THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

ERGONOMICS INFRASTRUCTURE

AN ORGANIZATIONAL ROADMAP TO IMPROVED PRODUCTION ERGONOMICS

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Ergonomics Infrastructure

- An Organizational Roadmap to Improved Production Ergonomics

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In fond memory of Bub, who taught me that curiosity is a virtue.

ABSTRACT

Ergonomics Infrastructure
- An Organizational Roadmap to Improved Production Ergonomics

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Improving production ergonomics is a pursuit common to many companies in different industrial sectors. At the core is an aspiration to eliminate risks for work-related musculo-skeletal disorders (MSDs), but modern views on ergonomics have evolved the discipline from a purely physiological, instrumental concern to an organizational, holistic systems-performance discipline (macroergonomics). This modern perspective implies that it is not enough to consider ergonomics as the domain of only ergonomics specialists; nor is it advisable to try improving it in isolation, without paying attention to the influences of the surrounding stakeholders and context.

This thesis proposes that the "ergonomics infrastructure" of an organization is made up of the structural, technical, organizational and stakeholder-relational conditions that enable or hinder improvement of ergonomics. These conditions focus on the positioning of different stakeholders towards ergonomics issues, the relations between stakeholders and strategies they use for persuasion, and the influences that arise from industry-specific culture, attitudes and procedural integration (or exclusion) of ergonomics into engineering processes. This in turn affects an organization's tendency to handle ergonomics proactively (i.e. at the design stage) or reactively (in response to injury, discomfort and compensation claims). It was found that stakeholder influence and relational interactions are of particular importance to the implementation of ergonomics improvements. Ergonomics practitioners who are politically aware and are able to link ergonomics improvements to business and production benefits are best poised to advance an ergonomics agenda.

The knowledge gleaned from the work in this thesis has been synthesized, together with relevant theoretical concepts found in the literature, into a "Tentative Framework" which guides empirical data collection aimed at mapping the "ergonomics infrastructure" in an organization. Its step-by-step systematic review of conditions at different hierarchical levels in the organization should serve ergonomics practitioners and managers alike in identifying pathways and roadblocks to improving production ergonomics. This contributes to the branch of macroergonomics literature, which to date has placed little focus on day-to-day ergonomics practice and organizational-relational influences on ergonomics work.

Keywords: *Production Ergonomics, Organizational Relations, Proactive Ergonomics, Organizational Ergonomics, Macroergonomics, Sociotechnical Systems, Qualitative research.*

LIST OF APPENDED PAPERS

Paper I: Berlin, C., Örtengren, R., Lämkull, D. & Hanson, L. (2009)

Corporate-internal vs. National Standard – A comparison study of two ergonomics evaluation procedures used in automotive manufacturing. International Journal of Industrial Ergonomics, Volume 39, Issue 6, November 2009, Pages 940-946.

Berlin performed the interviews, carried out the statistical analyses together with Hanson, and was first author of the paper.

Paper II: Berlin, C., Neumann, W.P., Theberge, N., Örtengren, R. (2011, submitted)

Stakeholder Influence on Ergonomics Work: Contrasting Work Practices of Canadian Industrial Engineers and Ergonomists

Berlin coded and analyzed interviews and was first author of the paper.

Paper III: Berlin, C., Neumann, W.P., Theberge, N., Örtengren, R. (2011, submitted)

"Avenues of entry": how Industrial Engineers and Ergonomists influence ergonomics issues

Berlin coded and analyzed interviews and was first author of the paper.

Paper IV: Berlin, C. (2011, submitted)

Human Factors experiences in context - comparing four industrial cases using a Soft Systems framework

Berlin performed, transcribed, coded and analyzed interviews and was first author of the paper.

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2009

Berlin, Cecilia; Örtengren, Roland; Lämkull, Dan; Hanson, Lars: Corporate-internal vs. National Standard - A comparison study of two ergonomics evaluation procedures used in automotive manufacturing. *International Journal of Industrial Ergonomics*, 39 (6) 2009, pp. 940-946.

Berlin, Cecilia: Production Ergonomics Evaluation - Needs, Procedures And Digital Human Modeling Tools. Göteborg: *Licentiate thesis,* Chalmers University of Technology.

Lämkull, Dan; Berlin, Cecilia; Örtengren, Roland: *DHM - Evaluation Tools* in *Handbook of Digital Human Modeling: Research for Applied Ergonomics and Human Factors Engineering* (Human Factors & Ergonomics). Vincent. G. Duffy (Ed.). Taylor & Francis, CRC Press 2009. ISBN/ISSN: 0805856463

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Lind, Salla; Krassi, Boris; Johansson, Björn; Viitaniemi, Juhani; Heilala, Juhani; Stahre, Johan; Vatanen, Saija; Fasth, Åsa; Berlin, Cecilia: *SIMTER: A Production Simulation Tool for Joint Assessment of Ergonomics, Level of Automation and Environmental Impacts.* Proceedings of the 18th International Conference on

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Högberg, Dan; Bäckstrand, Gunnar; Lämkull, Dan; De Vin, Leo; Case, Keith; Örtengren, Roland; Hanson, Lars; Berlin, Cecilia: Towards Dynamic Ergonomics Analysis of Work Sequences in Virtual Environments. *Proceedings of the 17th International Conference on Flexible Automation and Intelligent Manufacturing (2007 FAIM), Philadelphia, USA, June 2007*, pp. 581-588. ISBN/ISSN: 978-1-4276-2092-7

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THE 5-MINUTE VERSION

(With a grateful nod to PhD Carina Rislund)

"Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance."

(IEA, 2000)

This research sets out to make sense of the conditions in production companies that enable the 'best people' to carry out 'best practices' to improve ergonomics. I have chosen to call these conditions *Ergonomics Infrastructure*, because in my mind, they seem analogous to having functional roads and traffic systems in order to get to where you are going. In the same way, if there are no 'pathways' in an organization for ergonomics to travel by and reach work systems, the people responsible are going to face considerable 'roadblocks' to improving ergonomics. The most important thing I learned while doing this research was that industry-specific ideals and relations with other stakeholders will always have a profound effect on ergonomics practice, no matter how sophisticated the 'vehicles' (i.e. the technological means) used to advance ergonomics. The thesis rests on the results of four papers, which illuminate different aspects of ergonomics practice in industrial companies:

Paper I studied a case where an automotive manufacturer switched from one large-scale ergonomics evaluation procedure to another in its factories. The first procedure was company-internal and was carried out by cross-functional factory teams, while the other was based on a national legal provision and carried out by two ergonomists. Both procedures ranked ergonomics acceptability as red, yellow or green, yet statistical analysis showed that applying the two evaluation procedures to the same series of workstations did not produce equivalent evaluation results. Interviews revealed that the reasons behind those differences were that 1) the quantitative acceptability criteria were interpreted differently,

and 2) that the personnel carrying out the evaluations had very different work objectives.

Papers II and *III* were based on the same overarching study of how ergonomists and industrial engineers (IEs) in Canada practice ergonomics. *Paper II* focused on how they interact with other stakeholders (such as management and employees) and how this affected their perceived ability to influence the workplace – the paper also discussed which behaviours they use to gain power in relation to other stakeholders. The results showed that the influence of other stakeholders cannot be ignored, and that ergonomics practitioners must align their proposals to other stakeholders' goals and concerns in order to gain implementation.

Paper III focused on how participants relate their roles to ergonomics issues, and what strategies they use to achieve ergonomics goals. It was found that the strategies of ergonomists and IEs are different, since they are differently enabled at the outset to affect the workplace (as a result of organizational positioning and expectations from other stakeholders on what they can contribute). Ergonomists gain access to issues by using more empowered stakeholders as an "avenue of entry", and both IEs and ergonomists successfully achieve changes by "hooking" ergonomics agendas onto other business goals.

Paper IV studied how (and to what extent) ergonomics is practiced and systematically approached in four different industrial sectors: Automotive, Nuclear Power, Poultry and Auto parts. A sociotechnical soft-systems framework was used to guide the comparison of the four companies. This was done on seven system levels, starting from each company's ergonomics stakeholder and gradually expanding outwards to the societal environment for each company. The study showed that the specific product, industrial context, organizational culture and tradition of ergonomics acceptance in each industry strongly influence the company's ergonomics infrastructure, and that companies are best enabled to work proactively with ergonomics when they have embedded ergonomics into cross-disciplinary approval procedures.

The maincontribution of this thesis is to synthesize the lessons learned from each of these studies in a *Tentative Framework,* described in Chapter 6. In terms of future work, the framework (Figure 1) can be used in empirical studies as a

systematic field guide for "mapping" the ergonomics infrastructure in a production company. It covers the point of view of the company's ergonomics stakeholder(s), relations to their surrounding collaborators and how they in turn relate to the ergonomics issue, and the influence of different contextual "layers" expanding outwards towards the societal context. This framework combines theories from previous ergonomics research with the results of these studies, and should be helpful in identifying the conditions in companies that can act as pathways or roadblocks to effective implementation of ergonomics improvements. The framework is yet untested in empirical settings and needs future validation.

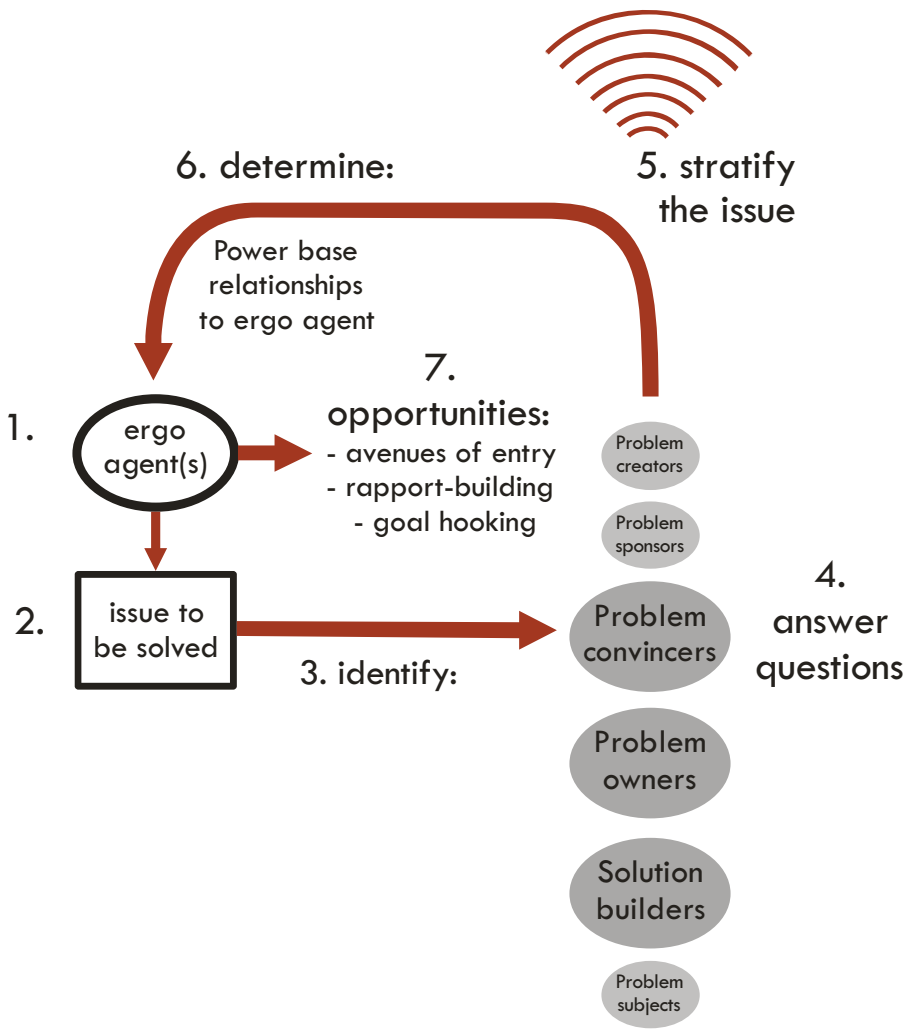

Figure 1 –the Tentative Framework. This step-by-step mapping guide helps to identify the organizational/structural and relational 'pathways' and 'roadblocks' to ergonomics improvements.

I propose that this framework will have a sustained relevance because ergonomics in organizations is a constantly changing object of study, due to the influence of new technologies; political, cultural and societal changes; and current ideals for who should be held accountable for ergonomics. Therefore, it is important to continually update the current 'state-of-the-art' with further studies of how contemporary companies practice ergonomics.

1. INTRODUCTION

This chapter gives an overview of the problem area and provides the context and rationale for the research presented in this thesis and the appended papers.

1.1 WHY IMPROVE PRODUCTION ERGONOMICS?

In production systems, human workers may be at risk for developing work-related musculoskeletal disorders (MSDs), resulting in pain, inability to work and high costs for the company in terms of compensation, productivity losses and replacement of personnel. Ensuring the health of production workers and decreasing the risk of work-related injury is a complex endeavour that is handled very differently by different organizations, depending on their means, resources and view of ergonomics. Size matters, as do organizational structure, experience and history of addressing ergonomics issues, the tools that are available to survey the workplaces, involvement of 'policing' functions (such as screening tools, national standard requirements or unions), and the expectations of management and workforce on the persons made responsible for Human Factors and ergonomics.

The core value of the present thesis research is that ergonomic risks must be avoided and eliminated from the production system – preferably in a proactive manner, so that timely design changes eliminate risks for MSDs in the system before any symptoms or negative consequences appear among workers. However, focusing only on elimination of MSD risks constitutes a limited view of how far the impact of improved ergonomics can reach. The recognized societal benefits of improved ergonomics have diversified in scope over the years. Ergonomics in production has been linked not only to health and sick-leave absence (Parenmark et al. 1988; Kuoppala et al., 2008; Morag, 2007; Westgaard and Winkel, 1997; Moreau, 2003) and psychosocial aspects (Fredriksson et al., 2001), but also to system performance aspects such as productivity (Manuaba, 1995; Neumann et al., 2006; Vink et al., 2006; Kazmierczak et al., 2007) and

quality (González et al., 2003; Erdinc and Vayyay, 2008; Falck et al., 2010; Axelsson, 2000; Helander and Burri, 1995; Eklund, 1995), with some contributions addressing several of these aspects simultaneously (Hägg, 2003; Laestadius et al., 2009; Falck 2009 ;Yeow and Nath Sen, 2003; Macleod,1994; Bloswick, 2006). As a consequence, economic gains have increasingly become an argument for advancing production ergonomics in recent literature – in a doctoral thesis, Falck (2009) concluded that early elimination of ergonomic risk in production leads to increased profit margins and savings.

1.2 THE DIVERSITY OF ERGONOMICS LITERATURE

In order to evaluate any form of ergonomics research contributions, it is important to know that ergonomics as a discipline and practice is very diverse, covering a wide variety of subject matter, areas of application and influences. "Mainstream" ergonomics tends to place its focus on interactions between humans and technology, but "changing frames of reference in modern scientific research and application" (Ergonomics Abstracts Online, 2011) have broadened the scope of ergonomics considerably since it became a research field in its own right during the late 1940s (Hendrick and Kleiner, 2001).

To get an idea of the diversity of contemporary ergonomics research, one need only consult the proceedings of any modern ergonomics conference. For example, the 2010 annual meeting of the *Human Factors and Ergonomics Society* categorized over 500 contributions into the following 23[1] topics (Human Factors and Ergonomics Society, 2010):

- Aerospace Systems
- Aging
- Augmented Cognition
- Cognitive Engineering & Decision Making

1 This list excludes headings not related to a research topic, e.g. Student Forum, Special Sessions, General Sessions, Plenary Session, Demonstrations and Posters.

- Communications
- Computer Systems
- Education
- Environmental Design
- Forensics Professional
- Health Care
- Human Performance Modeling
- Individual Differences in Performance
- Industrial Ergonomics
- Internet
- Macroergonomics
- Perception & Performance
- Product Design
- Safety
- Surface Transportation
- System Development
- Test & Evaluation
- Training
- Virtual Environments

Similarly, *Ergonomics Abstracts*, an online resource which indexes records of ergonomics research dating as far back as 1985, hierarchically classifies over 135,000 records from over 400 journals using as many as 638 classification terms in total. (Ergonomics Abstracts Online, 2011).

1.3 AN EVOLVING DEFINITION OF ERGONOMICS

In its early days, ergonomics was heavily influenced by epidemiology, biomechanics, sports medicine and mathematics, all of which are mostly quantitative disciplines. These research traditions were often strictly clinical and based on statistics, and the place of ergonomics in organizational contexts came to be studied much later. This heritage for some time served to "trap" ergonomics as a discipline accessible mainly to ergonomists, occupational health professionals

and physiotherapists. Therefore, it is meaningful to distinguish between ergonomics as a *science* and ergonomics as a *practice*:

"As a science, ergonomics is concerned with developing knowledge about human capabilities, limitations and other characteristics as they relate to the design of the interfaces between humans and other system components (...) As a practice, ergonomists around the world apply [human-system interface technology] to the design or modification of systems to enhance safety, health, comfort, and performance, including productivity and quality."

(Hendrick, 2008 p. 419)

Hendrick (2008) also argues that much of ergonomics research literature is in a format that is not useful to engineers and designers, and that scientific literature must be translated into practical 'how to' guidelines for engineering and design use.

As illustrated in the previous section, the research field of ergonomics is eclectic and open to many different influences, accepting both quantitative and qualitative research methodologies. Ergonomics as a discipline is also very *applied* in nature – historically, many of the gradual shifts of focus that have shaped the discipline have stemmed from realizations that ergonomics theory, when applied on real-life situations, has not always taken into account the additional social, cultural and organizational influences that contribute to problems in the human-technology interface.

Dray (1985, in Ingelgård, 1998) described three "generations" of research focus in ergonomics, which can be historically traced to influences from contemporary parallel research fields. The first generation focused on how human physical characteristics, anthropometry and perceptual abilities relate to the design of technology. The second, taking influence from cognitive psychology, shifted that focus to human cognitive capabilities and the demands placed on them by technology (especially computers). The third generation resulted from the realization that technological systems and organizational systems interact and impact each other – this one was known as the "macroergonomic" generation.

The modern definition of human factors/ergonomics adopted by the International Ergonomics Association (IEA) in 2000 officially widened the scope to include a more holistic systems view:

"Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance."

(IEA, 2000)

Thus, current forms of ergonomics research can include the consideration of organizational context and how it affects the uptake of ergonomics knowledge. Taking consideration of organizational structure, practitioners' needs and stakeholder attitudes towards ergonomics requires new approaches, making qualitative approaches taken from social sciences and management research increasingly relevant.

1.4 MACROERGONOMICS

Perhaps the most relevant sub-specialty of ergonomics literature that this thesis relates to is the branch called *Macroergonomics.* As explained by Ingelgård (1998), this branch of ergonomics (originally called Organizational Design and Management, *ODAM*) developed during the 1980s as a response to insufficiencies in traditional ergonomics (p. 50); as described by Imada and Carayon (2008, p. 415), researchers in a field dominated by physical ergonomics had realized that "Improving the physical aspects of work was necessary, but not sufficient for ergonomics to improve human condition *[sic]*. To make a real difference, the discipline needed to consider the context of that change and forces that facilitate and inhibit ergonomic improvements."

In particular, it was realized that ergonomics interventions, no matter how well-designed, often failed to reach system effectiveness goals due to a lack of attention to the organizational context that the intervention was launched into. H.W. Hendrick originally coined the term "macroergonomics", defining it in 2001 as:

"the subdiscipline of ergonomics that focuses on the design of the overall work system (...) a top-down sociotechnical systems approach to the design of work systems and the carry-through of the overall work system design characteristics to the micro-ergonomic design of the human-job, human-machine, and human-software interfaces to ensure that the entire work system is fully harmonized."

(Hendrick and Kleiner 2001, p. 121).

With reference to the generations described by Dray (1985), the goal of the "macroergonomic" generation was to "(...) maximize the acceptance and effective use of technology within the organization and to minimize its potential negative impacts on the organization." (Ingelgård, 1998 p. 50).

Macroergonomics as a discipline is described as *sociotechnical,* in the sense that it views organizations as "transformative agencies" transforming input into output, and consisting of three interacting, mutually interdependent sub-systems: a technological subsystem, a personnel subsystem, and a work system design made up of organizational structure and processes (Hendrick and Kleiner 2001, p. 22). A fourth element in this view is the external environment, which the three subsystems interact with. Failing to recognize the interdependence of these elements has been found by Hendrick to be a common reason why managers implement changes focused on a sub-system problem, often achieving a "ripple effect" which makes the system as a whole sub-optimal, or even dysfunctional.

Macroergonomics is often contrasted to *micro*ergonomics, which is taken to mean aspects of ergonomics concerning the design of interfaces between humans and technology, e.g. human-job, human-machine, human-software and/or human-environment (Hendrick and Kleiner 2001, p. 122)

Also, macroergonomics is known for including specific approaches for analyzing and designing interventions for organizations. Perhaps the most well-known macroergonomic approach is *participative ergonomics,* defined by Wilson 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" (1995, p. 37). Other techniques include interview studies, organizational questionnaires, field studies, focus groups, etc. On account of these different approaches, Hendrick and Kleiner

(2001) also describe macroergonomics as being not only top-down (strategic), but also "bottom-up" (participatory) and "middle-out" (focusing on processes).

It can be said that current (2011) macroergonomics literature tends to focus on participative ergonomics, intervention studies (action research) and change scenarios. The latter two can be explained by the heritage from ODAM, whose dominant focus lies on change management. However, not much macroergonomics literature studies the day-to-day ergonomics work in organizations, carried out by ergonomics practitioners in an environment that is mainly concerned with keeping an established production system running and functional. Studying these agents and their influences requires a non-invasive approach that captures what they *do,* as opposed to what their reaction is to an intervention. Also, little macroergonomics literature – from an ergonomics practice perspective – focuses on relational and political aspects of ergonomics practitioners' work. Some literature from a management perspective exists, connecting macroergonomics with business structures; however, the found examples treat the term 'macroergonomics' fleetingly and in an abstract, theoretical way that suggests an expansion of theoretical or research-methodological notions, rather than a concrete contribution to practice (Pacholski et al., 2011; Pacholski and Piotrowski, 2008).

This gap in research corresponds to many frustrations in ergonomics practice, based on the fact that many tools and methods are based on how ergonomics practitioners *ought to* work, rather than how they *do* work. Understanding how these practitioners make sense of their surrounding context, and approach challenges under the influence of existing constraints and their own experience, is a prerequisite to developing "practical 'how to guidelines" (Hendrick, 2008) that facilitate the pursuit of ergonomics objectives in an organizational context.

1.5 ERGONOMICS AGENTS AND THEIR SURROUNDINGS

One important implication of macroergonomics development is its impact on the ergonomics practitioner's role; the practitioner must then develop the necessary skill set to act as a facilitator and change agent consultant to management, in

addition to their other competencies. Hendrick and Kleiner (2001, p. 109) argue that this shifts the ergonomics practitioner's role from a "*reactive* technical specialist to being a *proactive* organizational planner and facilitator of work system changes", which will require new skills concerning sociotechnical systems theory, organizational theory, macroergonomics and work system design – subjects which may not typically be covered by traditional ergonomics education and training. This raises the question of what conditions allow ergonomics practitioners to live up to these new expectations - both in terms of their skill set, and what will in turn be required of their surrounding organizational context in order to support them in doing so.

Many different manifestations of ergonomics being applied to production systems can be found in industrial companies. This is often in the form of humans with expert knowledge of human factors and ergonomics, or in the form of implemented tools, processes, forums, meetings, guidelines etc. In this thesis I refer to these people, tools and methods as "*ergonomics agents*", because their presence and involvement enable organizations to reason about, evaluate and implement ergonomics improvements to systems. However, it is crucial to realize that the ergonomics agents act in a sociotechnical system context that invariably influences their decisions and must be taken into consideration. This has been pointed out in the conclusions of several contemporary research contributions (e.g. Broberg et al., 2011; Wulff et al., 1999; Westgaard, 2000; Theberge and Neumann, 2010; Waterson and Kolose, 2010; Andersson et al., 2011).

Quite often, the presence of ergonomics agents is manifested in the form of actors (with specific training, knowledge access and expertise) who are made responsible for Human Factors/ergonomics. Their presence sometimes constitutes the "method" itself for some organizations. This implies that the level of trust (from surrounding stakeholders) in what the ergonomics agents can contribute determines their ability to influence work systems. Examples of this include Theberge and Neumann's (2010) description of how ergonomists engage in "organizational work", and Broberg and Hermund's (2004) finding that occupational health and safety consultants need to act as "political reflective navigators" in order to further an ergonomics agenda.

Other stakeholders in organizations who are *not* ergonomics agents may still have a significant impact on the uptake of it in the organization. Costa-Black et al. (2000) and Cole et al. (2009) respectively point out a need to acknowledge how teamwork and the influences of stakeholders' differing and sometimes conflicting interests can influence ergonomics interventions. Vink et al. (2008) propose that more research is needed to determine the ideal involvement of stakeholders in participatory ergonomics processes, but also directed attention to important non-ergonomist stakeholders like employees, designers, top management and middle management.

Also, while some organizations display a modern view of ergonomics by proactively integrating it into systems design and engineering processes, others are stuck in a model where ergonomics expertise is applied in a mainly reactive manner, e.g. injury compensation claims, rehabilitation and responses to complaints. The ability of an organization to accept ergonomics as a legitimate issue is usually manifested by their level of proactive versus reactive ergonomics work. On a related note, Rislund (2006) showed that despite the plentiful existence of ergonomics knowledge, ergonomics strategies cannot propagate out into an organization unless its stakeholders find them meaningful for the organization's business objectives. An implication of this is that ergonomics strategies should be regarded as a *tool* for improving those objectives, rather than a goal in itself.

Hendrick (2003) cited the following characteristics for successful ergonomics interventions: there was management commitment in the form of resources; professional ergonomics leadership and expertise; participatory ergonomics (involving the knowledge and expertise of workers); picking the "low hanging fruit" first (i.e. promoting solutions with a quick cost-benefit payoff); and that productivity was improved as a result of ergonomic improvements.

There are also intermediate examples where ergonomics has been recognized as a business and productivity issue, but the ability to affect the system is not assigned to the ergonomics agent. This brings up issues of how different stakeholders relate to an ergonomics issue in terms of being affected by it, putting it on the agenda, being accountable for its solution, or actively solving it.

1.6 RESEARCH QUESTIONS

The general objective of the research in this thesis is to contribute to the ergonomics literature by exploring which contextual, organizational and relational aspects influence the ergonomics agents' strategic use of ergonomics arguments, tools, methods, alliances and work practices in day-to-day ergonomics work.

These considerations have been operationalized by the following research questions:

RQ1 Which ergonomics evaluation considerations are evident in approaches chosen by industrial manufacturing organizations?

RQ2 Do relations with other stakeholders influence the ergonomics improvement practices of ergonomics agents? If so, how?

RQ3 How do ergonomics agents relate themselves to ergonomics problems, and what strategies do they use in an industrial context?

RQ4 How do industry-specific concerns, processes and organizational culture influence ergonomics practice and the ergonomics agent's ability to address problems proactively and/or reactively?

1.7 INTENDED AUDIENCE

Potential benefactors of this research are ergonomics practitioners and corporate stakeholders who work together in a production design process to balance the factors that make up a healthy, economically feasible and well-performing production system. Identifying the conditions in a company that make up the ergonomics infrastructure is of practical value not only to practitioners and ergonomics agents – it is also valuable knowledge for higher-level management wishing to effectively integrate ergonomics objectives with production and business goals. The research in this thesis strives to highlight contextual factors which may act as facilitators or barriers to the work of ergonomics agents– recognizing them and using appropriate strategies to navigate around them can help ergonomics agents, surrounding stakeholders and management to steer clear of roadblocks and drive the development of supportive organizational structures and procedures.

1.8 PAPERS IN THIS THESIS

The research is represented in this thesis by the four papers summarized in Table 1:

Table 1 – Papers included in the thesis with research question, purpose and methods

Paper	***Research question***	***Purpose***	***Approach***
Paper I: Corporate-internal vs. National Standard – A comparison study of two ergonomics evaluation procedures used in automotive manufacturing.	Which ergonomics evaluation considerations are evident in approaches chosen by industrial manufacturing organizations?	- To study the case of a transition from one company-wide assessment method to another, and describe any implications from the change	Case study: statistical measurements and unstructured group interviews Statistical treatment (SPSS)
Paper II: Stakeholder Influence on Ergonomics Work: Contrasting Work Practices of Canadian Industrial Engineers and Ergonomists	Do relations with other stakeholders influence the ergonomics improvement practices of ergonomics agents? If so, how?	- To study if there were similarities or differences in how ergonomists and industrial engineers interact with and accommodate to surrounding stakeholders	40 Semi-structured interviews (same as Paper III) Categorizing Power Bases
Paper III: Avenues of entry: how Industrial Engineers and Ergonomists access and influence ergonomics issues	How do ergonomics agents relate themselves to ergonomics problems, and what strategies do they use in an industrial context?	- To describe how ergonomists and industrial engineers pursue and secure an ergonomics agenda using strategies	40 Semi-structured interviews (same as Paper II) Categorizing Stakeholder-problem taxonomy
Paper IV Human Factors experiences in context - comparing four industrial cases using a Soft Systems framework	How do industry-specific concerns, processes and organizational culture influence ergonomics practice and the Ergonomics agent's ability to address problems proactively and/or reactively?	- To study collaboration clusters in the context of the same company, centering on an agent specifically responsible for ergonomics	4 Case studies: 'Clustered' semi-structured interviews Categorizing Soft-systems framework

1.9 OUTLINE OF THESIS

The 5-minute version	This section provides an informal concise summary of the results and main contribution of the thesis and the research it is based on.
Introduction	In this chapter, the author introduces background knowledge of the problem domain that sets the scene for this research, and some theoretical concepts that capture the chosen aspects of the studied problem area.
Frame of Reference	Here, the author introduces background knowledge of the problem domain, and some theoretical concepts that capture the chosen aspects of the studied problem area.
Research Design	This chapter presents the design of the research in light of the theoretical background, the scientific outlook that influences the research design, and the quality criteria by which the resulting knowledge should be evaluated.
Results	This chapter provides a summary of the appended papers, describing the procedure and results.
Discussion	This section discusses general implications and evaluates the research from a research-methodological point of view.
Tentative Framework	Here, the author attempts to synthesize the findings of this research, the discussion and relevant theoretical elements into a *tentative framework*, providing a guide for mapping out the "ergonomics infrastructure" surrounding ergonomics agents in a company.
Conclusions	This section answers the research questions and summarizes the most important findings.
Further Research	This section proposes further potential areas of continued research.
Appendices	The appendices explain in detail how the different steps of the *Tentative Framework* (described in Chapter 6) are to be carried out.

2. FRAME OF REFERENCE

Here, the author introduces background knowledge of the problem domain, and some theoretical concepts that capture the chosen aspects of the studied problem area.

2.1 THE KNOWLEDGE BASE

2.1.1 Work-related Musculoskeletal Disorders

Ergonomics work is often geared at the elimination of risks for physical injury caused by potentially harmful body loading in the workplace. Work-related musculoskeletal disorders (WMSDs, according to Kuorinka and Forcier, 1995; also known as MSDs) are defined as "a heterogeneous group of disorders" caused by a multitude of potential (physical) factors. Pain, discomfort and fatigue are considered common first symptoms, while loss of function, limited movement range and loss of muscle power are more manifest signs of the presence of a MSD. It is suggested (Table 2) that they may be caused or triggered by one or more of the following working conditions:

Table 2: Working conditions that may cause WMSDs (Adapted from Kuorinka and Forcier, 1995).

- Repeated physical efforts, such as movements and postures
- Static work
- Continuous loading of tissue structures
- Lack of recovery time

NOTE: Accident-related sudden injuries are per definition excluded from the term's scope, according to Kuorinka and Forcier (1995).

2.1.2 Production ergonomics

Although it is difficult to describe a production design process that is universally applicable to all companies, the contribution of this thesis work may not appear clear without having been put in a production context. The domain of this body of research is that of manufacturing-based production systems, where a combination of human and automated resources are engaged to achieve the end goal of producing goods or services – in a timely and efficient manner – that are of commercial value. While engaging in such activities, the humans in production systems may come under physical loading and strain which may put them at risk for developing MSDs.

The issue of monitoring and improving ergonomics in production is handled differently depending on a number of contextual factors. Such factors may be the size of the company, the number of employees involved in the production planning process, the level of involvement that management allows the workforce over their tasks, the technological equipment and tools at disposal, the presence of an internal ergonomist or external occupational health service, and the company history of using formalized evaluation methods.

When planning a new (or re-designing an existing) production system, a great number of parameters need to be balanced against each other to achieve a cost-effectively designed system that maximizes productivity and minimizes the risk of quality deficiency and MSDs. Different objectives may influence the chosen approach for identifying, monitoring and controlling ergonomics problems that arise in production. Depending on where in the process ergonomics is addressed and what is considered the root of the problem, different basic approaches (or a combination of them) may be used.

Perhaps the most basic approach is *observation* of the work being performed. One or more actors with some degree of ergonomics knowledge may use this approach to investigate the on-going production ergonomics status, assessing the occurring work activities against some kind of baseline for acceptable/unacceptable conditions. Depending on the ergonomics agent's profession, the baseline may be professional knowledge and experience (as in the case of a trained ergonomist), a

corporate or national standard (e.g. an occupational health service provider), or an observation guide or method for assessment (e.g. a production engineer, a process designer, a worker or even a researcher). A great number of evaluation methods and guides have been developed for observation purposes, most of them related to posture analysis.

Another issue that needs to be resolved is whether to associate ergonomics assessment to human operators *or* to product- or production-related parameters (e.g. product construction features, workstations, equipment or materials). Depending on the supposed 'culprit' causing ergonomics problems, different stakeholders may choose different 'units of improvement' to associate assessment results with. An occupational health service professional may want to identify and remedy an identified unhealthy load exposure for one or more individuals (*reactive* intervention), while a production engineer or ergonomist may instead want to pinpoint product- or workstation-related parameters that can cause a risk for MSDs, thus being able to give feedback to product and production designers much earlier in the design process (*proactive* intervention).

2.2 CAPTURING THE PROBLEM: THEORIES

"Theory shapes and directs our vision. In fact theory is the 'instrument' or carrier that allows us to see what we want to see and not always in the way we want to see it. (…) Implicitly, it means that we can articulate what is theoretical and what is worth being seen and, thus, emphasised."

(Jonker and Pennink 2010, p. 60)

2.2.1 A Systems view

For a long time, the traditional outlook of ergonomics was to concern itself only with measuring and preventing musculoskeletal disorders, establishing methods that identified ergonomic risks by measuring posture, force and time of work tasks. While this focused rigorously on the components of cumulative physical injury, many such research efforts had a limited perspective and ignored the effects of the context that the method or measurement took place in – such efforts had an *instrumental* outlook. To accurately consider and study the implications of organizational context on ergonomics, a theory basis is needed that acknowledges

a holistic systems view where human involvement is taken into consideration. Keeping a general *systems view* (Skyttner, 2006 p. 53) in mind guides the investigation toward studies of how individual elements in a system connect with each other, sometimes as combinations of groupings, functional units and hierarchies, with the underlying idea that a system is goal-seeking, transforms inputs into outputs, and in its totality has properties and characteristics that are unique to the system as a whole.

In his systems taxonomy published in 1968, the psychologist Nehemiah Jordan (Skyttner 2006, p. 178) proposed three dualistic properties of systems which, when applied to the research herein, describe the studied companies as follows: they are *dynamic* rather than static (i.e. they change over time); they are *purposive* rather than non-purposive (they adapt to their environment to reach a desired state); and they are *organismic* rather than mechanistic (the system elements are densely and intricately connected, and any changes to the system may impact several elements). Many system theorists also share the view that complex systems (such as production organizations) are *synergistic* in the sense that the whole is not equal to the sum of its parts; this view acknowledges that when sub-elements are interconnected, they become invested with properties as a whole that do not appear in any of the isolated sub-elements (Hendrick and Kleiner 2001, p. 28).

However, in the 1980s a movement was started which proposed that traditional systems thinking had its limitations, especially when applied to the "messy" realities of business domains. Peter Checkland, taking part in a great deal of action research and application of systems engineering on management situations, soon found that "(…) the management situations we worked in were always too complex for straightforward application of the systems engineering approach." (Checkland, 2000, p. 14). Systems engineering strived to define real-world systems, clearly and technically, in terms of what their objectives were, in order to 'engineer' subsystems into achieving their objectives optimally. However, this view did not take into account the multitude of parallel objectives in any human activity system, or the fact that parallel objectives could sometimes be at odds with each other. Finding the systems engineering perspective too limited, Checkland

came to develop the distinction between "hard" and "soft" systems thinking which eventually led to his pioneering of *Soft Systems Methodology* (SSM).

The difference between hard and soft systems thinking is often misunderstood, but Checkland explains it as follows: *Hard* systems thinking assumes that systems exist as entities in the real world, can be characterized by their (well-defined) objectives, and can be engineered to meet those objectives better. It is appropriate when working with an 'obvious' problem requiring a solution. *Soft* systems thinking, on the other hand, recognizes that different people may or may not perceive a particular situation as problematic, and in exploring the situation, the inquiring process can be structured as a system of learning. In other words, there is a shift of "systemicity" from the world to the process of inquiry (Checkland, 2000 p. 17). Some key thoughts underpinning SSM include the modeling of human attempts of purposeful action; different perspectives on the situation being possible, making it necessary to explicitly declare a world-view; and that the learning process is ongoing.

Another flaw in traditional systems thinking when applied to organizational contexts (summarized by Ingelgård, 1998) is that it assumes that an organization has a goal which is unanimously pursued by all its members– this does not take into consideration aspects of power and conflicts of interest among its members. This view also neglects aspects of unequal input from different members, ownership, and which individuals benefit the most from the fulfilment of specific goals.

According to Wilson (2000, p. 557), ergonomics should be understood as "*the theoretical and fundamental understanding of human behaviour and performance in purposeful interacting socio-technical systems, and the application of that understanding to design of interactions in the context of real settings. This definition is justified in the financial, technical, legal, organisational, social, political and professional contexts in which ergonomists work.*" Carayon (2006) added to this notion of ergonomics as a sociotechnical discipline by stating that products and services are the result of interactions that traverse organizational, geographical, cultural and temporal boundaries. Carayon also argued that work across these boundaries benefits from better integration between human factors and

ergonomics and professionals in the domain of application who can provide industry-specific expertise.

An example of a hierarchical soft-systems framework is used in Paper IV in this thesis: Kirwan (2000) proposed a stratified, comprehensive framework for enhancing integration of HFE into organizations. Soft systems are understood to be "neither purely technical nor purely social in character" (Kirwan, 2000 p. 663). The framework addresses human factors and ergonomics (HFE) in organizations at seven hierarchical levels, starting with factors close to the ergonomics agent and gradually expanding outwards toward the organization's environment. Table 3 briefly summarizes the main concepts and manifested elements relevant to each level:

Table 3: Kirwan's Multi-level soft systems framework for increased HFE integration - adapted from Kirwan (2000, p.p. 666 -678).

Level	**Conceptual description**	**Manifested Elements**
Technical interface level	Where, how, and in what form interactions take place	Meetings, reports, other media, presentations, papers, press releases
Project level	The HF agent's relationship to project-related company functions, typically with Safety, Design/Engineering and Operations functions	Stakeholder (colleague) interfacing, the nature of the assignment(s), project duration, the HF agent's status as a team member or solitary actor, the possibility of using new HFE approaches, potential to show business potential of HFE
Company level	The organizational department (or corresponding sub-unit) in which HFE is positioned	(Depending on the organizational position): Access to end users, short- or long-term solutions, ergonomic design compliance, closeness/distance to operations, justification for HFE depending on safety or other concerns, time spans for finding solutions
Personnel level	Ranking of the HF personnel in the overall hierarchy	Hierarchical placement of HF agent, closeness to 'the top', understanding of business/product/ process aspects, level of understanding and support from senior management, ability to raise HFE issues 'high up', alignment of HFE matters to company's needs and goals
Extra-company level	Influence on HFE practice and integration from organizations and entities outside the company	Regulators, governing bodies, national/international standards, competitors, industrial forums, academic organizations, operator-based organizations

(Continued next page)

(Table 3, continued)

Environmental level	The company HFE function's response to company-external events, values and cultural shifts	Government policies, take-overs (or similar corporate change events), privatization, responses to incidents and accidents, public perception of HFE issues
Temporal dimension	How far the company has come in time-varying processes: 1) the system design life cycle, 2) the HFE integration process, and 3) environmental / organizational temporal characteristics.	How long the HFE presence has existed at the company and in what organizational form (e.g. person, committee, unit, department), how long it has taken to develop and integrate into the company's organization and 'business mission'.

2.2.2 Relational and political aspects – positioning, persuasion and power

There are a number of ways in which ergonomics-related issues in an organization can be viewed, and also a number of ways for different stakeholders to relate their professional role to the issue. In the context of organizational research methodology, Jonker and Pennink (2010, pp. 7-8) suggest that stakeholders in an organization have different ways of relating to a "problem" (or issue[2]), labelling the different stakeholder relationships as demonstrated in Table 4.

[2] "Problem" is the wording chosen by Jonker and Pennink; although the word "problem" may sometimes be interpreted in a negative sense, the term is used broadly in an organizational research sense, and can be interpreted as any issue needing to be resolved with some form of action. The wording here is presented as found in the reference, but in Paper III (where it appears) the wording is changed to "issue" to avoid negative connotations.

Table 4 – A taxonomy of stakeholders' relationships to a given problem, in terms of involvement and being affected by it – adapted from Jonker and Pennink (2010, p. 7-8)

Problem…	**How they relate to the problem/issue**
…creators	• have the authority and power to put the problem on the organisational agenda. • focus attention on a problem and often determine its priority level. • have fulfilled their task once the problem is put on the agenda and passed on to others.
… sponsors	• support keeping the problem on the organizational agenda, even though it does not affect them directly (providing a 'service' by doing so). • back up the problem notion (on the basis of various motives which may be political, financial or emotional). • *do not* contribute to reaching a solution.
… owners	• are voluntarily or involuntarily assigned 'rights of ownership' of a problem. • are appointed during the process of making the problem an item on the agenda by being passed on to the most relevant stakeholder (e.g. a functional manager) once the problem has been 'labelled'.
… solvers	• deal specifically with the problem: they are responsible for examining, advising and eventually solving the problem. • sometimes have the (dual) role of problem owners, but most of the time other people are appointed as (internal or external) advisors, trainers or researchers.
…subjects	• are the ones the problem is about, by being identified as the 'cause' or 'victims' of the problem. • might sometimes be individuals but are often a certain well-defined group of people in the organization who are battling the problem. • may or may not be involved in the process of problematizing, i.e. putting the problem on the agenda.

As mentioned earlier, improving ergonomics in an organizational context may sometimes involve engaging in political processes and using different kinds of persuasion tactics to achieve goals. Some of these tactics involve building rapport and alliances with other stakeholders in order to gain influence on the issue to be resolved - Theberge and Neumann (2010) call this "doing organizational work". Poggi (2005) uses the term "goal hooking" to explain processes where an actor aligns his or her goals with those of another stakeholder, in order to persuade that stakeholder that their objectives will benefit from fulfilling the persuader's request for support.

Buchanan and Badham (2008) propose that *power* is a relational property that is dependent on other stakeholders' perceptions, and that change agents can operate from several "*power bases*", which are classifications of strategies used when one agent (or group of agents) strives to achieve specific goals in interactions with other stakeholders. Eight such power bases have been defined, along with typical positive and negative behaviours (summarized in Table 5, adapted from Buchanan and Badham, 2008 pp. 48 – 50):

Table 5: Power Bases – characteristics and some examples (positive and negative)

Reward	The change agent has access to valued rewards which will be dispensed in return for compliance Remuneration, praise, awards, compliments etc.
Coercion	The change agent can administer penalties or sanctions that are unwelcome Use of threats, bullying, verbal and non-verbal put-downs, withholding of needed resources etc.
Authority (a.k.a. Legitimate)	The change agent has authority to give directions, within the boundaries of their position or rank Obligation of others to obey, 'playing the boss', abusing authority, exercising leadership in times of need
Referent	The change agent has desirable abilities and personality traits that can and should be copied Charisma, friendship, sharing personal information, enforcing common values, viewpoints and preferences, reciprocal IOUs, providing something of value to others
Expert	The change agent has superior knowledge relevant to the situation and the task at hand Possession of knowledge valued by others, given freely when solicited, helping others, unsolicited expertise, expertise offered in a condescending manner can be considered coercive, withholding expertise in times of need
Information	The change agent has access to desirable information due to positioning or connections Controlling of information flows, especially to and from superiors in a hierarchy;
Affiliation	The change agent is associated with an authority source and 'borrows' power from that association Acting as a surrogate for a superior, acting on superior's wishes, abusing the association to act on personal wishes, using negative affiliation power via rigid accounting and personnel policies
Group	The change agent is part of a group perceived as a rightful entity Collective problem solving, creative brainstorming, conflict resolution, domination by a few individuals, "groupthink"

3. RESEARCH DESIGN

This chapter presents the design of the research in light of the theoretical background, the scientific outlook that influences the research design, and the quality criteria by which the resulting knowledge should be evaluated.

3.1 BUILDING THIS RESEARCH

"(…) it is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail."

(Abraham Maslow, 1966)

Since different disciplines of research have different ideas of what should be considered legitimate and accurately obtained "knowledge", this section clarifies the basic assumptions that shape both this research and which criteria should be used when judging its veracity and utility. This is of special importance because the assumptions that may come from an engineering or traditional ergonomics background can sometimes be at odds with the social science-influenced methods that are extensively used in this research. In general, the goal has been to study and gain deeper understanding of processes, rather than to test hypotheses.

3.1.1 Research paradigm

The overall *paradigm* determines the researcher's view of "reality", i.e. what can be accepted as justifiable knowledge (*epistemological* and *ontological* considerations). *Epistemology* determines what can be regarded as acceptable knowledge in a discipline, in terms of whether the social world and its influence on observable events should be acknowledged or disregarded in 'good science' (Bryman and Bell, 2007, p.16). *Ontology* (in sociological endeavours) on the other hand describes whether social entities are to be considered external realities independent of social actors, or if they are constructions originating from the perceptions and actions of the people being studied (Bryman and Bell, p. 22).

As mentioned in the Introduction chapter, the research field of ergonomics has evolved under many influences and therefore accepts a variety of research methodologies as part of its knowledge generation arsenal; the delineations between the three "generations" of ergonomics suggest a gradual shift from natural-sciences approaches (with experiments, measurements and statistical correlations) towards more sociological concerns (with interviews, observations and field studies). This is important to acknowledge, since one of the research studies (Paper I) combines qualitative and quantitative approaches; in other words, questions of "how much" and "how" are studied alongside each other. However, the three following studies predominantly concern questions of "how" and "why".

Due to the focus being placed on stakeholders, organizational context and practices of ergonomics work, standpoints of *constructionism* and *interpretivism* (Bryman and Bell, 2007 pp. 19-23) characterize this research. *Interpretivism* is an epistemological stance that objects to the notion that the methods of natural science are able to grasp the meaning of social interaction – the *interpretation* of social phenomena must be considered. The *constructionist* (a.k.a. constructivist) paradigm assumes that realities are multiple and uniquely constructed by the individuals who experience them, meaning that the goal of the inquiry is deeper understanding of phenomena rather than generalization (Zoellner, 2009). One of the main reasons for emphasizing the perspectives of the people studied and the influence of particular settings is that this increases the potential of generating knowledge that informs practitioners (Bolster, 1983).

3.1.2 Research methodology

The research paradigm guides the *methodology*. There is oftentimes some confusion between *methodology* and *metho,d* due to inconsistent use of the terms, but this thesis adheres to the neatly formulated distinction by Checkland (2000): a *methodology* is a framework of coherent principles, which guide an approach to an inquiry. This means that inquiring into a process being studied involves a selection of methods from a "repertoire" of compatible ones - i.e. the *methodology*. Checkland also notes that certain methods can be said to be so dependable that they produce a guaranteed result, earning them the status of "techniques", when

used skilfully and in certain fields of study. However, the use of this term is sometimes not quite so strict; for example, Jonker and Pennink define techniques (2010, p.41) more broadly as the ways in which "data is generated, collected, classified and analysed".

Maxwell (2005) writes that qualitative studies with an interpretive approach not only examine physical events and behaviours, but also how participants make sense of these and how that understanding influences their behaviour (p. 22). Although there is a predilection in this body of research for adopting a qualitative approach, there is a rationale for combining *quantitative* and *qualitative* research methods in the research domain overall. *Quantitative* methods tend to use instruments as a medium for data collection (e.g. scales, tests, surveys) and are concerned with 'impersonal', precise, detailed reductionistic results, while *qualitative* research results are mediated through the researcher (observations, interviews) and aspire to provide rich, detailed descriptions and increase holistic understanding for the studied phenomena (Bryman and Bell, 2007 p. 426).

In this thesis, the only manifestation of quantitative method appears in Paper I, where a statistical evaluation of two corporate methods was carried out in conjunction with complementary interviews. However, it is nonetheless prudent to consider that qualitative and quantitative techniques answer very different questions about the phenomena being studied, which in combination can prove a much more powerful and robust approach than using just one or the other.

3.1.3 Research methods

Methodology in turn determines the coherent repertoire of research methods or techniques (the line between them may be best considered blurred in any research domain involving human situations). The ones used specifically in the appended papers are elaborated upon in the following two sections on data collection and analysis.

3.2 DATA COLLECTION METHODS

3.2.1 Case study (Papers I and IV)

According to Bryman and Bell, a *case study* implies "intensive examination of the setting" (2007, p. 62). Yin (2003) writes that a case study is an appropriate data collection approach when:

1) The objective is to answer questions like "how" or "why",

2) The investigator has a little or no possibility to control the events, and

3) The object of study is a contemporary phenomenon in a real-life context.

Inasmuch as the research in Paper I can be considered a single Case study, it displays the following characteristics (Bryman and Bell, 2007): it studies a single organization (an automotive manufacturer), a single location (a specific factory in Sweden) and a single event (the succession of two ergonomics evaluations). It consisted of a secondary analysis of company-internal records that were produced as part of ongoing ergonomics monitoring. Since it turned out that the results were not easy to interpret in themselves, the statistical treatment was combined with interviews.

Paper IV is a *multiple case study*, or a *comparative* study (Bryman and Bell, pp. 66-71) carried out for the purpose of comparing and contrasting ergonomics work at four different companies, based entirely on data in the form of interviews. The research in Paper IV can be regarded as *"cross-cultural"* research (Bryman and Bell, p. 66), in the sense that the cultures vary across companies in different industrial sectors within the same country. The focus of interest for the comparison is variation, and the idea that comparing more than one case will suggest concepts that are relevant to an emerging theory.

3.2.2 Document analysis and Data types (Paper I)

According to Flick (2006), the research performed in Paper I includes *document analysis*. A 'document' is defined as a standardized artefact that is produced as part of an ongoing development. Most often they come in a pre-determined format

(e.g. case reports, notes, PMs, certificates, letters, judgments etc.). Documents can be either *solicited* (i.e. requested from the studied actors by a researcher, in order to draw conclusions) or *unsolicited* (i.e. they are produced as part of ongoing routine regardless of the researcher's objectives). A further classification is that between *running records*, which are produced continuously as a result of administrative processes, and *episodic* or *private records,* which are produced occasionally (Webb et al., 1966 and Lee, 2000; both in Flick, 2006). The important point (according to Flick, 2006) is that documents are *contextualized* information, since the context influences the quality, representativeness and meaning of the documents. As suggested by Scott (1990, in Flick, 2006) it is important to keep in mind that the circumstances (who, when and where) under which the documentation was produced affects its quality.

Furthermore, there exists a distinction between *primary* and *secondary* (sometimes also *tertiary*) documents or data (Flick, 2006; Bryman and Bell, 2007). Although the exact boundaries between the types are not always clear, *primary* data tends to signify a scenario where the data stems from an 'eyewitness account', i.e. the collector of data and producer of the document are one and the same, while *secondary* data is generated by a study of primary documents (and not the actual object or event of study). Tertiary documents tend to be sources to find other documents (Flick, 2006). Thus, *secondary analysis* is "the analysis of data by researchers who will probably not have been involved in the collection of those data, for purposes that in all likelihood were not envisaged by those responsible for the data collection." (Bryman and Bell, 2007 p. 326)

In Paper I, document analysis is carried out in the sense that recorded data from the two evaluation procedures (which were *primary, unsolicited*, and *running records* for the duration of time that each procedure was valid at the company) were studied, in the form of data spreadsheets containing text and numerical values. The study of the evaluation records can be called secondary analysis.

3.2.3 *Interviews*

In Paper I, two interviews with company actors who had experience of the two studied ergonomics evaluations were conducted. They were carried out as focused interviews (Merton, Fiske and Kendall, 1956 in Bryman and Bell, 2007, p. 213), meaning that the interviewer asked predominantly open questions having to do specifically with the focus area (i.e. the two factory evaluations). Furthermore, the interviews can be labelled as *unstructured* (i.e. a list of topics and issues to discuss was used instead of formal questions) and as a *group interview* (Bryman and Bell, 2007, p. 213), since the interviews were carried out with more than one person at a time, both times. The interviews were recorded on-site via note-taking and some preliminary tables and charts of the study's quantitative results were shown to the interviewees during the interview as a 'prompt' for eliciting comments. After the interviews, a preliminary version of the paper was shown to respondents for further corroboration.

In Papers II, III and IV, interviews were semi-structured (meaning that a guide was used, but interviewees were encouraged to elaborate on topics that they themselves brought up that increased the scope of the interviews). They were audio-recorded, fully transcribed and sent back to interview participants for checking, in order to retain the confirmability of the raw data.

In all cases, the selection of interview participants was *purposeful,* meaning that they were selected deliberately on a basis of criteria rather than randomly, to represent their particular settings, roles and activities – also, it was in some cases a goal to establish particular comparisons to illuminate differences between settings or individuals (Maxwell 2005, p. 90).

3.3 DATA ANALYSIS METHODS

3.3.1 *Statistical treatment (Paper I)*

Paper I incorporates a comparison between the quantitative (or semi-quantitative) data that was collected in two factory-wide ergonomics evaluations, chiefly consisting of ratings on a workstation-level where each station was ranked as red (not acceptable), yellow (needing further attention) or green (acceptable).

This means that there existed *ordinal* data on three levels (i.e. belonging to categories that can be rank ordered but are not necessarily equal distances apart; see Bryman and Bell, 2007 p. 355), which could be subjected to bivariate descriptive statistics (Bryman and Bell, 2007 p. 360) and tested for agreement using the software SPSS 15.0 for Windows. There was also *nominal* data (i.e. categories with no internal order) on a *dichotomous* level (signifying only two possible categories; Bryman and Bell 2007 p. 365-357), since the two evaluations were also compared in terms of whether or not they pointed out one of four body segments (back, shoulder, neck or hand) as being at risk for unhealthy exposure. This data was also subjected to bivariate descriptive statistics.

In general, all data was cross-tabulated and subjected to built-in applicable mathematical tests for agreement in the SPSS software. The *odds* of either method identifying risk for a body segment were calculated manually. A significance level of 5% (α= 0.05) was used.

3.3.2 Coding processes (Papers II - IV)

In Papers II – IV, the interview data were subjected to a coding and categorizing process where the material was categorized in an emergent fashion based on iterative readings of the interview transcripts. According to Strauss (1987, p. 29), the goal of coding is to "fracture" the data and rearrange them into categories that facilitate comparison between items in the same category. Categorizing (Dey, 1993) sorts the data into concepts unifying a number of observations (fragmented data) which have some characteristics in common.

3.3.1 Conceptual frameworks

Miles and Hubermann (1994) define a *conceptual framework* as a visual or written product that "explains, either graphically or in narrated form, the main things to be studied – the key factors, concepts or variables – and the presumed relationships among them" (p. 18). This thesis and its appended papers make use of these sense-making tools in order to systematize concepts, assumptions, expectations, beliefs and theories that support and inform research. Conceptual frameworks (some taken from existing literature, some devised by the author) are

used mainly in Papers II – IV as sensemaking tools to structure the empirical analysis, as well as in the *Tentative Framework* (Chapter 6) developed in this thesis.

3.4 QUALITY CRITERIA

The large component of qualitative, empirical data in this research requires that a suitable set of evaluation criteria be used to establish its trustworthiness. As Maxwell (2005) writes, validity is relative: it has to be assessed in relation to the purposes and circumstances of the research, rather than being a context-independent property of methods or conclusions.

Establishing trustworthiness can be achieved in part by using strategies in the research design to mitigate any doubts that the presented data are credible, and also by providing (as far as possible) the reader with a reasonable guide for testing the proposed findings in a similar context.

The positivistic criteria for judging trustworthiness – *internal* and *external validity*, *reliability* and *objectivity* (Lincoln and Guba, 1985) – cannot be used since they assume that the research is carried out for the purpose of proving or disproving a theory, and that the data selected for study are randomly sampled in order for results to be generalizable to a variety of domains.

Instead, Lincoln and Guba's alternative naturalistic quality criteria for trustworthiness in qualitative research (Lincoln and Guba, 1985 pp. 301 – 327; Bryman and Bell, 2007 pp. 410-415) are used, addressing *transferability*, *credibility*, *dependability* and *confirmability* instead. Rather than explain the meaning of the terms here, this will be done 'in context' in the Discussion chapter.

It is really only the research presented in Paper I that can, to some extent, be scrutinized using classical criteria of trustworthiness (Internal/external validity, generalization, objectivity and reliability; Yin, 2003), since its content is partly quantitative. This is attempted; however it becomes quickly apparent that for certain issues, the alternative criteria are more suitable.

4. RESULTS (SUMMARY OF PAPERS)

This chapter provides a summary of the appended papers, describing the procedure and results.

4.1 PAPER I – TWO NON-EQUIVALENT ERGONOMICS EVALUATIONS

4.1.1 Procedure

The starting point of Paper I was a retrospective case study where two different ergonomics evaluation procedures (methods) had been used to evaluate the same factory of a Swedish automotive manufacturer. The company had invested a great effort into first using a method called *BME*, where factory teams assigned to a line of workstations had to agree on a consensual acceptability rating for each workstation, according to a highly specified corporate protocol with clearly defined criteria of acceptability. The evaluation teams had received a 3-week company training course to certify them as users of the method. After the factory had been evaluated using the BME method, the entire procedure was replaced with evaluation by two Occupational Health Service(OHS) professionals who were assigned to evaluate each workstation again, this time using the Swedish national standard provision *AFS 1998:1* (AFS, 1998) as acceptability criteria. Rather than follow a specified rating protocol, the OHS ergonomists performed an 'expert' evaluation based on their knowledge and experience, and evaluated ergonomics individually on a substantial number of workstations.

For both procedures, the common main principle for evaluation was that each individual workstation was classified as *red* (unacceptable ergonomics), *yellow* (needing further evaluation) or *green* (acceptable). Furthermore, both methods reported specific body segments considered at risk for injury at each rated workstation.

Post-completion of the two evaluations, a document study was commenced based on the corporate evaluation records. The working hypothesis being tested was that the two evaluation procedures were equally effective at identifying

ergonomically problematic workstations. This was investigated by comparing the ratings for every workstation given by the BME method and the national standard (AFS) respectively. Also, the specific body segments reported by either procedure were compared, to see to what extent there was agreement. The comparison was carried out using descriptive statistics, chiefly using simple statistical tests of agreement.

Since it was not immediately obvious what caused the differences in ratings, the statistical comparison was followed by a group interview with a team of pre-production ergonomists that had been present when the BME evaluations were performed, and a second one with the two OHS ergonomists who carried out the national standard evaluation.

4.1.2 Results

Though the methods were believed to be similar enough to be interchangeable, they differed significantly in how they rated workstations, and it was observed that the national standard tended to rate more severely (more classification into yellow and red) than the BME procedure. As for body segment reporting, the overall propensities for BME and the national standard to identify a workstation as a risk for a particular body segment were significantly different, although conclusions cannot be drawn with confidence regarding the hand category and the neck category is also doubtful.

Both interviewed groups stated that there were differences mainly in how the BME and national standard methods considered the middle 'yellow' rating; it transpired that there were other corporate-cultural contextual factors (not evident from the quantitative results) that also affected the interpretation of the yellow level.

Some ambiguities remain due to the study setup; among other things, it was not possible to determine whether the differences in ratings were specifically correlated to the methods or the persons who performed the evaluations. Inter-rater reliability testing would have been affected by confounding factors, since

a) the testing would have involved comparing the performance of one individual with that of a team of three people, and b) the relative difference in ergonomics

expertise among raters was not known, apart from the assumption that the OHS ergonomists had considerably greater experience. Intra-rater reliability was not applicable for testing, since each person or team had only given stations a rating once. Furthermore, although it had been assumed by the paper authors that the two evaluations had been carried out sufficiently close in time (with a gap of three months) to assume that no major changes to the workstations had been done, there is some uncertainty that cannot be completely accounted for.

Paper I proposes that large-scale corporations might inadvertently exchange one ergonomics evaluation method for another that has a different criteria basis, thus getting different results on the same workstations and not capturing the same ergonomics problems.

4.2 PAPER II – STAKEHOLDER INFLUENCE

4.2.1 Larger study context (Papers II and III)

This study was carried out in Canada in collaboration with a research team from Ryerson University. The starting point of both this paper and Paper III was an opportunity to compare two data sets consisting of interviews with 19 industrial engineers and 21 ergonomists. One main motivation for including both of these professional groups in a study is that they both study ergonomics and human factors as part of their training - it is therefore reasonable to expect that either type of professional may be given responsibility for ergonomics issues in Canadian industry. The approach was initially open and explorative, geared at exploring the different aspects of what it is like to work as an industrial engineer or ergonomist, and what facilitators and barriers participants perceived in their work.

The interviews were semi-structured and covered a variety of aspects regarding the work practices of each participant. Topics included organizational positioning, involvement with other stakeholders, priorities, tools and methods used in their daily work, attitudes within the organization towards ergonomics, and how assignments were distributed to personnel. All interviews were audio recorded and fully transcribed.

After collection of the data (which was done by two other researchers), the first author read through all the transcripts and took part of the categorization process (as described by Dey, 1993) that had been started by the research team on each data set separately. The first author performed a parallel categorization process based on common themes in both data sets, aiming to compare these two data sets and conceptualize on similarities and differences in their work practices regarding ergonomics.

4.2.2 Procedure

After creating several categories based on responses from both data sets, it was decided to focus Paper II on the participants' relations with other stakeholders, and how those relations affected their perceived influence on the workplace. This included reports of the participants' experiences with "the other" profession (i.e. ergonomists' interactions with engineers and vice versa). Interactions with two other main stakeholder groups that emerged in the data were also reported upon: Management and front-line Employees.

The interactions between stakeholders were understood to be distinctly political in many cases. To acknowledge these aspects in a structured way, the results were reflected upon using a theoretical framework of *Power Bases* (Buchanan and Badham, 2008) to classify the behavioural strategies the participants used to advance ergonomics goals in an organizational, political environment.

4.2.3 Results

The results of Paper II showed that because of organizational placement and varying levels of trust from other stakeholders, ergonomists and industrial engineers are differently enabled at the outset to influence ergonomics. The two professions reported very different perceptions about the freedom inherent in their role, with industrial engineers seeing themselves as empowered, independent improvement agents while ergonomists frequently supplied advice or viewed themselves as an expert advisor or internal consultant, or as a mediator or "go-between" between management and employees. In contrast, some industrial engineers reported that employees sometimes regarded them with suspicion as "part of the employer", and many participants reported that building

good rapport with employees was a crucial facilitator to getting acceptance for changes.

Ergonomists also reported that their interactions with engineers were often characterized by a lack of understanding for what ergonomists could contribute to design, and sometimes they would be restricted to a purely consultative function. Communication with engineers might therefore require specific persuasion tactics, such as communicating with numbers and metrics. Several participants also reported strategies for aligning their objectives with those of other stakeholders, to secure approval.

Both groups acknowledged the importance of having management support for ergonomics on a high organizational level, and making use of the work-related knowledge that employees possess. Both groups also reported some resistance at higher levels to implementing large-scale ergonomics changes, which they would mitigate by advocating "quick, cheap and easy" solutions first to "get the ball rolling".

In terms of *power bases,* both ergonomists and engineers primarily used the *expert*[3] power base to exercise influence, followed by *affiliation*[4] . Industrial engineers were more able to use the power base of *authority*[5] than ergonomists thanks to the high level of trust awarded to them by management. A power base that may increase in importance is the *referent*[6] power base, due to the prevalent strategy of aligning objectives and building good rapport with other stakeholders.

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[3] Having superior knowledge to the task at hand.

[4] Meaning that the participant is associated with an authoritative stakeholder that they "borrow" power from.

[5] Having authority, via rank or position, to give directions.

[6] Having desirable abilities and traits that can and should be copied.

4.3 PAPER III – "AVENUES OF ENTRY"

4.3.1 Procedure

Paper III was based on the same qualitative material and basic comparison premise as Paper II (the combined interview series with ergonomists and industrial engineers), and is identical up to and including the first author's constructing of categories (Dey, 1993) based on themes from both data sets.

The analysis focus in this paper was placed on how participants position themselves in relation to an issue when advancing an ergonomics agenda in their organization. Three categories emerged: perceptions from participants on what they can do in their role, prioritization of ergonomics in their organization, and how ergonomics could be tied in with other concerns. The paper discussed barriers and enablers to ergonomics practice related to control over ergonomics issues, persuasive techniques, alignment of ergonomics goals with those of other stakeholders, and relational rapport-building to gain acceptance. The results were discussed using a framework elaborating different ways that stakeholders relate to an organizational issue (suggested by Jonker and Pennink, 2010).

4.3.2 Results

Paper III proposes that the ergonomists' degree of influence on ergonomics is modest in comparison to that of the industrial engineers. In some accounts, this was explained by the ergonomists being organizationally distant from stakeholders in control of issues, e.g. engineering. Many ergonomists recognized that they themselves were not in a change agent role, and counteracted this by striving to gain access to workplace issues through a problem-owning stakeholder, aligning their objectives to that person's, and using tailored communication (such as formulating benefits in numbers and engineering metrics) to persuade other stakeholders that parallel benefits could come from ergonomics initiatives. Both groups emphasized the importance of getting management support (finding a "champion") and placing accountability for ergonomics on an upper-level superior. This was frequently achieved by using 'embedded' strategies such as ergonomics checklists for engineering, and management-level scorecards.

It was revealed that both ergonomists and industrial engineers had found it hard to implement long-term sustainable improvements since management quite often had an attitude of wanting to "get rid of problems" as quickly and cheaply as possible and then move on to other concerns. Perceived cost avoidance would often be a major driver for management preferring short-term interventions.

The paper proposed that a problem-owning stakeholder should be operationally defined as having 1) the mandate to determine when a problem has been solved, 2) is the most direct "avenue of entry" to the problem issue, and 3) can assign the problem-solver role to others. It was also proposed that three types of *"partial solution contributors"* should be recognised: 1) the *expert*, who provides decision support, 2) the *lobbyist,* who steers the solution in a particular direction, and 3) the *facilitator,* who breaks down the issue into smaller, more feasible components.

Some accounts indicated a gradually increasing acceptance for ergonomics as a legitimate issue and greater ability to discuss ergonomics in engineering terms, suggesting a cultural shift in many organizations. Still, some participants reported that some resistance or scepticism remains among older engineers who have not had ergonomics as part of their training.

4.4 PAPER IV – INDUSTRIAL CONTEXTS

4.4.1 Procedure

This study was also carried out in Canada. Drawing on the experiences from Papers II and III, the author intended to explore further the influence of stakeholders and the industrial context surrounding the person made responsible for human factors and/or ergonomics (called the HF agent in Paper IV) in a production organization. This study was carried out as a comparison study, where the author interviewed HF agents at four different industrial production companies (from the automotive, nuclear, poultry and auto parts sectors) and from there-on started a 'snowball recruitment' of up to three of the HF agent's close colleagues with other responsibilities. The intent was to compare the four case companies in terms of how the organization and practices at each company affected the HF agent's work with proactive and/or reactive ergonomics. All

interviews lasted between half an hour to one hour, and were audio recorded and fully transcribed.

The interviews were semi-structured and covered a variety of aspects regarding the work practices of each participant, focusing on the extent to which their involvement with ergonomics was proactive (design-related) versus reactive (improvements to existing systems). The perspectives of the non-HF-related stakeholders provided a deeper understanding of organizational industrial objectives, ideals and constraints that governed the way that human factors was approached.

With the intention of standardizing which aspects were compared across the four case companies, the author used a soft-systems framework proposed by Kirwan (2000) to guide the comparison. The framework is based on a sociotechnical "soft-systems" view and characterizes human factors work in organizations at seven different levels, starting close to the HF agent and expanding outwards towards societal environmental levels (see Frame of Reference).

4.4.2 Results

The study suggests that the company context-specific factors such as procedures, collegial relations, processes and culture all heavily influence the "infrastructure" the HF agents can make use of to advance and sustain a human factors/ ergonomics (HFE) agenda. Enablers for systematically improving HFE issues include vertical support in the company hierarchy (support and resource allocation from top-down, solution input and acceptance from bottom-up), technical tools and resources for demonstrating HFE benefits, and proceduralized accountability for HFE in projects.

Favourable conditions for HFE improvement were also discussed on different hierarchical levels. The importance of communication forums and technological interfaces that facilitate systematic follow-up of HFE alongside other concerns was emphasized by the participants. Some companies used electronically based systems for engineering processes where the HF agent's input was required. This appeared to be a successful way of ensuring HF involvement, since several participants reported that previous paper-based systems had a tendency to 'slip

by' the HF agent. In general, it seemed that formalized engineering change procedures with mandatory HF agent sign-off strengthened the HF agent's role regardless of their organizational position and 'rank'. External influences such as regulatory bodies, legislation, current societal events and ideals and historical events had influence on each company's HFE activities and priorities, but such influences mostly appeared to be very specific to each industrial sector (e.g. historical nuclear disasters still influence public perceptions towards nuclear power; conversely, a recall of fresh meat from the poultry factory was mainly considered a food hygiene issue, which transferred company focus and resources away from HFE temporarily). Finally, the extent to which HFE had been integrated into companies could be described as ranging between different 'maturity' levels, ranging from a phase of proving and justifying the worth of ergonomics to a phase of HFE integration into organizational structures, processes and culture.

The companies that were best able to handle HFE issues proactively had reached a phase where HFE input was procedurally required in all new project start-ups and the HF agent had a sign-off role. They had also, on a high organizational level, established linkage between HFE improvements and business objectives. In the least enabled companies, HFE was considered a pure medical or Health and Safety concern, and the HF agents were dependent on their own industry sector knowledge and ability to manoeuvre themselves into forums where their input might prove useful. Those agents were well aware of the need to emphasize how much productivity and business concerns could be improved with better ergonomics.

5. DISCUSSION

This section discusses general implications and evaluates the research from a research-methodological point of view.

5.1 GENERAL REFLECTIONS

The intellectual goal of this research started as an endeavour to understand what kind of information output from ergonomics evaluation methods would meet a company's needs, but over time the goal transformed into a desire to develop a deeper understanding of the organizational context that such methods are launched into. What was finally generated from the sum of the research was a stratified understanding of how ergonomics practitioners make sense of their contribution in a production system context, and how much they perceive that they are able to do given the organizational, relational, business-related and technological circumstances.

Performing these studies expanded the scope from a user-requirements perspective to one that includes corporate-cultural, political, tactical and hierarchical dimensions. It is the author's understanding that without knowledge about these dimensions, any technology (or 'vehicles') used to further ergonomics – no matter how sophisticated their inner workings or how good their intentions – may never enable ergonomics to 'arrive' if there is a lack of 'ergonomics infrastructure' in a company. (To draw the traffic metaphor just a little further, there have been 'carpooling' efforts where ergonomics rides along with other concerns in the same 'vehicle', such as in the cross-disciplinary digital reviews used by a case company in Paper IV – the success of such integrated efforts seem to imply a higher degree of sustainability for ergonomics involvement, especially in a proactive sense).

It seems that to be an ergonomics practitioner – in a setting where ergonomics is not yet fully embedded into company business and engineering processes – requires the ergonomics agent to have industry-specific experience and a certain degree of political awareness in order to successfully build rapport with

stakeholders that 'own' the ergonomics issue . Another requirement is to realize what other stakeholders are striving for and persuade them that ergonomics goals can be harmonized with their objectives. In many cases the practice of ergonomics improvement is decidedly political, therefore it seems to the author that it would be prudent for developers of tools, software, procedures, checklists etc. to gain a deep understanding of how the objectives of multiple stakeholders latch onto and are affected by ergonomics changes, sometimes in a negative way.

5.2 DISCUSSION OF PAPER RESULTS

The results of the comparison in Paper I showed that the two methods, which had apparently been considered interchangeable for ergonomics monitoring purposes, actually generated data that addressed different problems (one was task-based, one holistic). The non-agreement observed in evaluation scores were most likely caused by differences in acceptability criteria, but also by undisclosed agendas on the part of the evaluators. The fact that the methods both used the same red-yellow-green scale to report evaluation outcomes raised the concern that different groups within the company might end up misunderstanding each other due to differing traditions of how to interpret the intermediate yellow level.

The results of Paper I awakened a curiosity. Why was it that a company could decide to switch from one evaluation method – which quite apparently was placing ergonomics capability in the hands of production-floor stakeholders – to another, which was generically formulated and depended on the solid expertise of occupational health specialists? This seemed akin to moving away from democratization of ergonomics, towards letting it be the domain of an exclusive group of experts. The reasons behind the switch appeared to have nothing to do with insufficiencies in the methods (or the evaluation results) themselves, but rather with the pragmatic fact that the original evaluators felt that they were being burdened with extra work. This was a first clue to realizing that ergonomics methods, in and of themselves, are not enough to ensure healthy workplace ergonomics (i.e., an instrumental view): the needs and objectives of the stakeholders who generate and use that information (a sociotechnical systems view) must be established.

In the second and third papers, individual work-practices accounts from Canadian industrial engineers (IEs) and ergonomists were compared and contrasted. It was considered reasonable to believe that these two professional groups share a domain of responsibility for ergonomics in many industrial workplaces, and that there is a supposed 'closeness' between the two professions because they are both tasked with workplace HFE issues. Among other things, the study found that having an ergonomics specialist present in the organization was not necessarily a common experience among IEs, while the majority of ergonomists had some experience of working with engineers. It was found that the influence of other stakeholders on HFE issues was significant, and that especially ergonomist practitioners needed to build supportive relationships with more empowered stakeholders. IEs appeared to be more organizationally empowered and free to implement improvements (on a local level) while ergonomists were more often limited to an advisory role. Ergonomists found that engineers sometimes lacked an ability to understand what ergonomics could contribute to improvements at early project stages. Participants from both groups needed to be politically-minded and align ergonomics recommendations with the objectives of other stakeholders. They reported using strategies such as linking ergonomics to business metrics (e.g. cost-, waste- or injury rate reductions), securing management support, and starting off larger initiatives by first advocating low-effort solutions with a quick cost-benefit payoff, to demonstrate the benefits of ergonomics improvements.

Although the evidence is not conclusive in Paper II, the results suggested that there are several characteristics of how the studied practitioners perceived the essence of their role (improver vs. mediator), their influence on the workplace (direct vs. indirect), and their ability to independently make informed ergonomics decisions (level of confidence in ergonomics knowledge). Another finding of Paper II was that ergonomics agents use different tactics for persuading other stakeholders to agree with their recommendations using different "power bases" (Buchanan and Badham, 2008). This study raises the notion that increased awareness among practitioners of different power bases could benefit their ability to persuade empowered stakeholders to support an ergonomics agenda.

Paper III looked closer at positioning, strategies for persuasion ("goal-hooking") and the meaning and importance of "problem ownership". Especially ergonomists should be mindful of the organizational path they take towards a problem, and if possible should try to gain access to the issue via a problem-owning stakeholder. Although the notion of 'owning' a problem or relating to a problem owner implies an ability to directly decide what would be a sufficient solution to a problem, not much formal definition exists – therefore, Paper III used the study data to elaborate further on the concept of "problem owners" and "solution contributors", demonstrating that *owners* need to have the mandate to determine when a problem has been solved, and that *solution contributors* (rather than problem solvers) may fully or partially contribute to a solution; among the participants, it was found that *partial* contributors appear in the form of *experts* (who give knowledge input), *lobbyists* (who steer the problem in a specific direction to solve another agenda in parallel) and/or *facilitators* (who break down the problem or convince empowered stakeholders such as problem owners that the effort and resources involved are manageable).

The results of Paper IV imply that paving the way for communication, follow-up, accountability and association of ergonomics with engineering significantly enables a company to work proactively (i.e. at the design stage, in a preventative manner) rather than reactively. Different industrial sectors also seem to have different levels of cultural acceptance for the legitimacy of ergonomics. Those that have understood the 'ripple' effects of improving ergonomics seem better poised to tie in the role of the ergonomics agent with engineering processes, often upholding the ergonomics agent as important enough to be a sign-off role. Companies who focus on medical aspects, worker injury, absenteeism and on avoiding injury claims appear to have an instrumental, rather than systemic, view of ergonomics involvement. In the comparison, it appears that the most empowered ergonomics practitioners have had their involvement "embedded" into engineering processes, most often as a result of positive attitudes from upper-level management towards ergonomics effects on business. Further embedding the tracking of ergonomics by using management 'scorecards' seems to strengthen the status of ergonomics as a valid business concern. Suggested future research (based on this study) is to specifically examine how ergonomics agents' industrial

sector expertise affects their ability to persuade other stakeholders to improve ergonomics.

To summarize the knowledge gleaned from this body of research, it seems valuable for both ergonomics practitioners and upper-level management to be aware of the more systemic influences of *how* ergonomics is enabled in an organization, paying attention not only to the instruments and personnel put in place to ensure that ergonomics is monitored and improved, but also to the pathways that enable ergonomics agents to communicate with other company stakeholders whose influence over the issue may be vital to integrating ergonomics into company goals.

5.3 METHODOLOGICAL EVALUATION

5.3.1 Paper I

Paper I begins with the assumption that the results from two different ergonomics evaluation methods used in the same factory can be compared in a quantitative manner, since both methods generate results on the same type of red-yellow-green scale.

Also, the method of comparison in Paper I rests on categorization and reduction of data from the two result sets. The whole study is presented as a corporate-specific case study, where a) the comparison results cannot be directly generalized per se and b) the sample upon which the quantitative results are based is highly representative, but not selected at random. In other words, a purely quantitative comparison could not be interpreted or explained. To address these drawbacks, the comparison was ventilated in two group interviews with selected actors from the company who had insight into the usage of the two different methods. The research design evolved in an emergent fashion, with the qualitative part 'added on' as it emerged that a purely quantitative comparison would be difficult to justify.

Although the quality of the material itself has not been questioned in Paper I, it should be mentioned again that the two evaluations were performed by two different actor configurations (multiple line-based teams of three, vs. one factory-

wide team of two). Thus, there is reason to suspect that the evaluation data from either method, although similar in output, were collected for different end users and for different purposes because of who collected them.

The quantitative analysis was preceded by qualitative preparation work, in the sense that the material needed to be categorized and filtered in order to be numerically compared. For example, only workstations that had been evaluated by both methods were taken into account in the qualitative comparison (i.e. no random sampling) and since both methods arbitrarily reported specific body segments under load, the four most prevalent 'complaint segments' were compared and the remaining segment categories discarded, leading to further elimination of stations in the sample. The qualitative element of Paper I (the interviews) was considered essential by the authors in order to make sense of the quantitative results, which were saturated with constructed (context-specific) meaning not accessible to an outsider.

The strength of Paper I, method-wise, is that the combination of quantitative and qualitative methods gives added insight into a quantitative result that by itself is no indicator of a clear tendency. In all, the usefulness of the results increased thanks to the combination of methods. However, the basic criteria for evaluating reliability and validity regarding this study must take into account that the study itself is very context-specific (unique to both company and country). The paper itself gives a thick description of the studied evaluation methods, the circumstances at the factory, the personnel involved and also directs the reader to source material that tells more about the context, which hopefully enables future researchers to determine transferability to another context.

The external reliability (i.e. the study's replicability) in Paper I can be said to be low in the sense that the context and material made the results very situation-specific. However, the procedure for the actual quantitative comparison is richly described in the paper, as well as the context, actors and methods involved in the comparison. This alludes to Lincoln and Guba's (1985) quality criteria of *Transferability* – with the aid of the supplied thick description, future researchers should be able to decide whether other case contexts readily lend themselves to what was done in this study and can at least replicate the same principles for

sampling and comparison categories as in the paper. On the downside, the description of the qualitative work offers no direction as to what manner of questions were asked. The unstructured interviews were not audio-recorded, but noted down as the interview progressed. In a sense, the on-site note-taking made the subsequent analysis easier, as some of the filtering and categorization of answers was performed simultaneously with the data collection. On the other hand, the strong influence of the corporate context and personnel involvement was the major reason for allowing the interview to progress in an unstructured manner (making replicability virtually impossible to attain at the outset). Additionally, the results were affected by group dynamics between the interviewer and the interviewees (*reactivity*), the corporate context and the fact that the results were 'filtered' by the method of notation.

As for *internal validity*, or the match between what is observed and the theories developed, the degree to which this is fulfilled could be considered both high and low in Paper I – mostly because the authors have been very cautious about drawing conclusions based on the quantitative material, opting instead for basing conclusions on the synthesized results of the two data collections (and doing this very cautiously as well, stating that explanations for the quantitative results in this particular context arose from the qualitative interviews). In line with Lincoln and Guba's (1985) suggested criteria to ensure *credibility*, one might say that the research design involved at least a small element of triangulation (by combining quantitative and qualitative data collection; Bryman and Bell, p. 412). Also, one of the interview respondents was involved in proofreading the paper and giving feedback before submission – a form of respondent validation.

5.3.2 Papers II - IV

Papers II, III and IV were all carried out using the same succession of research techniques (semi-structured individual interviews, audio recording and transcription, a coding/categorization process and relating of the results to a chosen theoretical framework); therefore they are discussed together in terms of methodological considerations.

The main contributions of Paper II are 1) to offer deeper understanding for the political ability of ergonomists and industrial engineers to influence ergonomics based on their relations with other stakeholders, and 2) to add to this understanding by pointing out which behavioural strategies – power bases - are utilized and underutilized by these professionals to achieve implementation. This knowledge may benefit ergonomists and industrial engineers, as well as higher-level management wishing to leverage ergonomics expertise by assembling the right kind of organization around their ergonomics professional.

In all of these papers, one strategy to mitigate threats to validity and trustworthiness was the use of "rich" data (Maxwell, 2005 p.p. 109-110), in terms of detailed and varied accounts and verbatim transcription. As far as possible, the effects of researcher bias were minimized by grounding the theories in the verbatim data and reporting verbatim accounts. *Reactivity* - i.e. the effect of the researcher on the setting or individuals studied – was not actively mitigated in the research design, but taking part of the verbatim transcripts could make it evident to a reader if any misunderstandings or "missed nuances" could have affected the theories drawn from the data. As far as possible, conclusions were based directly on verbatim interview segments. Also, as a form of respondent validation, the completed transcripts were also offered back to interviewees in order for them to correct or amend any inaccuracies. In these ways, the researchers involved in Papers II-IV have strived as much as possible to provide evidence that the results are trustworthy, although it is impossible, for reasons of parsimony, to avoid some summarizing and condensed descriptions of the rich data. In terms of Lincoln and Guba's (1985) trustworthiness criteria, the transferability and credibility of these studies is not immediately evident in the papers themselves, since they do not supply the interview guides or transcripts – however, these can be accessed through contact with the paper authors, since participants have signed a release waiver that the results may be used once they have been de-identified and checked by interviewees for sensitive information (*member checking*). This, along with the reported criteria for sampling, the multiple verbatim quotes in Papers II and III and the thick descriptions of the four case companies in Paper IV, should certainly support readers in judging whether the procedure is transferable to other contexts, and most certainly the same themes can be explored in other settings. Thanks to

the transcripts, *confirmability* (the extent to which results are rooted in the data) is also strong since the quotes in the papers link the authors' interpretations back to the raw data, and is further supported by the 'member checking' of interviewees. *Dependability*, or the methodological stability of the studies, is reinforced by a consistent use of the same categorizing process (which is described) and relation of the data to conceptual frameworks based in peer-reviewed literature to study phenomena and concepts.

In a sense, although it was not intended originally, the results of Papers II-IV are a successive accumulation of theory development 'grounded' in data, which was transferred onward – i.e., the results of Papers II and III ended up informing the purpose of Paper IV, whose results were also deeply rooted in data - something which in total could be labelled as "Grounded Theory" (Glaser and Strauss, 1967)[7].

5.4 DISCUSSION OF HOW THE PAPERS RELATE

It can be said that all four papers illustrate different aspects of how ergonomics work on a day-to-day basis may be influenced by organizational/relational constraints. Paper I was a prelude hinting at this state of matters, while Papers II-IV explicitly investigate the different influences on ergonomics agents' work.

The first study (Paper I), although originally performed for other purposes, pointed to a puzzling concern: why did neither of the two ergonomics evaluation methods, for all their intents and design, function as the impartial instruments of measurement and assessment that they were meant to be? As it turned out, such complex instruments are rife with underlying notions of what is organizationally considered acceptable, and the 'old' thinking among some stakeholders coloured the interpretation (and therefore acceptance) of the new assessment method, even though criteria were different. This illustrates that method failure cannot be

[7] However, it should be noted that this research did not follow a "Grounded Theory Methodology", as this entails a more rigorous and intentionally iterative approach (e.g. Shannak and Aldhmour, 2009).

attributed only to the methods themselves; it is also necessary to understand the context that the method is 'launched' into.

The three subsequent papers incrementally increased the focus on surrounding organizational context and the actors that operate in them, as the main subjects of inquiry. However, the context itself, with all its constraints and 'rules of play', was only accessible through the descriptions of the stakeholders, meaning that focus then had to be placed on the sensemaking and interpretations of the study participants. The results of Papers II and III, which were performed concurrently, influenced the base of inquiry and the choice of methods for Paper IV. Papers II and III were informed by individual participants from a wide array of organizations, and revealed many different approaches to persuasion and rapport-building among ergonomics agents and their (reported) surrounding stakeholders. However, not many conclusions could be drawn regarding stakeholder collaboration aspects. To address this, the last study (Paper IV) was designed to enable studies of how stakeholders related to each other within the same company. The complementary reports from each cluster of stakeholders in each case company enriched the understanding of how different organizational configurations affect decision-making and approaches to solving ergonomics issues, and the purposeful selection of different types of stakeholders surrounding the ergonomics agent (chiefly managers and engineers) raised concerns at different organizational levels. This led to a more stratified view of how ergonomics concerns were affected by not just the practitioner him/herself, but also by organizational structure, personnel-related chains of command, and contemporary views of society in general.

One concern regarding the papers which should be mentioned is the gap between them regarding time and space. The study in Paper I was performed in Sweden and based on material generated in 2006, while the three remaining studies were performed in Canada in 2009 and were based on data collections performed between 2007 and 2009. The implication of the different national backgrounds is uncertain, but the main concerns may be differences in educational programs and certifications for ergonomics practitioners, differing societal organizations for enforcing workplace ergonomics, differing focus of application and differing national laws and standards. Comparing the results of Paper I (Sweden) with

Papers II-IV (Canada) does not conclusively reveal any major differences in what ergonomics practitioners do. However, Hendrick (2008) once stated that ergonomics work is the same, in science and practice, throughout the world, based on the results of a 1996 survey performed by the Human Factors and Ergonomics Society (p. 418).

5.5 THESIS CONTRIBUTION TO ERGONOMICS LITERATURE

As described in the Introduction chapter, ergonomics literature is at the crossroads of many scientific disciplines and is therefore very diverse, with influences from medical, technological, psychological, and sociological approaches. It was also suggested that macroergonomics literature tends to focus on participative ergonomics, change perspectives and action research. The chief contribution of this thesis is therefore to focus on how ergonomics work in day-to-day settings is currently approached by practitioners – this contributes to an updated understanding of contextual constraints that influence the actions and strategies of ergonomics practitioners. It can indeed be suggested that surrounding circumstances shape the "repertoire" of approaches suitable for each ergonomics practitioner, and that for them it is essential to have a good grasp of their organization's surrounding stakeholders and 'ergonomics infrastructure'.

This research as a whole also provides a stepping stone towards translating inaccessible ergonomics knowledge into practical guidelines for engineering and design purposes, a need described by Hendrick (2008). An attempt to do so, and to synthesize the knowledge from each of the studies with existing literature, is described in the following chapter, *Tentative Framework*. What this framework does is to structure a data collection geared at making sense of the roles that are active in relation to any ergonomics issue, providing the investigator with mental models to characterize power configurations and how stakeholders position themselves in relation to the issue. The result is a practical guide for making sense of the 'ergonomics infrastructure' in a company and how different stakeholders are able to make use of it.

5.6 THIS RESEARCH AS A LEARNING PROCESS

The result of using so much empirically-based research has been that the author has enjoyed a profound learning experience based on a large repository of practitioners' experiences. The lessons learned regarding strategies that ergonomics agents use to navigate organizational conditions and constraints, provide considerable insight into the tactics and strategies they use to secure support, credibility and buy-in.

Checkland (2000, p. 36-37) describes a framework called the LUMAS model, which serves as a good tool for reflection on the learning process that resulted from the work done in this thesis:

"(…) a user, U, appreciating a methodology M as a coherent set of principles, and perceiving a problem situation S, asks himself (or herself): What can I do? He or she then tailors from M a specific approach, A, regarded as appropriate for S, and uses it to improve the situation. This generates learning L, which may both change U and his or her appreciations of the methodology: future versions of all the elements LUMAS may be different as a result of each enactment of the process shown."

This model illustrates that every time a user (researcher) approaches a problem situation with methods, learning ensues. This may end up influencing both the user and the way he or she perceives the methodology. In other words, this model states that no methodology usage can ever be consistent, and that while no conclusions can be drawn about the methodology itself, something can be said about the LUMAS process as a whole (Checkland, p. 37).

What this learning process has led to is that the experience and wisdom of all the interview participants has been brought together in a way that clearly points out areas of improvement of the ergonomics discipline, both as a science and a practice. The needs of practitioners seem to have less to do with increased measurement precision and more to do with facilitating persuasion of managers and problem-solving stakeholders on their terms, in their language and with their objectives in mind. The author proposes that a first step towards enabling ergonomics practitioners to become more persuasive is to "zoom out" to a

stratified, organizational-relational perspective and start any persuasion goal by determining: what does the 'ergonomics infrastructure' allow?

A guide[8] for how to answer this question, based on the results of this research, is described in the following chapter, *Tentative Framework*.

[8] It should be noted that the framework is as of yet untested, and requires validation, but should be regarded as a synthesis of the knowledge developed in this body of research.

6. TENTATIVE FRAMEWORK

Here, the author attempts to synthesize the findings of this research and relevant theoretical elements into a tentative framework, providing a guide for mapping out the "ergonomics infrastructure" surrounding ergonomics agents in a company.

The findings of the four papers combined with the existing theoretical models (see *Frame of Reference*) conceptualize the contextual and relational factors of a production system that may influence the ergonomics agent. Applying this knowledge may be helped by a mental model of how the different aspects relate to each other. Here, the author has constructed a *tentative framework*, in the form of a flow diagram and four Appendices (A – D) with guiding prompts to be used as a data collection guide for mapping the "ergonomics infrastructure" at a company. The result of performing this analysis is that the analyst is made aware of possible ways to proceed with addressing an ergonomics issue, while keeping the sociotechnical, relational and political context in mind. This knowledge informs decisions about how to access the issue, which collaborations to build, and how to proceed with solving it in harmony with other stakeholders' objectives ("goal-hooking").

The framework includes the following theoretical aspects:

1. Stakeholders as the main focus (as suggested in Paper I and Paper II).
2. The relation of surrounding stakeholders to the issue (or "problem" in the words of Jonker and Pennink, 2010, p. 7-8). The framework also acknowledges the amendments to the relational definitions proposed in Paper III.
3. The stratified sociotechnical "infrastructure" that exists in the company and is relevant to the problem (based on Kirwan's (2000) framework and the use of it in Paper IV).
4. Power bases (Buchanan and Badham, 2008; as discussed in Paper II) that the ergonomics agents use in interactions with surrounding stakeholders.

The data collection is organized using the workflow demonstrated in Figure 2 and the stepwise instructions that follow.

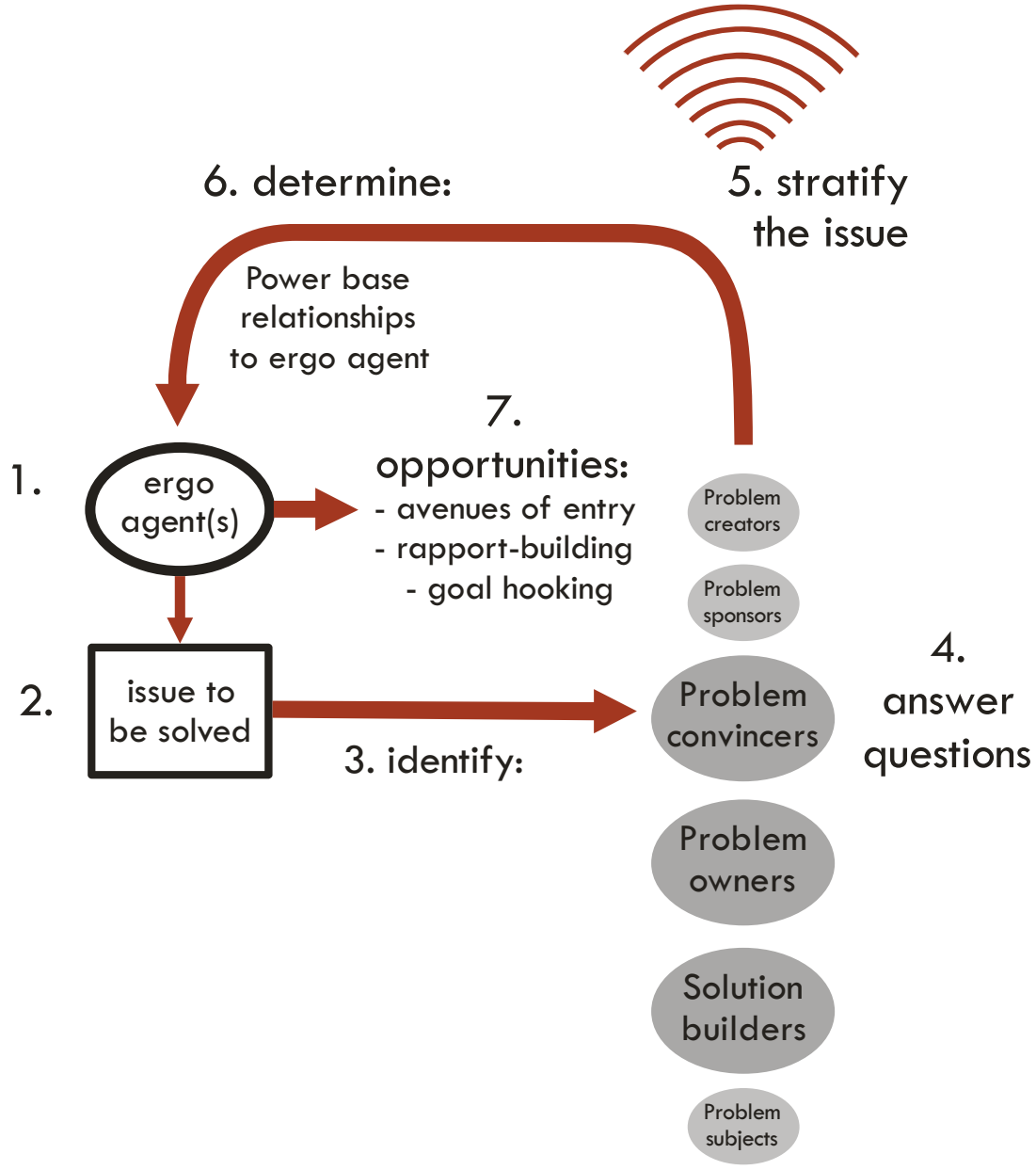

Figure 2: Mapping the results of this research into a data collection guide for identifying a company's "ergonomics infrastructure".

Suggested stepwise execution of data collection

Step 1: *Identify ergonomics agents (human and non-human)*

At this stage it is recommended to populate a list of all ergonomics agents both in the form of human actors and artefacts (such as checklists, tools, policies etc.). This is to ensure that the analysis covers the different ways that ergonomics work is manifested.

Step 2: *Formulate the issue to be solved*

This step should initially be expressed in as concrete terms as possible, but may be revisited and re-formulated if the findings from later steps reveal additional dimensions to the problem issue. However, formulating the issue to be solved at the outset provides a starting point (and the iterations may prove to be revealing in themselves).

Step 3: *Identify the stakeholders who relate to the issue*

This step helps to map out which stakeholders are directly or indirectly involved in the issue in terms of putting the issue on the agenda;, keeping it there for various reasons; convincing problem owners of the issue's legitimacy; having the authority to determine when the problem is solved according to established criteria; being tasked with solving the problem or contributing to the solution; and finally, being affected by the consequences of the issue, whether it be resolved or unresolved. *Appendix A* specifies the characteristics by which these stakeholders can be identified.

It may turn out that some stakeholders simultaneously adopt several of these relations to the issue.

Step 4: *Answer questions*

For each of the identified relationships between the issue and various stakeholders (from step 3), the analyst should answer the provided questions that reveal potential opportunities for rapport-building or

goal-hooking. The questions associated with each relation type are listed in *Appendix B.*

Step 5: *Stratify the issue*

The sociotechnical environment of the issue and the stakeholders needs to be accounted for. Using an adapted version of Kirwan's (2000) framework, *Appendix C* guides the analyst through different system levels where additional influences on the issue may be identified.

Step 6: *Identify Power Bases in relation to other stakeholders*

Using *Appendix D*, the analyst should reflect on which strategies for persuasion are used in the ergonomics agent's interactions with the stakeholders identified in step 3. For each of these relations, the analyst should identify power bases used in both directions (as some may only be applicable in one hierarchical direction; e.g. *authority* can be used by an upper-level management stakeholder on subordinates, but can rarely be reciprocated in the opposite direction).

Step 7: *Identify opportunities for using strategies*

The collected data may now serve to inform the analyst about which strategies are suitable for proceeding with a solution, based on the available "ergonomics infrastructure" in the company. The mapping out of the above aspects provides guidance for how to address ergonomics issues in a way that takes account of other stakeholders' objectives and abilities to influence the solution. This framework guide can be a valuable tool for pinpointing potential roadblocks to ergonomics agents *and* can serve as a discussion map for the organization to anticipate where inefficiencies or conflicts with higher-level objectives may arise.

The framework has yet to be tested and validated in empirical cases.

7. CONCLUSIONS

This section answers the research questions and summarizes the most important findings.

7.1 ANSWERS TO RESEARCH QUESTIONS

At this stage it is possible to attempt to answer the research questions posed in the introduction chapter:

RQ1 *Which ergonomics evaluation considerations are evident in approaches chosen by industrial manufacturing organizations?*

It appears that clear criteria of acceptability on a reasonably simple type of rating level (e.g. a stoplight-scale) are a popular option to ensure that results are understood by several actors. However, implicit factors may still cause differences in interpretation of such scales. Management should be aware of such risks when selecting an evaluation procedure, and especially when changing from one procedure to another. Depending on who performs evaluation and/or uses the resultant data to achieve intervention goals, corporate-internal methods can tailor evaluation methods to suit the 'units' considered the most relevant target for improvement, e.g. individual workers, workstations or product construction details.

RQ2 *Do relations with other stakeholders influence the ergonomics improvement practices of ergonomics agents? If so, how?*

Yes, stakeholder interrelations significantly influence ergonomics improvement practices among (industrial) engineers and ergonomists, demonstrating the political sensitivities of any ergonomics agent's role. The effects are varied and highly dependent on the political power relations and persuasion processes, as well as on the level of trust in the ergonomics agent from management and employee levels. Ergonomists seem to be in a lesser position of influence than industrial engineers and are more dependent on seeking support from and placing accountability on another stakeholder with problem ownership.

RQ3 *How do ergonomics agents relate themselves to ergonomics problems, and what strategies do they use in an industrial context?*

Different types of ergonomics agents – in this case, industrial engineers and ergonomists – may perceive *what* they are able to do differently, depending on their organizational positioning and access to the problem. IEs seem better positioned to solve ergonomics problems independently. Strategies for participants included gaining access to the problem by using better empowered stakeholders as an "avenue of entry"; assigning accountability for ergonomics with upper management "champions"; embedding ergonomics into engineering processes using checklists; using a quick, easy and low-cost solution to "get the ball rolling"; and using "goal hooking" strategies. The latter was used by both ergonomists and industrial engineers, with a tendency towards "goal alignment" strategies formulated to secure buy-in from stakeholders with other objectives than ergonomics.

RQ4 *How do industry-specific concerns, processes and organizational culture influence ergonomics practice and the HF agent's ability to address problems proactively and/or reactively?*

Companies that have integrated ergonomics involvement into their workflows and product development processes, positioning the ergonomics agent in a sign-off role, are (comparatively) better equipped to handle ergonomics issues proactively, i.e. in the product and production design phases. The corporate-cultural climate, business goals and ideals concerning ownership of ergonomics affects the nature of the integration on several system levels. The impact of the individual ergonomics agent's knowledge of their industrial sector can be of vital importance to further an ergonomics agenda; particularly in companies that traditionally have not regarded ergonomics as a legitimate issue, and do not yet have an integrated approach to ergonomics in their business and engineering processes.

7.2 SUMMARY

- This research has contributed to macroergonomics knowledge by focusing on the organizational/relational influences that constitute facilitators and barriers to day-to-day ergonomics work.
- It is proposed that industrial organizations should be aware that successful ergonomics improvements do not result from methods alone, but also from mindfully organizing relational support structures around their use.
- It was found that ergonomics agents are strongly influenced by their sociotechnical environment, relations with other stakeholders and industry-specific ideals regarding information needs and who should be held accountable for ergonomics.
- The following strategies that enable ergonomics agents to influence workplace ergonomics were identified:
    - rapport-building (establishing relations with other stakeholders)
    - gaining access to issues through an empowered stakeholder
    - placing ergonomics accountability with upper-level stakeholders
    - expressing ergonomics benefits in terms of business and/or engineering metrics
    - embedding ergonomics knowledge into engineering workflows using checklists, tools etc.
- Proactive ergonomics work is greatly enabled and facilitated by integrating ergonomics involvement into product development processes, with the ergonomics agent in a sign-off role.
- A synthesis of the research and its relevant literature has been made in the form of a *tentative framework* for mapping the "ergonomics infrastructure" in companies, combining the findings of the appended papers with some relevant theoretical frameworks from the literature.

8. FURTHER RESEARCH

This section proposes further potential areas of continued research.

Suggested further research is two-fold:

Firstly, the application of the knowledge generated by this research should be further investigated in empirical case contexts. In order to facilitate consistent application, the author recommends the use of the proposed *Tentative Framework* (Chapter 6) to guide a data collection that maps out a company's "ergonomics infrastructure". It is suggested that this framework be tested and evaluated in real cases as a strategic tool for ergonomics agents to decide how to proceed with solving ergonomics issues in collaboration with other stakeholders.

Secondly, the influence of organizational/relational aspects should be better incorporated in the development of new (instrumental) ergonomics methods, procedures and tools. Bringing this knowledge into method development could increase their chances of being connected with business objectives in companies and therefore more viable, persuasive and usable in contemporary corporate contexts.

APPENDIX A

Identify the stakeholders who relate to the issue (paraphrased from Jonker and Pennink, 2010 pp. 7-8, with amendments as suggested by Paper III).	
Problem creators	*Creators* (PCs) have the authority and power to put an issue on the organizational agenda. They bring attention to the issue and often assign its priority level. Once it is on the agenda, they delegate its solution to other stakeholders.
Problem sponsors	*Sponsors* (PSPs) are not directly affected by the issue, but without their support the problem might disappear from the agenda. Sponsors support the problem notion (for reasons that may be e.g. political, financial or emotional), but do not actively contribute to reaching a solution.
Problem convincers	*Convincers* (PCvs) convince decision makers of the need for action, often using measurement and quantification as evidence.
Problem owners	*Owners* (POs) are assigned 'rightful ownership' of the issue, and are often appointed during the process of putting it on the agenda. They have the mandate to determine when a problem has been solved to a satisfactory degree (also known as a "sign-off" role). They are also the most direct "avenue of entry" to a HFE/HS problem, meaning that other stakeholders can approach them to gain access to the problem. POs can assign the role of *problem solver* to others.

(Continued on next page)

Solution builders	*Solution Builders* (SBs) deal specifically with the issue and are responsible for examining, advising and eventually solving it. SBs can be *full* or *partial*, where *full* means having responsibility for deciding on and proposing the solution, and *partial* means contributing to some aspect of the solution with input, but not finalizing the solution. There are three types of *partial* SBs, who contribute to the solution with input or support: 1) *Experts,* who are solicited by POs or full SBs to provide a knowledge basis for decision-making, 2) *Lobbyists,* who approach the PO with a "sales pitch" and/or persuade a SB to solve the issue in a specific way, 3) *Facilitators*, who pave the way for a solution by toning down perceived difficulties, efforts or resource demands that may deter a PO from taking action – e.g. implementing a quick, easy low-cost solution before attempting a large-scale one, or breaking a larger problem down into increments.
Problem subjects	*Subjects* (PSUs), are the ones the problem is about. They are affected directly in their day-to-day activities by the issue, in terms of its consequences if it is not addressed, and in terms of the changes that may result from the proposed solution. PSUs may or may not be involved in the process where the PCs focus attention on the issue and bring it up on the agenda.

It should be noted that in the application of this classification, some overlap between stakeholder relationships to the issue may be identified. For example, the PO and SB may be the same stakeholder.

APPENDIX B

Answer these questions about the different types of stakeholders (identified in Step 3 of the Tentative Framework, Chapter 6) who relate to the issue.

Problem creators	• How did the issue come into focus? • What benefits are expected from solving the problem?
Problem sponsors	• What do they gain by keeping the problem on the agenda?
Problem convincers	• What competencies are expected of the convincer? • At what point in the process are they appointed, and by whom?
Problem owners	• When is the issue considered solved? • How can ergo agent gain access to issue? • Who is appointed problem solver by the problem owner?
Solution builders	• Who contributes expert decision support? • Who is lobbying a direction for the solution? • Who can break down/facilitate the problem?
Problem subjects	• How are they affected by the unresolved issue? • How are they affected by resolving the issue? • How can they be involved in the solution?

APPENDIX C

Identify factors on each of the following seven sociotechnical levels (adapted from Kirwan, 2000) that may affect the issue to be resolved:

Level	What to look for
Technical interface level	Where, how, and in what form does communication with other stakeholders take place, e.g. meetings, reports, correspondence, presentations, press releases?
Project level	How does the issue relate to project-related company functions such as Safety, Design/Engineering and Operations etc? How do stakeholders involved in the issue communicate? Is the issue addressed as a project or as continuous, day-to-day work? How long is the project duration? Is the ergonomics agent a team member or solitary actor,? What are the possibilities of using new ergonomics approaches or technologies? What is the potential to show business potential of an ergonomic solution?
Company level	The organizational department (or corresponding sub-unit) that the issue belongs to (relates to who is appointed as Problem Owner). Does this department have Access to the Problem Subjects? Is the proposed solution a short- or long-term one? Is there a requirement for ergonomic design compliance? Is there justification for an ergonomics perspective on the solution, depending on safety or other concerns? What is the time span for finding a solution?

(Continued on next page)

(Appendix C, Continued)

Personnel level	The effects of organizational positioning of the HF personnel in the overall hierarchy. Where in the hierarchy s the ergonomics agent placed? Does the ergonomics agent have access to stakeholders close to 'the top'? How good is the ergonomics agent'sunderstanding of business/product/ process aspects? What is the level of understanding and support from senior management? Can the ergonomics agent alignment ergonomics-related solutions to the company's needs and goals?
Extra-company level	The influence on the solution from organizations and entities outside the company Are there any regulators, governing bodies, national/ international standards that dictate the details of the solution? What solutions do competitors use? What industrial forums, academic organizations or operator-based organizations can be consulted for knowledge input?
Environmental level	The company HFE function's response to company-external events, values and cultural shifts How can government policies, corporate take-overs (or similar corporate culture change events), privatization, responses to incidents and accidents and public perception of related issues affect the choice of solution?
Temporal dimension	How far has the company has come in integrating ergonomics into its 'business missions' and work processes that are related to the solution? When in the system design life cycle is ergonomics usually involved? How long has the ergonomics agent's presence existed at the company and in what organizational form (e.g. person, committee, unit or department)?

APPENDIX D

Identify the Power Bases (paraphrased from Buchanan and Badham, 2008) used between the ergonomics agent and other identified stakeholders:	
Reward	The stakeholder has access to valued rewards which will be dispensed in return for compliance. Examples: Remuneration, praise, awards, compliments etc.
Coercion	The stakeholder can administer penalties or sanctions that are unwelcome. Examples: Use of threats, bullying, verbal and non-verbal put-downs, withholding of needed resources etc.
Authority	The stakeholder has authority to give directions, within the boundaries of their position or rank. Examples: Obligation of others to obey, 'playing the boss', abusing authority, exercising leadership in times of need
Referent	The stakeholder has desirable abilities and personality traits that can and should be copied. Examples: Charisma, friendship, sharing personal information, enforcing common values, viewpoints and preferences, reciprocal IOUs, providing something of value to others
Expert	The stakeholder has superior knowledge relevant to the situation and the task at hand. Examples: Possession of knowledge valued by others, given freely when solicited, helping others, unsolicited expertise, expertise offered in a condescending manner can be considered coercive, withholding expertise in times of need

(Continued on next page)

(Appendix D, Continued)

Information	The stakeholder has access to desirable information due to positioning or connections. Examples: Controlling of information flows, especially to and from superiors in a hierarchy
Affiliation	The stakeholder is associated with an authority source and 'borrows' power from that association. Examples: Acting as a surrogate for a superior, acting on superior's wishes, abusing the association to act on personal wishes, using negative affiliation power via rigid accounting and personnel policies
Group	The stakeholder is part of a group perceived as a rightful entity. Examples: Collective problem solving, creative brainstorming, conflict resolution, domination by a few individuals, "groupthink"

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