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ENHANCING INNOVATIVE  
ACTIVITIES AND TOOLS FOR THE  
MANUFACTURING INDUSTRY:  
ILLUSTRATIVE AND  
PARTICIPATIVE TRIALS WITHIN  
WORK SYSTEM CASES

UNIVERSITY OF OULU,  
FACULTY OF TECHNOLOGY,  
DEPARTMENT OF INDUSTRIAL ENGINEERING AND MANAGEMENT





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*HANNA-KAISA RAJALA*

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**Rajala, Hanna-Kaisa, Enhancing innovative activities and tools for the manufacturing industry: illustrative and participative trials within work system cases**

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***Abstract***

There has been little improvement over the last few decades in the annual accident rate in workplaces within manufacturing industries. Viable innovative methods in small and medium sized enterprises (SMEs) in the manufacturing industry are needed for developing more effective ways to enhance the understanding of safety. Therefore, enterprises need new illustrative and participative trials to boost their ongoing and incomplete work.

Research into the significance of design science (DS) as a framework for enhancing health and safety issues has provided new views. One reason is most likely the macro-ergonomic comprehensive approach, however, DS is comprehensive and thus the results do not usually correlate with practical occasions. In addition to DS the work system objectives have to be considered and be able to reveal the significance of health and safety issues.

In this study, a work system is utilised for trialling illustrative and participative activities along with the necessary tools for supporting quality and well-being at work. In these cases, DS was used as the main guideline. This study also highlights innovation for introducing something new that can improve performance.

The results of this study showed that the DS approach is applicable when developing a work system in SMEs. The innovative unification of the existing illustrative and participative methods produces new practical views for achieving improved performances. It was also shown that DS presents a new approach for modelling the development of innovations in relation to health and safety issues.

***Keywords:*** accident analysis, design science, innovation, occupational accident, well-being at work



**Rajala, Hanna-Kaisa, Innovatiivisten toimintojen ja työkalujen kehittäminen valmistavaan teollisuuteen: havainnollistavat ja osallistuvat kokeilut työsystemissä**

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***Tiivistelmä***

Työtaturmien vuosittaiset lukumäärät ovat parantuneet vain vähän viime vuosikymmenten aikana. Tarvitaan käyttökelpoisia innovatiivisia menetelmiä valmistavassa teollisuudessa, jotta pystytään kehittämään enemmän tehokkaita keinoja turvallisuuden ymmärtämisen parantamiseksi. Siksi yritykset tarvitsevat uusia havainnollistavia ja osallistuvia kokeiluja tehostaakseen meneillään olevaa ja vaillinaista työtä.

Suunnittelutieteen tutkiminen turvallisuuden ja terveellisyysviitekehityksessä on antanut uusia näkemyksiä. Yksi syy on ehkä makroergonominen kokonaisvaltainen lähestymistapa. Kuitenkin suunnittelutiede on kokonaisvaltaista ja tulokset eivät ole välttämättä käytännön tilanteisiin sovellettavia. Suunnittelutieteen lisäksi työsystemin objektit tuottavat tärkeitä näkemyksiä turvallisuus- ja terveellisyysasioihin.

Tässä tutkimuksessa työsystemiä hyödynnettiin havainnollistavien ja osallistuvien toimintojen ja työkalujen kokeiluun, jossa tuettiin yritysten toiminnan laatua ja työhyvinvointia. Näissä tapauksissa suunnittelutiedettä hyödynnettiin lähestymistapana. Tämä tutkimus korostaa lisäksi innovaatiota, jolla tuotetaan uutta parempaan suoriutumiseen.

Tutkimuksen tulokset osoittivat, että suunnittelutiede on sopiva lähestymistapa pienten ja keskiurten yritysten työsystemin kehittämiseen. Olemassa olevien havainnollistavien ja osallistuvien menetelmien innovatiivinen yhdistäminen tuottaa uusia käyttökelpoisia näkökulmia paremman suoriutumisen saavuttamiseksi. Tutkimuksessa osoitettiin myös, että suunnittelutiede tarjoaa uuden näkökulman turvallisuuden ja terveellisyysinnovaatioiden kehittämisen mallintamiseen.

*Asiasanat:* innovaatio, suunnittelutiede, tapaturma-analyysi, työhyvinvointi, työtaturmat





## **Preface**

This work was carried out in the Department of Industrial Engineering and Management at the University of Oulu.

I wish to express my thanks to my supervisor Prof. Seppo Väyrynen for his advice and encouragement to complete my thesis.

I gratefully acknowledge Dr Kari Kisko for his guidance at the beginning of my journey into the world of ergonomics. I would also like to thank the other co-authors of my publications.

The roots for this dissertation have grown over a 5 year period whilst working at the University of Oulu. Therefore, I would like to thank all the people who have motivated me during that time.

Finally, I warmly thank my family for their steady support during the many years of study and research.

Oulu, November 2011

Hanna-Kaisa Rajala



## List of abbreviations

DSR	Design Science Research
DS	Design Science
ESAW	European Statistics on Accidents at Work
FG	Focus Group
IMS	Integrated Management Systems
NPD	New Product Development
OHS	Occupational Health and Safety
PAR	Participatory Action Research
SHE	Safety, Health and Environment
SME	Small and Medium Sized Enterprises
TQM	Total Quality Management
WS	Work System



## Key definitions

The following definitions are given to clarify the meaning of the main terms used in this study context.

*Design science:* The design-science paradigm has its roots in engineering and the sciences of the artificial (Simon 1996). Design science consists of two basic activities, building and evaluation (March & Smith 1995).

*Ergonomics:* Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions amongst humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimise human well being and overall system performance (International Ergonomics Association 2010).

*Innovation:* Innovation is concerned with the exploitation of new possibilities, through the bringing to the market, or the bringing into practical use, of an idea or concept (Conway & Steward 2009).

*Participation:* The involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals (Wilson 1995).

*Work system:* A work system involves a combination of people and equipment, within a given space and environment, and the interactions between these components within a work organization (International Organisation for Standardisation 2004).



## List of original publications

This thesis is based on the following four publications, which will be referred to in the text by the following Roman numerals.

- I Rajala H-K & Väyrynen S (2010). Constructing “core stories” for contributing practical safety actions in industrial units. *Safety Science* 48(10): 1393–1401.
- II Rajala H-K & Väyrynen S (2011). Participative design science approach on the optimum work system: an argumentative review-based model with a case. *Theoretical Issues in Ergonomics Science* 12(6): 533–543.
- III Rajala H-K & Väyrynen S (2011). Participative Approach to Strategy Communication: A Case of Small- and Medium-Sized Metal Enterprises with a Review after Seven Years. *Human Factors and Ergonomics in Manufacturing & Service Industries*. DOI: 10.1002/hfm.20322.
- IV Rajala H-K, Väyrynen S & Karila T (2011). Argumentative and Economic Approaches for Enhanced Safety Management: A Log Factory Case Study. Manuscript.

In publications I, II and III the field study and data analyses were the author’s contribution and the manuscript was written in collaboration with the co-author. In publication IV the author’s contribution was the modeling work including model construction whilst the manuscript was written in collaboration with the co-authors.





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# 1 Introduction

Traditionally, work conditions need to be controlled (measured and developed) in order to achieve “outer” performance and well-being for employees at work (c.f. Drury 2005). The driving forces behind these comprise of humanitarianism, law and money (Brauer 1994). Well-being at work means safe, healthy, and productive work in a well-led organisation by competent workers and work communities who see their job as meaningful and rewarding, and see work as a factor that supports their life management (Anttonen *et al.* 2008). To achieve this development of work conditions is needed. In this study, development means both the improvement of existing conditions and the application of innovations (Väyrynen & Nevala 2010). Improvement is the action or process of enhancing, making or becoming greater or more complete (Oxford English Dictionary 2010). Innovation is the action of innovating; the introduction of novelties; the alteration of what is established by the introduction of new elements or forms (Oxford English Dictionary 2010).

Today, underperformance in growth productivity in small and medium manufacture enterprises has been cited as having many key factors. Innovative trials are an essential element for long-term growth and better performance with regard to health and safety issues.

## 1.1 Basics of design science research

Since the late 1960s, the theory has been to separate explanatory and design sciences, meaning that practical research within explanatory paradigm has been based on identifying elements in reality. The mission of design science (DS) is to develop knowledge for the design and realisation of elements and innovations, i.e. to solve construction problems, or to be used in the improvement of the performance of existing entities, i.e. to solve improvement problems (van Aken 2004, Järvinen 2004). The design science paradigm is fundamentally a problem solving paradigm with its roots in engineering and the sciences of the artificial (Simon 1996). Natural science tries to understand reality, whereas design science attempts to create things that serve human purposes (March & Smith 1995). The term design science is to be understood as a system of logically related knowledge, which should contain and organise the complete knowledge about and for design (Hubka & Eder 1996). Design science consists of two basic activities, building and evaluation (March & Smith 1995). Järvinen (2004) also

points out that the stage of an artefact may either mean replacing the old artefact with a new one or abandoning the use of the artifact altogether.

There are four types of design science products: constructs, models, methods and implementations (March & Smith 1995). The design science paradigm seeks to extend the boundaries of human and organisational capabilities by creating new and innovative artefacts (Hevner *et al.* 2004). People and their lives are themselves artefacts, and therefore constructed, and the major material in that construction is technology (Dahlbom 1996). In the design science paradigm, knowledge and understanding of the problem domain and its solution are achieved in the building and application of the designed artefacts (Hevner *et al.* 2004).

The purpose of design science research (DSR) is to develop general knowledge to create artefacts that serve human purposes. It is typical for constructive research to build new innovations, and this process is based on existing (research) knowledge and/or new technical or, for example, organisational advancements (Järvinen 2004). DSR produces artefacts which need modelling. Models become necessary when the actual system or a physical simulation are not available, which is usually the case when a new system is being developed and there is a need to explore system parameters whose values are unknown (Meister 1995).

Hevner *et al.* (2004) have published a set of seven guidelines which help evaluate DSR:

1. design as an artefact: design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation
2. problem relevance: the objective of design science is to develop technology-based solutions to important and relevant business problems
3. design evaluation: the utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods
4. research contributions: effective design science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies
5. research rigor: design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact
6. design as a search process: the search for an effective artefact requires utilising available means to reach desired ends while satisfying laws in the problem environment

7. communication of research: design science research must be presented effectively both to technology-oriented as well as management-oriented audiences. The purpose of evaluation is always to assess the effect of 'something' (Järvinen 2004, Sanders & McCormick 1993). Evaluation research seeks to describe the performance and behaviours of people using the new system (Sanders & McCormick 1993).

Many writers in broad areas of management and strategy, as well as those more specifically in the niche areas of innovation and new product development (NPD), use the terms 'invention', 'design', 'innovation' and 'change' very loosely, and often interchangeably (Conway & Steward 2009). Innovation is a successful production, assimilation and exploitation of novelty in the economic and social spheres (Commission of the European Communities 2003). Freeman (1974, quoted by Conway & Steward 2009) defines that industrial innovation includes the technical, design, manufacturing, management and commercial activities involved [bringing to market] of a new (or improved) product or the first commercial use of a new (or improved) process or equipment. Briefly stated, innovation is a matter of improving the earnings of companies by commercial application of new knowledge and ideas, either through introducing new and improved products or through the implementation of new processes, routines and procedures (Danish Enterprise and Construction Authority 2008).

Innovation can be incremental or radical, it can result from technology transfer or through the development of new business concepts, it can be technological, organisational or presentational (Commission of the European Communities 2003). In everyday business language, innovation is defined as "the introduction of something new, in order to bring about major, radical change" (Davenport 1993). Innovation skills are based on human creativity however "creative individuals alone do not make creativity happen. They need access to the right knowledge and information, and access to resources" (Csikszentmihalyi 2001). Achieving an innovation performance represents an enormous opportunity that can translate to work conditions in the manufacturing industry.

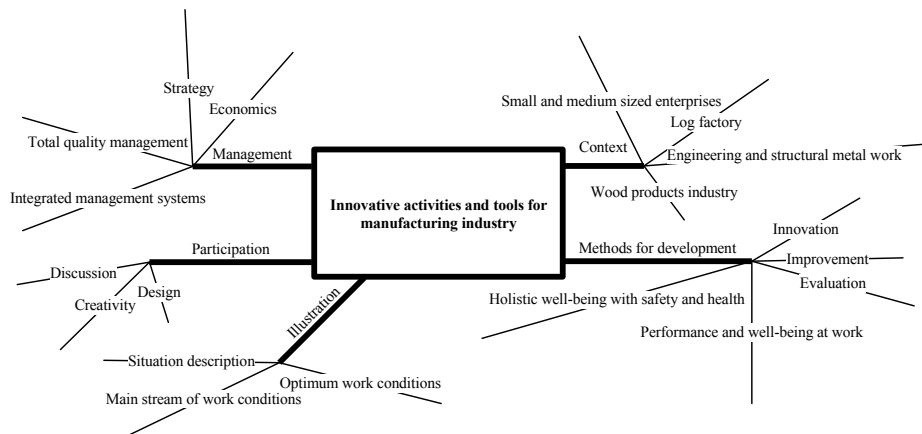
In this study, creativity is understood as being a part of innovation and DSR. Participants can create something new that possesses some kind of enhancing value in a work system. This study is aimed primarily at showing activities and tools that enable participants to develop improvement and innovations continuously.

## 1.2 Research approach and study design

In recent decades, innovative activities and tools is a theme that has entered the mainstream. In practice, innovation is vital to maintain a competitive edge within small and medium sized enterprises (SMEs) in the manufacturing industry. The research approach of this study is focuses upon considering whether design science research is applicable and useful in work conditions development in manufacture enterprises’.

Fig. 1 presents all the key terms used as a framework in this study. The main emphasis of this study is on the methods that can be used in illustrative and participative trials in the manufacturing industry, with an emphasis on the employees and employers of SMEs.

Essential key terms listed in Fig. 1 include innovative activities and tools for the manufacturing industry. Management meets the challenges of financial issues, strategy and quality covering different management systems in the context of health and safety. Taking part in the act or sharing in something produces communication and creativity as well as design. The field context enables trials in the actual use context. Illustration includes narrative description, main stream of work conditions and optimum work conditions. In this study, a variety of terms are used, depending on the method applied for the development of performance and well-being at work.



**Fig. 1. Mind map of the main background factors of the study approach described by key terms.**

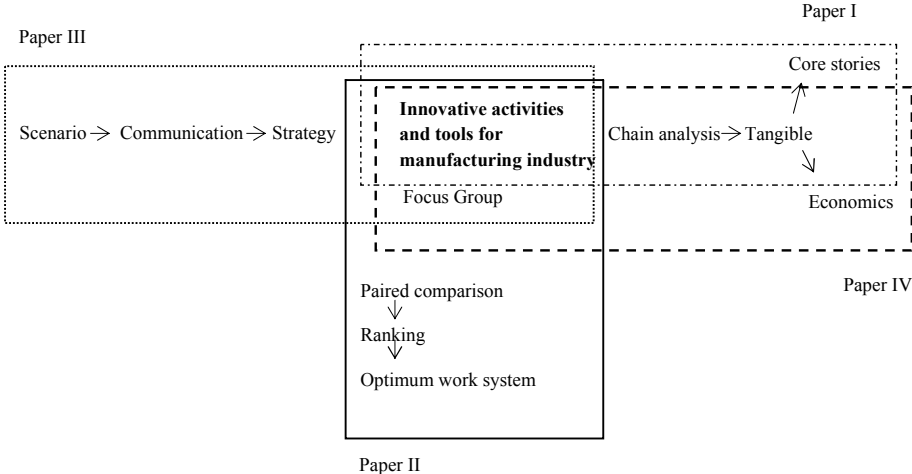
Table 1 shows the methods related to cases and other materials. The methods were trialled in materials to obtain empirical samples in different substances within the context of health and safety. The perspective is retrospective and prospective in building a holistic approach. All the methods are trialled in SMEs as well as engineering and structural metal work. Chain analysis was applied in the wood products industry including a log factory by examining its work including its accidents. A scenario was tested in heterogeneous Focus Groups (FGs) and expert groups. A FG was applied in the wood product industry, in a log factory using the national accident database in heterogeneous FGs and expert groups. Paired comparison contributed in face to face interview as well as ranking. The hits  $x_{21}$ ,  $x_{61}$ ,  $x_{71}$ ,  $x_{102}$  and  $x_{103}$  are used in research work and all other hits are applied in enterprises.

**Table 1. Methods related to cases and other materials in this study. The hits are marked with a cross and indexed by number.**

Methods	Cases and other materials									
	Small and medium sized enterprises (1)	Engineering and structural metal work (2)	Wood products industry (3)	Metal enterprise (4)	Log factory (5)	National accident database (6)	Accident notification form (7)	Interview of personnel (8)	Heterogeneous focus groups (9)	Expert group (10)
Chain analysis (1)	X <sub>11</sub>	X <sub>21</sub>	X <sub>31</sub>		X <sub>51</sub>	X <sub>61</sub>	X <sub>71</sub>			
Scenario (2)	X <sub>12</sub>	X <sub>22</sub>		X <sub>42</sub>					X <sub>92</sub>	X <sub>102</sub>
Focus Group (3)	X <sub>13</sub>	X <sub>23</sub>	X <sub>33</sub>	X <sub>43</sub>	X <sub>53</sub>	X <sub>63</sub>			X <sub>93</sub>	X <sub>103</sub>
Paired comparison (4)	X <sub>14</sub>	X <sub>24</sub>		X <sub>44</sub>				X <sub>64</sub>		
Ranking (5)	X <sub>15</sub>	X <sub>25</sub>		X <sub>45</sub>				X <sub>65</sub>		



The research consists of four separate publications focusing on different issues in the innovative activities and tools with illustrative and participative trials. The approach used throughout the study is to apply activities and tools in small and medium sized manufacturing enterprises to obtain information on their feasibility and to development them. All publications also stress the work system (International Organization for Standardization 2004) contexts. Figure 2 depicts the general framework for this study.



**Fig. 2. General framework for the study.**

This study uses both quantitative and qualitative approaches to constructing the narrative stories of occupational accidents in the context of manufacturing industry (Publication I and Publication IV) with economical aspects (Publication IV). The basis for perspective has been the traditional accident data as well as the work system (Publication III) and prospective scenarios of metal workshops (Publication IV) for strategic work. This study aims to show that from a specific narrow outcome it is possible to build a general holistic outcome with health and safety experiences that impact many things within enterprises such as economics, well being at work and productivity.

**1.3 Scope of the study**

The general aim of the study was to choose, develop and experiment with various methods applicable to the description and facilitation of safety-related decision-

making. Making a situation tangible and increasing participation was an essential part of the study. An essential part of the experimental study was participation in small and medium sized manufacturing enterprises at every level of the organisation. The obtained results, tested innovative activities and tools which can then be used in developing activities in the manufacturing industry. The tools can be applied alone or combined. All publications are studies from small and medium sized metal enterprises except Publication IV which is from the wood production industry. The main target of this research is to examine whether design science is an applicable and useful method in an innovative health and safety context. In practice, the last important aim of this research is to support manufacturing enterprises in their own safety work in an innovative way.

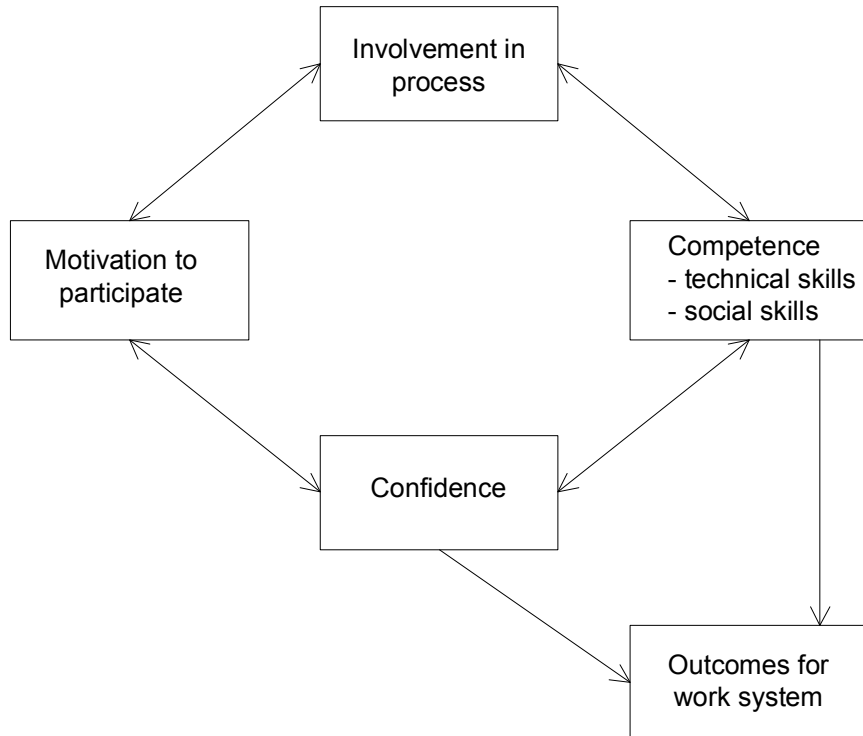
The purpose of deconstructing the work system is to identify better tools to do the work that has been undertaken up to this point in health and safety work. Considering the annual number of work accidents, which has remained at the same level for the last ten years (Tapaturmavakuutuslaitosten liitto 2011), this study will argue that health and safety work has now largely served its purpose, and that we need to move on, to establish better economical innovative tools. These tools include aspects of participation, illustration, statistical data, narration, and various forms of intellectual capital.

## 2 Key literature-based and chosen foundation

### 2.1 Concepts of work system, participation and descriptive methods

Work system (WS) has been used widely in many areas however this study tries to understand with more clarity its use when human participants perform work using resources to produce products for customers. A work system involves a combination of people and equipment, within a given space and environment, and the interactions between these components within a work organisation (International Organisation for Standardization 2004). Orlikowski (1992) states that the duality of technology allows us to see technology as enacted by human agency and as institutionalised in structure. The intention is to improve, (re)design or change work systems (International Organisation for Standardization 2004). An even broader definition based on macro-ergonomics and sustainability formulated by Doherty *et al.* (2009, quoted by Zink 2011) says “it is not surprising that again the concurrent development of economic, ecological, human, and social resources engaged in work processes is the main goal. Therefore sustainable work systems have to be able to function in their environment and to achieve economic or operational goals, while there is also a development in various human and social resources engaged in their operations.”

Participative design is a good approach with which to optimise WS (Fig. 3). The design of a work system emphasises the design of the whole system, including the work organisation, work task, work, working environment, tools and workspace (International Organisation for Standardization 2004). The comprehensive design is essential when ergonomic principles are implied (Bridger 2009). The outcomes are results of technical and social skills with confidence. The participatory ergonomics cycle needs besides motivation to participate and involvement in process. Participatory ergonomics is not a unitary concept, and participatory ergonomics initiatives can take a wide variety of forms, from a single re-design exercise to development of a full culture of employee development (Wilson & Haines 2000).



**Fig. 3. The participatory ergonomics cycle (modified from Wilson & Haines 2000).**

Many studies have indicated the importance of informal boundary-spanning exchange and communication to the innovation process, and particularly in relation to the transfer of tacit knowledge (Conway & Steward 2009). In this context a deeper understanding is urgently required of the relevance to experiential learning, including the emerging concept of tacit knowledge.

Tacit knowledge may be defined as ‘heuristic, subjective, and internalized knowledge’, which needs to be learnt through practical examples, experience, and practice (Conway & Steward 2009). Polanyi (1983) first came up with this distinction, based on the idea that “we can know more that we can tell”. When we speak or write, we use language to articulate some of our tacit knowledge in an attempt to pass it on to others. In spoken words, tacit knowledge takes the form of metaphors, models, concepts, and equations which express in a reduced and somewhat distorted form from the tacit knowledge of an individual (Sveiby 1997). Nonaka and Konno (1999) developed tacit knowledge further, in particular in the socialisation, externalisation, combination and internalisation (SECI) model,

which outlines different Ba (interactive spaces) in which tacit knowledge can be made more explicit.

Wilson (1995) defined participation in an ergonomics context as ‘the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals’. In participatory action research (PAR), some of the people in the organisation or community under study actively participate with the professional researcher throughout the research process from the initial design to the final presentation of results and discussion of their action implications (Whyte *et al.* 1991). There is a strong argument for a participative approach to ergonomics: both participation at an individual level – whereby workers are involved in workplace and work assessment and in providing solutions to any health and safety problems; and also participation at an organisational level – whereby engineering, production, medical and other staff develop their own programmes for ergonomics awareness and action (Wilson *et al.* 2005).

Amongst the advantages of participation are improved motivation and skills, personal development, better quality solutions, ‘a value itself’ and legitimisation of worker experience (Eklund 1997). Benefits are both for management (effective and accepted solutions and better motivation amongst employees) and for workers (their experience used, better working conditions and more satisfaction) (Jensen 1997). The relationship between participative processes and the development and gains from working in groups or teams is of great interest (Wilson *et al.* 2005). Another concern about the use of participation is the quality of outcomes from a process which is based upon group decision making (Wilson *et al.* 2005).

Design requires synthesis and creativity – integration of human and technology capabilities to create coherent and workable designs (McClelland & Suri 2005). Descriptive methods help to construct a common understanding. The value of description is its effect upon the extent to which organisations can both increase their shared knowledge at all levels of the organisation, as well as reducing the risk of misunderstanding and issues dealing with the inadmissibility.

## **2.2 Outcomes**

Properly applied, ergonomics optimises the performance and effectiveness of the work system, including the workers without detriment to their health, well-being and safety (International Organisation for Standardization 2004). These categories

along with performance include different retrospective parameters by which a work system should evaluate. In Finland, occupational health and safety (OHS) is understood to cover not only health and safety at work but also terms of employment, mental wellbeing, the functioning of management and the organisation, productivity, and codetermination (Ministry of Social Affairs and Health 2010).

Intangible resources refer to those assets that are, for the most part, 'invisible', such as brand and reputation, know-how, and the social networks of employees (Conway & Steward 2009). 'Human' capital may be defined as 'the knowledge, skills, and abilities residing with and utilised by[the] individual'; 'organisational' capital as 'the institutionalised knowledge and codified experience residing within and utilised through databases, patents, manuals, structures, systems, and processes' (Conway & Steward 2009). Intellectual capital consists of human and structural capital where human capital consists of the quality of human resources and their cooperation (Edvinsson & Malone 1997).

Meaningful work, in which the physical and mental health as well as the social health and safety of the individual are safeguarded, is of crucial importance to the quality of life and wellbeing (Ministry of Social Affairs and Health 2010). In general, it is difficult to conceive of measuring one of performance or wellbeing without measuring (or at least controlling) the other; at times this control is implicit (Drury 2005).

An occupational accident is an untoward transaction in work. An occupational accident is defined as an accident that occurs to an employee at work or in work-related circumstances, causing an injury or illness (Statistics Finland 2004). The Health and Safety Executive defines an accident as any unplanned event that results in injury or ill health of people, or damage or loss to property, plant, materials, to the environment or a loss of a business opportunity (Hughes & Ferrett 2004). Research on occupational accidents has exposed the negative impact these hazards have on their victims, families and co-workers (e.g., Dembe 2004). Apart from the employer and injured worker, accidents involve several other bodies such as medical institutions, police and judicial departments, private insurance companies and other authorities (Shalini 2009).

These discrepancies in the definition and interpretation of what is an occupational accident may obstruct an effective communication between employees, employers and governmental organisations. The definition used by institutional entities may not be shared by organisations, and organisations may have an official definition that is very different from what its employees think an

occupational accident is (Niza *et al.* 2008). Within the EU occupational accidents are divided into fatal accidents and accidents causing at least four days of absence from work. A common feature is that all countries have official notification forms for the reporting of accidents at work; this is not surprising since it is compulsory in the 15 member states. (Jacinto *et al.* 2004) On the other hand, it is likely that insufficient attention has been paid to minor non-fatal accidents in the higher lethality countries (Nishikitani & Yano 2008).

Performance should include quality and quantity. Better use and understanding of the work system helps to improve capacity and quality and is therefore essential for business. Understanding the use of tools and technology in their own working context is essential to designers so that they can design technology and an environment that supports the users and their work (e.g. Väyrynen *et al.* 2006). For example, an important development area for an SME in the metal industry is the ability to design their own products and evolve as a system supplier or component supplier (Iskanius 2006). Karasek and Theorell (1990) emphasise that increased employee awareness of the interplay between psychosocial work environment and health may start processes with a broad range of constructive and humane impacts on that environment. As pointed out by Hutchison (1997), the voices of the business, the customer and the employees are the three major components of total quality management (TQM), the so-called quality diamond.





### 3 Objectives of the study

The overall objectives of the study were to choose and experiment with some illustrative and participative methods applicable to innovative activities related to the well-being and productivity at work in manufacturing enterprises. The main focus was the work system and especially its health and safety matters. The study results were aimed at proven guidelines for developing activities at workplaces. The contribution between design science and work system is presented in the Table 2.

**Table 2. General view on overall objectives in the field of DS and WS.**

DS design goals	WS	Existing work system	Enhanced work system
What		Illustration Participation	Scenarios
Why		Needs for development	Achievement of improvements and innovations
Evaluate		Indicators Outcomes (e.g. accidents, costs)	Criteria of optimal system (employee, equipment, task, work environment, organisation)

The specific objectives of this study were:

1. to trial enhancing innovative activities and methods already described in the literature for description and creativity purposes,
2. to investigate if the methods have enough potential to yield more resources to development work in SMEs within a work system,
3. to obtain some proven examples of methodological approach, e.g.,
  - a) core stories of work accidents in addition to traditional quantitative data,
  - b) tangible prospective description of a future enterprise or optimum work system and strategic and
  - c) participation to support communication, creativity and innovation
4. to determine results in management context enhancing performance and well-being at work.

The procedures were suitable to different contexts of description and creativity. The original publications and the methods used in each specific objective have already been presented in Fig. 2.

## **4 Methods**

The studies employed various methods typical to various phases of design science research. The used methods were twofold (see Table 1, Fig. 1). The information collected by these methods could predominantly be utilised both in research and in the develop of enterprises. The research methods explored involved materials that were collected through national sources or enterprises creating information that was beneficial for development. Development methods were applied in manufacturing enterprises with the aid of researchers, participating employees and employers.

### **4.1 Selecting the methods and research process**

The methods used in the studies were a result of the author's and her team's own choices and piloting experiments. The basis for choosing these methods was the effectiveness of the chosen methods when tested and that they have been reported of in earlier studies. One main argument was to choose time-efficiency methods because the enterprises were small and medium sized with limited resources. To fulfil the criteria of being selected to join the study SMEs had to be manufacturing, as well as being small or medium in size. The participants from SMEs were named by enterprises with given definitions, e.g. number and position in the organisation. The methods were described briefly in the literature review, but have been presented in more detail in the original publications. This chapter focuses on the use of the methods in a study context enabling design science research for supporting manufacturing innovative activities and tools. The main emphasis of this study is on the methods that can be used either in combination or alone for the description and evaluation of a work system in both tangible and innovative aspects in enterprises.

Firstly, the data of work accidents in engineering and structural metal work was charted using chain analysis from accident notification forms of insurance companies (Publication I). Second, the model of an optimum work system was complemented in small and medium sized metal enterprises with the aid of paired comparison and ranking (Publication II). Thirdly, the information of future enterprise was gathered in small and medium sized metal enterprises using focus group and scenarios (Publication III). Fourth, the data of work accidents was charted by applying chain analysis from the national accident database system and the results were processed using a focus group (Publication IV).

Overall the studies employ an empirical illustrative and participative approach with practical field studies in small and medium sized manufacturing enterprises. The following sections examine the approaches in context of methods.

## **4.2 Methods for research and development within design science framework**

### **4.2.1 Chain analysis (I, IV)**

Chain analysis was developed by Klen and Väyrynen (1984) for presenting and analysing accident data. This analysis method is used in many accident studies (see Väyrynen 1986, Väyrynen *et al.* 1994, Niskanen & Lauttalammi 1989, Pekkarinen & Anttonen 1991, Klen & Väyrynen 1983). The chain of events of each individual accident can be followed through variables of the nominal scale codes, and finally “the sum” of all the separate case descriptions is collected in one illustration.

Chain analyses variables were the variables of the ESAW (European Statistics on Accidents at Work) methodology. The ESAW method is based on several accident theories, thus forming a model of the nature of an accident phenomenon. The deviation is a highlight of events in many theories, which also applies to the ESAW method. The primary framework is mostly based on the causal sequence theory, as the sequence of actions is clearly implied in the model. This “domino theory” includes the occurrence of an injury that invariably results from a complete sequence of factors – the last one in the sequence being the accident itself (e.g. Heinrich *et al.* 1980). The multi-linear events sequencing approach arranges the events on a timeline (Ferry 1981).

Chain analysis was used to help analyse work accidents (Publication I and Publication IV) for processing and presentation of case results. The data of work accidents was collected from accident reports and the national accident database.

### **4.2.2 Scenario (III)**

According to Nardi (1992), a scenario is a description of a set of users, a work context and a set of tasks that users perform or have a desire to perform. A scenario can say what happens in a particular situation without committing the details of precisely how things happen (Rosson & Carroll 2002). Scenarios have

often been used in ergonomics in the development of products or services (Suri & Marsh 2000, Moggridge 1993). Erickson (1995) differentiates between scenarios and stories; stories are concrete accounts of particular people and events, particularly situations, while scenarios are often more abstract – they are scripts of events that may leave out details of history, motivation and personality.

In narrative scenario-based discussion (Publication III), the participants discussed and evaluated three narrative optimal future workshop scenarios of year 2010 and described one by their own words.

#### **4.2.3 Focus Group (III, IV)**

In a Focus Group a group of people are asked interactively about their attitudes and feelings towards a cognisable matter (Morgan 1998). FGs are typically composed of five to ten people, but size can range from as few as four to as many as twelve (Krueger & Casey 2000). A moderator guides the group through a discussion asking specific questions and allowing the group to discuss arbitrarily (Morgan & Scannell 1998). The prototypical role for the moderator is to manage the implementation of the research process, including preparation, implementation, and analysis (Greenbaum 1993).

The main advantage offered by a FG is the opportunity to observe large amounts of interaction on a topic in a limited period of time (Morgan 1990). The benefits of a FG are direct access to participants and group dynamics, which can produce unique comments (Langford & McDonagh 2003). The technique is suited for exploratory purposes, as questions with an open-ended nature can be examined (Bruseberg & McDonagh-Philp 2002). The main practical disadvantage is that, frequently, one or two members are particularly dominant. This may mean that the opinions that are apparently those of the group as a whole may, in fact, simply reflect the opinions of this individual or individuals (Jordan 2001).

Altogether, three groups from the engineering and structural metal work were involved in the FG session which was operated by a moderator with aid of a narrative guideline (Publication III). Afterwards, the participants (n = 13) rated the scenarios. In the FG, the participants discussed the wood products industry with reference to what kind of accident scenarios could occur or have occurred at a workplace and how they can be prevented in the future (Publication IV). Researcher made notes of FGs.

#### **4.2.4 Paired comparison (II)**

There are many procedures for determining the assessing criteria (see Kirvesoja 2001, Roozenburg & Eekels 1995, Väyrynen *et al.* 1999/2000). Roozenberg and Eekels (1995) point out that the problem lies in the weighing of the good and less good properties. The use-value analysis (Pahl *et al.* 2007) systematises the evaluated alternatives by means of a hierarchical objectives tree. Weighings are based on factors ranging from 0 to 1. According to Cross (1994), by using this procedure it is easier to assign weights with some consistency, because it is relatively easy to compare sub-objectives in small groups of two or three and with respect to a single higher-level objective. The weakest attributes are identified by lower values compared to the middle level (Pahl & Beitz 1990).

In the optimum human work study (publication II) Mitchell's paired comparison method was used to weigh nine working criteria. In the weighing process, altogether 36 pairs of criteria were compared. The weighing was conducted by 50 persons  $N_{\text{employer}} = 10$ ,  $N_{\text{white-collar employee}} = 10$ ,  $N_{\text{blue-collar employee}} = 30$  from 13 different SMEs in the steel product industry. The comparison was determined using the importance of each objective to each person. Subjects were given nine objectives each and asked to indicate which of the two they considered more important in assessing decisions.

#### **4.2.5 Ranking (III)**

The rank order correlation method relies on making a comparison between two variables based upon their relative ranked positions (Cacha 1997). The target of statistical analysis is to induce if a summary of some sample is divergent of the mean as much that the sample is assumed to be better or worse than others (Lokki 1980).

Ranking was applied to find the best and probable future workshop amongst three written narrative scenarios (Publication III). The ranking was performed individually by each participant in groups ( $n = 3$ ). The participants were allowed to become familiar with all scenarios in the FG session before making their judgment.

## 5 Results

As shown in Table 1, 22 cases and 27 other material types were applied to the field context in which research methods yielded background and support material. In this chapter, the contributions of research results and used methods are presented with the aid of numbering used in Table 1.

### 5.1 Making well-being and performance situation tangible (I, IV)

In the occurrences of metal manufacturing industry accidents ( $N = 345$ ), the chain analysis may be specified by three variables: specific physical activity, deviation, and contact – mode of injury ( $x_{21}$ ,  $x_{71}$ ). Applying chain analysis and ESAW variables to the accident data helps to discover the mutual relationships of the variables. Chain analysis enabled the extraction of separate case descriptions to the extent that the two most frequent chains of events cover around 14% and 10% of all detected accident chains of events. The most frequent accident chain of events ( $n = 47$ ) consisted of the following variables: working with handheld tools; loss of control of a handheld tool; contact with a pointed material agent. The second most frequent accident chain of events ( $n = 36$ ) consisted of the following variables: carrying by hand; body movement, physical stress; physical or mental stress. The third most frequent accident chain of events ( $n = 20$ ) consisted of the following variables: movement; body movement not physical; contact with agent. These findings of accident mainstreams were utilised to formulate draft core stories.

The above results were further processed to construct narratives of mainstream accidents. The following three drafts were constructed for generic core stories:

1. Based on the data of 47 accidents: A person was working with a handheld tool. He/she lost control of the tool. Injurious contact occurred when the person's body made contact with a sharp or otherwise hazardous material agent.
2. Based on the data of 36 accidents: A person was carrying something in his/her hands. During the activity, an uncontrolled body movement causing extraordinary physical stress occurred which led to an internal injury.
3. Based on the data of 20 accidents: A person was performing work tasks that included body movement. The tasks did not include extraordinary physical

stress connected with overload but still led to an injurious contact with a sharp or otherwise hazardous material agent.

The findings of applying chain analysis to working accidents ( $n = 18\ 195$ ) in the wood products industry show that the most frequent accident chain of events ( $n = 167$ ) in accidents which resulted in 7–14 days absence from work consisted of the following variables: carrying by hand; physical stress; back; dislocations, sprains and strains ( $x_{11}$ ,  $x_{31}$ ,  $x_{61}$ ). The second most frequent accident chain of events ( $n=148$ ) consisted of the following variables: handling of objects; body movement, no physical stress; fingers; wounds and superficial injuries. The most frequent chain of events ( $n = 44$ ) in accidents causing over 30 days absence from work (fatal not included) consisted of the following variables: movement; slipping, stumbling and falling; lower extremities (not including ankle); dislocations, sprains and strains. The main advantage of this assessment approach is the chain of events which makes the accident narrative.

The identification of these accident mainstreams were utilised to formulate draft core stories. The above results were further processed to construct narratives of mainstream accidents. The following two drafts were constructed for generic core stories:

1. Based on the gathered data of 167 accidents: A person was carrying an object in his/her hands when during the activity, an uncontrolled body movement occurred causing physical stress to his/her back.
2. Based on the collected data of 148 accidents: A person was holding an object when he/she stepped on or was wounded by a sharp object as he/she passed by. As a result the person had a superficial wound or injury to his/her fingers.

These core stories were used as stimuli for Focus Groups of a specific workplace ( $x_{51}$ ). Based on the stories, people in focus groups can generate their own cases that are based on the employees, workplace, tasks, tools, and other real contextual factors of their workplace. These cases then provide a starting point for the discussion about what kind of accident scenarios could occur or have occurred at their workplace and how they could be prevented in the future.

## **5.2 Prospective view (III)**

Narrative scenarios (I-III) were applied to identify the features of future workshops in engineering and structural metal work ( $x_{12}$ ,  $x_{22}$ ,  $x_{42}$ ). The



participants in heterogeneous reflection groups ( $n = 3$ ) from metal enterprises ( $x_{92}$ ) as well as the expert group (review group) ( $x_{102}$ ) discussed a number of scenarios which yielded a new scenario for a future workshop as a result. Altogether using the same material, a period of seven years separated the review group and the reflection groups.

Remarkably, each reflection group thought that cellular production may limit the know-how of the employees, but in the review group the limits of processual manufacturing were highlighted in scenario I. The review group stated that most workshops are nowadays similar to scenario I although this was based on events from seven years earlier. Metal enterprises as described in scenario I are seen as unlikely and aged by the reflection group seven years before. A computer-aided real-time reporting system was seen as a key factor for success in the reflection groups, as well as in the review group; although this group thought that these systems do not serve manufacturing enough in scenario II. All the reflection groups agreed that a lack of social events is not good while the outsourcing of cleaning services was seen as positive in all the reflection groups and in the review group. Mobile equipment described in scenario III was met with some reservations and resistance in all the reflection groups, yet after seven years it was thought that employees commonly use mobile equipment.

Scenario IV is a narrative which was produced by the reflection groups 1–3 in 2003. Scenario IV is a combination of all the groups, highlighting the most common outcomes. In scenario IV the amount of operational employees has been reduced in a metal enterprise. The managers' role has increasingly been focused on the design stage nevertheless planning has become more important. Employees receive their tasks from those in supervisory positions and execution is dependent on their own design. Employees are highly professional and versatile. The entire personnel will participate in the workshop development. Much attention has been given to the well-being of the employees. Human contact is emphasised in human asset management with entrepreneurs responsible for the welfare of the employees as a whole. Technology is highly advanced with the use of an IT system for production control and planning. Robots handle part of the work and production is largely processual. Production points may be far apart, because the IT system will provide links to other shops. There is good ventilation and adequate lighting. Workstations are clean and in order.

### **5.3 Communication groups (III, IV)**

FG was a chosen method in scenario-based discussion in engineering and structural metal work in heterogeneous groups ( $x_{13}$ ,  $x_{23}$ ,  $x_{43}$ ,  $x_{93}$ ) and expert group ( $x_{103}$ ). FG yielded material that can be used to assess scenarios and to compile new prospective scenarios for future workshops (see chapter 5.2 scenario IV).

The two core stories, compiled with the aid of chain analysis, was used as stimuli for the FG of a workplace in a log factory ( $x_{33}$ ,  $x_{53}$ ,  $x_{63}$ ). These cases provided a starting point for the discussion of the possible kinds of accident scenarios that could occur or have occurred at a workplace and how they could be prevented in the future. Core stories help to solve problems and develop a safer place to work. In the FG the participants created two core stories from their own accident chains. These stories included their own working environment, tools, machines, products etc. The empirical study showed that constituting core stories with a workplace's "own language" makes numerical data more user-friendly and illustrative.

One of the core stories was based on the most common chain of events for less than four days absence from work. At the log factory there was a machine which was quite noisy when switched on. One day the machine was fixed and when an employee started to clean it up a blade grazed his/her knuckles. He/she thought the machine was off because there was no noise. In this case, maintenance is good as long as you also inform the employees of any chances or improvements to equipment or machinery.

### **5.4 Weighing factors for prioritising and trade-offs (II)**

Mitchell's paired comparison method was used to derive criterion weights for nine different criteria of optimum human work in engineering and structural metal work ( $x_{14}$ ,  $x_{24}$ ,  $x_{44}$ ). Mitchell's paired comparison method provides an opportunity to evaluate how people rank and rate criteria and to compile an overview by using these rating results. The participant compares one pair at a time and chooses the criteria he/she prefers ( $x_{84}$ ). In this case the number of pair was 36 so the comparison of pairs did not take too much time.

A case showed that human work comprised mainly of organisational issues (45%) followed by cognitive (41%) and physical (15%) ones. Within each category, the most important sub-issues were data management (18%), own skills (17%) and working postures (9%). There were no significant differences between

groups of entrepreneurs or white-collar employees. Instead, significantly the blue-collar employees were statistically unanimous, as they showed, on average, more clearly to favour physical issues.

### **5.5 Evaluating argumentation evidence (III)**

The ranking of various types' scenarios I-III was easy for the participants ( $n = 13$ ) in heterogeneous groups from engineering and structural metal work ( $x_{15}, x_{25}, x_{45}$ ). The scenarios were to be placed in rank order which was easy for the participants ( $x_{85}$ ).

There was a good consensus between the rankings by the participants concerning the choice of best and probable scenario. The results showed that scenarios I and II are not statistically divergent from the mean, the best ones being classed as equally "good", however scenario III is significant in that statistically  $P < 0.01$  (i.e. the worst one).



## **6 Discussion**

### **6.1 Theoretical and practical issues**

Innovative trials and activities have received little attention in the context of safety, health and well-being even though many management systems support all of these elements. Generally it is also assumed that it is desirable to boost innovative work in SMEs to improve economic performance. SMEs are encouraged and motivated to innovate by pressures and challenges, notably to customer requirements, competition and the desire to create new products and services. Innovation encompasses more than just the successful application of research results. Innovation is a challenge for design science. This challenge has now been met by combining the “basic” design science research with the strong role of the work system approach and participation. The findings of the research provide evidence that used methods are suited well within a work system in manufacturing SMEs. All methods yielded more information than traditional resource methods for supporting health and safety work in enterprises where resources are considerably limited by financial and skill factors. Most of the methods allowed results to be tangible which makes them more understandable and also aids employee’s participation at all levels of the organisation.

Different authors have somewhat varying views of the basic principles and foundations of TQM, but customer focus, process orientation, employee participation and continuous improvements are generally regarded as the most central (Eklund 1997). Companies manage and report their regulatory and social performance along a number of critical dimensions: environment, health and safety, employment practices and community investment (Kaplan & Norton 2004). According to Hutchison (1997), the vision of management and the voice of the customer are linked to the company’s capabilities, which include personnel, facilities, its safety component, equipment and financial resources. Integrated Management Systems (IMS) is now seen as part of the organisation’s management portfolio (Wilkinson & Dale 2007). IMS meets the challenges of safety and quality supporting standards covering specific requirements. According to Kjellén (2000) many large companies, including those in Scandinavia, have developed safety, health and environment (SHE) policies, on the argument that these aspects are of equal importance to the economy. The traditional safety management programs do not always improve the level of safety because they are

exclusively centred on the technical requirements and obtaining short-term results (Weinstein 1996).

Kaplan and Norton (2004) were the first to produce popularised strategy maps in the strategy area. Strategy mapping helps in describing the strategy amongst executives and employees (Kaplan & Norton 2004). The strategic planning category examines how the company sets strategic directions and how it determines key action plans (Hutchison 1997). Leadership can be defined as a process that outlines the future of an organisation, aligns people with a vision, and inspires and motivates progression despite obstacles (Kotter 1996). Strategic decisions are those determining the overall direction of an enterprise and its ultimate viability in light of predictable, the unpredictable, and the unknowable changes that may occur in its most important surrounding environments (Mintzberg *et al.* 2003).

People widely use mental models for planning and decision-making and thus it is likely they have formed or are forming a mental model of the system. This mental model (or conceptual model) may be accurate or inaccurate, usable or worthless, but nonetheless the notion of mental models is attractive and useful for ergonomics (Wilson & Rajan 1995). The storytelling approach helps to make a strategy concrete and build support for the implementation efforts. Collective memory is created out of orality (speeches, conversation, and chatter), textuality (files, reports, web pages, and accounting), and visuality (photos, décor, architecture, and gestures) (Boje 2008). Participative methods illustrate a strategy and are an efficient vehicle for involving participants. In this study participative methods used in enterprises produced shared experiences as well as mental models for planning and decision-making bringing participants together towards a shared understanding.

“The story to tell and to whom” should be the major goal for collecting information about accidents and for the type of analyses to be done on the basis of this information (Jørgensen 2008). Chain analysis method was chosen because it is at its best when analysing chronological and “causal” chains that also form the basis for narrative illustration. In this study, the chronological sequence was of special importance, which makes this analysis technique particularly well suited for presenting data. Chain analysis enabled the revealing of mainstream events within accidents by providing the backbones of illustrative core stories. In this study, the use of chain analysis will be explored in respect of storytelling to produce a thorough picture of the most frequent events connected with the occurrence of an occupational accident.

Although forecast errors are usually large, multivariate models produce somewhat better forecasts than univariate models, implying that the correlations found amongst variables have some relevance when forecasting the time series involved (Carnero & Pedregal 2010). An accurate prediction of occupational accidents is a difficult and complicated endeavour. If accidents could be reliably foreseen, they could all be prevented (Attwood *et al.* 2006). The tool is useful for identifying prevention and protection mechanisms and giving statistical information on failures at a level of detail never seen before (Bellamy *et al.* 2008). From having focused on one disease, one factor or one individual, prevention has come to refer to more complex disorders, multifactorial relationships, many or all persons in society, and the environment as a whole (Andersson & Menckel 1995). Clients are also responsible for the safety of personnel employed by subcontractors when they are working in their facilities at shared industrial work sites, which also contains safety training (Väyrynen *et al.* 2008).

Regional clusters are geographical concentrations of interconnected companies and associated institutions, including end producers, universities, research laboratories, service providers, and a highly specialised pool of labour, often focused around a specific area of economic activity (Conway & Steward 2009). The degree of concentration of firms along the supply chain of a particular sector is likely to have an impact on the concentration of economic benefit and therefore the locus of innovation (Conway & Steward 2009). There is clear indication of the importance of regional systems of innovation. Close relationships may emerge between suppliers and producers in an innovation process where there is technological uncertainty, and where the producer has limited internal expertise or where knowledge is ‘sticky’ (Conway & Steward 2009). Knowledge-intensive business service may be of crucial importance for the support of innovating SMEs’ and constitute a “relevant subject” for both innovation and regional policies (Muller & Zenker 2001 quoted by Conway & Steward 2009). The means to take the innovation imperative into account in an enterprises’ strategic work in regional clusters in addition to their concern is important. The findings show that informality participation establishes a better understanding of the interfaces of management and employees.

Any one method may not be adequate for evaluating the effectiveness of activities within a work system. The problem of assessment is difficult when combination and interactions are very different. An example of an evaluation is the European excellence model EFQM (European Foundation for Quality Management) where there are five ‘enablers’ and four ‘results’ (EFQM 2009).

In the long term, the meaning of usability continues to increase. The work system in this respect includes usability whilst the capacity of an optimal work system could easily be added.

## **6.2 Managerial issues**

This research emphasises that design science is retrospective and prospective with respect to the work system. It focuses on creating and evaluating elements that enables an illustrative and participative trial in small and medium sized manufacturing enterprises. The findings indicated that it is possible to further process health and safety data to yield more information of the same material in workplaces. For example accident statistics combined with narrative methods produce illustrative and very versatile material for many purposes.

Communication in enterprises brings participants closer to concepts and solutions. Proactive and timely communications support open and interactive preparation and enables fruitful cooperation (Ministry of Social Affairs and Health 2011). Participative design and participation are values which, as such, increase well-being and productivity (Vink *et al.* 2006, Langford *et al.* 2003, Kogi 2006, Väyrynen *et al.* 2006, Skoglund-Öhman & Shahnava 2004). Giving participants the chance to get to know each other as fully rounded individuals is more likely to create the climate of mutual respect that is necessary for airing controversy (Morgan 1998).

There have been a number of organisations who have found that involving participants further down the organisation in discussing specific programmes they have been able to gain greater commitment and use valuable expertise (Eden & Ackermann 1998). Involving an employee in the design of an organisation's own work system means that the employee is involved in a meaningful manner. Specifically, the practice goes beyond concern for design's functional sustainability and usability – its physical and cognitive 'fit' – to include consideration of emotional, social and cultural dimensions (McClelland & Suri 2005).

## **6.3 Relevance to industry and society**

The procedures developed in this study support all the aims of ergonomics in workplaces. They highlight the importance of safety and participation, which promote well-being at work, leading to an increase in the quality of the work.



Health and safety are of crucial importance for the attractiveness of employment in the metal, engineering and technology-based industries (CEEMET 2010, Sipilä 2010). Focusing on well-being will extend careers, people will find more meaningful work and see their work as having meaning (Sipilä 2010). The happier people feel in the workplace and the healthier they are, the longer their working careers will be and the more productive they will become in the long run (Ministry of Social Affairs and Health 2011).

Attention has been given to work accidents in part due to the costs involved but in recent years the number of occupational accidents in companies and their cluster has also been followed up. According to new estimates, more than 2.3 million people die every year because of fatal occupational accidents or work-related diseases. This means that every day approximately 7,000 people die as a result of an occupational incident. Furthermore, over 960,000 workers a day are injured at work. (Hämäläinen *et al.* 2009). The results suggested that an occupational accident experience can influence a workers' sense-making about the subject and this could be found in both causal attributions and definitions (Niza *et al.* 2008). The evaluation of accident cost showed that 2/3 of the costs of occupational accidents are visible in the Danish corporate accounting systems while 1/3 is hidden from management view. Hidden accident costs, defined after their visibility in the accounting information system, amounted on the average to 35% of the total accident costs. This could vary from 2% to 98% depending on the accident characteristics. (Rikhardsson & Impgaard 2004).

User-driven innovation is to be understood as a systematic approach to the development of new products, services, processes, forms of organisation, etc., on the basis of research or inclusion of users' life, practice or needs, including the identification of non-realised needs that are expected to subsequently materialise in terms of demand from larger user segments (Danish Enterprise and Construction Authority 2008). Employee-driven innovation is about systematic inclusion of knowledge from the employees that are not otherwise part of the work on innovation in the company (Danish Enterprise and Construction Authority 2008). Innovation is not caused by the creativity of one person, it is a more structured activity in organisations and societies. Enhancing innovation forms a cornerstone for representing an enormous opportunity to enterprises for better performance. Active employee participation in a workplace has an essential impact on the level of success achieved in such transformations (e.g. Oosi *et al.* 2010, Väyrynen 2011). An appropriate degree of psychological safety is also

required, where staff do not feel as though they must go ‘out on a limb’ to explore new ways of doing things (Eder & Ackermann 1998).

Reiman and Väyrynen (2011) implemented sociotechnical aspects into the work environment and its management, and recognised that it is important to focus on human and organisational factors in addition to technical and environmental aspects. In this study the involvement in the process of personnel in enterprises was remarkable (compare Fig. 3). Participation developed their competence and increased shared understanding in non-concrete essential issues like strategy.

#### **6.4 Future needs for research**

The conclusions of this study also highlight some interesting possibilities for future research. The most important possibility lies in using innovative tools and activities within work system based on the design science approach. In enterprises there is a lot of valid material on health and safety issues which can be processed in a more practical and tangible way to achieve better results. Design requires synthesis and creativity – integration of human technology capabilities to create coherent and workable designs (McClelland & Suri 2005).

The tangible assets, such as core stories of accidents, seem to be practical and useful. Based on the literature, the analogue with product development supports the idea that this new approach is suitable for safety work. Further experiences are needed, as is evidenced by the effects of the method on TQM, SHEQ (safety, health, environment and quality), safety management and accident prevention, and, moreover, not only in manufacture enterprises but also in other contexts.

#### **6.5 Reliability and validity**

The basis of this study was to obtain information of design science’s tools and activities in a work system context. The results of this study are not a model or method but rather they are outcomes for supporting design science. The study includes qualitative and quantitative methods for achieving a more complete view. The methods chain analysis (Publication I and Publication IV) and FG (Publication III and Publication IV) were applied in two different studies. The participants methods scenario (Publication III), paired comparison (Publication II) and ranking (Publication III) were from different organisational levels to achieve a comprehensive view.

In this study the reliability of results are proven with the aid of Hevner’s guidelines (Table 3).

**Table 3. Assessment of study with DS research guidelines.**

DS research guideline	Assessment
1. Design as an artefact	Innovative activities and tools are tested in a field study. The study produces a viable view for enhancing a work system in design science context.
2. Problem relevance	Health and safety issues are not only humane but also an economic problem to enterprises.
3. Design evaluation	The evaluation of results for applying tools and activities has not been made. The main reason for this is that tools and activities were tested in enterprises, and the follow-up study did not appear.
4. Research contributions	Trialing innovative activities and tools is, in itself a contribution to the research community.
5. Research rigor	Both construction and evaluation has been considered in the study framework.
6. Design as a search process	The focus is very rigorous on design science and the work system.
7. Communication of research	This study includes relevance to the industry and society.



## 7 Conclusions

This study proved that innovation activities and tools can be introduced into SMEs in the manufacturing industry.

The specific objectives of this study were achieved. The achievements are numbered in the same order as they were introduced in Chapter 3:

1. Innovative activities and tools were trialled on the basis of the literature and applied to various cases. The emphasis was in feasible and easy-to-use methods that are easily applicable to small and medium sized manufacturing enterprises.
2. By using these methods, as the results showed, it is possible to yield more information on existing material as well as to get employees and employers to response to design solutions.
3. The methods used provided some examples of illustrative and participative results
  - a) tangible core stories of accidents in the metal manufacturing industry and wood products industry.
  - b) narrative scenario of a future enterprise in the year 2010 and evaluated criteria of an optimum work system
  - c) creative and integrated focus group sessions
4. Activities and trials in a research context can enable performance and well-being at work. Evidence was gathered for methodological recommendations in a field context.



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## Original publications

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- II Rajala H-K & Väyrynen S (2011). Participative design science approach on the optimum work system: an argumentative review-based model with a case. *Theoretical Issues in Ergonomics Science* 12(6): 533–543.
- III Rajala H-K & Väyrynen S (2011). Participative Approach to Strategy Communication: A Case of Small- and Medium-Sized Metal Enterprises with a Review after Seven Years. *Human Factors and Ergonomics in Manufacturing & Service Industries*. DOI: 10.1002/hfm.20322.
- IV Rajala H-K, Väyrynen S & Karila T (2011). Argumentative and Economic Approaches for Enhanced Safety Management: A Log Factory Case Study. Manuscript.

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