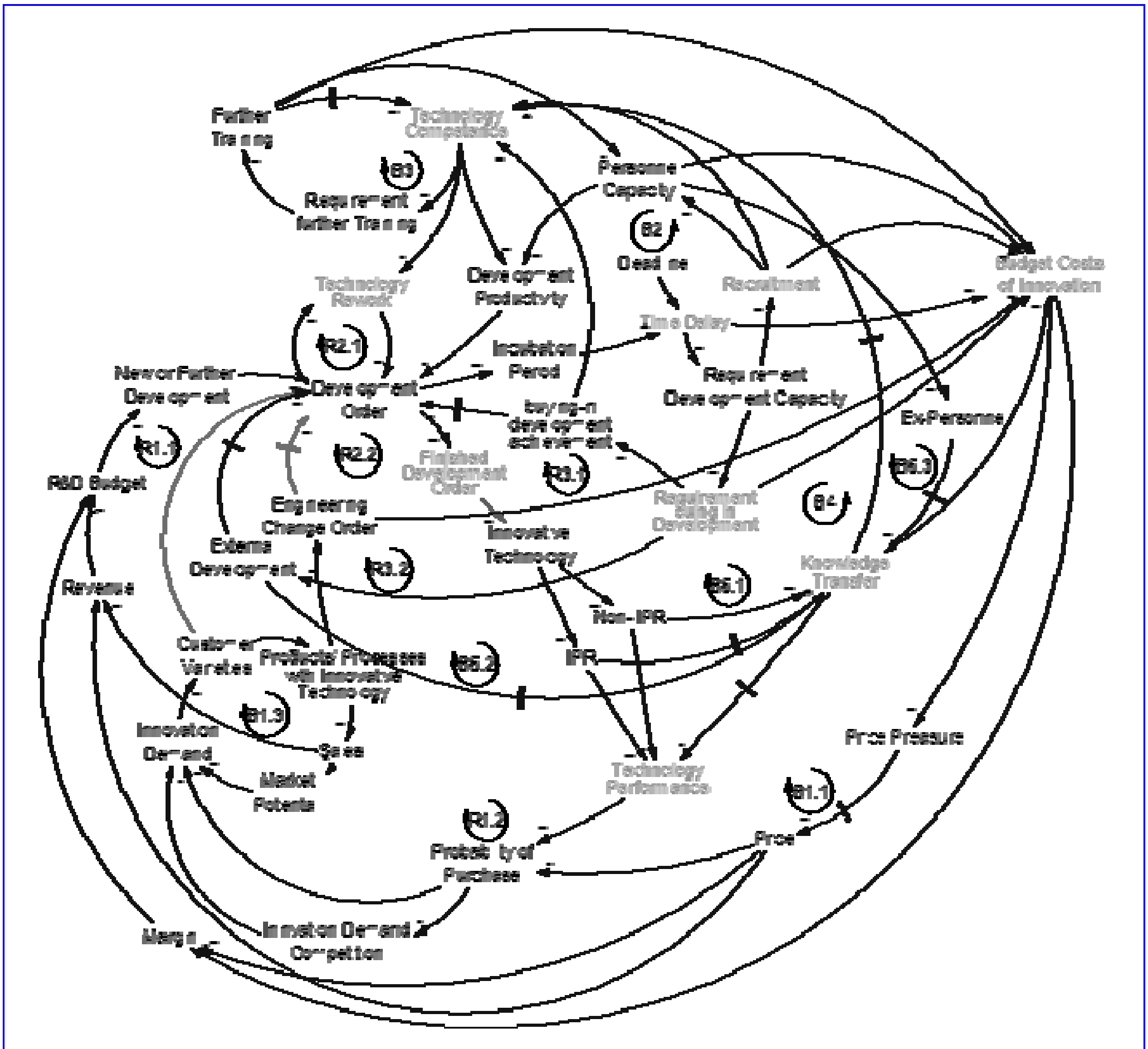

Fig. 8: Holistic Innovation-Risk-Net for the Machinery and Plant Engineering

Next step is the transfer of the CLDs in stock and flow diagrams in order to simulate the Innovation Risk. The challenging task will be to transfer the multidimensional risks (highlighted in red) which will be quantified in the model in terms of time, capacity, performance and quality in a unified measurable variable – extend of losses − in order to make a clear statement about the companies risk bearing ability over time. Therefore the base-run will determine the starting situation while all other runs will show the development of risk positions of choosing different policies.

Innovation Aspect	Feedback loops	Risk Factors
1. Technology Leadership	R1.1 R&D Policies R1.2 Competition B1.3 Market	Technology Performance
2. Competitive Price	B2 Pricing	Innovation Budget
3. Quality	R3.1/2 Internal/External Rework Cycle	Technology Rework
4. Development Time		Time Delay
5.1 Internal Capacity	R5.1 Internal Capacity Expansion	Recruitment
5.2 External Capacity	R5.2 External Acquisition R5.3 External R&D Placing	Requirement buying in Development
6. Technical Qualification	B6.1 Internal Acquisition of Knowledge B6.2 External Acquisition of Knowledge	Technology Competence
7. Knowledge Transfer	B7.1 Knowledge Drain Reverse Engineering B7.2/3 Knowledge Drain External/ Internal	Knowledge Transfer

Tab. 5: Loops and Risk Factors for the Innovation-Risk-Net in the MPI Industry

4. Conclusion

Enterprises of the MPI are acting in an environment which is driven by innovative high risky projects. It is not only the number of the risks which set the degree of the complexity. It is also the kind of the relations linking the in-house risks of the company with their competitive environment. Managing innovation becomes more difficult. These effects are increasingly perceived in the innovation risk management. It is not only the risk of technical feasibility; it is also the efficiency risk, the timing risk, the resource risk, the innovation selection risk and the links between these risks *(Heck, 2003)*. Several innovation risks linked in non-linear and time delayed feedback structures influence the enterprise risk position to a high extend.

This challenge is not reflected enough in the applied risks methods in theory and even more in practice. Limitations are that cause-effect-relations are not considered in an adequate way by the application of existing methods. Although innovation management is closely linked to project management, which also considers time, cost, quality and performance, no existing approach considers innovation risks in these systemic and multidimensional perspectives. Scientists were evaluating the usability of several methods for risk assessment in the context of innovation *(Heck, 2003).* They had chosen the dimensions technical risks, efficiency/ economical risks, timing risks, interdependences risk, selection risks and resource risks. No existing method was able to model all requirements and risk dimensions and therefore they are not fully appropriate for assessing innovation risks.

System Dynamics can be used to explore system behavior and to combine various perspectives on risk. It also incorporates complicated, causal and time referred relations and allows analyzing inferences from the simulation in a multi-dimensional perspective. Risk analysis based on System Dynamics can be a solution for minimizing and objectify the current management of innovation risks.

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