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How to measure added value of CRE and building design

Knowledge sharing in research buildings

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de rector magnificus, prof.dr.ir. C.J. van Duijn, voor een commissie aangewezen door het College voor Promoties in het openbaar te verdedigen
op maandag 17 februari 2014 om 16.00 uur

door

Henrica Anna Johannes Antonius Meulenbroek

geboren te Eindhoven
Dit proefschrift is goedgekeurd door de promotoren:

prof.dr.ir. B. de Vries
en
prof.dr.ir. M.C.D.P. Weggeman
PREFACE

My defence of this dissertation takes place around the time of my 10-year anniversary as an assistant professor at this university. Due to circumstances, it took me more than 8 years to finish this book. But although I have the tendency to have second thoughts about decisions that I made, I always knew that someday I would be writing this preface. I am very proud that this day now has come. And also, that I am able to express my view on the added value of corporate real estate for organisations with this book on knowledge sharing.

As a master student, I never imagined staying in the academic world. But the fast and commercial consultancy world I jumped into, soon started to bore me. I have always had a craving for learning new things, and what better place to gain knowledge than at the university. So, I switched back from practice to university and promised to start my PhD research. That my dissertation would regard corporate real estate was clear to me from the beginning. When I realised that I could gain knowledge about knowledge management, the idea for this thesis was born. Innovation was, and still is, a buzz-word in modern organisations, so what better goal for an academic than to help improve the innovative power of businesses. I have tried to make my tacit knowledge explicit in a little over 77,000 words. But the essence should be clear after reading the summary, which is much shorter.

Writing a dissertation next to a full-time job as assistant professor was not easy. When my husband and I became parents of our beautiful son a few years after I started, it became nearly impossible. Therefore, I am very thankful for all the support I have received over the years, and the knowledge that others have shared with me.

First, I want to thank Bauke de Vries and Mathieu Weggeman for questioning and evaluating this research as my supervisors. Thank you for sharing your own experiences and skills with me and for the positive attitude towards my ideas. In my turn, I supervised the thesis of 70 master students over the years, of which I need to thank two in particular. Ben Feijts and Yvette Ramakers, thank you for making the knowledge you gained explicit in your master theses, which helped me place my own research within a larger framework of strategy alignment.

Next, I would like to thank my current and former colleagues from the real estate management & development group. I always feel welcome to ask you questions or evaluate new ideas that come up in my ever-busy-brain. My absence must have made the already heavy work load for you even worse. I thank you all for your continuous help, and belief in my return. I specifically want to thank Jos Smeets for still warning me, when I start to run amuck again without taking time to rest. And thank you to my former roommates, Ingrid Janssen and Dave Havermans, for listening to the frustrations that every PhD student goes through.
I want to thank my parents for encouraging me to reach for the top and helping me go to university. Coming from a family where nobody has a degree, this must have required vision, patience and a lot of love and devotion. Thank you for believing in me and helping me build the skills I needed for life. I will make sure to hand them down to my son Davy, whose arrival has enriched my life enormously. His unconditional love and belief in my unlimited abilities, has given me more confidence and self-respect. I promise to share all my knowledge with him. As he is still very young, this leads to many fun discussions. Especially the next quote on knowledge sharing makes me think of him and smile:

“I know that you believe you understand what you think I said, but I’m not sure you realize that what you heard is not what I meant.”
Robert McCloskey

It was a bumpy road to get where I am today, which I would have stranded on permanently if it was not for my wonderful husband Alex! Thank you for co-creating the highlights of my life. And also for all your love and support when I hit rock-bottom. I know that, at times, I have demanded a lot from you. You will have my love and gratitude forever!

I hope to continue on for many more years gaining knowledge and sharing it with family, friends, colleagues and business partners. Because knowledge that is not shared, is not reaching its full potential.

"Wat is wijsheid die niet gedeeld wordt? Kennis wordt pas echt kennis als je in staat bent die aan iemand anders over te dragen. Het is het universele principe van geven om te ontvangen."
Anne Finch

Rianne Appel-Meulenbroek
Nuenen, November 2013
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Chapter 1 Introduction

Only a few decennia ago, Corporate Real Estate (CRE) decisions used to be made ad hoc and at the last moment, with no overall strategy in mind. Also, the real estate choices were often made without consultation and coordination with other important business units, such as human resources, technology, capital and communication (Gibler, Black and Moon, 2002). But as De Vries (2007) has shown, ignoring CRE does not only prevent an organisation from obtaining its potential benefits, but can even have a negative effect on the organisation. So luckily this is changing; lately real estate is getting more and more attention from general management. It has formed its own discipline named Corporate Real Estate Management (CREM), which is best described as: “The management of a corporation’s real estate portfolio by aligning the portfolio and services to the needs of the core business (processes), in order to obtain maximum added value for the businesses and to contribute optimally to the overall performance of the corporation.” (Krumm, Dewulf and De Jonge, 2000)

CRE is a costly resource, often the second largest behind labour cost (Pole and Mackay, 2009). Maybe therefore, general management mostly measures the performance of CRE with financial input indicators. Although the main goal for CRE might always be to limit these costs, the focus appears to be moving towards a cost/benefit ratio (Jensen, 2009; Pullen, Van der voordt and Hanekamp, 2009; De Vries, De Jonge and Van der Voordt, 2008; Nenonen, 2005). And ‘benefit’ in this ratio should be seen as a broader term, than just direct or indirect return on investments in real estate. Lindholm and Leväinen (2006) identified five additional (output-related) ways in which CREM can add value to the organisation. Besides direct return (‘Reducing costs’) and indirect return (increase in the ‘Value of assets’), these are ‘Promoting marketing and sales’, ‘Increasing innovation’, ‘Increasing employee satisfaction’, ‘Increasing productivity’ and ‘Increasing flexibility’. But as De Vries, De Jonge and Van der Voordt (2008; also De Vries, 2007) showed, it is still reducing costs that is aspired most, confirmed again by a survey of Corenet1 among 271 CRE managers worldwide (Gibler, Lindholm and Anderson, 2010). De Vries, De Jonge and Van der Voordt also mentioned a lack of outcome indicators to show the added value of these other five CRE strategies. Apparently, CRE managers know more about reducing costs than increasing revenue (Brown, 2008). This (previous) focus on unit costs and building condition rather than overall costs and business outcomes is the reason that CREM still keeps failing to capture full strategic attention (Price, Ellison and MacDonald, 2009).

“The idea that the workplace can be a strategic tool has been voiced by others... However, there is little evidence that this is true beyond a few case studies. Nor is there any viable knowledge of how such a linkage occurs and whether successes in

---

1 CoreNet Global is the world’s leading professional association for corporate real estate and workplace executives serving leading multinational companies from the Fortune and Global 1000; www.corenetglobal.org
one context can be replicated in others.” (Kampschroer and Heerwagen, 2005). More recent studies (Blakstad, Hatling and Bygdås, 2009; Steen and Markhede, 2010) still mention this import knowledge gap of empirical evidence in the field of scientific real estate research. De Jonge (2000) mentions how practice needs this gap to be filled too, in order to provide CREM with reliable techniques for quick pre-occupancy evaluations of designs or buildings. “The quality and value of architectural designs have been a matter of debate since the ancient Greeks organised a design competition in 448BC for the design of a war monument at the Acropolis” (Volker et al, 2008). Evaluation is what delivers the power to justify their decisions to general management, because it is a way of measuring both worth and value (Pawson and Tilley, 1997). Pawson and Tilley were the first to view evaluation from the viewpoint of critical realism theory (developed in the 1970’s). Critical realism stresses that scientists should improve the concepts they use to understand the mechanisms that take place when implementing new (CRE) programs. They coined the term Realistic Evaluation, as (scientific) research into the mechanisms behind the working of programs. It is a research theory trying to perfect a particular method of evaluation and thus relevant for CREM research on added value.

Previous research trying to evaluate CRE interventions shows several complicating factors. Often investments in real estate go hand in hand with other changes in the organisation, which makes it hard to separate the actual effect of CRE on the organisation (Bell and Anderson, 1998). Such before/after-studies may have shown an effect of CRE on the organisation (either direct/financially or indirect/effectiveness), but have not succeeded in explaining how this effect works. What is the underlying mechanism? Also previous studies relied mainly on qualitative descriptions of the workplace (e.g. collaborative spaces, open layout), making it hard to compare those (Franz and Wiener, 2005); and even harder to prove which mechanism(s) take(s) place. Examples of the few quantitative metrics that are used are workplace size, density or gross/net-ratios, which are mostly used to describe buildings and less to show their added value for outcome metrics. So there is a need to quantify CRE in measurable aspects and correlate these statistically to organisational outcome metrics, to identify the mechanism(s) through which CREM contributes to organisational performance. Stamps (2005) makes an interesting parallel to the difference between the work of Plato and his student Aristotle. Aristotle relied on verbal terms to describe the formal features of the environment, but Plato preferred to use mathematics. CRE research should have a look at the way of the master himself, as the Aristotle way is not helping them to add maximum added value, nor proves what they are helping with.

Besides this need for quantification of CRE, measuring added value is also troubled by a lack of outcome indicators for some of the added values. Direct and indirect return of the real estate itself can be measured in terms of money gained or lost with buying and later selling the land and properties on it. The added value of increased flexibility becomes visible in times of change. Flexibility makes it easier for the organisation to adapt their CRE to a new situation, which can also be expressed in terms of money. But Feijts (2006) suggests that although CRE is able to influence organisational performance directly, the indirect effects explain the majority of
performance changes. The other four ways of adding value to the organisation are such indirect effects, however, they are less easy to express in financial values. They do not only have an effect through the real estate itself but also through the behaviour of their employees (innovation, satisfaction, productivity) or clients (marketing and sales). Practice has picked up on this assumption of being able to add value through employee behaviour: “hundreds of companies ... have redesigned their buildings and workplaces with the intent of reshaping employees attitudes and behaviors” (Robbins, 2003). But evaluating whether these designs have succeeded in their goals is difficult and hardly ever done.

1.1 Problem statement
Looking at the modern western world (where CRE is most abundant), there is one added value in particular that organisations seem to strive for these days, namely innovation. Firms are convinced that their future depends on it, hoards of consultants try to sell their advice on it and at all government levels stimulating innovation has become a hot topic (Fagerberg and Verspagen, 2009). In the Corenet 2010 survey mentioned earlier, CRE managers were asked to rank the 7 possible real estate strategies. After reducing costs and increasing productivity and flexibility (mostly efficiency/financial metrics), encouraging employee innovation was the most important strategy focussing more on the outcome of the organisation.

The interest in innovation also becomes apparent from the amount of attention that scientific research is giving the subject. Fagerberg and Verspagen (2009) mention a particularly rapid growth since the early 1990s. Their survey identified over 5000 researchers in innovation studies worldwide. The Centre for Development of Entrepreneurs of the University of South Australia (2005) mentions on their website a bibliometric analysis of online databases, which produced a list of journals covering innovation, also showing that it is widespread in science.

Although innovation is getting attention from both social studies researchers as CREM practitioners, the added value of CRE for innovation remains to be hardly studied by academics, judging from several quotes throughout the years:

- “..with few exceptions there has been little in the way of formal research into the effects of the design of the workplace on the performance of creative or innovative organisations.” (Penn, Desyllas and Vaughan, 1999)
- “Research on creativity has focused almost exclusively on the social environment and organizational context. Very little attention has been paid to the physical work environment...” (Heerwagen, 2002)
- “Current empirical evidence of the effect of physical settings on the innovation process or R&D work is scarce.” (Kauttu, 2003)
- “there are few if any relevant studies on the physical environment and its influence on creativity and innovativeness in work situations for knowledge workers ...” (Hemlin, Allwood and Martin, 2004)
- “...there is still a lack of an approach, which combines the elements of workplaces and the fundamental structure of the learning process and knowledge creation...” (Nenonen, 2005)
• “...very few studies have considered the innovation process in relation to individuals’ and organizations’ day-to-day work patterns and the immediate spatial context they operate in.” (Toker and Gray, 2008)

• “even though normative knowledge and theories about office design advocate that open plan offices enhance learning and knowledge sharing, the evidence of this has so far been limited and anecdotal, with relatively little empirical evidence.” (Blakstad, Hatling and Bygdås, 2009)

• “Much work needs to be done to develop more solid knowledge of the spatial influence on the knowledge processes.” (Steen and Markhede, 2010)

• “empirical evidence on the impact of physical space on network formation is still scarce.” (Sailer and McCulloh, 2012)

Also, there is little accordance among the scholars that did study the subject on exactly how the CRE – ‘organisation outcome’ relationship exists (Sailer and Penn, 2009). As only the outcome is studied, inconsistencies across different initiatives have come forward (Koch and Steen, 2012a). So this is an added value of CRE that is worth to be studied in more depth. Realistic Evaluation is a relevant theory to study such mechanisms.

Both Berends (2003) and Van den Bulte and Moenaert (1998) point out that the importance of communication for successful innovation is well acknowledged by both practitioners and researchers, due to the extreme specialisation of knowledge workers these days. For effective innovation, people have to talk and share knowledge to advance the innovation process (Allen and Henn, 2007; Nenonen, 2005). It is long known that it is important to try and stimulate brief informal interactions when innovation is a high priority (Heerwagen et al., 2004). Communication and social networks are a mediator between innovation and places (Toker and Gray, 2008; Kautt, 2003; Wineman, Kabo and Davis, 2009). It is not expected that CRE can stimulate innovation of organisations directly. Instead, it should stimulate innovative behaviour like knowledge sharing to stimulate organisational learning and innovation.

In most Knowledge Management literature there is a distinction between explicit knowledge (information) and tacit knowledge (experiences, skills, attitude), first distinguished by Polanyi (1966). Especially knowledge that is more tacit is said to only be shared when spending time in the same environment (Nonaka and Konno, 1998). But more research is needed on the facilitation of different types of knowledge sharing (Berends, 2005). Studies that did look into the workplace and collaborative behaviour have focused more on technology for remote collaboration (Covi, Olson and Rocco, 1998) or solely on observation of brief interactions instead of collaborative behaviour (Heerwagen et al., 2004). The impact of space on complex behaviours as innovation is still an unsolved riddle (Sailer and Penn, 2009). It is expected that “designing for improved collaboration involves more than creating collaborative spaces.” (Brown, 2008).

If CREM can show general management that an investment in real estate can significantly add value through the amount of knowledge sharing, they will be more inclined to grant the necessary budget for real estate interventions. To evaluate
design quality, both tangible and intangible aspects can be taken into account. Clients prefer to base decisions on the tangible ones because they are less skilled to read plans (Volker et al, 2008). Also, they have difficulties in expressing what they need because of a functional fixedness on what they already know (Weber, Weggeman and Van Aken, 2012). So, to be able to show added value it is necessary to have suitable quantitative metrics and discover the underlying mechanism for evaluating CRE.

Therefore, the goal of this dissertation is:

To develop and test a list of suitable quantitative metrics that can prove through which mechanism(s) CRE(M) adds value to knowledge sharing behaviour within an organisation.

The problem statement is:

Which quantitative CRE metrics can prove the added value of CRE for knowledge sharing behaviour within an organisation, and how should CRE be managed to reach alignment with corporate strategy?

1.2 Research setup
The problem statement can be broken down in 8 research questions. The first 2 questions will be answered in chapter 2. Chapters 3 through 8 will each deal with one of the questions (in the order below).

1. How can CREM add value to the organisation and reach alignment with corporate strategy?
2. Which quantitative and qualitative CRE aspects have been identified to add value to an organisation?
3. What is knowledge sharing and what kind of knowledge sharing behaviour can be distinguished within an organisation?
4. Which CRE mechanisms exist and which quantitative metrics might prove their added value for knowledge sharing within an organisation?
5. Which methodologies are best to collect data on these quantitative CRE metrics in an organisation?
6. Which statistical tests can be performed on the CRE metrics to show added value for KS behaviour?
7. Are the CRE metrics suitable to prove through which mechanism(s) CRE adds value to knowledge sharing behaviour within an organisation?
8. How should CRE be managed to reach alignment with the corporate strategy?

Most knowledge work these days takes place in offices and office-like buildings (with mainly offices inside, but also some lab areas with low environmental/air demands).
The ‘suited-up’ laboratory work is a much more specialised process than office work and therefore left out of the focus of this dissertation. So when the term research buildings is used, this refers to office(-like) buildings where research & development (R&D) activities take place.

Previous studies have shown examples of the influence of context in studies of CRE and employee behaviour. Sailer and Penn (2009) studied the effect of proximity on frequency of interaction and showed that each organisation had a unique behaviour pattern as a result of the workplace environment. Blakstad, Hatling and Bygdås (2009) even showed a different effect of similar office space within the same organisation. Also De Vries, De Jonge and Van der Voordt (2008) showed that the impact of CRE cannot be isolated from the external context and from the organisational characteristics. As Koch and Steen (2012a,c) put it, the organisation itself and the space interact to form a certain spatial practice. Realistic evaluation puts context in a formula to show causation (see Figure 1-1). Others came to similar approaches, calling it CIMO logic and adding the I of Intervention (Weber, Weggeman and Van Aken, 2012).

\[
\text{Mechanism (M) + Context (C) = Outcome (O)}
\]

\[\text{Mechanism(s)} \quad \text{Context} \quad \text{Outcome (= change in KS behaviour)}
\]

\[\text{CRE metrics}
\]

\[\text{Figure 1-1 Causation according to Realistic Evaluation}
\]

Pawson and Tilley (1997) stress that the best way to find the causal mechanism(s) is to study within program variation in outcome of different subjects. Because the mechanisms take place in a large open system with many sub-systems inside, it is possible to only open the black box of the sub-system that you want to study and let the rest remain a black box (De Vries, 1997). This is a big advantage of Realistic Evaluation, because it provides the opportunity to leave the very many context variables influencing KS (culture, personal characteristics, etc. etc.) that are not within the expertise area of this dissertation outside of the scope of the fieldwork. So, we want to try and keep the context as constant as possible, to focus on identifying the mechanism(s) by studying the differences in outcome in KS behaviour.
for employees with different values on CRE metrics. The in-depth analysis of a single organisation is most useful to clarify causal mechanisms, because cross-unit variation is said to be mute with respect to causal mechanisms (Gerring, 2004). As the context and perhaps even the mechanism(s) might differ for each organisation (and thus also the outcomes) only one case is studied for this dissertation. That way it became an in-depth study of a known context for more scientific insight in CRE mechanisms. Plus, it could show the benefits of such a quantitative approach and realistic evaluation for CREM in practice. As Brown (2008) argues, the weakness of a field experiment (or case study) – that it cannot be generalised to a larger population – becomes a strength within the strategic context of an organisation.

Figure 1-2 The realist evaluation cycle (Pawson and Tilley, 1997)

Studies with the realistic evaluation approach stick with the conventional science wheel, as can be seen in Figure 1-2. One begins with identifying the theories that need to be tested, which is done with literature study on the added value of CREM in general (Chapter 2), Outcomes (Chapter 3) and Mechanisms (Chapter 4) in different Contexts. In Chapter 4 context-specific hypotheses are formulated. Hypotheses in realistic evaluation are not testable phrases, but presumptions of a context-mechanism-outcome configuration. Quantitative metrics are defined in this chapter too, to test these presumptions with two conceptual models. The Observations step of the cycle is done through multi-method data collection and analysis as discussed in Chapters 5-7. Chapter 6 also gives a more in depth description of the specific context of this study by describing how the employees at this case study share
knowledge. In Chapter 7 this context is further discussed through a face validity of the results with the case study stakeholders, to get to a program specification for renovation of this particular building. Chapter 8 looks back at the theories from the literature study and discusses the implications for CREM’s ability to show added value and obtain alignment with the needs of the client organisation. Chapter 9 contains the final conclusions and recommendations for further research (see also Figure 1-3).

Figure 1-3  Structure of the rest of the dissertation
Chapter 2 Corporate Real Estate Management

This chapter gives an introduction of CRE and CRE management (CREM) as a framework for this dissertation. The first paragraph will start with a short history of the evolution of CRE(M), followed by paragraph 2.3 on CRE strategy and its alignment with corporate strategy. Paragraph 2.4 describes how CRE can support different CRE strategies through its quantitative and qualitative aspects. This chapter ends with conclusions and the answers to the first 2 research questions.

2.1 History and evolution of CRE(M)
Krumm, Dewulf and De Jonge (2000, see also Krumm, 1999) have written an extensive description of the history of CRE(M). As they describe, up to the 19th century work related activities were usually deployed in the dwelling of the company owner or in adjacent buildings. This owner was also the responsible person to deal with management issues regarding the accommodation. Specific CREM departments did not come into being until the industrial revolution demanded more and more buildings to be constructed. This constant need for new accommodation lasted until long after World War II and thus kept the focus of these growing departments on construction activities. The international expansion of many organisations later in the 20th century was the first time that CREM was forced to show added value. Their focus on international growth increased a focus on how to allocate (financial) resources (Krumm, Dewulf and De Jonge, 2000). CREM had to compete with other internal departments to get the necessary funds for their tasks. To reduce costs, the use of external service providers increased.

The CREM departments of the industry sector preceded those of the services sector in professionalising, and also had to perform different activities (Krumm, 1999). The industry needed new accommodations, while the services sector was focusing on finding the best locations and limiting capital allocated to real estate assets. The recession following in the ‘80s of the 20th century increased general management’s attention for (the financial output of) CREM. The financial benefits of CRE (internal rental incomes and an increase of the real estate value) shrunk and CREM was forced into pursuing efficiency and still be effective in providing speedy accommodation. The competences of the CREM departments moved from highly-trained technicians to financial managers. A more central CREM department became popular, because it could provide more efficient space use and an increase of profitability, which were the real estate performance criteria of that time period.

Weggeman, Wijnen and Kor (2000) and Van Ree (2002) describe how the number of different organisational performance criteria in general increased over time, from effectiveness and efficiency in the 1950’s, through the addition of productivity in the 1960’s and 1970’s, flexibility in the 1980’s and creativity coming up in the 1990’s. But, the focus of CREM in many organisations remained solely on efficiency up till the 21st century. The other criteria that organisations did start to use to rate the added value of their primary process, were not applied to CREM. This is remarkable,
because for all 5 criteria it seems possible to identify the added value of CRE(M) for an organisation, for example:

- **Effectiveness** – facilitate supportive services and offer a varied work environment to support employee productivity in different tasks
- **Efficiency** – design with a favorable gross/net ratio in buildings
- **Productivity** – study cost/benefit ratio of investment in accommodation
- **Flexibility** – look for options in financing CRE and build-in extension possibilities
- **Creativity** – offer a design that stimulates innovativeness.

The academics, developing theory on different ways of adding value with CREM since the 1990s, have identified all of these performance criteria, but practice still seems not convinced of their relevance. Also, the interrelations between the 5 performance criteria make it impossible to choose only one and not influence the other. Especially effectiveness of the organisation through better CREM is disregarded a lot in practice, but efficiency metrics cannot be implemented without influencing effectiveness, and thus productivity. So the need for more attention seems evident.

### 2.2 Added value

With regard to added value, already in classic economic theory in the 19th century, a distinction was made between exchange and use value. With the former, the focus lies on cost (difference between output and input), so reducing cost by increasing efficiency leads to added exchange value. The latter focuses on the output: “qualitatively different and improved output by increased effectiveness leads to added use value” (Jensen, 2009). This distinction can also be projected on the ways CREM can add value (as described in chapter 1). CREM can deliver added exchange value through ‘Reducing costs’, ‘Increasing the value of assets’ and ‘Increasing flexibility’. Added use value should be sought through ‘Increasing innovation’, ‘Increasing employee satisfaction’, ‘Increasing productivity’ and ‘Promoting marketing and sales’. While exchange value lies fully within the expertise field of the CRE manager, he needs to tune with other business functions to be able to deliver use value (e.g. human resources, research & development, marketing & sales). The effect of CRE(M) on the organisation’s outcome is indirect for these strategies, and as the resource-based view stresses, coordination is essential to achieve synergy. The impact of CRE cannot be isolated from these other variables (De Vries, De Jonge and Van der Voordt, 2008), which makes it hard to prove the relevance.

To be able to coordinate with all these other business functions, CREM needs to be at the strategic table. But, although some CRE managers have long evolved into a strategic manager, many companies still see CREM as a technical rather than strategic issue. Ventuvuori et al. (2007) mention 3 paradoxes that cause this:

1. How can a strategic discipline have most practitioners situated at an operational level?
2. How can you be at the heart of organisational development, when many services are outsourced?
3. How can you be proactive, when up till now you are mostly reactive?

These thoughts hinder the possibility of CREM to be taken seriously by general management.
When CREM started to professionalise in certain organisation in the 1990’s, Joroff et al. (1993) developed a model with 5 evolutionary stages that CREM goes through to become a strategist (see Figure 2-1). Lambert, Poteete and Waltch (1995) later identified the tasks that could be assigned to each stage. As Krumm, Dewulf and De Jonge (2000) mention, the model is additive, so a business strategist will deal also with the tasks identified with the levels below him. The taskmaster is the CRE manager of the early days during the industrial revolution, whose focus lied on planning new buildings and maintenance and renovation of the existing stock. The controller focuses on efficiency through managing on costs. The dealmaker negotiates (as the name suggests) about leases, sales and acquisitions, but is still focusing on costs. The entrepreneur is the first stage where a real estate strategy is drafted and activities are benchmarked to make sure that added exchange value is delivered. The business strategist is the CRE manager that sits at the strategic table with the other business functions, and should be able to add both use and exchange value.

![Figure 2-1 Evolution of CREM (Joroff et al., 1993)](image)

A survey of 59 leading organisations that questioned the relationship of CREM with the other business functions (Bouri, Acoba and Wu, 2008) showed that only 40% of the respondents collaborated routinely with HR, IT and finance. Another survey of 87 organisations from New Zealand showed that 80% of the respondents indicated that real estate decisions were dominated by consideration of immediate business needs and not by strategy (Mc Donagh and Nichols, 2009). Roulac et al. (2005) is one of the rare studies that distinguishes industrial versus non-industrial companies and showed that of the industrial sub-sample even a mere 18% (versus 67% of the total sample) had a strategic CRE plan. So the majority of CRE managers has yet to climb up onto the higher levels in the evolution. And as Mc Donagh and Nichols state, CREM that is several levels removed from overall strategy, cannot maximise its contribution to the organisation. It is the essence of strategic management as
defined by Drucker (1977) that an overview of the entire organisation is necessary to make the right decisions.

In chapter 1, the following definition of CREM was given (Krumm, Dewulf and De Jonge, 2000): “The management of a corporation’s real estate portfolio by aligning the portfolio and services to the needs of the core business (processes), in order to obtain maximum added value for the businesses and to contribute optimally to the overall performance of the corporation.” If only CREM at the level of the ‘business strategist’ can add both types of value, this is the level that can provide maximum added value for the organisation. And the way this is done, is through alignment of the portfolio to the core business. Since companies can follow many different corporate strategies, achieving alignment means choosing an adequate CRE strategy to help support corporate goals. The next section will discuss CRE strategies and alignment to add value through CREM.

2.3 Strategy and alignment of CRE
Strategy comes from the word stratēgōs, which means a general. The field of strategic management contains a lot of military words, like objectives, mission, strengths and weaknesses (Swayne, Duncan and Ginter, 2006). This field started to professionalise in the 1950s with long range planning of demand. The increasing volatility of organisations (in the 1960s and 70s) demanded strategic planning, evolving in the 1980’s into strategic management. At that time, it became clear that a strategy continuously needs evaluation and adjustment. For the same reason, the alignment of the CRE strategy with the organisational strategy also needs to be monitored.

Ramakers (2008, see also Appel-Meulenbroek, Brown and Ramakers, 2010) compared studies on the alignment of CRE, finding only 8 journal articles on the subject, of whom 7 date from the 2000’s. So alignment has only recently received increased attention. These studies show concordance in their lists of possible real estate strategies. Nourse and Roulac (1993) were the first to determine CRE strategies. Their work has been embraced by some others (Roulac, 2001; Lindholm, Gibler and Leväinen, 2006). Around that same time De Jonge (1996) published a list of CRE strategies, that has been embraced by some European academics (Krumm and De Vries, 2003; Scheffer, Singer and Van Meerwijk, 2006; Lindholm, Gibler and Leväinen, 2006). Lindholm, Gibler and Leväinen combined both lists, because they almost covered the same goals, leading up to a complete overview of 7 CRE strategies (as mentioned earlier):

- Reduce costs
- Increase value
- Increase flexibility
- Increase innovation
- Increase productivity
- Increase employee satisfaction
- Promote marketing and sales
Looking at the corporate strategies, only half of the studies based their corporate strategies on previous work (by Tregoe and Zimmerman, 1980; Kaplan and Norton, 2000 or Porter, 1996), while the others ‘make up’ their own list. Because of this, the lists used to determine the corporate strategy differ greatly. This makes identifying a clear alignment difficult for CREM. As Ramakers concluded, there is still a lot of work to be done in studying the alignment of real estate strategies and corporate strategies. Up till now, the alignment process depends mostly on expert knowledge which is not available in CREM departments at the lower levels of the evolutions. A New Zealand survey (McDonagh and Nichols, 2009) confirmed this, because only 55% of respondents thought their property plan was well (or highly) aligned with corporate strategy.

Ramakers also suggested placing the alignment of CRE in the strategic thinking map of Swayne, Duncan and Ginter (2006), who distinguished between strategic thinking, strategic planning and strategic momentum (see Figure 2-2). For a long time real estate was seen as a ‘support strategy’, that was determined at the time of planning the implementation of corporate strategies for other business functions. Ramakers argues for it to be placed under the ‘directional strategies’ that are part of the initial strategy formulation. This is where the mission, vision, values and goals of an organisation are determined, and that is what CREM needs to support and be aligned with. Also, she recommends continuing the alignment further along the strategic thinking map towards the implementation and evaluation.

![Figure 2-2 Strategic thinking map (Swayne, Duncan and Ginter, 2006)](image)

To implement a chosen CRE strategy that would achieve alignment with the corporate goals, CREM must know what it is about CRE that will guarantee the right outcome for each specific CRE strategy. Feijts (2006) performed an extensive literature study on which CRE aspects have been proven to have an effect on an organisation. He identified 38 relevant publications of empirical studies, frameworks or experiences from practice. The authors behind these studies belong to several
different research areas, like ergonomics, environmental psychology, facility management, logistics, engineering, sustainability and indoor environments. This explains why CREM has such a difficult task, because ideally CREM would need to have knowledge on all these different areas of expertise. Feijts compiled a list of 51 CRE aspects that were proven to have an effect on organisational performance, through his content analysis of literature. The aspects are grouped by Feijts into the categories structural, installations and location aspects. Within these groups, he made a second classification, subdividing structural aspects in size (building, floor and workplace), installations aspects in general and specific and location aspects in parties, accessibility and environmental influences (see Table 2-1).

<table>
<thead>
<tr>
<th>Structural</th>
<th>Installations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building</strong></td>
<td><strong>General</strong></td>
</tr>
<tr>
<td>Orientation</td>
<td>Capacity</td>
</tr>
<tr>
<td>Building form</td>
<td></td>
</tr>
<tr>
<td>Building age</td>
<td>Energy</td>
</tr>
<tr>
<td>Amount of glass in facade</td>
<td>Controlling possibilities in general</td>
</tr>
<tr>
<td>Construction type</td>
<td>Controlling possibilities in specific locations</td>
</tr>
<tr>
<td>Expanding possibilities</td>
<td>Connection possibilities</td>
</tr>
<tr>
<td>Building depth</td>
<td>Standardisation of installation (units)</td>
</tr>
<tr>
<td>Building height</td>
<td>Technical condition of installations</td>
</tr>
<tr>
<td>Building volume</td>
<td>Connection of installation elements</td>
</tr>
<tr>
<td>Total amount of square meters</td>
<td>Production of noise</td>
</tr>
<tr>
<td>Number of floors</td>
<td>Production of heat</td>
</tr>
<tr>
<td>Building layout</td>
<td>Specific</td>
</tr>
<tr>
<td>Materials, forms and colours</td>
<td>Characteristics of ventilation installations</td>
</tr>
<tr>
<td>Standardisation of elements</td>
<td>Characteristics of lighting installations</td>
</tr>
<tr>
<td>Detailing of elements and connections</td>
<td>Characteristics of cooling installations</td>
</tr>
<tr>
<td><strong>Floor</strong></td>
<td>Characteristics of heating installations</td>
</tr>
<tr>
<td>Spatial characteristics and flexible elements</td>
<td>Characteristics of air moisturising installations</td>
</tr>
<tr>
<td>Floor layout</td>
<td></td>
</tr>
<tr>
<td>Materials, forms and colours</td>
<td>Characteristics of IT installations</td>
</tr>
<tr>
<td>Standardisation of elements</td>
<td></td>
</tr>
<tr>
<td>Control of environmental characteristics</td>
<td></td>
</tr>
<tr>
<td>Amount of glass in facade</td>
<td></td>
</tr>
<tr>
<td><strong>Room/workplace</strong></td>
<td><strong>Location</strong></td>
</tr>
<tr>
<td>Room/workplace layout</td>
<td>Parties</td>
</tr>
<tr>
<td>Materials, forms and colours</td>
<td>Proximity of labour market</td>
</tr>
<tr>
<td>Control of environmental characteristics</td>
<td>Proximity of selling market</td>
</tr>
<tr>
<td></td>
<td>Proximity of suppliers/sources</td>
</tr>
<tr>
<td>Amount of glass in facade</td>
<td>Proximity of related organisational departments</td>
</tr>
<tr>
<td><strong>Accessibility</strong></td>
<td><strong>Environmental influences</strong></td>
</tr>
<tr>
<td>Presence of supporting facilities</td>
<td>Charisma/image location and environment</td>
</tr>
<tr>
<td>Logistic infrastructure (airports, highways, railways)</td>
<td>Sources of noise</td>
</tr>
<tr>
<td>Accessibility facilities on site (e.g. parking)</td>
<td>Exposition, orientation and climate</td>
</tr>
</tbody>
</table>

*Table 2-1 Relevant CRE aspects (Feijts, 2006)*
In a continuing joint paper, an allocation of the structural aspects to each CRE strategy was attempted (see tables at the end of the next paragraph and also Appel-Meulenbroek and Feijts, 2007), which is described in more detail in the next paragraph. The installations and location aspect are also allocated to the CRE strategies in the next paragraph. The installation aspects are treated as one aspect only (called installations), because this specialised area does not lie within the expertise of this dissertation.

2.4 CRE strategies and CRE aspects
This paragraph shortly explains the allocation of the different CRE aspects to each CRE strategy (based on content analysis of literature). If a published study has proven effect of one of the CRE aspects on one of the strategies, then this is marked in the tables at the end of this paragraph. The working of the effect that was proven by other studies is discussed per strategy in the text below. First the ‘exchange value’ strategies will be discussed, which are most common to CRE managers and lie fully within their own expertise. Then the ‘use value’ strategies are discussed, which have an indirect effect on the organisation and require more coordination with other resources.

2.4.1 Exchange value strategies
The direct effect of CRE aspects on an organisation is often linked to minimising the operational costs of CRE to maximise exchange value. But besides the reduce costs strategy, also increasing flexibility and increasing the value of assets might be relevant, because all 3 strategies are interrelated. Minimising costs and increasing flexibility are not totally separable, as flexibility often requires extra investments, but can also save costs later on (Becker, 2002). Flexibility is also related to the CRE strategy increasing value of assets, as functional flexibility makes the market value of the asset higher. With more functional flexibility the real estate is easier to sell and for a better price (Nourse and Roulac, 1993). Even some ‘use value’ strategies (discussed later) are related to minimising costs in an indirect way, because productivity and satisfaction of employees can lower operational costs (e.g. sick days) and increase revenues (more output/person). These are not real estate costs, but organisational costs that are influenced indirectly by the real estate strategy. Each strategy will be discussed individually, but they are partly inseparable.

Reduce costs
The real estate costs can be divided in fixed and flexible costs. The fixed real estate costs (mortgage, taxes) are influenced by the buildings materials and the location, because they determine the initial investment. Also an investment in ergonomics (Hendrick, 1996) and the prevention of emission of harmful substances in the air (Seppänen and Fisk, 2004) saves employee costs later on. The flexible real estate costs are costs like maintenance and energy. Especially structural aspects like building form (depth/width), building materials, use of glass in the surface, orientation and usage of natural resources (night cooling, natural ventilation) may influence the energy consumption of the building (Mulligan, 1993; Mills, 1994; Todesco, 1996 & 1998). Mills adds that the control of users of the indoor climate influences energy use as well. The maintenance costs of the building may be
influenced by aspects like building age, floor height, construction type, material properties, fixation of elements and construction characteristics (Mills, 1994; Al-Hammad, Assaf and Al-Shihad, 1997; El-Haram and Horner, 2002). Van der Voordt (2004) adds that the building and floor layout are relevant, because open layouts show lower refurbishing costs and faster moves of departments. Also, May (2009) shows an example of cost saving when better space allocation to employees in the layout is achieved. Canen and Williamson (1998) add that in production environments the building layout can also provide more efficient logistics and perhaps smaller stocks, which is an indirect effect of real estate on organisational costs.

The installations type can have a lot of effect on energy costs (Mulligan, 1993; Mills, 1994; Todesco, 1996 & 1998). Also, with regard to location aspects, the same CRE aspects that influence organisational productivity are relevant because they might save organisational costs, influenced indirectly by real estate decisions.

**Increase flexibility**

Flexibility is important for organisations in markets that change fast, which is the case for more and more sectors in the modern economy. There are 3 forms of flexibility, namely physical, functional and financial (Gibson, 2000). Financial flexibility is not an issue here, but entails for example using short term leases with specific options (Lindholm, Gibler and Levainen, 2006). Functional flexibility means that changed activities can still be accommodated. Physical flexibility (adaptability of the building) is extensively described by Arge (2005) for office buildings, mentioning several building aspects and the installations. Building aspects mentioned were building depth, floor height, fixation of construction elements and the layout of the building with the accessibility of different facilities. Slaughter (2001) stated earlier that the construction type, surface finishing and standardisation are ways to increase flexibility. The floor layout is relevant, because open layouts provide more flexibility (Van der Voordt, 2004; Nourse and Roulac, 1993), just like the position of facilities in these layouts. The location can add to this strategy if it allows future extensions or reductions.

**Increase value of assets**

“*Valuation, in its simplest form is the determination of amount for which the property will transact on a particular date.*” (French, 2004). So that value is what this strategy seeks to increase. To follow this strategy, organisations need to own their CRE, what is still the case for some organisations (especially in Europe). As Brounen and Eichholtz (2005) show, CRE ownership differs strongly between different industrial sectors, but in general is decreasing over time. A possible reason is the appearance of studies that show a negative correlation between CRE ownership and company results (e.g. Deng and Gyourko, 1999), and an increase in profitability for stockholders if CRE is sold (e.g. Glascock, Davidson and Sirmans, 1991). The possession of CRE makes organisations vulnerable for real estate market risks. Also it is better to free up capital by selling CRE and investing it in the primary process, which should provide better yields because it is the expertise of the organisation. The past decennium many European companies sold their CRE. Sale-and-leaseback
transactions are a common way to free up capital, increase flexibility and also have tax advantages\(^2\) (Hordijk, Rompelman and Koerhuis, 2010). The new IFRS (International Financial Reporting Standards) regulations planned for 2016 will make all leases visible in the financial statements of (listed) companies. These changes will force companies to recognise and motivate the amount of CRE they use and why decisions to own and/or lease align with corporate strategies (Schelle and Baltussen, 2013).

With regard to relevant CRE aspects to steer on asset value, no extensive studies could be found. But Mansfield and Pinder (2008) state that: “it is clear that the depreciation of value is a function of two distinct negative processes: physical deterioration and obsolescence”. These come with age, but they point out that physical deterioration is property specific and obsolescence is even more unpredictable. According to Mansfield and Pinder, flexibility is the way to minimise functional obsolescence. So besides age and aesthetics/representativeness, the other structural and installations aspects would be the same as mentioned under the flexibility strategy. Nourse and Roulac (1993) agree that buildings that are easier to adapt and suitable for different types of users are easier to sell and for a better price than more specialised buildings. With regard to location, Mansfield and Pinder mention that environmental obsolescence is caused by increased noise and a changed infrastructure or image of the environment.

2.4.2 Use value strategies
Indirect effects of CRE through the effect on people that occupy the CRE have been studied most in office environments. People are the most expensive production factor, so using their capacity effectively needs to be a regular aspect of each business (Weggeman, Wijnen and Kor, 2000). Employees are influenced by physiological, physical and aesthetic CRE aspects (Chartered Institution of Building Services Engineers (CIBSE), 1999). The physiological aspects appear to be more relevant for production environments, while for the office environments physical and aesthetic demands seem more relevant (Feijts, 2006). The aspects might influence a person’s physical, mental and social wellbeing (which are also interrelated).

Increasing productivity and satisfaction are interrelated CRE strategies, because a lower employee satisfaction has a negative effect on productivity (Fisk and Rosenfeld, 1997; Wyon, 2004), although the exact relationship is not clear. Increasing innovation and satisfaction are related CRE strategies as well, because work environments that foster creativity will also enhance job satisfaction (Dul and Ceylan, 2006). One could argue that satisfied employees also improve the marketing and sales strategy. So although each strategy will be discussed individually, again they are partly inseparable.

\(^2\) “Without the ownership of the building, the company does not pay property taxes. At the same time, the rent paid to the lessor is generally fully deductible, which could lower income tax.” (Hordijk, Rompelman and Koerhuis, 2010)
**Increase productivity**

Productivity of employees can be influenced by CRE in two ways, namely through decreasing absence due to health problems caused by the work environment, and through supporting increased output when present at the workplace. This output is easier to measure in production than in office environments though. Studies on office employees usually work with subjective metrics of perceived productivity. A well-known impact both on health and output is that of ergonomics, studied by Tarcan, Varol and Ates (2004) among hospital employees (and mentioned by Brill, Weidemann and Olsen (2001)). The productivity of employees can also be influenced by aesthetics and the floor and workplace layout (CIBSE, 1999). Vilnai-Yavetz, Rafaeli and Schneider Yaacov (2005) suggest that aesthetics are an important factor for steering peoples' behaviour. People tend to behave differently when for example material things and properties are pretty, then when their surroundings are messy and filthy. The auditive privacy in the layout influences productivity because of irritation among employees (Chigot, 2004), just like visual privacy (Van den Sigtenhorst, 2003). The position of facilities influences walking distances and thus the time lost when walking around (Wilde, 1996), just like the accessibility of the building (Carter and Whitehead, 1976). Structural (depth, width, span) and installation aspects (installation grid, connecting possibilities) affect the layout flexibility for placing equipment and therefore the possibility to create the optimal process environment and logistics (Sheth, 1995).

Employee health can be influenced by inaccurately designed, operated or maintained installations and the individual control (Rostron and Moores, 1997; Leaman and Bordass, 1999; Seppänen and Fisk, 2002). The installations are also possible perpetrators of SBS-symptoms (Sick Building Syndrome3) and can spread contagious diseases (Rostron and Moores, 1997; Fisk and Rosenfeld, 1997; Seppänen and Fisk, 2002; Witterseh Wyon and Clausen, 2004; Wyon, 2004). Artificial ventilation systems cause significantly more health complaints than natural ventilation, especially when air conditioning is used (Leaman and Bordass, 1999; Seppänen and Fisk, 2002). The emission of these harmful substances must be controlled and possible reservoirs (carpets, airco) removed (Seppänen and Fisk, 2004). Bhatnagar and Sohal (2005) measured the impact of location factors on productivity and mention the proximity of labor market, clients, suppliers, other departments or collaboration parties and the logistic infrastructure.

**Increase employee satisfaction**

Van der Voordt (2003) has tried to map the many aspects that influence employee satisfaction. As mentioned under the productivity strategy, ergonomics is very important (Tarcan, Varol and Ates, 2004; Brill, Weidemann and Olsen, 2001). The quality of the finishing of materials is relevant too (Vischer, 1996). Consistency in the interior design and furnishing increases the ‘sense of belonging’ and satisfaction with

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3 “Sick building syndrome (SBS) is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified.” (http://en.wikipedia.org/wiki/Sick_building_syndrome)
relationships (Becker, Sims and Schoss, 2003). Also daylight has a strong preference for employees and thus the amount of glass in the façade supports satisfaction (Juslén and Tenner, 2005). The spatial layout can result in friendship opportunities (Heerwagen et al., 2004) and finding each other useful (Penn and Vaughan, 1995 in: Shpuza, 2006; Penn, Desyllas and Vaughan, 1999), what improves satisfaction. The presence and position of facilities also showed a significant influence on satisfaction (Madhavi and Unzeitig, 2005), just like the accessibility (Vischer, 1996).

On the negative side, the individual workplace layout, representativeness and aesthetics can provide dissatisfaction if they do not match the status of the job (Van den Sigtenhorst, 2003). The control of auditive privacy in the individual workplace layout can have a negative effect on satisfaction as well (Wyon, 2004; Tarcan, Varol and Ates, 2004).

The installations that produce the indoor climate (e.g. ventilation, temperature, light, noise) and the possibility of (individual) control are well known aspects that influence employee satisfaction (Palonen, Seppänen and Jaakkola, 1993; Leaman and Bordass, 1999; CIBSE, 1999; Niemëla et al., 2002; Juslén and Tenner, 2005; Madhavi and Unzeitig, 2005), just like emission of substances as mentioned under productivity. The accessibility and parking facilities are location aspects that influence employee satisfaction (Vischer, 1996).

**Support marketing and sales**

Some CRE aspects may influence visitors (potential costumers) and determine the (first) impression this person may have (Madhavi and Unzeitig, 2005). Also employees can have a powerful impact on consumers' perceptions of both the brand and the organisation (Harris and De Chernatony, 2001), so the effect of CRE aspects on them is also communicated on to the client. Van Kempen (2008, see also Appel-Meulenbroek et al., 2010) studied the impact of CRE aspects on corporate branding in the services sector. She mentions in her literature study, that very few studies exist on the actual effect on customer’s perception. She refers to Bitner (1992), who explored the impact on the perception of customers and distinguished ambiance conditions (like temperature, sound, light and smell), space and function. Van Kempen also mentions Hatch and Cunliffe (2006) and Strati (1999) who distinguished location, lay-out and style as important factors for creating an image of the company by its stakeholders. In her own study, Van Kempen asked CRE managers which aspects they thought were relevant (so no actual influence on sales was proven). Although CRE is not considered to be the most important aspect for design and communication for any of the companies interviewed, they all thought it can play an essential role. Relevant structural aspects mentioned were materials and their finishings, representativeness, aesthetics, layout and accessibility. Installations were mentioned as well and for the location, the accessibility, facilities on site and image of the location came forward. For industrial organisations, aspects like proximity of the labour market, clients, suppliers and sources is important, plus the logistic infrastructure (Ulaga, Sharma and Krishnan, 2002; Bhatnagar and Sohal, 2005).
Increase innovation

With regard to innovation, two different issues should be distinguished, which both can be influenced by CRE. There is the individual’s creativity, which is generally defined as the production of novel and useful ideas. Innovation starts when these ideas are adopted in the organisation (Dul and Ceylan, 2006). The other issue is knowledge sharing between employees as mentioned in Chapter 1 as the focus of underlying dissertation. Dul and Ceylan wrote a review on the few studies that exist on the effect of the physical environment on creativity. The relevant CRE aspects they found are amount of glass in the façade (window view), finishing and aesthetics (colors; especially green makes creative according to Lichtenfeld et al. (2012)), installations and control (with regard to lighting) and control of auditive privacy. In another paper (Ceylan, Dul and Aytac, 2006) they describe a case study among line managers, who rated pictures with work environments with the same aspects as the more creative ones. An additional aspect that came forward was the complexity of the individual workplace layout.

With regard to knowledge sharing all the layout aspects may support this process. The individual workplace layout is relevant, because a desk facing away from the entrance of a workspace decreases interaction with colleagues (Hatch, 1987). The floor layout and depth/width is relevant, because most interactions are limited to colleagues sitting within 30 meters proximity (Allen, 1977). Also central spaces on a floor show more unplanned interactions with passers-by (Wineman, Kabo and Davis, 2009). On a building layout level, centrality is relevant, because interaction between floors is limited (Allen and Henn, 2007) and influenced by vertical circulation. The accessibility on the floor increases awareness of other people’s need for help (Nonaka and Konno, 1998). The position of facilities on the floor is relevant, because for example the distance to meeting areas influences whether they are used for interacting (Brager et al., 2000). Slangen-De Kort (2001) mentions that aesthetics of the work environment stimulate people to help each other and makes that they find each other more useful, so this is another structural aspect.

Location aspects can be relevant with regard to external cooperation, which literature refers to with the term ‘innovation system’. The core of an innovation system exists of companies, universities and public institutions (Niosi, 2002). Besides these so-called horizontal relationships, vertical relationships (with users/customers) are also part of an innovation system (Solleiro and Castañón, 2004). Several studies have shown why cooperation in an innovation system is beneficial to innovation (Soete and Voskamp, 2004; De Jong and Vermeulen, 2004), for example through smaller risks, a more effective learning process (Rogers, 2004; Piergiovanni, Santarelli and Vivarelli, 1997) and access to complementary know-how (Nieminen and Kaukonen, 2001). So the proximity of suppliers, collaboration parties and related organisational departments seems relevant. Becker, Sims and Schoss (2003) add facilities on site like cafeterias and fitness centres as contributors to interaction between colleagues. According to Hisrich and Smilor (1998 in: Chan and Lau, 2004), the access to high technology support facilities on a science park is one of the elements that creates synergy between these companies.
<table>
<thead>
<tr>
<th>Structural Aspects</th>
<th>Exchange value CRE strategies</th>
<th>Use value CRE strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building orientation + expanding possibilities</td>
<td>Building location and orientation</td>
<td>X</td>
</tr>
<tr>
<td>Building age</td>
<td>Building age</td>
<td>X</td>
</tr>
<tr>
<td>Construction type</td>
<td>Construction type</td>
<td>X</td>
</tr>
<tr>
<td>Detailing of elements and connections</td>
<td>Minimal connection of elements</td>
<td>X</td>
</tr>
<tr>
<td>Building height + volume</td>
<td>Floor height</td>
<td>X</td>
</tr>
<tr>
<td>Spatial characteristics and flexible elements</td>
<td>Fixation/mobility of elements</td>
<td>X</td>
</tr>
<tr>
<td>Standardisation of elements (building + floor)</td>
<td>Standardisation of elements</td>
<td>X</td>
</tr>
<tr>
<td>Materials, forms and colours (building + floor + workplace)</td>
<td>Material properties (e.g., reflection, insulation)</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Construction characteristics and details</td>
<td>X  x  x</td>
</tr>
<tr>
<td></td>
<td>Grid dimension + free spanning distance</td>
<td>X  x  x  x</td>
</tr>
<tr>
<td></td>
<td>Ergonomics of workplace</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Materials, finishing</td>
<td>X</td>
</tr>
<tr>
<td>Control of environmental characteristics (floor + workplace)</td>
<td>Control of auditive/visual privacy</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Control of indoor climate</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Emission of/reservoir for harmful substances</td>
<td>X  x  x</td>
</tr>
<tr>
<td>Amount of glass in façade (building + floor)</td>
<td>Amount of glass in façade</td>
<td>X</td>
</tr>
<tr>
<td>Building form</td>
<td>Representativeness</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Aesthetics</td>
<td>X</td>
</tr>
<tr>
<td>Room/workplace layout</td>
<td>Individual workplace layout</td>
<td>X</td>
</tr>
<tr>
<td>Floor layout</td>
<td>Floor layout</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Position of facilities</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Accessibility</td>
<td>X</td>
</tr>
<tr>
<td>Building depth/width</td>
<td>Building depth/width</td>
<td>X</td>
</tr>
<tr>
<td>Building layout + total amount of square meters</td>
<td>Building layout</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 2-2  *Structural aspects' influence on added value*[^4^]

[^4^]: For the empty places in these tables no studies were found that have proven the relevance of this aspect for this particular strategy. This does not mean that there might not be a relationship proven by future research.
Installations and location aspects

<table>
<thead>
<tr>
<th>Installations and location aspects</th>
<th>Exchange value CRE strategies</th>
<th>Use value CRE strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Organisational costs</td>
<td>Organisational flexibility</td>
</tr>
<tr>
<td>Installations</td>
<td>Characteristics and individual control</td>
<td>X</td>
</tr>
</tbody>
</table>

### Location

<table>
<thead>
<tr>
<th>Parties</th>
<th>Proximity of labour market</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proximity of selling market</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Proximity of suppliers/sources</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Proximity of related organisational departments</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proximity of collaboration parties</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Presence of supporting facilities</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accessibility</th>
<th>Logistic infrastructure (airports, highways, railways)/accessibility</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Facilities on site (e.g. parking)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Extension possibilities</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental influences</th>
<th>Sources of noise</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charisma/image location and environment</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 2-3  Installation and location aspects’ influence on added value

2.5 Discussion and conclusions

The literature discussed in this chapter shows that CREM can add both exchange and use value to the organisation. But to be able to do this, it is necessary to choose the right CRE strategy, which is aligned with the rest of the organisation. This alignment should be started when directional strategies for the entire organisation are determined, and then continued further along the strategic thinking map. A chosen CRE strategy can then be implemented by making choices for the relevant CRE aspects when planning the implementation of the different strategies that were formulated for the entire organisation and its resources.

With regard to the quantitative and qualitative CRE aspects that are mentioned in literature (see Table 2-2 and Table 2-3), especially the structural aspects contain only a few quantitative metrics (e.g. dimensions, materials, construction type). Most structural aspects are more qualitative, like layout and building form and not easy to quantify to identify the mechanism behind their working. The installation aspects
mainly measure the installation specifications (e.g. energy consumption, capacity, technology) and performance (e.g. indoor air quality, temperature and range, lighting level), which can be done with the available technology and instruments that produce clear quantified metrics. The location aspects are quantifiable too, with metric distances and the number of facilities. Only ‘charisma/image’ would be a difficult aspect to measure. So, for quantifying the location and installations several well-known metrics and/or apparatuses exist, to describe them and their outcome, but the structural aspects lack this. The rest of this dissertation will focus on quantifying the structural aspects and does not include location or the installations.

For the structural aspects, 3 groups of aspects came forward with regard to their potential impact on the different CRE strategies (see the boxes drawn in Table 2-2):

- The way the building is constructed, with a possible impact on the exchange value strategies (organisational flexibility, –costs and value of assets).
- The design of the personal workspace and the individual control, with a possible impact on the use value strategies (employee satisfaction, productivity, innovation) and through this also on costs.
- Building form (representativeness and aesthetics) and layout, with a possible impact on all 7 strategies.

Looking at the measurability of these groups of aspects, it is building form and layout which is hard to measure because they are mostly described with very qualitative aspects. Studies in the past have used metrics to describe these aspects, but in very different and subjective ways. The mechanisms through which the layout supports different strategies have not been identified yet. Therefore, these aspects cannot be implemented straight into building designs, nor used effectively or be evaluated by CREM.

Specifically for the innovation strategy, the layout aspects appear to be the most important way for CREM to support knowledge sharing behaviour. The other aspects mentioned to influence innovation (material/glass use, aesthetics and control) stimulate the other issue of innovation mentioned, namely the individual’s creativity. So the mechanism through which layout stimulates KS behaviour is the focus of the rest of this dissertation. In the next chapter (Chapter 3), knowledge sharing will be analysed in further detail, to get a better grip on the behaviour that CREM needs to support with the layout. Then, in Chapter 4, the literature on how layout aspects specifically influence this behaviour is analysed in more detail leading up to a conceptual model to hypothesize on possible mechanisms and quantitative metrics to identify them with.
Chapter 3 Knowledge management

This chapter gives a description of theory on knowledge sharing (KS) and identifies KS behaviour. The first paragraph describes epistemology and will show the development of a knowledge management model, followed by paragraph 3.2 on cooperative behaviour. Paragraph 3.3 describes possible KS activities in more detail. This chapter ends with conclusions and the answer to the 3rd research question.

3.1 Epistemology

Epistemology is the “Philosophy addressing the nature of knowledge” (Hislop, 2009); it deals with definitions and measurability of knowledge. Hislop refers to several authors that have identified 2 streams of epistemologists in a similar way. He states that the objectivist perspective is the most dominant in knowledge management literature. It assumes that knowledge is a manageable resource and that knowledge management has positive effects for everybody. The practice-based perspective is addressed much less in literature. It emerged mostly over the past decade (Berends et al, 2011). It stresses the embeddedness of knowledge in human activity. It is called practice-based, because it sees knowledge as embedded in work practices and thus is more related to KS behaviour.

The objectivist perspective on knowledge is rooted in the philosophy of positivism that strives to measure cause and effect by observation and statistical testing. The underlying theory is the knowledge based theory of the firm, a specific development of the resource-based view of the firm. These academics often start with the mathematical communication model of Shannon and Weaver (McKinnell Jacobson, 2006; Den Otter, 2005; Meadow and Yuan, 1997) when trying to get a grip on things like cooperation and KS. Sharing of knowledge cannot take place without some form of communication (Te’eni, 2006) and this model treats knowledge as an entity that can be codified and then transferred. Shannon (Shannon and Weaver, 1949) composed this model in which communication is a linear process between an information source and a receiving destination (see Figure 3-1).

![Figure 3-1 Communication model of Shannon (Shannon and Weaver, 1949)](image)

The practice-based perspective cannot be assigned to a specific theory or philosophy (Hislop, 2009). But to develop a knowledge management model from this perspective, several extensions of Shannon’s model in later studies can be used. First, Meadow and Yuan (1997) have extended the model through placing it in the
context of the hierarchy of data-information-knowledge. They incorporated Weaver’s original ideas about 3 distinguished levels of communication (Shannon and Weaver, 1949). The first level (technical) relates to the transmitting of symbols/data; hard facts which objectivists see as the main character of knowledge. This traditional look at knowledge as “justified true belief” dates back to Plato and is still used as a definition by objectivists (Nonaka and Takeuchi, 1995; Berends, 2003). The original communication model of Shannon focused on this level and disregards the other two levels. The second level of communication (called semantic by Weaver) deals with meaning of the transmission, and the third level (effectiveness) deals with the effect. Den Otter (2005) supports the second level by stating that “the judging of data, its possible acceptance as information, and its incorporation into a knowledge base all depend on use of the existing knowledge base.” So, the meaning of the transmission is necessary to turn data into information and let the knowledge base grow. This implies a continuous loop in the model in the mind of the receiver (see Figure 3-2) and makes knowledge inseparable from a person. This changes the objectivist type definition of knowledge into a more practice-based definition, as Nonaka and Takeuchi have compiled: “a dynamic human process of justifying personal belief toward the truth”. This definition shifts the emphasis towards knowledge as a process. As Hislop (2009) described, knowledge is then embedded in purposeful human activity.

![Figure 3-2 Extended communication model](image)

This practice-based perspective of knowledge as a process has been taken up by some academics, especially when looking at innovation processes. For example, Weggeman defined knowledge as the “capacity that enables someone to perform a particular task” (Van Daal, De Haas and Weggeman, 1998) and Spiegler (2003) as “the capacity for effective action”. In these definitions the third level of communication called effect by Weaver (Shannon and Weaver, 1949) comes forward, with the effect being the ability to perform tasks. Among these tasks or actions should be giving feedback (McKinnell Jacobson, 2006), which is necessary for the transmitter to make sure that his codified knowledge has come across and that the receiver has transformed it into knowledge of his own. This involves communication again but this time from receiver to transmitter. Weggeman (1997) has composed a knowledge model that can be used as a basis to portray these extensions to the original communication model, leading up to a knowledge management model which is not linear, and portrays the practice-based perspective (see Figure 3-3).
The definition of knowledge by Davenport and Prusak (1998 in: Aarons, 2006) best represents this model:\(^5\): “Knowledge is a fluid mix of framed experience (E), values (A), contextual information (I), and expert insight (S) that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the mind of knowers.” These knowers are both the transmitter and the receiver. This definition encompasses implicitly the common distinction in most Knowledge Management literature between explicit knowledge (information) and tacit knowledge (E=experiences, S=skills, A=attitude) in accordance with Polanyi (1966). The objectivists take this split very literally and prefer explicit knowledge (which is objective, a fact) over tacit knowledge (which is subjective). But as Hislop (2009) argued, objectivists erroneously base this hard split on Polanyi, who did not mean to make such a strict separation of the types of knowledge. Polanyi mentioned that pure explicit knowledge does not exist, and that it is always connected to tacit knowledge.

Weggeman (1997) formulated this connection in the form of an equation:

\[ K_{\text{knowledge}} = I_{\text{information}} \cdot (E_{\text{experience}} \cdot S_{\text{skills}} \cdot A_{\text{attitude}}) \]

The two knowledge components have therefore been placed on a continuous dimension by practice-based academics (Nonaka and Takeuchi, 1995; Aarons, 2006). The effect of sharing each knowledge component on performance can differ greatly, as shown in the example of Haas and Hansen mentioned by Hislop, (2009). In this example explicit KS led to time saved, while tacit KS led to improved task quality.

In firms, three key knowledge processes should take place, namely knowledge creation, knowledge codification and KS (Hislop, 2009). Knowledge codification is the main aim of objectivists, but this is not sufficient, because it does not stimulate certain knowledge related mechanisms that are very important (thinking along,

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\(^5\) Characters between brackets are added
pushing) (Berends et al. 2006). All 3 processes are represented in the developed knowledge management model. Codification takes place on the left side of the model, where both receiver and transmitter can codify parts of the shared knowledge into data. Knowledge creation and application on an individual level is portrayed in the original knowledge model of Weggeman. KS (knowledge creation on an organisational level) is the middle part of the model which can be partly codified and partly tacit. As Berends defined it, KS is “the application of knowledge for the benefit of oneself or another person in interaction” (Berends, 2003). Combined with the knowledge definition on the previous page, this leads to the following definition of KS used for this dissertation:

Knowledge sharing is the application of a fluid mix of framed experience (E), attitude (A), contextual information (I), and skills (S) for the benefit of oneself or another person in interaction.

An important consequence of KS is called organisational learning, caused by the loop in generating new knowledge with existing knowledge (knowledge creation). Berends, Boersma and Weggeman (2003) defined organisational learning as “the process leading to changes in possible organizational practices, based on the development of knowledge of the actors executing those practices” and also state that “Organizational learning arises from the actions and interactions of individuals.”. Nonaka and Takeuchi (1995) identified a spiralling process for organisational learning through the interaction of both knowledge components (see Figure 3-4). The spiral shows that KS is necessary both through cooperation within groups (externalisation) as cross-functionally between departments (combination). Socialisation between two individuals might be necessary on both organisational levels. The Internalisation step of the knowledge spiral is an individual process that cannot be done in teams (Weggeman, 1997), and therefore will not be part of this research. According to Nonaka (1994), knowledge creation starts at the socialisation step.

Ortiz and Aldazabal (2005) place the different steps of the knowledge spiral in history by mentioning 3 generations of knowledge management research. The first generation was focused on knowledge content and storing it digitally. This is also referred to as information management, and can be seen as the ‘externalisation’ step in the knowledge spiral. This generation connects most clearly with the objectivists. The second generation changed its focus towards the flow and circulation of knowledge. Ortiz and Aldazabal state that the central activity was disseminating experiences. Especially the fact that they speak of experiences makes it seem that this generation of KM is occupied most with socialisation in the knowledge spiral and connects most clearly with the practice-based perspective. The third, most recent, generation looks particularly at context and the capitalisation of knowledge. This is a very important objective of cross-functional cooperation and can be seen as ‘combination’. On a smaller scale this could also be the cooperation between different research teams.
3.2 Knowledge sharing through cooperative behaviour

Looking at cooperative behaviour, many synonyms are used, like collaboration, communication, interaction and integration. Some authors have tried to describe ways in which these different concepts are related to each other, but still interpret the same words differently. But looking at all these definitions, the same dichotomy comes forward. A distinction is made between (brief) interactions and more time-consuming and interdependent collaboration (Kahn, 1996). Kahn defined both types of behaviour as follows:

- "Interaction adds structure to how departments interrelate ... formally coordinated activities between departments, including routine meetings, planned teleconferencing, routine conference calls, memoranda, and the flow of standard documentation. These activities ... regulate communication through frequency of occurrence, adherence to a routine schedule/plan, and/or upper management mandates."

- "Collaboration represents the unstructured, affective nature of interdepartmental relationships... an affective, volitional, mutual/shared process where two or more departments work together, have mutual understanding, have a common vision, share resources, and achieve collective goals. Such activities are intangible, not easily regulated, difficult to sustain without joint efforts, and represent a higher level of interrelationship."

Most research focuses on the first level, because it is a behaviour that is relatively easy to quantify, measure, influence and change by management. Collaboration has the same interactive behaviour but with more interdependence and combines this
with attitudinal aspects, which are harder to measure, because they are inside the human mind. Therefore, much is known about factors that improve interaction, but “very little is known about the ones that promise high level of collaboration” (Jassawalla and Sashittal, 1998). Also today, stimulating collaboration remains more of a lacuna, and is what the practice-based perspective academics refer to as KS.

Kahn (1996) measured the effect of both levels of cooperative actions on the innovation process. He found that the effect of both is significant and that collaboration has a more positive influence than interaction, which was proven again later by Olson et al. (2001). It seems logical that more interdependence leads to more sharing. Kahn’s factor analysis brought about three independent scales (two for interaction, one for collaboration) regarding their effect on innovation outcome:

1. Interaction
   - Meetings (meetings, committees/task forces, phone conversations, phone mail, electronic mail)
   - Documented information exchange (forms, memorandums, reports, fax)

2. Collaboration
   - Activities to achieve goals collectively, have a mutual understanding, informally work together, share idea’s information and/or resources, share the same vision for the firm and work together as a team.

However, looking at the proposed activities and communication channels, it seems relevant to split collaboration too, in actual behaviour (work together) and the attitude during or arising through that behaviour. Sometimes, the tacit knowledge component is split up in these 2 dimensions as well, namely technical (know-how) and cognitive (Nonaka and Konno, 1998).

Although other studies do not distinguish between interaction and collaboration, the metrics they used can be divided over Kahn’s behaviours as discussed below (see also Table 3-1), showing the relevance of his work.

Song, Montaya-Weiss and Schmidt (1997) used five metrics, of which one is called interaction and the other four are collaboration aspects literally mentioned by Kahn (give-and-take, similar goals/objectives) or implying collaborative behaviour (open communication) or attitude (overall satisfaction with interdepartmental relationships). In an earlier study (Song, Neeley and Yuzhen, 1996), they only used information exchange (interaction) and involvement.

Olson et al. (2001) refer to Kahn’s splitting up of interaction and collaboration and choose to only measure interaction, because it ensures a simpler test and behaviour is easier to change by management than attitude. They ask three interaction questions, namely the frequency of communication, the amount of information, advice and technical assistance exchanged and the level of work transferred.
<table>
<thead>
<tr>
<th>Interaction</th>
<th>Meetings + Documented information exchange</th>
<th>Communication exchange</th>
<th>Interaction</th>
<th>Contact, keep each other informed</th>
<th>Providing information</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Informally work together / Work together as a team</th>
<th>Influence each other</th>
<th>Flexibility (adjust to each other)</th>
<th>Being involved with other departments</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Collaboration</th>
<th>Share idea's information and/or resources</th>
<th>Open communication</th>
<th>Support for ideas</th>
<th>Information exchange (help each other)</th>
<th>Jointly generate new ideas</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Attitude</th>
<th>Have a mutual understanding</th>
<th>Give and take</th>
<th>Give and take</th>
<th>Understanding</th>
</tr>
</thead>
</table>

| Achieve goals collectively | Critical evaluation | Solidarity |

**Table 3-1**  Cooperation activities and channels

Kivimäki et al. (2000) asked 40 questions about communication and constructed eight scales with factor analysis. Although they refer to Kahn’s work on distinguishing formal and informal cooperation, they do not incorporate this in their scales. Of these eight scales, only six refer to internal cooperation and all had a separate significant influence on perceived organisational innovation, in order of descending influence:

1. Participative climate;
2. Sufficient collaboration;
3. Cooperation between departments;
4. Support for ideas;
5. Critical evaluation;
6. Understanding between departments.

Scale 2 ‘sufficient collaboration’ should be placed under interaction, although the name they gave to it suggests otherwise, because the questions asked deal with the amount of communication and informing, not sharing tacit knowledge. Scale 3 ‘cooperation between departments’ is such a universal term that it could belong to both, so it has not been appointed in the table. Scales 4 and 6 literally refer to some aspects of collaboration. Scale 5 ‘critical evaluation’ is placed under ‘attitude’, because Nonaka and Konno (1998) mention the “concern to achieve high performance” as a cognitive component of collaboration. Unfortunately, scale 1, with the most influence on innovation, is made up out of both interaction and collaboration aspects. Although it mainly consists of collaboration aspects, it is not clear what is responsible for influencing innovation. They can be divided over interaction (contact) and three collaboration aspects, namely understanding (give and take), sharing information and working together (influence each other).

Hillebrand and Biemans (2004) focus on cooperative norms, because they want to relate external cooperation to internal cooperation and not to performance. Their scale of cooperative norms has three items: flexibility, information exchange and solidarity. Flexibility, as adjusting to each other, is like working together as a team. Their information exchange is used in the context to help each other, so it also placed under collaboration and not interaction. Solidarity is explained with being committed to improvements that benefit all, and therefore interpreted as the attitude to achieve goals collectively.

Lu and Yang (2004) distinguish several steps within the design and development phase of the total innovation process. For their steps, they measure whether marketing and R&D work together, are involved in specific activities and/or provide information. Providing information is an interaction type of meeting, but both working together (on new ideas) as being involved are attitudinal aspects and thus belong under collaboration.

Pearce and Ensley (2004) only looked at shared vision, which is a collaboration aspect.

As tacit and explicit knowledge are not totally inseparable, similarly the line between interaction behaviour and collaboration behaviour in Table 3-1 is not very clear. The same communication channels and activities can be used. The difference lies more in the willingness of actually wanting to achieve something together (like sharing knowledge) or just exchanging information. So collaboration is seen as a subset of interaction. Berends, Van der Bij and Weggeman (2006) mention something similar with regard to knowledge integration (applying knowledge of different persons to an organisational process) and introduce an involvement dimension to deal with this distinction. Following their arguments, this dimension is also relevant for the
knowledge-sharing step of Knowledge Management. “Being deeper involved ... takes more time and effort ... of both sender and receiver” (Berends, Van der Bij and Weggeman, 2006).

So KS behaviour can be represented as a conceptual 2 dimensional system: the knowledge component to share and the involvement level for sharing (see Figure 3-5). Nonaka and Konno (1998) emphasize that the tacit knowledge component (ESA) can only be exchanged through joint activities, as spending time/living in the same environment. So they imply that more involvement is necessary to share more than just information, placing Socialisation at the bottom-right end of Figure 3-5. Combination is the sharing of explicit knowledge, for which interaction is sufficient, so this is placed at the left top. Externalisation is placed in between. This conceptual representation is tested with the fieldwork. The next paragraph identifies KS activities to operationalise the behaviour for this test.

![Figure 3-5 Conceptual representation of KS behaviour](image)

### 3.3 Knowledge sharing activities

Activities for KS have been identified through extensive observation of industrial researchers of 2 organisations (Philips and Shell) in the dissertation of Berends (2003, also published in Berends, 2005). He identified a taxonomy of 29 ‘moves’, which he defines as being “a meaningful unit of communication”. A move is a unit of communication in which knowledge is shared in a certain way. These moves and the 5 categories that they have been grouped into, are appointed to the interaction and collaboration behaviour based on whether these activities involve sharing just information or also experience and skills (see Table 3-2 and Table 3-3). The 5 categories seem very suitable to use as metrics for underlying research. Also, they are very commonly used words for activities and therefore it should be clear to both researchers as the subjects that will be studied what is meant by them. The single moves can be used as examples of what an activities category encompasses.
### Table 3-2  **KS activities for interaction** (adapted from Berends, 2003)

In Table 3-2 and Table 3-3 the involvement dimension can be introduced. “Suggestions, questions and evaluations are often more personalized….These moves require a higher level of involvement with each other’s work and more direct interaction than descriptions.” (Berends, 2005). In his dissertation, Berends (2003) explains this thought with an analysis of origination mechanisms that have caused the moves to take place. He placed the moves on 3 dimensions (see Table 3-4):

- new versus existing knowledge,
- problem orientation and
- source of determination (Init.= Initiator, the one who decided on the subject to touch upon).

Of 24 possible origination mechanisms, 9 accounted for 93% of the cases. When these 9 mechanisms are placed in a cross table with the move categories (see Table 3-4) the difference between ‘descriptions’ and the other 4 categories becomes really clear.

Descriptions are the moves made most often (42% of the times). They are initiated by both people in an interaction, but mostly stem from the existing origination mechanisms. So nothing new is broached with regard to a problem (own, other, shared) or something else, that not one of both persons already knew. When giving a description of something the communication is mostly one way and the receiver is not asked to become involved. He/she can listen to the information that is given and decide for himself what to do with it. So the feedback and other loops of KS are not present (or negligible). As Berends (2003) puts it: “What is said was already existing.” Descriptions can be easily stored in databases (Berends, 2005). Later on, the receiver can work with this information and thus create new knowledge with it. For the ‘combination’ step in the learning cycle descriptions-sessions are often organised by management to stimulate (cross-functional) cooperation, like presentations, recurring meetings and an open culture to talk with others. It is not likely that tacit knowledge will be shared. One of the ‘actions’, namely handing over

<table>
<thead>
<tr>
<th>Cooperation activities</th>
<th>KS moves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INTERACTION</strong></td>
<td><strong>Moves</strong></td>
</tr>
<tr>
<td>Behaviour</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Meetings</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Descriptions</strong></td>
</tr>
<tr>
<td></td>
<td>Reporting about others</td>
</tr>
<tr>
<td></td>
<td>Describing</td>
</tr>
<tr>
<td></td>
<td>• own activities</td>
</tr>
<tr>
<td></td>
<td>• own knowledge</td>
</tr>
<tr>
<td></td>
<td>• own problem</td>
</tr>
<tr>
<td></td>
<td>• findings or theory</td>
</tr>
<tr>
<td></td>
<td>• earlier interaction</td>
</tr>
<tr>
<td></td>
<td>• experiment</td>
</tr>
<tr>
<td></td>
<td>• own results</td>
</tr>
<tr>
<td></td>
<td>• technology</td>
</tr>
<tr>
<td></td>
<td><strong>Actions</strong></td>
</tr>
<tr>
<td></td>
<td>Handing over publications</td>
</tr>
<tr>
<td></td>
<td><strong>Documented information exchange</strong></td>
</tr>
</tbody>
</table>
publications, deals with written information, so also just explicit knowledge is shared during this (short) interaction. It is kind of a description, but on paper. An important indirect effect of descriptions that Berends observed was that they yield knowledge about others. As he states, management is more likely to want to stimulate KS with a direct effect of contributing to solutions, because this is related most to performance.

<table>
<thead>
<tr>
<th>Cooperation activities</th>
<th>KS moves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informally work together / Work together as a team</td>
<td>Actions showing on the spot calculating or trying expressing observation</td>
</tr>
<tr>
<td>and</td>
<td>Questions asking a question questioning asking for help</td>
</tr>
<tr>
<td>Share idea’s, information and/or resources</td>
<td>Proposals/suggestions hypothesizing suggesting:</td>
</tr>
<tr>
<td>and</td>
<td>• technical solution</td>
</tr>
<tr>
<td>and</td>
<td>• experiment</td>
</tr>
<tr>
<td>and</td>
<td>• new research</td>
</tr>
<tr>
<td>warning instructing referring to:</td>
<td>Evaluations giving arguments agreeing rejecting concluding redescribing and summarising</td>
</tr>
<tr>
<td>• person</td>
<td>• literature or interactions</td>
</tr>
<tr>
<td>Changing degree of consensus</td>
<td></td>
</tr>
<tr>
<td>Share the same vision for the firm and</td>
<td>Development of knowledge about others; about their:</td>
</tr>
<tr>
<td>and</td>
<td>• activities</td>
</tr>
<tr>
<td>Have a mutual understanding and</td>
<td>• problems</td>
</tr>
<tr>
<td>Achieve goals collectively</td>
<td>• knowledge</td>
</tr>
<tr>
<td>and</td>
<td>• literature and interactions</td>
</tr>
<tr>
<td>Development of questions and interests</td>
<td></td>
</tr>
</tbody>
</table>

*Table 3-3*  
*KS activities for collaboration (adapted from Berends, 2003)*
The other 4 categories contain moves that aid with the development of solutions. Especially Proposals and Evaluations dominate when new content is constructed during the communication, no matter whose problem it regards (own, other or shared). What is shared during this communication, did not yet exist at the beginning of it, but came up during the interaction. Apparently, ego mostly starts up this kind of communication moments by starting to talk to the other. That might explain why also 1/3 of the ‘pushing’ mechanisms are followed by proposals (‘pushing’ was only observed in 8% of the cases). Ego is convinced that his knowledge can benefit the other, and thus not only describes it, but also instructs how to work with it and/or refers to others or literature on the subject. The names given to the origination mechanisms by Berends (2003) already suggest involvement of the other (e.g. thinking along, collaborative problem solving). So these activities seem to demand more involvement; the sender and receiver start to work together and may start sharing experience and skills.

Actions and questions are activities that are not used as often to share knowledge as the other moves. Questions come forward clearly for ‘reaction-demanding’, which seems a logical way to get somebody’s reaction. But also during more involved sessions questions will be asked. ‘Collaborative problem-solving’ accounts for most of the actions, and then only the subcategories ‘on the spot calculating or trying’ and ‘expressing observation’ which are logical activities during collaborative work. This difference in level of involvement of descriptions versus the other 4 categories of KS moves is an assumption that is tested in the fieldwork.

In the moves ‘attitude’ does not come forward, because it is not behaviour. But it has been suggested that attitude derives from certain behaviour. Berends (2003) also shows this, because he identified a taxonomy of effects of his moves. Some of
his indirect effects can be appointed to the collaboration attitude as described (see Table 3-3). Berends distinguished 4 indirect effects, namely:

- changing degree of consensus,
- development of knowledge about others,
- development of background knowledge and
- activating within interaction.

The first two effects are clearly a change in attitude towards other people and their knowledge, which will help in having a mutual understanding and working towards the same goals. “The better your relationships with your coworkers and the more opportunities you have to interact, the greater the possibility of knowledge sharing” (McKinnell Jacobson, 2006), so these effects also show the cyclical nature of the KS process. Social psychologists call the reason behind this ‘transactive memory’, referring to metaknowledge (knowledge about the knowledge and skills of others) that helps identifying opportunities for KS (Berends, Van der Bij and Weggeman, 2006). Berends, Boersma and Weggeman (2003) refer to Giddens’ structuration theory that social structures are both the medium of interaction and also an outcome. The other two effects do not relate to attitude, but do show the cyclical nature again, namely that the sharing of knowledge leads to new KS actions (activating) and/or to a knowledge base that will be useful in the future (background knowledge). The same goes for the direct effects that Berends identified.

To manage knowledge and KS activities, the focus of objectivists lies strongly on ICT, because this is very suitable to share explicit (codified) knowledge. The practice-based perspective, claiming that all knowledge is tacit to some extent, focuses on face-to-face KS. Earl (2001) distinguished between 7 schools of knowledge management, based on the role ICT and HRM (human resource management) play. His 7 schools are placed under 3 main streams:

1. technocratic (systems, cartographic, engineering)
2. economic (commercial)
3. behavioural (organisational, spatial, strategic)

The 3 technocratic schools all rely strongly on ICT systems. The economic school is aimed at commercialising knowledge. The 3 behavioural schools have an emphasis on people management and interpersonal sharing of knowledge. This dissertation can be placed under the behavioural stream and specifically under the spatial school, because it will study face-to-face KS. The other behavioural schools are organisational (focussing on creating networks and communities of practice) and strategic (shaping attitudes and values), but fall outside the scope of this research.

### 3.4 Discussion and conclusions

KS is not as simple a process as objectivists see it, with the communication of codified information. Transmitting meaning with this information and sharing experience, skills and values requires face-to-face meetings and can require several loops during the communication process. The necessary behaviour to share knowledge during meetings can be split into interaction and collaboration, and can be operationalised with KS moves. These moves determine the (type of) knowledge that can be shared, based on the involvement during the cooperation between persons. While interactions have been shown to help in sharing explicit knowledge,
this might not be enough to share tacit knowledge like experience, skills and attitude. Interaction activities are giving descriptions and reporting on explicit information in either an oral or written form. For more tacit KS collaboration seems necessary, identified with activities involving proposals, evaluations, questions and engaged actions.

For researchers in knowledge organisations to be able to learn and share more and more knowledge (achieve organisational learning), these activities must take place on different organisational levels: both within groups as between groups. For so-called ‘combination’ of explicit knowledge between groups, interaction activities should suffice. For within group ‘externalisation’, during which the individual tacit knowledge is made explicit to be shared among team members, more involved activities are a condition. For socialisation, whether within groups or cross-functionally, a lot of involvement is necessary, leading up to the actual sharing of tacit knowledge. This can also result in attitude changes.

So to study KS outcomes with a more practice-based perspective, just looking at the amount of KS meetings is not enough. In the case study, KS will be studied more in-depth with the moves and origination mechanisms discussed. Because this research tries to measure the effect of quantified CRE metrics on KS behaviour, it will use statistics which is so typical for the positivistic method of research used by objectivists. However, these statistics are used on metrics of face-to-face meetings that reckon with the embeddedness of knowledge in human activity, so typical for the practice-based academics, and the behavioural school. So it is really a combination of both epistemology streams.
Chapter 4 Mechanisms of a layout

In this chapter, the qualitative aspects for building layout will be studied more thoroughly in literature to identify relevant metrics to describe them and identify mechanisms. Paragraph 4.1 describes a more extensive literature study on the effect that layout could have on KS specifically. After discussion of the shortcomings of previous studies (paragraph 4.2), a list of possible mechanisms with quantitative layout metrics is constructed in paragraph 4.3 as the answer to the 4th research question. The chapter ends with conclusions and conceptual models.

4.1 The effect of layout on knowledge sharing

With regard to the support that CRE can give KS, both innovation and KM literature emphasize that face-to-face interaction and physical proximity are key to collaboration and transferring tacit knowledge. But the CRE aspects included in empirical research are limited to mentioning the location or to see if being in the same building helps cooperation (Kahn, 1997). CRE literature goes into this support function of the physical environment for cooperation to much more extent, but not always within the context of KS (although increasingly so). Therefore the CRE-literature empirically proving a positive influence of CRE on cooperation has been interpreted in a content analysis to identify in more detail the layout mechanisms that might increase the outcome of interaction and/or collaboration as defined with the KS moves in chapter 3.

Previous studies on interaction (Rashid et al., 2005; Steen and Markhede, 2010) distinguish between effects on a local level (called Co-presence) and global level (called Movement). As the unit of analyses are the employees of an organisation and not the building, movement in this study should be renamed to Position in the building. Thus the results of the content analysis are split in local mechanisms (par4.1.1; Co-presence) and global mechanisms (par 4.1.2; Position in the building).

The empirical work has been done in many different sectors and every study reviewed investigated only a few companies, but all with office-environments. Due to the nature of office organisations, to a large extent their employees have similar work processes and behaviour (Shpuza, 2006; Steen, 2009). Since research buildings also have laboratories, besides office space, after the content analysis a few studies on labs will be discussed (par 4.1.3) to get an indication whether the aspects mentioned are similar to the office studies. Laboratory research is a much more specialised process than office work, and thus the results from these types of studies cannot be generalised to other situations as easily.

4.1.1 Co-presence

For the office workplace, two mechanisms come forward influencing both interaction and collaboration (see Table 4-1):

- Proximity and
- Visual/aural accessibility.
**Proximity** is the most studied and mentioned mechanism. Face-to-face interaction is obviously stimulated through proximity. People in close proximity interact more, because they bump into each other when moving around in the vicinity of their workplace. During these ‘chance’ interactions, KS moves as giving descriptions and reporting about others can take place. The action of handing over publications is not studied, but it seems plausible, that this could be a result of these chance meetings, when they take place close to the workplace (and thus the personal archive) of employees. Allen (1977) pinpointed the limit for a ‘chance’ meeting effect at about 30 meters, although it is not just a matter of distance. As Brown (2008) showed, proximity is not a direct function of density, but also depends on circulation paths and complexity.

On a larger scale, proximity is still relevant for interaction. The frequency of interaction between people who work on different floors inside a building is less than between people on the same floor, although the effect is a lot smaller than for people working in close vicinity (Parsons, 1976 in: Rashid et al., 2006; Spiliopoulou and Penn, 1999) and becomes even smaller when the floors are bigger (Grajewski, 1992; Becker, Quinn and Tennessen, 1995). Allen and Henn (2007) show that beyond one’s own floor the interaction declines dramatically and is almost equal to interaction with people from other buildings or locations. Only a strong functional relationship makes people interact between floors.

Sailer et al (2009) show the working of this mechanism on an even larger scale, proving that collocating people from three buildings in one building increased both interaction and finding each other useful (attitude). The influence of context can be seen in the study of Moenaert and Caeldries (1996), where the opposite effect took place. They found that collocation of several R&D teams in one building did not increase the frequency of interaction, but did increase the positive influence of this interaction on innovation. Apparently, here the context prevented the mechanism to increase interaction frequency, but layout changes did have other positive outcomes.

**Proximity** also helps collaboration, especially for KS between groups. Heerwagen et al. (2004) mention that collaborative group work between units is more likely to succeed when there are few structural barriers between groups. The forced encounters that take place because of proximity in a building break down boundaries and forces people from different communities to understand each other better (Ward and Holtham, 2000). Kahn and McDonough (1997) found higher levels of achieving goals together and sharing the same vision as positive results of proximity, although not between all groups. So this time it was the group-context that influenced the mechanism of proximity. With regard to attitude, Bulte and Moenaert (1998) mention that it helps bring separate thought worlds closer together, and heightens perceptions of personality differences. On the other hand, Becker, Sims and Schoss (2003) measured no difference in sense of belonging.

Besides being close to each other, it also matters for interaction whether there is visual/aural accessibility. Working in the same project room provides accessibility, but also normal workspaces that are visually open enhance face-to-face interaction.
through seeing and overhearing (Markhede and Koch, 2007; Sailer et al., 2007). When coping with a problem or having a ‘eureka’-moment, we have a tendency to describe this to the first person in sight.

<table>
<thead>
<tr>
<th>Proximity</th>
<th>Accessibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction</td>
<td>Collaboration</td>
</tr>
<tr>
<td>Allen, 1977</td>
<td>X</td>
</tr>
<tr>
<td>Grajewski, 1992</td>
<td>X</td>
</tr>
<tr>
<td>Becker, Quinn and Tennessen, 1995</td>
<td>X</td>
</tr>
<tr>
<td>Moenaert and Caeldries, 1996</td>
<td>no</td>
</tr>
<tr>
<td>Kahn and McDonough III, 1997</td>
<td>X</td>
</tr>
<tr>
<td>Bulte and Moenaert, 1998</td>
<td>X</td>
</tr>
<tr>
<td>Covi, Olson and Rocco, 1998</td>
<td></td>
</tr>
<tr>
<td>Spiliopoulou and Penn, 1999</td>
<td></td>
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<tr>
<td>Penn, Desyllas and Vaughan, 1999</td>
<td></td>
</tr>
<tr>
<td>Becker and Sims, 2001</td>
<td></td>
</tr>
<tr>
<td>Becker, Sims and Schoss, 2003</td>
<td>X</td>
</tr>
<tr>
<td>Van der Bij, Song and Weggeman, 2003</td>
<td>X</td>
</tr>
<tr>
<td>Rashid et al., 2006</td>
<td>X</td>
</tr>
<tr>
<td>Markhede and Koch, 2007</td>
<td></td>
</tr>
<tr>
<td>Brown, 2008</td>
<td>X</td>
</tr>
<tr>
<td>Toker and Gray, 2008</td>
<td>X</td>
</tr>
<tr>
<td>Sailer et al., 2007</td>
<td></td>
</tr>
<tr>
<td>Sailer et al., 2009</td>
<td>X</td>
</tr>
<tr>
<td>Sailer and Penn, 2009</td>
<td>X</td>
</tr>
<tr>
<td>Blakstad, Hatling and Bygdås, 2009</td>
<td></td>
</tr>
<tr>
<td>Steen, 2009</td>
<td>X</td>
</tr>
<tr>
<td>Steen and Markhede, 2010</td>
<td>X</td>
</tr>
<tr>
<td>Sailer and McCulloh, 2012</td>
<td>X</td>
</tr>
<tr>
<td>Koch and Steen, 2012a</td>
<td></td>
</tr>
<tr>
<td>Total # of studies</td>
<td>15 X, 1 no</td>
</tr>
</tbody>
</table>

*Table 4-1 Literature on local mechanisms*
If people can see each other (accessibility) at their workstations, they can collaborate, share tasks and ideas more easily and provide assistance (Jassawalla and Sashittal, 1998), because they are more aware of other people’s need for help (Nonaka and Konno, 1998; Brager et al., 2000; Sailer et al., 2007). “Working in visual proximity created increased opportunities for young staff to ‘learn by observation’ from older, more experienced staff.” (Becker, Quinn and Tenessen, 1995) This can be viewed in the light of the theory of cognitive apprenticeship, developed by Collins, Brown and Newman (1989) and is typical for the practice-based perspective on KS. This awareness increases KS moves as making suggestions, expressing observations or referring to relevant knowledge sources. More visual contact contributes to fewer unwanted interactions, by changing the timing of communication (Becker and Sims, 2001). With regard to attitude, less visual barriers also “force” different people to understand each other better (Ward and Holtham, 2000) and increases finding each other useful (Penn, Desyllas and Vaughan, 1999; Sailer et al., 2007). Collocated people imitate each other, which is an important part of organisational learning (Covi, Olson and Rocco, 1998). According to studies of the brain, this is caused by the recently discovered mirror neurons (Goleman and Boyatzis, 2008). As they state “the brain is peppered with neurons that mimic, or mirror, what another being does” and “these neurons create an instant sense of shared experience.”

4.1.2 Position in the building

For the building as a whole, three mechanisms can be identified of which only the first one has been shown to influence both interaction and collaboration. The other two, so far, only have a proven influence on interaction (see also Table 4-2):

- Exposure;
- Centrality and
- Meeting areas.

The global mechanisms that is mentioned most, is called centrality. It is studied extensively by academics from the space syntax community. A building will be more “integrated” by linking different parts of a building together. The more integrated parts are located in the centre of a building. Becker, Quinn and Tennesen (1995) mention the central location of a ‘clubhouse’ within the office making it a preferred workplace for directors of multiple and dispersed project teams. Everybody walked through or near this area often. If floors are poorly connected, less vertical circulation and interaction between floors takes place (Grajewski, Miller and Xu, 1991 in: Shpuza, 2006). According to Grajewski (1992) the amount of interaction is not so much linked to the location within the building of an individual workplace, but to this location of parts/segments/areas within a building. Spaces that are centrally located and have connections to many other places enhance unplanned interaction on well-trafficked pathways (Becker, Quinn and Tennesen, 1995; Heerwagen et al., 2004). Wineman, Kabo and Davis (2009) even empirically link centrality to an increased innovation outcome.
Centrality is only linked to collaborative attitudes. Both Sailer et al (2007) and Penn, Desyllas and Vaughan (1999) found that it heightens being found useful by others. This is an attitude aspect, and the KS moves placed under collaborative behaviour remain unstudied in this context. But as attitude is said to be the result of that behaviour (Berends, 2003), it seems safe to say that an effect exists.

Exposure is also a predictor of interaction. Layout is the main instrument to expose people to each other who are not within proximity distance. It controls the flows of people on a floor and who get to know each other. Social psychologists call this ‘transactive memory’, referring to metaknowledge (knowledge about the knowledge and skills of others) that helps identifying opportunities for KS (Berends et al., 2006). According to observations, employees spend an average of 7% of their working time moving (Steen, Blombergsson and Wiklander, 2005). Backhouse and Drew (1992 in: Penn, Desyllas and Vaughan, 1999) reported that even “over 80% of observed work-related conversations took place in a manner that was unplanned”, just because people get into conversations by being spotted by others. Also because of exposure, employees sitting close to the flows of movement interact more. Both the depth to these flows as the distance to the entrance should be as low as possible for more interaction (Penn, Desyllas and Vaughan, 1999). This effect increases with more density (more people) in an area (Grajewski, Miller and Xu, 1991 in: Shpuza, 2006; Ward and Holtham, 2000).

Exposure is not mentioned in any of these studies with regard to collaboration.

Covi, Olson and Rocco (1998) distinguished eight different cooperative spaces of which one (the project room) is mentioned under the co-presence section. The other seven spaces can all be seen as meeting areas, called not live-in project rooms, group area with commons, owned meeting rooms, scheduled meeting rooms, video conference rooms, cafeterias used for meetings and training rooms. Since meetings are meant for interaction, observation showed a non-surprising result that a lot of talking takes place in meeting areas (Penn, Desyllas and Vaughan, 1999). Meeting areas are specifically designed and equipped for KS moves like giving descriptions and handing over publications. These spaces increase their use for interactions if they are well connected and visible for people on the move (Toker and Gray, 2008) and if they have places to sit that do not block the other flows (Heerwagen et al, 2004). Brager et al. (2000) found that people with offices close to meeting spaces do not use them more often, so unplanned use of meeting areas appears to be nearly extinct. In that case it might not so much be a possible mechanism, but a support of organisationally defined planned meetings. This will be tested in the fieldwork. Meeting areas are not linked by anyone to collaboration either. Formal meetings help convert tacit knowledge to explicit knowledge (Nonaka and Konno, 1998), but are probably too short to influence collaboration.
4.1.3 Studies on Laboratory real estate

Although some studies talk about doing research in laboratories, these laboratories mostly consist of office space only. Besides the work of Allen (1977, discussed before), only a few groups of architectural academics have been found, that have looked in depth at real development (R&D) buildings. In general R&D buildings contain the following types of rooms/areas (Hain, 1995, Watch, 2001, Braun and Grömling, 2005):

- Offices
- Formal and informal meeting areas
- Laboratories
- Test areas for prototypes etc.
- Technical rooms
- Storage of materials, instruments, etc.
- Archives
- Wash and sanitary facilities.

First, in the late 80’s/begin 90’s at the Bartlett school of architecture and planning several studies have been done. Research on a sample of 24 floors in seven laboratory buildings on five sites in the UK was published in several papers (Penn and
Hillier, 1992; Hillier and Penn, 1991; Hillier et al., 1985). A study of seven other UK organisations with ‘bench scale’ laboratories was done around the same time (Hillier et al., 1990). Specifically movement and interaction are studied. Although they use different types of metrics, these relate strongly to the mentioned layout mechanisms in the office studies. Three mechanisms come forward to stimulate interaction, namely proximity, accessibility and exposure.

Second, at the Georgia institute of technology, a study of two laboratory buildings was performed (Serrato and Wineman, 1999). This showed that half of the interactions occurred within private offices of which again half was in an office of group leaders, lab directors or other managers. Only 5-6% of the talking took place in hallways. The spread of these offices through the layout is what determined where the interactions took place. Surprisingly, proximity was not a strong predictor of interaction here. It was exposure and approachability during such (standing close to hallway, not sitting at desk), which determined whether researchers interacted or not.

More recently, Toker and Gray (2008) studied university research buildings with laboratories. They also showed that exposure and layout (spatial configuration + walking distances) determine the amount of interactions, with spatial configuration as the main predictor, followed by exposure and walking distances.

Unfortunately, these few studies do not give a clear result of how the effect of layout takes place in laboratories. It were, however, the same mechanisms influencing interaction that came forward in the office studies. Practitioners in designing laboratories have picked up on this the same way as office designers. For example, the importance of collaborative space in research facilities is mentioned in the lab design handbook (Spears, 2004).

4.1.4 Context-Mechanism-Outcome configurations

Besides the empirical works discussed in the previous sections, a few literature reviews are relevant to discuss here, because they refer to innovation and place (Kauttu, 2003), knowledge creation and place (Ward and Holtham, 2000) or collaboration and place (Heerwagen et al., 2004). Both Kauttu as Ward and Holtham mostly give a vision on knowledge work and how space should support it. They only mention proximity as a mechanism that can help, and do not discuss many empirical works. Heerwagen et al., on the other hand, do give an extensive overview. Although they do not state it that way, the literature they reviewed all together (some overlapping with our content analysis), identified the same five mechanisms. And they are related to both interaction and collaboration, except exposure and the presence of meeting areas (again only related to interaction). So no new mechanisms or relevant studies came forward here, suggesting that the 28 studies in the content analysis have provided all relevant mechanisms. So the following five context-mechanism-outcome configurations can be formulated, to test with the fieldwork:
An organisation with innovation in their corporate strategy, that wants to align the CRE strategy by increasing knowledge sharing of their employees through optimisation of the building layout.

<table>
<thead>
<tr>
<th>Context</th>
<th>Mechanism</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual/aural accessibility triggers awareness of what other employees are doing, and whether one can provide help.</td>
<td></td>
<td>Increased interaction and collaboration.</td>
</tr>
<tr>
<td>Proximity triggers bumping into each other when moving around in the vicinity of one’s workplace.</td>
<td></td>
<td>Increased interaction and collaboration.</td>
</tr>
<tr>
<td>Exposure triggers being spotted by others that are moving around.</td>
<td></td>
<td>Increased interaction and collaboration.</td>
</tr>
<tr>
<td>Centrality within the building triggers walking over to colleagues.</td>
<td></td>
<td>Increased interaction.</td>
</tr>
<tr>
<td>Presence of meeting areas triggers their use.</td>
<td></td>
<td>Increased interaction.</td>
</tr>
</tbody>
</table>

4.2 Shortcomings of previous studies
As the content analysis showed, studying layout mechanisms to influence KS behaviour is not new. But it also showed that none of the empirical studies focus on all of the mechanisms. Of the 28 studies, 17 focused on one mechanism only. Except for exposure, all other mechanisms have been individually studied this way. Six studies looked at two mechanisms, combing a local and a global mechanisms or studying the two local mechanisms. And four studies have showed proof for three mechanisms. Taking a closer look at these four studies, shows that only Becker, Quinn and Tennessen (1995) studied both interaction and collaboration. However, they do not relate this behaviour statistically to layout metrics. Steen and Markhede (2010) show statistics for a relation between only one of the mechanisms and interaction, not making it possible to compare the outcome with the other two mechanisms that they studied qualitatively. The other two studies only looked at interaction too. Two studied each mechanism within different case-studies, so they cannot compare the mechanisms within one organisation either. Toker and Gray (2008) are the only study of four mechanisms, which they all studied within six university research centres and with statistics. So this is the only study found, that compares the strength of the different mechanisms. They related centrality, exposure and proximity to intentional unscheduled interaction at the workplace with a multivariate analysis, showing that centrality was the strongest predictor, followed by exposure, followed by proximity. As, they related the centrality and visibility of meeting areas only to spontaneous interaction within these areas, this correlation cannot be compared with the other three. And this way, they also missed spontaneous interaction around the workplace, which has been shown to take place by several others too. Unfortunately, they ignored the accessibility mechanism,
which is proven by ten others to be relevant too. As they only look at individual
rooms/areas and not at the people inside, they miss the behaviour that is most local.

A closer look at how previous studies identified the causal effects between layout
and behaviour shows several shortcomings in the metrics that are used too. First of
all how outcome is measured. Several of the studies work with perceived
information on communication, obtained by holding surveys (Becker, Quinn and
Tennessee, 1995; Covi, Olson and Rocco, 1998; Brager et al., 2000; Becker, Sims and
Schoss, 2003, Wineman and Adhya, 2007; Markhede and Koch, 2007; Sailer and
Penn, 2009) or experiences from consulting practices are given as examples
(Hargadon and Sutton, 2000). As Becker and Sims (2001) found out, survey data do
not always give a correct representation of what really happens. They found no
significant differences in the amount of perceived communication in office types
with different amounts of visibility in the survey data of 229 employees at 9
companies. All respondents mentioned high levels of interaction. But in-depth
interviews and observations did not only show significant differences in the
frequency, but also in the nature and character of the interactions. Blakstad,
Hatling and Bygdås (2009) found similar discrepancies between perceived survey data and
more in depth data. So asking for the perceived frequency of communication, does
not deliver valid data, and a different approach will be searched for in the fieldwork
for this dissertation (see chapter 5).

Also, these studies measure communication, without taking into account the content
of what is shared. The data report only on frequency of communication. Sometimes
the duration of a conversation is taken into account too (e.g. Becker and Sims, 2001)
or the movement path through the building (e.g. Penn, Desyllas and Vaughan, 1999;
Spiliopoulou and Penn, 1999). But all conversations could just as well be about how
somebody likes their coffee, and thus not helping organisational learning. Some
(e.g., Covi, Olson and Rocco, 1998; Peponis et al., 2007) come closer to the issue of
collaboration, by also asking respondents about their awareness of each other. But
that was a perceived awareness, and it is not measured if the awareness helped in
sharing knowledge. Also the effect was related to a move with a pre-post
questionnaire, without identifying how CRE exactly caused the change in awareness
(except for topological integration of the layout, see shortcoming 3 below). Steen
(2009, see also Steen and Markhede, 2010) identifies two types of knowledge, but
only hypothesizes on the distinction and does not test it. Ward and Holtham (2000),
Kauutu (2003) and Heerwagen et al. (2004) do discuss knowledge
management/innovation in more detail, but relate layout to it based on a literature
study of (similar types of) these studies and do not provide empirical evidence. So it
does not become clear in current literature if the layout has provided added value
for the organisation through increased KS; only an increased amount of
conversations is measured. Several studies point out the disadvantage of increased
talking and movement on the work floor, through lack of concentration and other
items negatively influencing productivity (Backhouse and Drew, 1992; Blakstad,
Hatling and Bygdås, 2009; Sailer et al., 2009; Steen, 2009; Koch and Steen, 2012b).
And as Steen and Markhede (2010) add, it is possibly the work based on more tacit
knowledge that is disturbed most by the surroundings. As Moenaert and Caeldries

55
(1996) stated already before most of these studies took place: “…future network research could complement the quantitative measurement of communication network structures with an assessment of the quality of the information received.” But unfortunately, this suggestion has not been taken up by many so far. Steen and Markhede (2010) do philosophise shortly on a possible difference between fact-related knowledge and judgement-related knowledge. The second might require more proximity, while the other is an easy transmittal of information. As they suggest, obtaining concrete information about the content of an interaction, might force researchers to develop new theories. This dissertation will try to do so, by collecting more data besides frequency on what type of knowledge is shared (as outcome was operationalised in paragraph 3.3).

Both these shortcomings deal with KS as the outcome of CREM. But the most important shortcoming, resides in the front side of the ‘equation’, namely how layout is measured. A few ways of measuring layout can be distinguished, each with its own shortcomings (or advantages, discussed in 4.3):

1. Different types of spaces (Covi, Olson and Rocco, 1998; Brager et al., 2000; Becker and Sims, 2001; Nenonen, 2005) → it is hard to extend a certain type of space to other buildings, because the mechanism might function differently there. It is disprovable, whether the exposure or openness of such a space is the same in a different layout or building. Also, these studies have not defined the rooms quantitatively in size or any other way.

2. Before vs. after collocation (Becker, Quinn and Tennessen, 1995; Moenaert and Caeldries, 1996; Kahn and Mc Donough III, 1997; Bulte and Moenaert, 1998; Sailer et al., 2007 + 2009; Blakstad, Hatling and Bygdås, 2009) → longitudinal studies are interesting, but very context sensitive. The same employees have a certain amount of communication before and after being collocated with different colleagues. Often organisational changes are made parallel to this regrouping decision, making it hard to separate the effect of CRE on its own (Bell and Anderson, 1998). Also, the layout is not always quantified, so a total CRE solution is judged, without understanding the underlying mechanism that enforced the change in communication. The more recent studies do start with quantifying the layout, but mostly in a topological way (see also the next shortcoming).

3. Topological configuration (Grajewski, 1992; Penn, Desyllas and Vaughan, 1999; Spiliopoulos and Penn, 1999; Rashid et al., 2006; Wineman and Adhya, 2007; Peponis et al., 2007; Toker and Gray, 2008; Wineman, Kabo and Davis, 2009) → a controversy of these types of studies is that metric properties of spaces are lost in the analysis, only leaving the way they connect to each other (Ratti, 2004). The underlying methodology is often used for studies dealing with unfamiliar places and way finding (many times on an urban level), where visibility over longer lines is more important in guiding people than actual distance. Haq and Zimring (2003) point out several studies that have shown that people get a different mental representation of a building when they get to know it. Their so-called ‘route map’ with topological relationships is said to change into a ‘survey map’, that has more accurate Euclidian properties. So as soon as someone wants to walk over to a
colleague’s workplace and 2 options exist to reach him/her, the shortest one (in metric distance or time) will most probably be the preferred (and thus used) one. As Sailer (2007) and Koch and Steen (2012a) state, a more programmed space, like an office building, has attractors influencing movement too (e.g. copiers, toilets). Integration is a metric of ‘intelligibility’ of the layout, which is not at all equivalent to accessibility (Peponis et al., 2007) or exposure.

4. Density of occupation (Grajewski, 1992)  
this is less a CRE description, because Grajewski means the time spend at the workplace. That is more a proxy for the use of the workplace, then the design of it.

So, as stated in the introduction, methods for linking outcomes to the features and attributes of a space need to be more fully developed. The mechanisms underlying a causal effect of layout on KS are far from clear, and not yet compared amongst each other in the same organisation. Appropriate metrics should be constructed, to describe the mechanisms more quantitatively. It is important, that these metrics cannot only describe CRE quantitatively, but are also close to an intuitive understanding of space (Shpuza, 2006). Otherwise, non real estate people, what general management usually is, will not understand it. The next paragraph will discuss possibilities for such metrics.

4.3 Quantitative metrics of a layout
Where the previous paragraph discussed the shortcomings of studies, now the promising metrics that were brought forward by others will be identified, and completed with new seemingly interesting ones. This will generate a list of metrics for studying the five mechanisms.

Co-presence - Visual/aural accessibility
An R&D building, like most other buildings, is made up of more than one room. So not everybody is able to see and/or hear each other. Many different layout concepts are used to connect rooms. The more open concepts do not only save space but are also designed to let people meet each other. The cellular offices are used to give people more privacy. Today, most buildings contain a combination of both, creating privacy for some people/functions, while others are placed in group rooms or in even larger open spaces. The awareness between people assigned to a room or area is very important for KS. Previous studies have examined co-presence for group spaces (e.g. Becker, Quinn and Tennessen, 1995 and Covi, Olson and Rocco, 1998), looking at interaction with or without their use. But it would be better if all types of work spaces in layout varieties can be quantified in the same way.

A promising metric mentioned before (by Spiliopoulou and Penn, 1999) is:

1. density

of occupation in an area which can be interpreted with the m²/workplace of all employees in the room. A possible error is that the workplaces and participants are not necessarily spread out evenly over the room, so for some the room might feel more dense than for others. A new metric that might compensate for this is:
2. location inside the room
This is an indication of where somebody is located in an (open) area. When the workplace is at the boundary of the area, the average walking distance to everybody else in the (visible) area is relatively large and vice versa, and thus that is a good way to operationalise this metric.

In group spaces, it is presumed that everybody can see each other. In larger open areas, this might not be the case, when there are columns, screens or other visual obstructions. Therefore a metric of:

3. how many workplaces can somebody see from their desk
seems relevant to test. Adding to that, the fact that seeing someone work at a far distance possibly has a different effect than seeing someone closer by, another new metric comes forward:

4. the compactness of the visible workplace
This metric has been used a lot by architects, but mostly to relate it to costs and environmental conditions (Shpuza, 2006). A spiky visual field might indicate that somebody can be seen at the end of a long corridor, while in reality the distance is too large to be aware of that person.

Another group of interesting metrics can be identified by looking at accessibility between each dyad (= a pair of employees) that could be sharing knowledge. The most obvious one is indicating whether

5. workplaces are in the same room
Markhede and Koch (2007) went a step further by testing whether

6. workplaces have intervisibility
This could be complemented by checking whether

7. workplaces are within hearing distance

Co-presence - Proximity
It is a utopia that every employee could be within visible and hearing distance of all other employees in an organisation. Also, this would not create the desired accessibility mechanism as described in the literature study before. But as others (Allen, 1977; Wineman, Kabo and Davis, 2009) showed, there could be a difference between people in different rooms which are still relatively close by and people whose rooms are further apart, so a relevant metrics is:

8. walking distance per dyad.
A metric that also has been used before (Spiliopoulou and Penn, 1999; Becker, Sims and Schoss, 2003) is

9. being on the same floor
Position in the building – Exposure
There are several reasons why people move around in a building, like arriving at work, going to meet other people, copiers, printers, etc. As mentioned by others (e.g. Moenaert and Caeldries, 1996; Wineman, Kabo and Davis, 2009) the exposure of someone’s workplace for these people walking through the building influences the amount of talking of that person. Some people are sitting closer to the entrance of their room then others. This means that more people pass them by when they visit somebody else in the room, so they are more exposed and interact more (Penn, Desyllas and Vaughan, 1999; Spiliopoulou and Penn, 1999) depending on their distance to entrance.

Also, working in a larger area with more workplaces increases your exposure to people that came to visit somebody else in the room. The size of the visible workplace could be a proxy to measure this opportunity to be recruited into conversation. If a person is surrounded by walls or screens, the possibility of seeing people pass by (and being seen by them) is small. Some office concepts therefore try to enhance exposure and simultaneously limit sound disturbance by using a lot of glass in the walls. A new metrics that might indicate this exposure to passers-by, is the: openness of the perimeter of the work area.

Position in the building - Centrality
The average walking distance to everybody in the building can differ, because of a certain centrality of the workplace. Toker and Grey (2008) related this to innovation outcomes. A metric for de-centrality would be: average walking distance to other workplaces.

Position in the building – Meeting areas
Only one previous study (Toker and Gray, 2008) mentioned testing the effect of presence of meeting areas.

4.4 Discussion and conclusions
Through literature study 5 relevant layout mechanisms have been identified to affect KS behaviour. These mechanisms can be tested with fourteen possible quantitative layout metrics:
• Co-presence
  o Visual/aural accessibility
    1. density
    2. location inside the room
    3. how many workplaces can somebody see from their desk
    4. the compactness of the visible workplace
    5. workplaces are in the same room
    6. workplaces have intervisibility
    7. workplaces are within hearing distance
Both of the co-presence mechanisms and exposure have been mentioned to be able to stimulate both interaction and collaboration, although the evidence for exposure (to people that are moving) supporting collaboration is rather thin. The other 2 building position mechanisms have only been linked to an increase in interaction, and thus do not seem able to stimulate all types of KS.

The metrics for Position in the building are all related to individuals, except meeting areas which could be used by dyads (or larger groups). The co-presence metrics also relate partly to individuals and partly to dyads, so two conceptual models have to be distinguished:
- for the individual’s workplace aspects (see Figure 4-1) and
- for the co-presence metrics of dyads (see Figure 4-2).

A CRE manager that wants the support of general management for his CRE strategy (and the necessary budget to achieve a better alignment and thus more added value), will have to start with identifying the KS process and layout mechanisms within his own organisation. This dissertation will study which metrics could be relevant to use in such an analysis. Therefore a hypothesis of association with the amount of KS meetings will be tested for each individual metric. It is best to test this association the same way for all metrics, so that it becomes clear which ones have the strongest association and thus are most relevant.

After testing the association of layout metrics with the amount of KS meetings in both models, relevant other descriptors of KS are studied to get more insight in what has happened during the meeting. The KS behaviour (KS activities identified in Chapter 3) is visualised for all CRE metrics, and tested with hypotheses of difference. This way it becomes clear whether individuals and/or dyads show different KS behaviour at a workplace with a specific level of co-presence or at a specific position in the building. For CRE metrics with a relatively high association with the amount of KS meetings (and low interdependence), it is also relevant to study the KS process in even more depth, by looking at the origination mechanisms and involvement (as discussed in Chapter 3).
Figure 4-1  Conceptual model for individual workplaces

Figure 4-2  Conceptual model for the workplace relationship of dyads
Chapter 5 Research approach

Now that the theories on KS outcomes and on the possible mechanisms behind the layout-KS relationship have been described and broken down in chapter 3 and 4, the research approach will be explained. Realistic evaluation sees the advantage of using multiple methods to study mechanisms. Paragraph 5.1 explains how the data on KS can be collected in practice, and how this was tested before this method was used for the actual empirical work. Then paragraph 5.2 describes how the data on the layout aspects (co-presence and position in the building) can be generated with spatial network analysis software. These two paragraphs answer the 5th research question.

5.1 Collecting data on KS

Chapter 3 identified the behaviour during which knowledge is shared, called KS moves, which was divided over 5 categories:

- Descriptions
  - Reporting about others
  - Describing own activities, own knowledge, own problem, findings or theory, earlier interaction, experiment, own results or technology

- Actions
  - Handing over publications
  - showing
  - on the spot calculating or trying
  - expressing observation

- Questions
  - asking a question
  - questioning
  - asking for help

- Proposals/suggestions
  - Hypothesizing
  - suggesting technical solution, experiment or new research
  - warning
  - instructing
  - referring to person, literature or interactions

- Evaluations
  - giving arguments
  - agreeing
  - rejecting
  - concluding
  - redescribing and summarising

Since data on behaviour needs to be collected, it makes sense to look at research methods for human behaviour. Runkel and McGrath (1972) grouped these methods into 4 quadrants of strategies, based on their shortcomings and advantages (see Figure 5-1). Most studies reviewed in the previous chapters use observations to identify behaviour, mostly complemented with questionnaires/interviews. For
example Hillier et al. (1985) observed all people on a floor by means of ‘snap round’ techniques many times during several days, to locate who is where and doing what with whom. Steen, Blombergsson and Wiklander (2005, and Steen and Markhede, 2010) combined interviews, observations, private logbooks and questionnaires. Also Rashid et al. (2006) held interviews, combined with behaviour observation.

Looking at Figure 5-1, it becomes clear that these layout-behaviour studies can be placed under either category I or III. Interviews and mail-questionnaires are examples of what Runkel and McGrath called ‘sample surveys’, belonging to quadrant III. Observation and keeping diaries (= self reported observation) are ‘field studies’, belonging to quadrant I. Quadrant IV does not measure actual behaviour in practice at all and therefore seems not relevant for this explorative kind of research. Quadrant II puts a maximum concern on the precision of behaviour measurement, but for a work environment it is hard to create settings as precise as necessary for this type of studies. Use of virtual reality comes to mind, but that seems more appropriate to test the effect of new environments on people and not to create the
habitual surrounding they are used to work in. So, a methodology should be chosen from either quadrant I or III.

Choosing between sample surveys and field studies/experiments, the following considerations should be made. Sample surveys can have excellent generality (if executed correctly by the researcher), but lack precision of measurement of behaviour and context. Blakstad, Hatling and Bygdås (2009), for example, show significant discrepancies between how and where people think they spend their day, and how they actually behave. Field studies, on the other hand, are usually based on one or a few cases because of the intensive contact (time) needed, and therefore it is not sure if the results are representative for other organisations. A ‘field experiment’ (field studies in which the researcher deliberately manipulates one or more variables) with questionnaires/interviews has also been performed in previous studies through quasi-experiments (Koch and Steen, 2012a; Allen, 1977; Moenaert and Caeldries, 1996; Van den Bulte and Moenaert, 1998). Organisation members are asked for their perceptions of their own behaviour both before and after a move to a different building or a regrouping within the existing building, so several changed CRE aspects are the manipulated variables. A disadvantage here is that the change in CRE is unique and composed of different CRE aspects. So it does not become clear through which mechanisms CRE changed the behaviour. Another downfall of field experiments is that a lot of time is needed for adapting the CRE/preparing to move to another location, which prolongs the research. Employees first have to get used to their new work environment too, before they start acting according to it.

The conclusive argument is that observation in a field study gives a researcher more influence on the completeness of information reported than with using surveys. A diary outperforms a questionnaire in the validity of the data it provides on trips and activities undertaken (Tan, 2003). And since this research has the intention of testing mechanisms instead of looking for the generality of results (and therefore only uses one case) the loss of generality is not as important as completeness and validity. Therefore a logbook is chosen to collect the behaviour data.

5.1.1 KS logbook
The first page of the logbook asks for some personal information on the days of the week one is present at work. Also everybody has to point out where their desk is located in the building layout.

The rest of the logbook contains identical pages as can be seen in Figure 5-2, to collect all the information necessary to measure KS outcome as described in Chapter 3. First of all, the date, start time, duration and conversation partners are asked for all face-to-face interactions in which work related issues have come up. This is necessary to see if all partners filled in the same conversations. This extra verification also makes it possible to complete the database if some people forgot to fill in a meeting, and thus helps identify the most complete data on the amount of KS meetings.
Next the **KS activities** that took place during the conversation have to be identified. Only the five main categories are displayed in the logbook, because these categories are more reliable than the detailed sub-categorisation (some of these were only observed a few times by Berends). Also this helps to keep the logbook simple for the participants. To make sure that participants interpret these five activities the same, the subcategories are used as examples in an explanation in the back of the logbook. Also this general indication of their meaning is added there:

- **Descriptions**: when giving a description of something the communication is mostly *one way*. The receiver can listen to the information that is given (written or oral) and decide for himself what to do with it.
- **Actions**: are undertaken, when you are *trying out* something *together* either physically or sitting behind the same computer. It is more a matter of doing than a deep thought-process.
- **Questions**: are asked to invite an answer from the other, which is often further explanation or *clarification*.
- **Proposals**: are made when you *suggest a thought* that you have regarding a (research) problem or work activity; how to do something or not, possible causes and resources.
- **Evaluations**: then you try to appoint a value to and/or *show your belief about* something during the interaction with the other, with the hope to come to a *conclusion*. This demands a deeper thought process about the issues addressed.

Then, the **location** of the conversation had to be marked. This can be either at the own workplace or the workplace of someone else, in a meeting area or project room, at the coffee machine or in the hallway. Although location might appear to be one of the layout metrics identified in Chapter 4, this has nothing to do with that. The layout metrics can be generated from the building drawings (see 5.2), and the logbook is only to collect KS data. This question about location is an aspect of the conversation, while the other layout metrics are aspects of a person’s (or dyad’s) workplace(s). The location of a conversation is asked to be able to compare the answers of different participants of the same conversation. It makes sure that both are writing about the same conversation, like the questions on start time and duration. Also, it is interesting to see if different locations show different ways of KS (e.g. different KS moves).

The intentionality of a conversation is relevant too. Planned meetings are less likely to be a result of the physical work environment as unscheduled conversations (Peponis *et al.*, 2007; Toker and Gray, 2008). And Allen (1997) explains that the type of communication that promotes creativity, tends to be the most affected by spatial arrangements and occurs in spontaneous encounters. Also, spontaneous face-to-face encounters form the majority of KS meetings (Toker and Gray, 2008). The unscheduled conversations can be divided into (Brown, 2008; Koch and Steen, 2012b):

- ‘*Intentional unscheduled visits*’, for which the initiator of the conversation decided to walk up to the other partner(s), and
conversations *'Initiated after coincidental visual contact'* , so partners happened to see each other and at that moment thought of starting up a conversation.

Figure 5-2 Example logbook page

Conversations that were *'Scheduled in advance'* are asked to be logged, to check whether these bring about special types of KS. It was also asked who the initiator of the conversation was, to make sure that both sorts of unscheduled conversations
can be distinguished. For example, if person A walks intentionally up to person B, the latter one might have thought that they coincidentally met each other.

The next block on the logbook pages deals with the issues addressed, to be able to identify the KS origination mechanism behind the meeting (as discussed in Chapter 3), together with the data on the initiator. This makes it possible to have a more in depth look at the KS process. Also, the literature on KS makes a distinction between tacit and explicit knowledge, as discussed before. Therefore, it is asked if there may have been an alternative source to acquire the same knowledge. This can be either another person or a more explicit document. Last, the involvement of the other person is asked to test the assumptions made in Chapter 3 on possible differences between interacting and collaborating.

Besides the information gained from the logbook, the organisational structure has to be studied as well, because it is an important context variable. Allen and Henn (2007) point out, that “...two management tools – organizational structure and physical space – are co-equal partners in moving the innovation process forward”. They found that both influence the amount of communication, but independently from each other. A certain relationship is to be expected though, and should be checked before testing the conceptual models. Also, this information is necessary to check the assumed conceptual (2-dimensional) representation of KS behaviour (see Figure 3-5). A database filled with these logbook data must be recoded before testing the conceptual models. This is discussed next, followed by a test of the logbook.

5.1.2 Recoding of database

With the logbook data it is only possible to check whether certain activities take place more often at certain locations. Although this is interesting, it does not look at a possible effect of co-presence and position in the building on KS, as taken up in the conceptual models. For such an analysis the logbook data have to be recoded into 2 different databases.

1) For each participant all KS meetings have to be added up to study the influence of workplace characteristics on a person’s KS behaviour (see Chapter 4, metrics 1-4 and 10-14): DATABASE 1.

2) For each dyad all KS meetings have to be added up to study the influence of their physical ‘connection’ on their KS meetings (see Chapter 4, metrics 5-9): DATABASE 2.

The first recoding creates a database with for all participants the number of times that each item in the logbook was checked and his/her workplace characteristics can be added later. The second recoding must be created by hand with custom tables made for each dyad. Since each meeting is present in the database from the viewpoint of every participant, the duplications are removed randomly, so that each meeting is present only once in the new database. This creates a database with for each dyad the number of times that each item in the logbook was checked for their mutual meetings and their joint workplace metrics (e.g. the walking distance between their workplaces).
5.1.3 Logbook test

The KS activities in the logbook were constructed by Berends (2003) based on his own observations. To test the presumption that participants will know what is meant by these terms, the logbook has been tested first. During one week, 40 employees of a Dutch University filled in the logbook. They were all located on the 8th floor of one building, representing 59% of the population of this floor. In this week, they marked 251 unique conversations between them in the logbook. When comparing the answers of (both) participants of the same conversation on which KS activities took place, they agreed on whether or not an activity took place for 73% on average, and at least for 68% (see Table 5-1). So it seems that the terms are clear for use in the logbook.

<table>
<thead>
<tr>
<th></th>
<th>Same answer (yes/no)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptions</td>
<td>71%</td>
</tr>
<tr>
<td>Actions</td>
<td>81%</td>
</tr>
<tr>
<td>Questions</td>
<td>72%</td>
</tr>
<tr>
<td>Proposals</td>
<td>73%</td>
</tr>
<tr>
<td>Evaluations</td>
<td>68%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>73%</strong></td>
</tr>
</tbody>
</table>

Table 5-1 Matching answers on KS activities in logbook

Another, more general, check was done by comparing the duration of the meeting. In 45% of the times, both participants agreed on the duration, and in 89% of the times the difference between the duration filled in was five minutes or less. So also the interpretation of the duration of a meeting is something that people can adequately do. Naturally, the test subjects were also asked how they experienced filling in the logbook. They all indicated that they had no major problems filling in the logbook.

5.2 Collecting data on co-presence and position in the building

Chapter 4 identified fourteen layout metrics that seem relevant to test the five mechanisms through which layout might influence KS behaviour. These were:

- Co-presence
  - Visual/aural accessibility
    1. density
    2. location inside the room
    3. how many workplaces can somebody see from their desk
    4. the compactness of the visible workplace
    5. workplaces are in the same room
    6. workplaces have intervisibility
    7. workplaces are within hearing distance
  - Proximity
    8. walking distance per dyad
    9. being on the same floor
• Position in the building
  o Exposure
    10. distance to entrance
    11. size of the visible workplace
    12. openness of the perimeter of the work area
  o Centrality
    13. average walking distance to other workplaces
  o Meeting areas
    14. Presence of meeting area

As mentioned in the previous paragraph, metrics 1-4 and 10-13 are individual workplace metrics, which have to be generated for each participant in the logbook. Metrics 5-9 and 14 have to be generated for each dyad.

Some of these layout metrics are not so difficult to generate, for example, density and whether workplaces of dyads are in the same room (for co-presence), or the distance to an entrance (for position in the building). Other aspects, however, require complicated calculations of distances that are very laborious to do by hand, for example, the location inside the room (for co-presence) and the average walking distance to all workplaces in the building (for position in the building). Luckily, “Recent years have seen the development of more sophisticated analytic techniques for describing spatial layouts and their properties.” (Wineman, Kabo and Davis, 2009). One of those techniques belongs to the area of spatial network analysis and is called space syntax analysis. Space syntax techniques have been applied to many different spatial urban environments and types of buildings. It has been used, for example (all stemming from the 2007 proceedings of the bi-annual space syntax symposium6), to study:

- religious architecture, looking for genotypes (Aazam) or studying lighting levels (Antonakaki)
- domestic spaces, looking for genotypes (Çil) or describing the work of certain architects (Sanli, Dursun and Saglamer)
- musea, studying its use by visitors (Psarra et al.) or describing layout changes (Zamani and Peponis)

and of course workplaces, of which some studies already came forward in chapter 4. Two of the many different space syntax techniques, will be explained here because they can be used to generate several of the identified layout metrics. These two techniques are called:
  1. isovist analysis and
  2. visual graph analysis (VGA).

**Isovist analysis**

Tandy appeared to be the originator of the term ‘isovist’ at a symposium landscapes in 1967 (Turner, 2001; Batty and Rana, 2004). Others state Benedikt (1979) as the first, because he introduced a set of analytic measurements of isovist properties to be used for analyzing spatial environments. An isovist as defined by Benedikt is “the

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set of all points visible from a given vantage point in space and with respect to an environment” (see Figure 5-3).

Figure 5-3 Example of isovists at eye-level from 2 different workplaces

According to Franz, Von der Heyde and Bülthoff (2005) isovists allow to generically describe spatial properties. An appealing side of isovists and visibility analysis is that they provide a description of space as how the user perceives it, interacts with it and moves through it (Turner, 2001; Turner, 2003) and have the potential to reveal more of the life that occurs in a space than by just studying the space itself (Peatross, 2001). Although Brown (2008) argues that the visibility pattern of an isovist is not necessarily what a person who is moving through a workplace is focused on, Franz and Wiener (2008) showed the relevance of isovists for how people experience their environment (e.g. spaciousness, complexity) through an experiment with Virtual Reality. Also, geographers describe space with similar discrete elements like area, perimeter and radial axes from centroid to perimeter (Sphuza, 2006).

"Isovist analysis to date has been restricted mainly to house plans associated with famous architects,...” (Batty, 2001). Especially for underlying research, isovists are useful though, because they describe the exact CRE area that supplies visual accessibility (co-presence). The viewpoint of the isovist will be the place where the researcher is sitting behind his/her desk. Sailer and McCulloh (2012) discuss why this is a valid choice. An isovist is often taken at the height of the eye level. Vision can be obscured by walls, partitions, file cabinets, etc. Benedikt (1979) formulated 6 metrics for isovists, of which the relevant ones will be discussed under the CRE aspect that it can be used for.
VGA analysis

Turner et al. (2001) used isovists, placed on a regular grid of one meter (because it is a human scale), to derive a visibility graph, which is a “graph of mutually visible locations in a spatial layout” (see Figure 5-4). The darker areas are seen from fewer points than the lighter areas in this example. So a lot of the workplaces are located in areas that are seen by very few people moving through this “building” (see Figure 5-4). Each grid point is called a node and if it is connected to another node a line (also called edge) can be drawn between those two nodes. Just as isovists describe single observation points, visibility graphs describe the layout of the floor as a whole from the viewpoint of exposure (Franz, Von der Heyde and Bülthoff, 2005) which is a big advantage. Each node can be seen as a potential place for another person, which is relevant both for co-presence as position in the building. The first application of VGA analysis to buildings is allotted to Braaksma and Cook (1980 in: Turner, 2001), who applied it to an airport terminal. With the more and better computer programmes being developed over time to calculate VGA metrics, academics have used many different metrics since then. The relevant ones will be discussed under the CRE aspect that it can be used for. The VGA is calculated for all the grid squares in the layout, but the values of the different metrics can be appointed to a specific workplace by linking the workplaces with the grid square that best represents them. Turner et al. (2001) distinguish between a visibility graph and permeability graph (= visibility graph at floor level, to include furniture and other obstacles). The metrics can be applied to both these graphs in case differences are to be expected because of use of “see-through” partitions and windows.

A problem of visual graphs is that the bigger spaces appear to be “better” for some metrics, because they have the potential to see many other nodes where people can be at a certain time (position in the building). For co-presence in larger open-office spaces it seems also interesting if only those nodes that represent another person’s workplace are used to calculate VGA metrics. This is a slightly different approach of VGA analysis which has not been taken up yet in any previous VGA study, as far as known. Since a VGA is based on nodes that can see each other, this way of making a VGA is only suitable to look at individual rooms or open areas with several people within visibility. The rooms/areas are no longer connected like in a regular VGA. However, it provides extra opportunities that isovist analysis does not, by looking at open sections in a building more closely this way. Workplaces that cannot be seen from any other workplace (like in single person cellular office spaces) are excluded from this type of analysis.
Several software programs have been developed to generate the metrics used in both these techniques. For underlying dissertation, the program called Depthmap (version 7.12) was used, developed by Turner (2004, 2001), because it can generate many metrics, that are necessary for this research. Depthmap first imports architectural drawings made in AutoCAD. Next, it can place a grid over the drawing, creating many grid squares with certain dimensions (e.g. 1x1 meter). Each grid square is appointed an original number, so each workplace grid square can be linked in SPSS to the participant using it. The grid squares that you want to include in an analysis then have to be selected, so that the metrics can be generated for each grid square. Only grid squares that can reach each other through the layout (are not boxed in by lines from the AutoCAD drawing) are related to each other in a VGA. By making different layers within an AutoCad drawing (e.g. one for furniture, one for walls, one for glass, etc.), different VGA graphs can be made, because in Depthmap each layer can be turned on/off, before running the analyses. This makes it possible to create both visibility and permeability graphs. How each distinguished CRE metric is generated will be discussed next.

5.2.1 Co-presence
Now that it is clear what an isovist and visual graph is, this subparagraph and the next one will describe different metrics that can be generated for an isovist or visual graph, which seem proper to measure the identified layout metrics.

Visual/aural accessibility
To generate the accessibility metrics using a visibility graph, only the AutoCAD layers with walls, columns and other nontransparent physical attributes are turned on. The
furniture layer and glass (transparent) partitions/windows are turned off, so that Depthmap does not see those as obstructions in visibility.

1. Density
This is not a complicated metric. It will be measured as the inverse of the number of m²/workplace, which can be calculated from information provided by the CRE manager on the size of rooms/areas and the number of employees inside.

2. Location inside the room.
The density in a room can be very diverse. Therefore, this metric is an indication of where somebody is located in an open area with regard to the others. When the workplace is at the boundary of the area, the average walking distance to everybody else in the (visible) area is relatively large and vice versa. Although this could be measured by hand from the AutoCAD drawings, this would be a lot of work. Depthmap can generate it quickly, by making a VGA of the grid squares that represent people’s workplaces and generating the metric called Metric mean shortest path distance.

![Figure 5-5 Screenprints large open areas with average walking distance to indicate the location inside the room (cold colours/blue is central; warm colours/red is at the edge)](image)
In Figure 5-5 Depthmap screen prints from large open areas are shown with the workplaces coloured for the value of their average walking distance. The indicated ‘warmer’ workplaces (red colours) are places that are more at the centre of their visible group of colleagues. This does not only add information to density but also to metric 3 (described next), because although these people see the same amount of people, they are not in the midst of ‘the action’.

3. How many workplaces can somebody see from their desk
The number of other participants that a person can see from the workplace is not complex, but still laborious to count by hand. Depthmap can generate it with one of the VGA metrics, called Connectivity, if a VGA is made of the workplaces only.

4. The compactness of the visible workplace.
Batty (2001) tried to measure how far one could see as a proxy for how much one could see, with the maximum, minimum and average radials within an isovist. Combined, they form a metric for compactness (average distance/maximum distance). On the one hand a more compact place seems to be closer to representing co-presence, because seeing someone work at the end of a long hallway, does not provide aural accessibility for example. On the other hand, spikiness shows that someone can be seen both from close-by as from a larger distance, which might have a positive effect on KS too. A perfect circle would hold a compactness value of 1, while a line has value 0.

5. Workplaces are in the same room.
This is not a complicated metric. It can be generated with the information provided by the CRE manager on who is sitting in which room/area.

6. Workplaces have intervisibility.
This is not a complicated metric. It can be measured from the AutoCAD drawings.

7. Workplaces are within hearing distance.
To measure the hearing distance, the speech transmission index (STI) is mostly used, developed by Houtgast and Steeneken at TNO Netherlands. The STI as used by acoustics academics estimates the intelligibility of sounds. It varies between 0 and 1, and has to be 0.6 or higher for good or excellent sound intelligibility (Steeneken, 1998). The ‘paradox of verbal communication’ in offices that is often spoken about, is that on the one hand privacy is needed for concentration but on the other hand speech intelligibility helps cooperation. Most studies by acoustics academics focus on speech privacy, while for this dissertation the opposite is more relevant. Studies focusing on intelligibility mostly look at warning sounds (e.g. fire alarm). Besides distance between sound and receiver, other relevant aspects to determine intelligibility differ per office and conversation, like the background noise, speech level and room acoustics (Wenmaekers et al., 2009). So, one specific distance is not mentioned. But studies into the distance to achieve an STI of at least 0.6 (Keränen, Virjonen and Hongisto, 2008 and 2007; Wenmaekers et al., 2009) in general find a value for hearing distance between 5 and 10 meter. Since the exact distance is case-dependent, it will be studied further in the actual case.
When a distance is chosen, this is a complicated metric to generate by hand, but also with the help of Depthmap. By hand, each dyad in a room has to be checked in the AutoCAD drawing whether they are within hearing distance. With Depthmap, a VGA analysis on the entire floor has to be done. Then for each dyad in a room the Metric straight-line distance can be generated. But since Depthmap does not work with dyads, an individual analysis has to be done for each person, generating his/her distance to all the other persons on the floor. These results can be imported into SPSS, and then the value can be allocated to each dyad via the ‘merge’-function.

Proximity
From here on in the conceptual models, the metrics no longer deal with a single room. So to do a VGA analysis it might be necessary to generate distances over more than one floor, connecting people vertically through stairs and elevators. Turner, the developer of Depthmap, explains how to best make this connection (Turner, 2004; Turner, 2001), through a merge-option that he programmed for this. “In the merge, the global analysis functions in Depthmap simply regard the merged cells as co-present at the same physical location, and continue to analyse from there.” (Turner, 2004) For a straight staircase, you can merge all the points on it with the same staircase drawn in the layout for the other floor; for a staircase with a mezzanine landing, you can merge this landing. For elevators it is harder, because they connect several floors and not just 2 and also they cause a time lag. Turner suggests the following solution: “In order to cope with this, when I make graphs, I assign a few points outside all space. These points will all naturally see each other, and therefore be one step apart. I then merge each lift point with each intermediate point. The result is a one step relationship to any other floor within the building.” (Turner, 2004). To be able to merge, the different floors have to be in the same Autocad drawing.

Also, there is no longer the issue of visibility, but of permeability, so a permeability graph must be generated by turning on all AutoCAD layers, including the furniture that someone has to walk around. Depthmap uses the VGA grid when it determines metric distances. This is a close approximation of the actual metric distance, because it measures distance from the centre of one grid square to the centre of another, but does move around obstacles in the drawing. So with a small enough grid the approximation is close enough.

8. Walking distance per dyad.
Matela and O’hare (1976 in: Shpuza, 2006) distinguished 3 distances between pairs of cells in polyominoes, being Taxicab, Euclidean and Graph metric. Only the Graph metric distance is relevant here, because the other 2 distances do not account for the impermeability of walls. There is a difference between the (Euclidean) Metric straight-line distance and the Graph metric distance when walking through the layout. This is clearly visible in Figure 5-6 (see next page), which shows the mean walking distances to every other place on the floor belonging to the test-case for the logbook. Naturally, the centre of the building has the best connection to other places in general (color = blue). But the bottom layout of this (partly 2-storey) floor is more realistic, because it measures the distance going around obstacles and walls, and
also using stairs. The Graph metric distance implies using the shortest way known, like in transportation analyses, but following the layout. Matela and O'hare found it to be the best suitable to approximate circulation routes in buildings. This metric is complicated to generate though, in the same way as discussed under the previous one. By hand it seems almost impossible to derive from a drawing, but with Depthmap generating the right distance also requires a lot of work. First, the distance from a workplace to every other gridsquare inside the building has to be generated with the Metric shortest path distance for each individual workplace. Subsequently, in SPSS the distance for each dyad must be selected and allotted to each dyad in the table.

9. Being on the same floor. This is not a complicated metric. It can be seen in the AutoCAD drawings or derived from the information provided by the CRE manager on who is sitting in which room/area.
Figure 5-6  Mean metric straight line distance (top) and Mean metric shortest path distance (bottom)
5.2.2  Position in the building

Exposure

10. Distance to entrance.
The distance from the workplace to the entrance of the room is calculated with the Metric shortest path distance in Depthmap. First a gridsquare must be selected that represents the place where a room is entered and the biggest part of it becomes visible. Then the Metric shortest path distance to each other gridsquare can be generated with the VGA of the entire layout, and the values of the gridsquare representing people in this room can be selected. This has to be repeated for each room/entrance.

11. Size of the visible workplace.
In Depthmap this is called Isovist area. It relates a lot to the room size, but is usually not entirely the same because of partitions, columns and other physical obstructions. Especially workplaces in large open areas could show a difference between the room size and the Isovist area. When a VGA of the entire layout is done, Depthmap can generate the isovist metrics for each grid square. Then the values of the gridsquares representing the workplaces can be selected.

12. Openness of the perimeter of the work area.
In Depthmap, a metric that intuitively seems to relate to this is called Isovist occlusivity. It measures the part of the perimeter of the visible workplace (isovist) that is open/permeable (not represented by walls or other solid boundaries). A higher value (more m² of open perimeter) means that the workplace is exposed more for people passing by, because the chance that someone steps into the visible field is bigger. When a VGA of the entire layout is done, Depthmap can generate the isovist metrics for each grid square. Then the values of the gridsquares representing the workplaces can be selected.

Centrality

13. Average walking distance to other workplaces.
This is the most complicated metric to generate with Depthmap, because it only wants to look at the walking distances between somebody’s workplace and the workplace of all the others. So, although the VGA has to be done for all the gridsquares in the entire building, only the values for the grid squares that represent a workplace must be used to calculate this distance. It can be derived from the analyses done for the previous metric on walking distances per dyad. For each person the distance to all his possible dyad-participants has to be summed up and then divided by the number of participants. Then the average walking distance comes forward.

Presence of meeting area.

14. Presence of meeting area.
An easy metric, visible in the layout.
5.3 Résumé
A logbook seems the best way to collect the necessary behavioural data for the outcome measurement, because it outperforms a questionnaire in validity, and sample surveys in precision of measurement. The logbook data can be used to create two databases; one for each conceptual model. A test of the logbook showed that the KS items chosen to study the KS process in more depth are clear to its users.

To obtain the layout metrics, isovist and visibility graph analysis seem appropriate. These spatial network analyses methodologies can complement the few simpler layout quantifications, and thus test all metrics in the conceptual models to identify layout mechanisms.

So, to be able to test the conceptual models (mechanisms) and study the KS process in more depth (outcome), the following information is necessary:
- The KS logbooks of participants;
- An AutoCAD drawing of the building layout (complemented with a guided tour);
- An overview of who sits where;
- An overview of the organisational structure (= context);
- The Depthmap software.
The next chapter will describe the variables in the conceptual model as they were collected during a case study.
Chapter 6 Data description case study

This chapter starts with a description of the case organisation (context) that is used for data collection to test the conceptual models. In paragraph 6.2 it is explained why some of the logbook variables needed to be recoded and how the employees of this organisation share knowledge. Paragraph 6.3 gives a description of the CRE metrics at the case organisation. Paragraph 6.4 clarifies which statistical tests can be used, based on the quality of the variables, followed by conclusions and the answer to the 6th research question.

6.1 Case organisation

Because past studies have shown that KS is very important in that sector (Berends, 2005), an industrial research organisation is chosen as a case. Also, the moves distinguished by Berends (2003) were identified from the behaviour of researchers in that sector. The case organisation is Océ7, one of the world’s leading providers of document management and printing for professionals. The broad Océ offering includes office printing and copying systems, high speed digital production printers and wide format printing systems for both technical documentation and color display graphics. Océ is also a foremost supplier of document management outsourcing. Many of the world’s Fortune 500 companies and leading commercial printers are Océ customers. The company was founded in 1877. Océ is active in approximately 100 countries and employs some 22,000 people worldwide. Total revenues in 2009 amounted to € 2.7 billion. In 2010 Océ joined the Canon group.

Océ wants to stay a company based on innovation with advanced R&D projects, dedicated to digital printing and related technologies. Through its own Research & Development (R&D) Océ develops its own basic technologies and the majority of its product concepts. The headquarters is located in Venlo, The Netherlands, where a large part of the R&D takes place. At the time of the fieldwork of this dissertation, Océ research in Venlo consisted of over 1000 employees. The building with most researchers is called 3G and therefore was chosen as the subject of this case-study. It was built in 1984 and has not been renovated since. Renovation plans were being made at the time of the fieldwork. In total 269 employees had a workplace in the 3G building (excluding general staff, e.g. secretaries), which were all approached at their workplace to ask if they wanted to participate. All participants filled in the logbook during one week in October 2007. In total 1418 logbooks were handed out and returned which is a 52% response rate. Océ assigns each employee a code based on their name, which is used in this dissertation to refer to persons if necessary.

Océ has a matrix structure, where people are part of departments (which are split up in teams) and are also appointed to projects. The participants from the 3G building are spread over all the departments that use this building, and at least 1/3 of the

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7 All Océ information stems from www.oce.com February 2011.
8 Of these 141 participants only 138 were included in the analyses, because 3 (CH, HITZ, QTP) did not participate in meetings that met all requirements.
employees of each department participated. Also most of the teams within the departments are still represented by at least 1/3 of the team members, with only two exceptions (electronics & informatics 2 and 3). In absolute numbers though, a few teams are very small with just a few participants (see Table 6-1). As can be seen, the projects that the participants have been assigned to are strongly related to their department. Because more than half of the participants is part of only two projects, there is not as much diversification as in the team members.

| Department and team analysis & measurements development electronics & informatics engineering consumables & processes mechanical engineering research on products & processes software development software engineering |
|---------------------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Project 1 N=51/36%                                           | 2               | 17              | 6               | 5               | 2               | 1               | 6               | 5               | 1               | 5               | 1               |
| Project 2 N=3/2%                                              | 1               |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
| Project 3 n=22/16%                                            |                 |                 | 3               | 8               | 11              |                 |                 |                 |                 |                 |                 |
| Project 4 n=13/9%                                             |                 |                 |                 |                 |                 | 3               | 9               | 1               |                 |                 |                 |
| Project 5 N=6/4%                                              |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 | 6               |
| Project 6 N=19/14%                                            |                 |                 |                 |                 |                 |                 | 6               | 6               | 4               | 3               |                 |
| Project 7 n=1/1%                                              | 1               |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
| Project 8 N=7/5%                                              |                 |                 | 1               | 3               | 3               |                 |                 |                 |                 |                 |                 |
| Project 9 N=8/6%                                              |                 |                 |                 |                 |                 | 7               |                 |                 |                 |                 | 1               |
| Project 10 N=10/7%                                            |                 |                 |                 |                 |                 |                 | 1               | 2               | 3               |                 |                 |
| Total                                                         | 1               | 11              | 17              | 9               | 5               | 2               | 1               | 6               | 11              | 1               | 5               |
| % of team                                                     | 33              | 38              | 46              | 35              | 71              | 17              | 20              | 50              | 46              | 50              | 63              |
|                                                               | 67              | 73              | 60              | 69              | 70              | 77              | 50              |

Table 6-1  Departments, teams and projects of participants

Building 3G has two floors (see Figure 6-1), which are connected with central stairs and outside stairs at both ends of the building. Although the outside stairs were previously emergency exits only, they are now used for normal vertical traffic as well and thus in the analyses are treated the same way as the central staircase. As can be seen, the case building has both large and small rooms, ranging from single-person rooms to open areas with up to 29 workplaces. Small lab areas without daylight are concentrated around the corridors, and a few large lab areas with less specific climate conditions are located in areas similar to the offices. The layout is quite full besides the desks and chairs that form workplaces, with cabinets, loose tables and equipment. Figure 6-2 shows only the workplaces, where the participants are made darker as the rest. As can be seen they are spread out over the building. People are located in the building according to the project that they are working for. Project 1
occupies most of the ground floor (two rooms are for Project 2), and the other projects are clustered on the top floor.

Figure 6-1  Layout Océ building 3G

Figure 6-2 All workplaces in layout (participants are bold)

The following rooms will be considered to be one room in the analyses, because they have no closed walls between them so they provide co-presence:

- 3G03 and 3G04
- 3G07 and 3G08
- 3G56 and 3G57.
The following rooms are treated as two/three separate rooms in the analyses, because they have closed walls that separate the workplaces although they have the same room number:

- 3G59 → 3G59.3 and 3G59.4
- 3G62 → 3G62.3 and 3G62.4
- 3G73 → 3G73, 3G73.3 and 3G73.4
- 3G76 → 3G76.2 and 3G76.3

6.2 Recoding and description of KS data

The following types of KS indicators can be derived from the logbook:

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Type of variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of KS meetings</td>
<td>Interval</td>
</tr>
<tr>
<td>KS activities</td>
<td>Nominal</td>
</tr>
<tr>
<td></td>
<td>(descriptions, actions, questions, proposals, evaluations)</td>
</tr>
<tr>
<td>Location</td>
<td>Nominal</td>
</tr>
<tr>
<td></td>
<td>(workplace, meet area, project area, coffee machine, hallway)</td>
</tr>
<tr>
<td>Intentionality</td>
<td>Nominal</td>
</tr>
<tr>
<td></td>
<td>(intentional unscheduled visit, initiated after coincidental contact)</td>
</tr>
<tr>
<td>Issues addressed</td>
<td>Nominal</td>
</tr>
<tr>
<td></td>
<td>(problem of one person, shared problem, not problem oriented)</td>
</tr>
<tr>
<td>Alternative source</td>
<td>Nominal</td>
</tr>
<tr>
<td></td>
<td>(No only this person, yes other person, yes non-human)</td>
</tr>
<tr>
<td>Involvement</td>
<td>Interval</td>
</tr>
<tr>
<td></td>
<td>(1 - 5)</td>
</tr>
</tbody>
</table>

All variables were entered in a database in SPSS, where each line is an occurrence entered by a person in his/her logbook. Before this database was used to generate DATABASE 1 and 2 (adding the occurrences for resp. persons and dyads), several actions were undertaken to clean up the data-set and make it more complete (see also appendix Appendix I), which is discussed shortly below.

In total 141 logbooks were collected and numbered, with 1944 valid logged occurrences to be entered into the database. In 623 of these occurrences (32%) the other person did not participate in the study. As explained in appendix Appendix I,

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9 To prevent confusion with the concept ‘interaction’ (next to ‘collaboration) as defined in Chapter 3, each time two or more employees shared knowledge, regardless whether it was planned or coincidental, is called a meeting. Because a meeting can (and should) be logged by more than one of the participants, the term ‘occurrence’ is introduced to refer to each individual logbook entry. This way, possible confusions are prevented until the duplicate occurrences are matched into actual meetings.
these are tagged “partner no logbook” and kept out of the analyses. The 1321 remaining occurrences are matched to see if all partners filled in their KS meeting with each other. This is done manually, by sorting all occurrences by ‘date’ and ‘start time’. If the same partners mentioned meeting each other within a 30 minute timeframe, this is considered a match and both/all occurrences are given the same match-code.

As a precaution, several tests have been run to validate the choices made (see also appendix Appendix I). First, it was tested whether the following three groups of occurrences show differences in any of the KS indicators from the logbook:

1. Occurrences that took place with people that did not participate in the study (coded “partner no logbook”),
2. Occurrences that could not be matched although the partner did fill in a logbook (coded “no match”) and
3. Occurrences that could be matched (coded “match”).

Since this is a test of differences between nominal data on three groups, a Chi-square analysis is done, analysing these three groups against all logbook information in the adjusted database. This showed that the matched occurrences are a reliable representation of the total database. The few significant differences between matched and unmatched occurrences were either logical (e.g. short meetings showed less matches because they are easier to forget) or seemed irrelevant (e.g. on Thursday significantly less matches could be found). The meetings with non-participants showed no relevant differences with the meetings between participants, whether matched or unmatched, so it is no problem to remove them.

Next, it was checked in several ways whether the participants in a meeting interpreted the different KS activities the same way as their meeting partners. Looking at the KS activity ‘Descriptions’, in 69% of the meetings both people in a meeting agreed whether it did or did not take place (134 (no/no) + 27 (yes/yes)/233= 69%). For ‘Actions’, ‘Questions’ and ‘Proposals’ this was 73% and for ‘Evaluations’ 72%. Further analysis of the KS activities that they did not agree on (see Appendix Appendix I), does not show any indication that terms were interchanged or unclear.

All occurrences that were ‘scheduled in advance’ (176 = 13%) are moved to a separate file, because (as discussed before) it is very likely that they have not been a result from the building design. As can be read in appendix Appendix I, these meetings have a very different nature than the unscheduled ones.

Besides removing planned meetings and meetings with non-participants, the non-participants are also removed from the meetings with more than 2 participants. Because of this only meetings with 4 or less participants remain in the database (see Table 6-2) on the next page.
<table>
<thead>
<tr>
<th>Nr of persons</th>
<th>All occurrences in logbooks</th>
<th>%</th>
<th>Unplanned occurrences (participants only)</th>
<th>Matches</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1036</td>
<td>78,4</td>
<td>1068</td>
<td>406</td>
</tr>
<tr>
<td>3</td>
<td>157</td>
<td>11,9</td>
<td>68</td>
<td>39</td>
</tr>
<tr>
<td>4</td>
<td>61</td>
<td>4,6</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>51</td>
<td>3,8</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>0,8</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>0,4</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1321</td>
<td>1145</td>
<td>1907</td>
<td>918</td>
</tr>
</tbody>
</table>

Table 6-2  Removing non-participants in groups

The database was then manually completed by matching and duplicating logged occurrences for all individual partners, when they forgot to fill in the meeting themselves. It is clear that they were present, but just forgot to fill in the logbook. This led to a complete DATABASE 0 with 1907 occurrences that represent 918 meetings between 138 participants (see Table 6-3). From this file, the database with individuals (DATABASE 1) and the database with dyads (DATABASE 2) is created. DATABASE 1 contains 138 lines, representing the participants and their indicators of KS. DATABASE 2 contains 9453 lines, representing the dyads and the indicators of KS within each dyad.

<table>
<thead>
<tr>
<th>Participants in meeting</th>
<th>Unplanned occurrences logged</th>
<th>Occurrences matched</th>
<th>Occurrences after completion</th>
<th>Nr. of Matches</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1068</td>
<td>406</td>
<td>1710</td>
<td>855</td>
</tr>
<tr>
<td>3</td>
<td>68</td>
<td>39</td>
<td>165</td>
<td>55</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>5</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>1145</td>
<td>450</td>
<td>1907</td>
<td>918</td>
</tr>
</tbody>
</table>

Table 6-3  Completing the missing occurrences

Of the KS meetings, 85% took place between people from the same project and another 3% with at least two people from the same project. So the influence of the project structure is evident and will not be studied further. Apparently people share very little knowledge outside of their project teams. Since Océ has a matrix structure, it is also interesting to look at the functional composition of teams and departments. Almost half of the meetings took place between team members (see Table 6-4), and 51,9% between people from the same departments. But still 38,1% of the meetings regarded KS between people from different departments. In Chapter 8.2 it will be checked if these meetings are different than the ones within the departments or teams, as discussed with Figure 3-5 in Chapter 3.
Next the different KS indicators from the logbook are described, to get an impression of the KS that took place at Océ that week. For more details, it is also interesting to test hypotheses of differences for the logbook data, for example whether different KS activities need different types of conversations (time of day, location, etc.) or whether tacit knowledge has different prerequisites than explicit knowledge. This paragraph will only briefly describe the data that were collected with the logbooks. For more insight in the KS process at Océ see appendix Appendix II.

**Amount of KS and KS activities**

On average, participants had 14 KS meetings per week (SD = 8), with a minimum of 1 and a maximum of 35. The spread is not normal and it was not possible to recode in a relevant way that would make it normal. With intervals of 2 meetings the same histogram image appears and with intervals of 3 (or more) meetings the slope leans to the left. Not all 138 participants have had KS meetings with each other during the week that was studied. Of the 9453 dyads, 372 have shared knowledge with each other, which is 4%. The dyads that shared knowledge, had an average of 3 KS meetings that week (SD = 3), with a minimum of 1 and a maximum of 17, so not spread normal either. On average participants shared knowledge with 5 different colleagues that week, with a maximum of 12 different colleagues (see also Figure 6-4).

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Valid %</th>
</tr>
</thead>
<tbody>
<tr>
<td>same team</td>
<td>891</td>
</tr>
<tr>
<td>different team, same department</td>
<td>289</td>
</tr>
<tr>
<td>different departments</td>
<td>727</td>
</tr>
<tr>
<td>Total</td>
<td>1907</td>
</tr>
</tbody>
</table>

*Table 6-4  Cross-functional, between teams and within team meetings*

*Figure 6-3  # of KS meetings for participants and dyads*
During 56% of the meetings knowledge was shared by asking and answering questions, while the other four KS activities took place in about 20% of the meetings. In 73% of the meetings, 1 KS activity took place, and in another 20% there were 2 activities.

<table>
<thead>
<tr>
<th>KS activities</th>
<th>Frequencies</th>
<th>Valid %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptions</td>
<td>423</td>
<td>22.4%</td>
</tr>
<tr>
<td>Actions</td>
<td>321</td>
<td>17%</td>
</tr>
<tr>
<td>Questions</td>
<td>1067</td>
<td>56.4%</td>
</tr>
<tr>
<td>Proposals</td>
<td>372</td>
<td>19.7%</td>
</tr>
<tr>
<td>Evaluations</td>
<td>395</td>
<td>20.9%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2578</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th># of KS activities during the meeting</th>
<th>Frequencies</th>
<th>Valid %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1379</td>
<td>72.9%</td>
</tr>
<tr>
<td>2</td>
<td>376</td>
<td>19.9%</td>
</tr>
<tr>
<td>3</td>
<td>104</td>
<td>5.5%</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>1.3%</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

**Table 6-5  KS activities at Océ**

A check for possible combinations of KS activities (see Table 6-6) shows that in case of more than 1 activity during the meeting, especially a proposal is often combined with questions (43% of the proposals). But also the other three activities are combined with questions a lot; 36% of the actions, 32% of the descriptions and 26% of the evaluations. So although questions can stand on its own as a KS activity, the other four activities often use it as an addition.

The time of the day that the meetings started, shows an almost logical picture of a standard Dutch working day, with lunch between noon and one o’clock. The morning shows more KS then the afternoon, with a clear peak at the beginning of the workday. There are no significant differences between morning and afternoon meetings with regard to any of the other variables in the logbooks.
On average, people spend 45 minutes of their day involved in unplanned meetings (with a minimum of 1 min./day and a maximum of 6 hrs. + 38 min./day), which is over 10% of a normal workday of eight hours. Looking at the duration of all meetings, 45% lasted 5 minutes or less and 80% lasted up to 15 minutes. So most KS took place during very short meetings. In almost 90% of the meetings, 2 participants were involved in the KS (9% with 3 persons, 2% with 4 persons).

**Locations for KS**

Participants were also asked to mention the type of location where the KS took place. As Table 6-7 shows, 78% took place at a workplace. The labs (= project area) account for 14.4% of the meetings. Very few unscheduled meetings took place in the meeting areas, but more surprisingly, the hallway or coffee machine also do not accommodate many unscheduled work related meetings. Perhaps, the coffee machine is more a place of informal talk about non-work related matters or not a cozy place to be. But these aspects were not asked in the logbook. Another explanation could be that maybe people forgot to log these meetings, although it does not seem likely that this would explain such a large difference with meetings at the workplace. From the meetings at the workplace, 13% took place between people that could talk with each other from behind their desk, because their desks are next to each other in the same room. So in general, one of the participants had to walk over to this workplace for the meeting. As this confirms the expectation, that meeting areas is not a relevant mechanisms, this will be discarded.

<table>
<thead>
<tr>
<th>Frequencies</th>
<th>Valid %</th>
</tr>
</thead>
<tbody>
<tr>
<td>workplace</td>
<td>1486</td>
</tr>
<tr>
<td>meeting area</td>
<td>22</td>
</tr>
<tr>
<td>project area</td>
<td>274</td>
</tr>
<tr>
<td>coffee machine</td>
<td>81</td>
</tr>
<tr>
<td>hallway</td>
<td>39</td>
</tr>
</tbody>
</table>

**Table 6-7 Location of KS**

The type of KS activity differs per location when the single KS activities\(^\text{10}\) are taken into account ($\chi^2 (8, 1335) = 82.7, p < .01$). The meetings in the hallway and in meeting areas had to be left out of the analyses because the individual cell values were too low. The most important reason for the significant difference, is that 1/3 of

\(^{10}\) Single KS activities refer to the meetings during which only 1 KS activity took place (=73%).
the actions took place in a project area, which relatively is a lot (see Table 6-8). This is not strange, considering that this is partly what labs are for, doing experiments together. Berends (2005) also mentioned that moves in this category are situated and depend on a material environment. A second determining factor for the high $\chi^2$ value is that evaluations take place relatively often at the coffee machine, which is a place that is not mentioned often in the entire sample. A surprising finding is that there were no questions asked in the meeting areas and relatively few at the coffee machine; two places that would seem very suitable to ask questions. Formal planned meetings in a meeting room might not deal with matters that call for questions or culture could impede participants from asking questions. But with unplanned meetings these issues should not be relevant.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Count</th>
<th>Expected</th>
<th>Count</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workplace</td>
<td>154</td>
<td>161.1</td>
<td>95</td>
<td>123.1</td>
</tr>
<tr>
<td>Project area</td>
<td>33</td>
<td>28.9</td>
<td>52</td>
<td>22.1</td>
</tr>
<tr>
<td>Coffee machine</td>
<td>12</td>
<td>8.9</td>
<td>5</td>
<td>6.8</td>
</tr>
</tbody>
</table>

**Table 6-8 Single KS activity and Location $\chi^2$-test**

**Tacit or explicit knowledge**

The knowledge that was shared is very tacit, as it was described in chapter 3. A clear explicit knowledge form is a non-human source, like the internet, a dvd or a book. But only 4.2% of the shared knowledge could also have been found in such a source as an alternative. Knowledge could also be said to be more explicit, if several people within an organisation contain the same knowledge, what was the case for 18.6% of the meetings (where another person would have been available as alternative source for the knowledge that was shared). So 77.2% of the meetings dealt with knowledge that only this particular person could provide (according to the person that filled in the logbook).

Looking at the intentionality, 72% of the meetings took place because somebody intentionally walked over to meet the other person, or they have their workplaces so close that they can talk with each other from behind their desk. The other 28% took place because people happened to see each other, and then decided to interact. The coincidental meetings lasted shorter on average ($M = 11.23, SD = 11.48$) than the intentional meetings ($M = 13.84, SD = 22.55$), although the difference is not very large. This could only be tested with a Mann-Whitney U test, because duration is an interval variable that does not have a normal spread and intentionality has become a
dichotomous variable (as the planned meetings were removed). The test showed that the difference was not significant (Z = -.211, p = .83).

Of the meetings, 11% did not have a problem of one (or more) of the participants as a reason for the meeting (see Table 10-10 in appendix Appendix II) and in 45% of the times, it was not a shared problem. So this is not a requisite for sharing knowledge. But when participants did share a problem (44%), they evaluated much more often; \( \chi^2 (8, 1374) = 207.56, p < .01 \) (see Table 6-9). In case of a problem for only one of the participants, the knowledge was significantly shared more often through asking questions and less evaluating took place. In case of shared problems, less questions had to be asked. During not-problem oriented meetings, descriptions and evaluations were useful ways of sharing knowledge.

<table>
<thead>
<tr>
<th>Issues addressed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Problem of one person</td>
</tr>
<tr>
<td>descriptions</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Actions</td>
<td>98</td>
</tr>
<tr>
<td>questions</td>
<td>47</td>
</tr>
<tr>
<td>proposals</td>
<td>46</td>
</tr>
<tr>
<td>evaluations</td>
<td>45</td>
</tr>
<tr>
<td>Total</td>
<td>685</td>
</tr>
</tbody>
</table>

Table 6-9 Issues addressed and single KS activities \( \chi^2 \)-test

The involvement of the other person in the meeting is generally estimated to be very high, with 81% rating it 3 or higher on a 5-point scale (see Figure 6-5).
6.3 Generation and description of layout data

The following types of layout metrics are taken up in the conceptual model:

**Individuals**

1: Density
Type of variable: Interval

2: Average walking distance to visible workplaces
Type of variable: Interval

3: How many participants can somebody see from their desk
Type of variable: Interval

4: The compactness of the visible workplace
Type of variable: Interval

10: Distance to entrance
Type of variable: Interval

11: Size of the visible workplace
Type of variable: Interval

12: Openness of the perimeter of the work area → recode
(dichotomous; yes/no visible from entrance room)
Type of variable: Nominal

13: Average walking distance to other workplaces
Type of variable: Interval

**Dyads**

5: Workplaces are in the same room
(dichotomous; yes/no)
Type of variable: Nominal

6: Workplaces have intervisibility
(dichotomous; yes/no)
Type of variable: Nominal

7: Workplaces are within hearing distance → recode
(dichotomous; yes/no)
Type of variable: Nominal

8: Walking distance per dyad
Type of variable: Interval

9: Being on the same floor
(dichotomous; yes/no)
Type of variable: Nominal

To be able to generate the Depthmap metrics, an AutoCAD drawing of building 3G with both floors was imported into the program. Then a grid of 0.50 x 0.50 meters was placed over the entire layout of both floors covering 30217 grid squares (see Figure 6-5).
Figure 6-6\textsuperscript{11}. The distance of 0,50 meter is justified by Franz and Wiener (2008), saying it lies between the average human step length (± 0,6 m) and body width (± 0,45 m). Each square is assigned a reference number. The 138 workplaces of participating employees can be identified with this number during all analyses. The floors are connected at the three stairs.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{layout_3G_with_depthmap_grid.png}
\caption{Detail of layout 3G with Depthmap grid}
\end{figure}

The accessibility metrics (1 through 7) are generated with the doors-layer turned on (which means doors are closed), because the doors between the rooms/areas are always closed (not locked). So that is the best representation of visibility during the day. The proximity and building position metrics (8 through 14) are generated with the doors-layer turned off (which means doors are open) to get a representation of walking distances and exposure during movement. All these metrics are calculated with a layout with only the partitions and high closets inside.

Next, the spread of each CRE metric at the Océ case will be described. Since the dependent variables in both conceptual models (for individuals and for dyads) do not have a normal spread, this is not a requirement for the CRE metrics either; non-parametric tests are the only option anyway. But the spread is discussed to look for important outliers and to describe the metrics. Since these metrics are generated by me there are no missing values. For the individuals’ metrics of their workplace N = 138. The metrics 1 through 4 are for co-presence and 10 through 13 for position in the building. For the dyads’ metrics of their workplace relationship N = 9453. The metrics 5 through 9 are for co-presence and no metrics are in the model for position in the building, as meeting areas was discarded.

\textsuperscript{11} The area between both floors in the AutoCAD drawing is also assigned gridsquares, but they are not taken up in any analysis, because these take place inside the walls of the building.
6.3.1  CRE metrics of individuals

Metric 1) Density of the room where the workplace is located (m²/workplace)
Looking at building 3G, most participants have between 10 and 15 m² per person as a workplace (M = 15, SD = 9.9; min. = 8, max. = 64), which is normal in an open plan area in the Netherlands. The more dense work areas (8 or 9 m²/workplace) are small group rooms with six workplaces inside. The less dense work area with 18 m² per person is also such a group room, but it had empty workplaces at the time of the data collection. The open areas that do not only accommodate office workspace, but also lab areas with R&D equipment are outliers to the right ranging from 31 to 64 m²/workplace. These eleven participants (=8%) will be left out of the analyses of this metric (see histogram on the right). As said the metric itself is the inverse of m²/workplace, to fit the term density (meaning an increasing value of the metric for more dense areas).

Metric 2) Average walking distance to the visible workplaces (m)
In the case of building 3G, the average distance within a room varies from 0 (=no other participants in the room) to 14,3 meter (M = 6, SD = 2.6). The workplaces with high average distances are located in the larger open areas at the outskirts of the room. The ones with low values are the small rooms or larger areas with very few participants inside which are all seated close to each other. The spread of this metric is fairly normal.
Metric 3) How many participants can somebody see from their desk (# of workplaces)
The connectivity generated with Dephtmap ranges in this case from 0 to 17 people ($M = 7; SD = 4.3$). The spread is not normal, but multi-model. The first top is caused by the fact, that the small group offices (all are situated on the 1st floor) have very few workplaces inside so these 26 participants all have a low connectivity.

Metric 4) The compactness of the visible workplace (..)
The compactness of the visible work areas of the participants varies from 0.108 to 0.714 ($M = .34, SD = .18$). Looking at the histogram, the open area’s and small group offices form 2 different groups. The compactness of the 112 participants with workplaces in more open areas ranges from 0.108 to 0.431 with a fairly normal
spread and the group offices with 1 up to 6 workplaces (26 participants) have a compactness between 0.645 and 0.714 (is nearly a constant).

Metric 10. Distance to entrance of the room (m)
The distance to the room entrance varies between 68cm and 17,2m (M = 8.4, SD = 3.1) with a fairly normal spread.
Metric 11. Size of the visible workplace (m²)
As it should, in this case the Isovist area relates a lot to the room size (correlation = 0.879), but is not entirely the same. For 79% of the participants’ workplaces, the isovist area is smaller than the room size. Especially the workplaces in the large open areas (composed of several rooms) show a big difference between the room size and the visible room size (isovist area). This is caused by rows of closets in these areas and/or the fact that the project rooms are located within such large areas. In the most extreme case, the isovist area is 41% of the actual room size. The isovist area ranges from 30 to 341 m² (M = 168, SD = 70). A histogram shows that again the people in the group offices disturb the normal spread. They all have an isovist area between 52 and 54 m² making this metric for them almost a constant.

Metric 12. Openness of the perimeter of the workarea
This metric should represent the exposure of the workplace to people passing by. However, looking at the occlusivity values in the layout of the case building, they do not appear to do so. The 3 workplaces with the highest occlusivity values are shown in Figure 6-7. For the 3rd highest value (number 3), the isovist is colored in grey, because it shows the problem with this metric. Although a big part of the isovist perimeter is not solid, this does not increase the exposure of that workplace for passers-by. So not only workplaces that are visible from the hallway (like numbers 1 and 2), have high occlusivity values. In this particular building it is more the shape of the room that determines this value than the location of the workplace with regard to the passageways. With the closed laboratory areas between the hallway and the office area’s, this building does not provide much exposure for passers-by to anybody, except when they enter your room to talk with a roommate.
As an alternative way of measuring this metric, it is recoded into a dichotomous variable for the people visible from the moment of entering the room and people that sit out of sight of the entrance. In total 63% are visible (87 participants) and 37% is not (51 participants).

**Metric 13. Average walking distance to other workplaces (m)**
The average walking distance to all the other workplaces varies from 50 to 89 meters (M = 61, SD = 7.5). The 89 meter is a clear outlier, since this is a person in a single office on a hallway where no other participants are located, because the rest of these offices belong to support staff (excluded from this study). The spread is not exactly normal, because it leans to the left side.
6.3.2 CRE metrics of dyads

Metric 5) Workplaces are in the same room (yes/no per dyad)
Naturally, not all dyads are located in the same room. The opposite is to be expected. In this case, 570 dyads (=6%) share a room and 8883 dyads do not.

Metric 6) Workplaces have intervisibility (yes/no per dyad)
Not all workplaces within the same room can also see each other although the difference is small in this case; correlation $r(9453) = .95$, $p < .01$. Some rooms have a high partition or closet that blocks the view of each other for some dyads. The visibility of each other’s workplace has been interpreted from the layout (not with depthmap). The columns (300x300 mm) have not been taken into account during this interpretation, because they are not so obtrusive. The workplace is large enough, to sit at different positions during the workday, and thus be able to see each other by looking past the column. In total, 521 dyads have intervisibility (=5.5%) and 8932 have not.

Metric 7) Workplaces are within hearing distance (yes/no per dyad)
Since the doors between the rooms are generally closed, only the dyads that are in the same room (N = 570) are selected. In the previous chapter, it was explained that the hearing distance depends on many factors, but probably would be between 5 and 10 meters. Looking at a histogram of the straight line distance between all the dyads in the same room it becomes clear that most dyads sit within 10 meters distance (69%) and even 27% sits within 5 meters. The spread leans strongly to the left. The average distance is 8.2 m ($SD = 4.5$; min. = 1, max. = 27).
Without a clear cut point in hearing distance, it is not possible to construct a dichotomous variable to study a possible association with KS. But it is not within the expertise of this study to find such a cut point, and also hearing distance depends on the hearing capability of each individual. So instead, a possible difference in KS between groups will be studied for all possible cut points in the distance between the dyads sharing a room (with t-tests).

**Metric 8. Walking distance per dyad (m)**
The walking distance between dyads varies from 1,1 meter up to 148 meter (M = 61, SD = 29), and is multi-modal.
Metric 9. Being on the same floor (yes/no)
As it should, this dichotomous metric should be about evenly spread. For the participants at Océ, 48% of the dyads work on different floors (4505 dyads) and 52% (4948 dyads) work on the same floor.

6.4 Possible tests and prerequisites
Below the final conceptual models are shown. A hypothesis of association with the amount of KS meetings will be tested for each individual metric.

The spread of all variables has been discussed in the previous two paragraphs. Since the amount of KS meetings is not spread normal, both models are tested with Spearman’s correlation. The Spearman test uses ranks to test for association and does not depend on the assumption of an underlying normal distribution or any other distribution. Spearman correlation is valid for both linear as curvilinear relationships, but not for hyperbolic so this has to be checked for each metric.

Figure 6-8 Final conceptual model for individual workplaces
For the individuals’ conceptual model, only the scatterplot of metric 1: ‘density’ versus ‘number of KS meetings’ shows weird outliers. These 11 people have a certain type of workplace (10 have their office area combined with lab area equipment and 1 is a director), what gives them more than average space. Without these outliers, the scatterplot is regular. All other scatterplots of individuals’ metrics appear to suggest a linear relationship.

For the dyads’ conceptual model, both interval metrics (the rest is dichotomous) appear to have a curvilinear association with KS, so there is no reason not to use Spearman’s test.
As said before, after testing the association in both models with the amount of KS meetings, the KS behaviour (KS activities) will be visualised for all layout metrics, because this shows what happened during these KS meetings. It is also interesting to study the other indicators in the logbook a little further for the metrics with the
highest association with the amount of KS meetings (otherwise this does not seem relevant). This way a further insight in the KS process is obtained.

With hypotheses of difference, it will be tested whether individuals (or dyads) show different KS behaviour (the KS activities) or have other differences in KS if their workplace(s) differ(s) on these metrics. Except for ‘involvement’, all the KS indicators are nominal variables which are usually tested with $\chi^2$-tests. The layout metrics would have to be recoded into logical groups (some are already dichotomous) and in such a way that the prerequisite of $\chi^2$-tests (expected values > 5) is met. Another option is to leave the layout metrics as they are, and switch the relationship of dependence. By assuming that the layout metric would be the dependent variable and the # of KS meetings the independent variable, an analysis of variance would be possible, to see if a certain KS activity differs significantly on the mean value of a layout metric. Unfortunately analysis of variance has 3 prerequisites (independent selection, normality and homogeneity of variance) which are not all met because the number of KS meetings is not spread normal (nor several layout metrics). So this is not an option.

Unfortunately, in this case of Océ, a recode of layout metrics to make them nominal causes difficulties too. Because this study is explorative, there is no indication for relevant cut-points to divide the layout metrics into nominal groups. An attempt with several metrics and cut-points showed that all $\chi^2$-tests are significant, but only through one or two cells in the cross-tables. An example is visualised in Figure 6-13, for metric 1 (density). The metric is recoded into similar intervals, grouping the tails with outliers together. The 3 circles show the differences that add most to the significance of a $\chi^2$-test, which obviously do not suggest a certain trend for KS activities with a decrease in density. So such a test does not provide relevant information and seems more likely to give erroneous acceptations of supposed differences. This is not a problem for the dichotomous metrics or for some metrics where a logical cut-point does present itself. But the rest of the metrics will only be analysed with $\chi^2$-tests on the lower versus the higher halves of the participants’ scores on the possible values of the metric. Further subdivision of these metrics will be used to provide a visualisation of the KS activities, but not tested statistically. To study the other KS indicators (analysed only for the highest association and for metrics that do not correlate with that particular metric), the metrics are sometimes split in 2 equal halves and also in 4 equal parts (if the requirement of the $\chi^2$-test that individual expected cell counts must be 5 or higher is met) to look for further trends.
6.5 Conclusions

After recoding and completing the data on 918 KS meetings taken from the logbooks of Océ, they are transformed into 3 databases together with the layout metrics of Océ:

- DATABASE 0: 1907 lines (one for each occurrence), as written down in the logbooks.
- DATABASE 1: 138 lines (one for each participant), containing the value of a participant’s combined KS meetings and his/her layout metrics.
- DATABASE 2: 9453 lines (one for each dyad), containing the value of a dyad’s combined KS meetings and their layout metrics.

With regard to the KS that took place at Océ during the week of the fieldwork, the following came forward. On average, participants had 14 KS meetings this week with 5 different colleagues, which were mostly one-on-one meetings and took place at a workplace (78%) or in a project area (14%). Of the possible dyads 4% shared knowledge that week. Since there are no similar studies on KS within the exact same context to compare these results with, it is not possible to conclude anything on whether KS at Océ is good or bad. The results are only used to test the added value.
of CRE for KS behaviour. Questions were the most common way to share knowledge (56%), but the other 4 KS activities also took place (+ 20%); actions mostly in the project areas. During a day, an average of 45 minutes was spent in unplanned KS meetings, with 80% of the meetings lasting up to 15 minutes. The hallway and coffee machine might be places where a lot of talking takes place, but not to share work-related knowledge in the way that was studied here. The knowledge that was shared appears to be very tacit, because it was often (77%) available through one person only. Most meetings were intentional (72%) and concerned a problem (89% of which 44% was a shared problem). Involvement in each other’s problems was generally high (3-5 on a 5-point scale).

With regard to the layout metrics at Océ, the following came forward. On average, a participant:

- has 15 m²/workplace,
- sees 7 roommates from behind his/her desk,
- sits 8 meters from the entrance,
- has a visible rooms size of 168 m² and
- has an average walking distance of 61 meters to the other workplaces in the building.

Participants are spread over the rooms (so some are in the centre, others are at the outskirts). The group offices provide their inhabitants with a more compact and smaller work area, than the larger, rectangular, open areas. 63% of the participants is visible from the entrance of the room. This metric is used as a substitute way of measuring openness of the workplace perimeter, because occlusivity values at Océ did not portray openness correctly. For the density metric, eleven participants will be treated as outliers, since their work area is much less dense because it is combined with lab area equipment.

The layout metrics of dyads show that:

- 6% share a room,
- 5.5% can see each other at their desks,
- 27% of dyads sharing a room sit within 5 meters, 69% within 10 meters,
- 61 meter is the average distance between their workplaces,
- 52% work on the same floor.

No clear cut point for hearing distance was found, so this has not been recoded into a dichotomous variable as was originally planned.

Because both the dependent variables in the conceptual models (number of KS meetings) and many independent variables (layout metrics) do not have a normal spread, Spearman’s correlation will be used to test the associations in both conceptual models (for individuals and for dyads). All assumptions for this type of test are met. The five categories of KS activities (descriptions, questions, actions, proposals, evaluations) will be visualised and tested with χ²-tests for possible differences in KS behaviour for certain values of the layout metrics. If a layout metric is not dichotomous nor has a logical split in categories, the test will be done on low versus high halves of the participants to look for certain trends. The other KS indicators (location, intentionality, initiator, alternative source, involvement) are
studied with $\chi^2$-tests as well, but only for the layout metrics with the highest association with the amount of KS meetings (and also for layout metrics that do not correlate with these metrics). The results of all tests are described in the next chapter.
Chapter 7 Results - a test of suitability of metrics

This chapter describes the statistical analyses that were performed to test the conceptual models on suitability of the layout metrics and get an in depth look at the mechanisms behind their effect on the KS process outcomes. The effect of each individual metric on the KS within Océ is visualised and measured statistically. Paragraph 7.1 describes the tests on the conceptual model for individuals and paragraph 7.2 for the conceptual model for dyads. Paragraph 7.3 sums up the conclusions for Océ technologies that can be drawn from the analyses, for a program specification for building 3G. This is then subjected to a face validity test with Océ (paragraph 7.4). The chapter ends with conclusions and the answer to the 7th research question.

7.1 CRE metrics and KS of individuals

This paragraph first discusses the metrics with regard to co-presence and then the metrics with regard to position in the building.

Co-presence

In Chapter 4, co-presence is operationalised with four metrics for the accessibility mechanism:

1. Density (inverse of m²/workplace),
2. Location inside the room (average walking distance in m),
3. Visible workplaces (#) and
4. Compactness (0-1).

As Table 7-1 shows, all metrics correlate with the amount of KS meetings, but density (.181) and location inside the room (.168) less strongly than visible workplaces (.355) and compactness (-.328), and only on a 95% threshold. Visible workplaces and compactness also correlate with each other (-.510), and location inside the room correlates with both visible workplaces (.739) and compactness (-.518) as well. It is not unexpected that compactness correlates negatively with the number of visible workplaces. Because of Dutch daylight regulations, the larger areas (with more people inside) have to be rectangular. The strong correlation between location inside the room and the number of visible workplaces is also logical (if you can see more people the average distance to all these people increases), just like the correlation between location inside the room and compactness.

To make sure that the almost constant value of compactness for the small group offices is not an issue, metric 4 was also tested without these 26 participants. As Table 7-1 shows all significant correlations decrease in strength but remain significant.

So with regard to accessibility, the number of KS meetings increases most when the number of visible workplaces in an open area increases and the compactness decreases. Visible workplaces and compactness do correlate with each other (-.510),
which possibly makes compactness irrelevant. But Spearman does not offer the possibility for testing partial correlations, so this cannot be demonstrated. The location inside the room is less relevant for Océ, because it correlates strongly with both these metrics and has a less strong correlation with the amount of KS meetings. Only density is a separate issue, with a significant (but less strong) correlation.

<table>
<thead>
<tr>
<th>Spearman’s rho correlation</th>
<th>metric 1: density</th>
<th>metric 2: location inside the room</th>
<th>metric 3: visible workplaces</th>
<th>metric 4: compactness (without group offices)</th>
</tr>
</thead>
<tbody>
<tr>
<td># of KS meetings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N =</td>
<td>127</td>
<td>138</td>
<td>138</td>
<td>138</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-277(**).181(*)</td>
</tr>
<tr>
<td>metric 1: density</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N =</td>
<td>1</td>
<td>.046</td>
<td>.167</td>
<td>.037 (-.204)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>metric 2: location inside the room</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N =</td>
<td>1</td>
<td>1.739(**)</td>
<td>-.518(**)</td>
<td>-.223(*)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>metric 3: visible workplaces</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N =</td>
<td>1</td>
<td>-.510(**)</td>
<td>-.255(**)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>metric 4: compactness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N =</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 7-1 Correlations co-presence and # of KS meetings individuals

position in the building

Position in the building is operationalised with four metrics for the exposure and centrality mechanisms:

Exposure
10. Distance to entrance (m)
11. Size of workplace (m²)
12. Visible from entrance (yes/no)

Centrality
13. Average walking distance (range)

As Table 7-2 shows, the distance to the entrance and being visible from the entrance do not correlate with the amount of KS meetings. Only the size of the workplace (.233) and average walking distance (-.183) correlate with the amount of KS meetings; average walking distance less strongly and only at the 95% threshold. The distance to the entrance correlates with the visibility of it (.331) and with the size of the visible workplace (.307), which was to be expected.

To make sure that the almost constant value of workplace size for the small group offices is not an issue, metric 11 was also tested without these 26 participants.
Workplace size then loses its significant correlation with the amount of KS meetings. Because the size of all the group offices is small, apparently the fact that participants with many KS meetings have an open area workplace made the correlation significant. The size of the visible workplace correlates strongly with the co-presence metrics compactness (-.743) and visible workplaces (.657) (see Table 7-3). Spearman does not offer the possibility for testing partial correlations, but it seems that size of workplace is not functioning as a building position metric here (offering exposure), and thus is not relevant.

So, with regard to the position in the building, only the centrality mechanism is triggered and not the exposure mechanism. The number of KS meetings decreases when the workplace is located less centrally in the building (which makes average walking distances larger).

<table>
<thead>
<tr>
<th>Spearman's rho correlation</th>
<th>metric 10: distance to entrance N= 138</th>
<th>metric 11: size of workplace N= 138</th>
<th>metric 11: visible from entrance N= 112</th>
<th>metric 12: average walking distance N=137</th>
</tr>
</thead>
<tbody>
<tr>
<td># of KS meetings</td>
<td>.105</td>
<td>.233(**)</td>
<td>.137</td>
<td>-.183(*)</td>
</tr>
<tr>
<td>metric 10: distance to entrance</td>
<td>1</td>
<td>.307(**)</td>
<td>.042</td>
<td>.331(**)</td>
</tr>
<tr>
<td>metric 11: size of workplace</td>
<td>1</td>
<td>1</td>
<td>.135</td>
<td>-.123</td>
</tr>
<tr>
<td>metric 12: visible from entrance</td>
<td>-.168</td>
<td>1</td>
<td>-.002</td>
<td>1</td>
</tr>
<tr>
<td>metric 13: average walking distance</td>
<td>-.192(*)</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 7-2 Correlations position in the building, and # of KS meetings individuals

<table>
<thead>
<tr>
<th>Spearman’s rho correlation N= 138</th>
<th>metric 10: distance to entrance</th>
<th>metric 11: size of workplace</th>
<th>metric 12: visible from entrance</th>
<th>Metric 13: average walking distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>metric 1: density</td>
<td>.004</td>
<td>-.026</td>
<td>-.012</td>
<td>-.587(**)</td>
</tr>
<tr>
<td>metric 2: location inside the room</td>
<td>.160</td>
<td>.605(**)</td>
<td>.226(**)</td>
<td>-.194(*)</td>
</tr>
<tr>
<td>metric 3: visible workplaces</td>
<td>.219(**)</td>
<td>.657(**)</td>
<td>.214(*)</td>
<td>-.484(**)</td>
</tr>
<tr>
<td>metric 4: compactness</td>
<td>-.221(**)</td>
<td>-.743(**)</td>
<td>-.190(*)</td>
<td>.114</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 7-3 Correlations co-presence and position in the building metrics of individuals

Going back to the total conceptual model for individual workplace metrics, five of them correlate with the amount of KS meetings, through two mechanisms: Accessibility

- Density .181
- Location inside the room) .168
- Visible workplaces .355
- Compactness -.328/-277
Centrality
- Average walking distance (in building) \(-0.183\)

Accessibility has a stronger association with the amount of KS meetings than centrality, mainly through the number of visible workplaces and the workplace compactness. The most relevant individual metric is the number of visible workplaces from behind your own desk.

The following five boxplots show how the number of KS meetings increases with visible workplaces (see Figure 7-1) and location inside the room (see Figure 7-2) and decreases with more m²/workplace (less density, see Figure 7-3), compactness (see Figure 7-4) and average walking distance in the building (see Figure 7-5). The correlations with less strength are still hard to see with the naked eye, even though it is a boxplot. The positive sign of the correlation of location inside the room with the number KS meetings is unexpected. A closer look at the boxplot suggests it might be a parabolic association with the top at 6-8 meters. If that is the case, Spearman is not a valid test, but the scatterplot did not appear parabolic, so this is not a certainty.

Figure 7-1  Visible workplaces and the # of KS meetings (in categories)
Figure 7-2  Location inside the room and the # of KS meetings (in categories)

Figure 7-3  m²/workplace of a room and the # of KS meetings (in categories)
Figure 7-4  Isovist compactness and the # of KS meetings and (in categories)

Figure 7-5  Average walking distance in the building (Centrality) and the # of KS meetings (in categories)
7.1.1 Other KS indicators

This section will visualise if any differences come forward with regard to KS activities that were used by participants with different values for each separate layout metric. If no logical cutpoint is present for a metric, a test will be done on the high versus low halve of the participants’ values for the metric. The other KS indicators are analyzed for possible differences in the way the KS meetings took place for the most relevant metric (visible workplaces) and for density (because it has no correlation with any of the other metrics) to study KS behaviour in more depth.

Metric 1) Density of the room where the workplace is located (inverse of m²/workplace)

The KS activities do show some differences with a change in density (see Figure 7-6), but when split in equal halves (values density 8 – 12 and 13 – 19, without outliers), a χ²-test is not significant (χ²(4, N=1268) = 8.527, p = .074). So it seems irrelevant here.

![Figure 7-6 m²/workplace and KS activities](image)

If the less dense areas (the outliers) with both lab equipment and office workplaces are studied in more detail (see Figure 7-7), these areas show very different KS behaviour, which probably depends on the type of equipment in them. Some
equipment demands more descriptions (e.g. room 3G32), while with other machines mutual actions are performed (e.g. room 3G09).

![Figure 7-7](image.png)

**Figure 7-7  \(m^2/\text{workplace and KS activities of outliers}\)**

The other KS indicators are mostly nominal variables, so density is split up too so that the results can be visualised and tested (with \(\chi^2\)-tests in DATABASE 0). The participants are split up either in two equal halves (8 – 12.5 and 12.5 – 19, without outliers) or in four equal parts (8-11; 11 – 12.5; 12.5 – 13.5; 13.5-19), depending on the requirement of the \(\chi^2\)-test that individual expected cell counts must be 5 or higher. The results are discussed below.

A \(\chi^2\)-test for \(m^2/\text{workplace}\) (split in halves) with the location where knowledge is shared, shows a significant difference (\(\chi^2(5, \text{N}=1758) = 11.412, p < .05\)), caused by the fact that the participants in more dense environments use meeting areas more often; possibly not to disturb the others. If the meetings in meet areas are removed from the sample, the test is no longer significant (\(\chi^2(4, \text{N}=1736) = 3.615, p = .461\)). A test on alternative sources is significant too (\(\chi^2(2, \text{N}=868) = 12.821, p < .01\)), based on the fact that the participants from denser areas mention more often that they also could have gotten the knowledge that was shared from a non-human source, and participants from less dense areas mention this significantly less (see also Figure 7-8). No obvious explanation comes to mind.

The other tests are not significant and involvement is also similar for both halves, so apparently density within a room does not cause differences in intentionality (\(\chi^2(1, \text{N}=1721) = .049, p = .825\)) or issues addressed (\(\chi^2(2, \text{N}=1728) = 4.560, p = .102\)).
Metric 2) Location inside the room (m)
The KS activities do not show clear differences with a decreasing centrality in the room (see Figure 7-9). The participants located at the edges of the room (> 10) appear to have used a lot more evaluations. When split in equal halves (values 0 – 6 and 6 – 15), a $\chi^2$-test is significant ($\chi^2(4, N=1379) = 10.972, p < .05$), but this significance cannot be appointed to a certain activity. All cells add a little to the $\chi^2$-value, except ‘questions’ which is spread as expected. Centrally located participants used more descriptions and proposals and less actions and evaluations; participants on the outskirts of the room the other way around. Perhaps the relative calm of the outskirt provides more opportunity to evaluate. Also some of the rooms/areas have equipment at the outskirts, with the operator located close by.
Metric 3) Visible workplaces (#)
The KS activities do differ among the visible workplaces categories, but no (curvi-)linear relationship appears to be present. When split in equal halves (values 0 – 6 and 7 – 16), a $\chi^2$-test is not significant ($\chi^2(4, N=1379) = 8.798, p = .066$). Some values for visible workplaces appear to be very different in KS activities, e.g.:

- Visible workplaces = 4 + 5: more descriptions and actions $\rightarrow$ possible explanation is that the rooms where these participants are located also have equipment in them.
- Visible workplaces = 9: many evaluations $\rightarrow$ possible explanation is that most of these participants are located in the large office area 3G55, and apparently needed to evaluate more that week than their colleagues.
- Visible workplaces = 13: many descriptions $\rightarrow$ these were six participants, of which five were located in one part of the large office area 3G70.
Since visible workplaces has the strongest association with the amount of KS meetings, the other KS indicators are analysed for this metric. The other KS indicators are mostly nominal variables, so visible workplaces is split up too so that the results can be visualised and tested (with \( \chi^2 \)-tests in DATABASE 0). The participants are split up either in two equal halves (0 – 6 and 7 – 16) or in four equal parts (<3; 4 – 6; 7 – 11; >12), depending on the requirement of the \( \chi^2 \)-test that individual expected cell counts must be 5 or higher. The results are discussed below.
A χ²-test for visible workplaces (split in halves) with the location where knowledge is shared, shows no significant differences (χ²(4, N=1902) = 8.923, p = .063). If the meetings in meet areas are removed from the sample, it is also possible to split the visible workplaces metric in four equal parts, which does lead to a significant test (χ²(12, N=1880) = 23.683, p < .05). The participants with many visible workplaces have significantly more KS meetings at the coffee machine (and account for half of all meetings at the coffee machine). Also, 54% of these meetings at the coffee machine were intentional (versus 38% for the other visible workplaces levels), which might indicate that they go there not to disturb the many colleagues working within hearing distance. In general, participants with few visible workplaces have significantly more coincidental KS meetings and significantly less intentional ones (and the other way around for participants with many visible workplaces, see Figure 7-11, χ²(1, N=1891) = 7.360, p < .01). Apparently, visual accessibility of the workplace increases the amount of intentional visits. Perhaps the participants with few visible workplaces, made up for these intentional visits by non-face-to-face meetings. If visible workplaces is not split up, the test is also significant (χ²(16, N=1891) = 78.628, p < .01) which is caused strongly by the group of participants with 6 visible workplaces (which is the mode of this variable). These are all the participants in two rooms (3G05 and 3G58), which have significantly more coincidental KS meetings and significantly less intentional ones. There is no obvious explanation why these two rooms have a different way of meeting. Perhaps this depends on the type of work they do.

![Figure 7-11 Visible workplaces and intentionality](image)

Participants with less visible workplaces (split in halves) have significantly more KS meetings that deal with the problem of one person or are not problem-oriented, while participants with a more visible workplaces have more KS meetings for shared problems (χ²(2, N=1899) = 6.532, p < .05). The test stays significant for visible workplaces split in four parts (see Figure 7-12, χ²(6, N=1899) = 68.082, p < .01), showing that especially the participants with 3 or less visible workplaces have significantly more KS meetings for individual problems and less for shared problems.
It appears as if researchers with a more individually focused job (less shared problems) are located in smaller rooms, while the participants sharing problems are collocated, which is a logical way of allocating employees to workplaces. The other KS indicators on the issues addressed and involvement also show that this group with few visible workplaces is special. They mention more often that another person than the one they met could have provided the same knowledge (see Figure 7-13, $\chi^2(6, N=949) = 14.319, p < .05$). If they do not share a problem, but need help on a certain expertise, they might be asking a random team/department-member about specific team/department-knowledge. Because it is not the other person’s problem, the mean involvement of this other person is judged a little lower (3.48) compared to the higher visible workplaces values 4-6 (3.78), 7-11 (3.59) and 12-16 (3.71). So it appears as if this group of more ‘solitary’ participants have their own issues and do not expect others to be involved in their work.

![Figure 7-12 Visible workplaces and issues addressed](image)

![Figure 7-13 Visible workplaces and alternative source](image)
Metric 4) The compactness of the visible workplace
Because the compactness values of the open areas differ so much from the (almost constant value for compactness of the) group-office rooms, these two groups are analysed with a $\chi^2$-test, which showed no significant differences in the KS activities that were used (see also Figure 7-14, $\chi^2(4, 1379) = 8.00, p = .09$). Visualising the values of the open areas separately, shows that the participants with a compactness between .35-.44 (grouped into 0.4) use relatively more evaluations (see Figure 7-15). In compacter rooms all people can see each other which might induce more evaluations of a shared issue. Also, seven of the twelve participants in this group belong to room 3G55, which was mentioned under the previous metric as well as a room with people that might have needed to evaluate more that week.

Figure 7-14  Compactness and single KS activities
Figure 7-15  Compactness and single KS activities of open areas

**Metric 10. Distance to entrance of the room (m)**
The KS activities do not show clear differences with an increasing distance to the entrance (see Figure 7-16). When split in equal halves (values distance 0.5 – 8.5 and 8.5 – 17.5), a $\chi^2$-test is not significant either ($\chi^2(4, N=1379) = 4.578, p = .333$). So it seems irrelevant here.
Metric 11. Size of the visible workplace (m²)
Because the values for the isovist area (size of the visible workplace) of the open areas differ so much from the (almost constant value of the) group-office rooms, these two groups are analysed with a χ²-test. The test showed no significant differences in the KS activities that were used (see also Figure 7-14, χ²(4, 1379) = 8.00, p = .09). Because of the high correlation of this metric with metric 4 ‘compactness’, a visualisation of the KS activities for these two groups would look exactly the same as Figure 7-14. Visualising the open areas separately, does not show much difference in activities either (see Figure 7-17). So, again, it seems irrelevant.
Figure 7-17 Workplace size (m²) and single KS activities

Metric 12. Visible from entrance (yes/no)
The KS activities show significant differences for participants that are visible from the entrance and participants that are not ($\chi^2(4, 1379) = 16.409, p < .01$, see also Figure 7-18). The visible participants use descriptions and actions significantly more often to share knowledge, while the non-visible participants use these two activities significantly less. For the other KS activities there are no big differences. Perhaps the visible participants are consulted more for quick needs for a description or to help with a task or equipment issues.
Figure 7-18 Visibility from entrance and single KS activities

Metric 13. Average walking distance to other workplaces (m)
The KS activities do not show clear differences with an increasing average walking distance in the building (see Figure 7-19). When split in equal halves (values distance 49 – 60 and 60 – 77, without one outlier), a $\chi^2$-test is not significant either ($\chi^2(4, N=1379) = 6.061, p = .195$). So it seems irrelevant here. For the centrality mechanism this metric had the highest correlation with the amount of KS meetings. To have a further look at distinguishing interaction and collaboration for this mechanism, the mean involvement and number of times that the shared information was so tacit that only this dyad could have shared it are tested by comparing means. Both tests do not show much difference for more or less centrally located people, and therefore are not statistically significant ($F_{\text{only this person}}(132, N=133) = .003, p = .953; F_{\text{involvement}}(128, N=129) = .067, p .796$).
CRE metrics and KS of dyads

This paragraph discusses the metrics with regard to co-presence (there are no dyad metrics with regard to position in the building).

**Co-presence**

In Chapter 4, co-presence of dyads is operationalised with five metrics for the accessibility and proximity mechanisms:

1. Accessibility
2. Workplaces are in the same room (yes/no)
3. Intervisibility of workplaces (yes/no)
4. Hearing distance between workplaces (m)
5. Workplaces are in the same room (yes/no)
Proximity
8. Walking distance between workplaces (m)
9. Same floor (yes/no)

As Table 7-4 shows, all metrics have a significant correlation with the amount of KS meetings. But they also all correlate with each other. In the case of Océ, sharing a room and intervisibility metric the same thing (.953), both correlating with the amount of KS meetings equally (.46), so one of them can be discarded. The hearing distance is only relevant within a room, so this makes metric 5 a constant for correlation with that metric. In the case of Océ, hearing and walking distance in a room is the same thing (Spearman’s rho = .998, p = .000, N=570), because there are very few partitions that one has to walk around. For dyads sharing a room these two metrics correlate with the amount KS meetings equally (.422). Therefore Table 7-4 only displays the correlation of metric 8 for dyads not sharing a room; the walking distance still correlates with the amount of KS meetings (-.132).

<table>
<thead>
<tr>
<th>Spearman’s rho correlation</th>
<th>metric 5: same room</th>
<th>metric 6: intervisibility</th>
<th>metric 7: hearing distance</th>
<th>metric 8: walking distance</th>
<th>metric 9: same floor</th>
</tr>
</thead>
<tbody>
<tr>
<td># of KS meetings</td>
<td>N=9453</td>
<td>N=9453</td>
<td>N=570</td>
<td>N=8883</td>
<td>N=9453</td>
</tr>
<tr>
<td>metric 5: same room</td>
<td>.460(**</td>
<td>.465(**</td>
<td>- .422(**</td>
<td>-.132(**</td>
<td>.178(**</td>
</tr>
<tr>
<td>metric 6: intervisibility</td>
<td>1</td>
<td>.953(**</td>
<td>.953(**</td>
<td>.242(**</td>
<td>.230(**</td>
</tr>
<tr>
<td>metric 7: hearing distance</td>
<td>1</td>
<td>-.259(**</td>
<td>1</td>
<td>.368(**</td>
<td>1</td>
</tr>
<tr>
<td>metric 8: walking distance</td>
<td>1</td>
<td>.230(**</td>
<td>1</td>
<td>.368(**</td>
<td>1</td>
</tr>
<tr>
<td>metric 9: same floor</td>
<td>1</td>
<td>.230(**</td>
<td>1</td>
<td>.368(**</td>
<td>1</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).

Table 7-4 Correlation co-presence and # of KS meetings dyads

Going back to the total conceptual model for dyad workplace metrics, four of them correlate with the amount of KS meetings, through two mechanisms:

** Accessibility**
- Sharing a room .460
- Hearing distance within room -.422

** Proximity**
- Walking distance within building -.132
- Same floor .178

The accessibility metrics (within a room) have a much stronger association with the amount of KS meetings than the proximity (in the rest of the building). The most relevant individual metric is whether a dyad shares a room. Dyads from the same room have 1.4 KS meetings on average (SD = 2.68) and from different rooms 0.03 KS meetings (SD = .30). Both these means are very low, because also 348 (61% of the) dyads that shared a room did not have a KS meeting, but only 150 (1.5% of the) dyads in different rooms had a KS meeting. Of the 372 dyads that shared knowledge, 14 were located on different floors. This makes the average number of KS meetings for dyads from different floors 0 (SD = .07). So KS between people on different floors is nearly extinct. Of these 14 dyads, 12 had 1 KS meeting and 2 met each other twice to share knowledge (M = .21, SD = 1.1).
A boxplot shows how the number of KS meetings decreases with hearing distance in the room (see Figure 7-21) and walking distance between rooms (see Figure 7-20). Both many dyads in close proximity and at long walking distances have indicated having 0 KS meetings. Not counting the outliers, dyads with 3 or more KS meetings have a walking distance of less than 22 meters. Adding up the frequencies, 70% of the KS meetings took place between dyads within 10 meters, 83% within 20 meters and 90% within 30 meters.

![Boxplot showing KS meetings vs walking distance](image)

**Figure 7-20 Walking distance and the # of KS meetings**

With regard to hearing distance, it is obvious that the dyads with the highest number of KS meetings are within hearing distance. From a distance within the room of 8 meters or more, only outliers are visible in the boxplot. Unfortunately, a clear cut point for hearing distance is not visible. Significant results were sought with t-tests for all possible cut points in the distance between the dyads sharing a room (see Figure 7-22). Because the high values for KS of dyads within a few meters, this test is significant (p < .01) from 3 up to 19 meters. The mean difference in the amount of KS decreases until it starts undulating around a mean difference of 1 KS meeting.
7.2.1 Other KS indicators

This section will visualise if any differences come forward with regard to KS activities that were used by participants with different values for each separate CRE metric. Sharing a room and/or a floor are both dichotomous metrics, but no logical cutpoint is present for walking and hearing distances. As for the individual tests, a test will be done on the high versus low halve of the participants’ values for these metric. The
other KS indicators are analyzed for possible differences in the way the KS meetings took place for the most relevant metrics (same room and hearing distance if room is shared) to study KS behaviour in more depth.

**Metric 5) Workplaces are in the same room (yes/no)**

A $\chi^2$-test shows that the behaviour through which knowledge is shared (the KS activities) does not differ between dyads working in the same room and dyads with separate rooms/areas; $\chi^2(4, N=1385) = 8.03, p = .09$. Although dyads from different rooms ask each other more questions, and propose/evaluate less, the differences are not statistically significant. Looking at the location of the meetings (see Figure 7-23), significant differences do come forward. A $\chi^2$-test shows that the people from different rooms share more knowledge in the hallway, at the coffee machine and in project areas than dyads sharing a room; $\chi^2(4, N=1385) = 15.85, p < .01$. The fact that only dyads from the same room use meeting areas for unplanned meetings suggests that they move to a meeting area if the workplace is too disturbing or unsuitable for the meeting.

![Figure 7-23 Observed frequencies of KS location and same room](image)

Surprisingly, the amount of coincidental visual contacts that led to KS versus intentional visits to share knowledge was not significantly different for employees in the same room as for employees from separate rooms; $\chi^2(2, N=845) = 0.26, p = .61$. So the thought that people in the same room share more knowledge because they bump into each other coincidently more often, is not supported here. They also intentionally look for a certain roommate to share knowledge.

A $\chi^2$-test of the issues addressed (see also Figure 7-24) shows that people in the same rooms share more knowledge about shared problems, while dyads from different rooms more often share knowledge to help the other one; $\chi^2(2, N=846) = 27.49, p < .01$. Dyads from different rooms indicate more often that they could also have gone to another person to gain this knowledge (see also Figure 7-25), but the $\chi^2$-test just misses the 95% threshold ($\chi^2(2, N=717) = 5.82, p = .054$). The mean...
involvement is judged a little lower between dyads from different rooms (3.4) than from the same room (3.6), but there is no significant difference. A t-test (equal variances can be assumed) was not significant, t(325) = 1.39, p = .17.

**Figure 7-24** Observed frequencies of issues addressed and same room

<table>
<thead>
<tr>
<th></th>
<th>different rooms</th>
<th>same rooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>not problem oriented</td>
<td>30</td>
<td>66</td>
</tr>
<tr>
<td>shared problem</td>
<td>64</td>
<td>303</td>
</tr>
<tr>
<td>problem of one person</td>
<td>130</td>
<td>253</td>
</tr>
</tbody>
</table>

**Figure 7-25** Observed frequencies of alternative source and same room

<table>
<thead>
<tr>
<th></th>
<th>different rooms</th>
<th>same rooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>No, only this person</td>
<td>137</td>
<td>425</td>
</tr>
<tr>
<td>Yes, other person(s)</td>
<td>39</td>
<td>87</td>
</tr>
<tr>
<td>Yes, non human</td>
<td>3</td>
<td>26</td>
</tr>
</tbody>
</table>

**Metric 7) Hearing distance within room (yes/no)**
The KS activities do differ among the hearing distance categories, but no clear relationship appears to be present. When split in equal halves (values 0 – 7 and 7 – 27), a $\chi^2$-test is significant ($\chi^2(4, N=1058) = 13.610, p < .01$). The participants at larger distance (> 7m) within the room share significantly less descriptions and ask each other more questions. The other activities are spread as expected. As mentioned at the analysis of metric 1 (density) for the individuals, perhaps sitting closer to each other increases awareness, which prompts people to give descriptions if this seems
helpful. At a distance, it might be necessary to ask things that would otherwise have been clear by overhearing/awareness.

**Figure 7-26 Hearing distance between dyads and their KS activities together**

Since hearing distance has a strong association with the amount of KS meetings, additionally to sharing a room, the other KS indicators are analysed for this metric as well. The other KS indicators are mostly nominal variables, so hearing distance is split up too so that the results can be visualised and tested (with χ²-tests in DATABASE 2). The participants are split up in two equal halves (<7; 7>) or four equal parts (<4.5; 4.5 – 7; 7 – 11; >11), depending on the requirement of the χ²-test that individual expected cell counts must be 5 or higher. Even if the test allows a further subdivision, this is not done, because the intention is to study a tendency, without having a lot of different (meaningless) categories that can cause irrelevant
significance in the test. None of the tests are significant\textsuperscript{12} and involvement is also similar for all categories, so apparently hearing distance within a room does not cause differences in the other KS indicators, but only in the amount of KS meetings.

**Metric 8. Walking distance between workplaces (m)**

Naturally, most of the dyads have large walking distances between them, and just a small group of dyads is located within proximity. But because most of the KS meetings took place within 30 meters, five groups are visualised separately for their KS activities. Visually (see Figure 7-27), the large group of dyads located more than 50 meters apart use more evaluations and less questions to share knowledge. Also, the group between 20-30 meter uses more actions and less evaluations. But a \(\chi^2\)-test just misses the 95% threshold \((\chi^2(16, N=354) = 25.680, p = .059)\). A \(\chi^2\)-test on equal halves of walking distance \((< 65; > 65)\) was not significant at all \((\chi^2(4, N=354) = 3.853, p = .426)\). So apparently, the differences are not substantial and it is irrelevant here.

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\textsuperscript{12} location: \(\chi^2(4, N=772) = 7.135, p = .129\); intentionality \(\chi^2(1, N=622) = 1.215, p = .270\); issues addressed \(\chi^2(6, N=622) = 8.319, p = .216\); alternative source \(\chi^2(2, N=538) = 1.208, p = .547\)
Metric 9. Same floor (yes/no)
A \( \chi^2 \)-test shows that the behaviour through which knowledge is shared does not differ between dyads working on the same floor and dyads from separate floors; \( \chi^2(4, N=1385) = 1.929, p = .749 \). So it seems irrelevant here. For the proximity mechanism this metric had the highest correlation with the amount of KS meetings. To have a further look at distinguishing interaction and collaboration for this mechanism, the mean involvement and number of times that the shared information was so tacit that only this dyad could have shared it are tested by comparing means. Both tests confirm more involvement and tacit knowledge sharing when working on the same floor, but these differences are not statistically significant \( F_{\text{only this person}}(335, N=336) = 1.290, p = .257; F_{\text{involvement}}(326, N=327) = 1.718, p .191 \).
7.3 Conclusions for Océ

In Figure 7-29 the layout metrics from both conceptual models are shown as they were found at Océ to be associated with the number of KS meetings. The strongest associations came forward for accessibility (co-presence) between dyads, followed by accessibility on an individual level. From the five mechanisms identified from literature, three come forward at Océ as having an association with the amount of KS meetings when studied with quantitative metrics (in order of importance):

1. Accessibility,
2. Centrality,
3. Proximity.

The 4th mechanism, ‘exposure’ was not triggered at Océ and the 5th mechanism, ‘meeting areas’ could not be tested.
Looking at the metrics used for these 3 mechanisms, the first and most important mechanism ‘accessibility’ appears to include two different mechanisms. Because accessibility is used in literature sometimes for visibility and sometimes for hearing distance or other placement issues, it seems best to split it into two different mechanisms:

1a. (Accessibility through) Visibility,
   - Same room .460
   - Visible workplaces .355
   - Compactness -.328/-.277

1b. (Accessibility through) Placement within the room,
   - Hearing distance within room -.422
   - Density .181
   - Location inside the room .168

2. Centrality in the building
   - Average walking distance to other workplaces -.183

3. Proximity in the building
   - Same floor .178
   - Walking distance if not in room -.132

The number of KS meetings increases with more people in a room/area, and also between these people sharing a room. The compactness metric also shows that in
bigger rooms, more KS meetings took place because of visibility. The placement within the room metrics show that there must be a limit to the visibility mechanism, because an increase in distance between dyads in a room (and decrease in density) lowers the amount of KS meetings. Beyond 8 meters only a few outliers of the dyads still share knowledge. The individual average distance to colleagues shows an optimum at 6-8 meters as well, after which KS decreases; meaning that participants at the outskirts of a large room share less knowledge than their roommates. This metric gives ambiguous results, because the positive sign of the association suggests that an increase (so sitting further from your roommates) increased the amount of KS meetings. But the boxplot shows this increase turns around after 6-8 meters. The distances in the building metrics all show a decrease in the number of KS meetings with a decrease in proximity, with the dyads with 3 or more KS meetings having a walking distance of less than 22 meters (not counting outliers) and 90% of the meetings taking place within 30 meters.

So, with regard to ideal room size, a clear limit does not come forward. Océ works in both small and large rooms, sometimes with up to 29 people (17 participants) having a workplace in one room/area. The maximum distance in this (largest) room (3G07/08) from corner to corner lies around 30 meters. If the average number of KS meetings/person for each room is put against the room size visually (see Figure 7-30), it is clear that an increase in room size does not mean that the individuals in the room have less KS meetings on average. So it appears that it would be beneficial to put as many people in a room as possible to optimally trigger the visibility mechanism, although the placement metrics show that this cannot be true. The figure does show that the larger (combined) areas do not have the highest amount of KS meetings on average. Perhaps Océ has created rooms that just meet the maximum size that still triggers the visibility mechanism. Previous studies (Allen, 1977) have shown that after 30 meters the amount of meetings between people decreases strongly, and in this case study of Océ also 90% of the meetings took place between dyads within 30 meters proximity.

![Figure 7-30 Room size (in m²) on vertical axis, average # of KS meetings per person per room](image)
Unfortunately, Spearman correlation does not have the opportunity to do multivariate analyses and look for the unique contribution of the different metrics of a mechanism. Also, the data on dyads and on individuals cannot be run together in such an analysis. The individual visibility metrics ‘visible workplaces’ and ‘compactness’ correlate -.510, which suggests that they might not both be necessary to study. The same, although less strong (-.368), could be the case for both dyad proximity metrics ‘same floor’ and ‘walking distance’. The individual placement metrics ‘density’ and ‘location inside the room’ do not correlate with each other.

A further look at the KS process shows for the visibility metrics, that all 3 have no significant differences in the KS activities that were used. Compactness (the one with the lowest association) even showed no further differences in the KS indicators at all. The differences for sharing a room or not and for the number of visible workplaces are similar. Participants that share a room had more shared problems, while participants from different rooms share less tacit knowledge (they could also have consulted someone else), and mention a lower involvement of others. This came also forward for the individuals with less than 3 visible workplaces, so it appears as if more solitary workplaces contain employees that work on their own issues, consult other disciplines if needed but do not expect others to be involved in their work. Sharing a room does not assure more intentional visits to each other, but in general having more visible workplaces does associate with more intentional meetings. The participants from larger rooms/areas had more intentional meetings at the coffee machine, perhaps trying not to disturb the others. Dyads from the same room were also the only ones that used meeting areas for unplanned meetings (perhaps for this same reason). Although most meetings took place at a workplace, the dyads that did not share a room accounted for more meetings at all the other possible locations (except meeting areas), meeting coincidentally. Specific room issues that came forward were participants from room 3G55, that evaluated more, and from rooms 3G05 and 3G58 that met less intentionally and more by coincidence. All in all, this theme points out that the larger the room, the more knowledge is shared intentionally and through more cooperative behaviour.

The metrics under placement within a room show that there is an influence of the room size on the way knowledge is shared as well. A larger distance between dyads in a room and individual participants in less dense rooms are both associated with less descriptions (and more distance also with more questions asked), while the participants with a central placement among roommates give more descriptions. Perhaps sitting closer to each other increases awareness which prompts people to give descriptions if this seems helpful. At a distance, it might be necessary to ask things that would otherwise have been clear by overhearing/awareness. The participants at the ‘outskirts’ of an area appear to have more opportunity there to evaluate or perform actions together; activities that might disturb others. Participants from the more dense areas evade to meeting areas more often. The presence of equipment at the outskirts and in certain rooms clearly influenced the KS activities too. These metrics showed no differences in any of the other KS indicators. So this theme points out that a room can be too large to stimulate KS among all inhabitants, which also influences how they share knowledge.
The metrics for **centrality** and **proximity** in the building have a (weak) association with the amount of KS meetings, but there are no further differences in KS behaviour. On the other hand, the **exposure** metrics had no association with the amount of KS meetings, but do show differences in KS activities. Participants visible from the entrance use descriptions and actions significantly more often to share knowledge. Perhaps the visible participants are consulted more for quick needs for a description or to help with a task or equipment issue, when people enter the room.

Overall, the association of layout with the number of KS meetings at Océ is not really strong. The strongest association (.460 of sharing a room) is still considered ‘moderately strong’ for Spearman correlations in general. But it does show that the CRE manager can add value through considering the influence of the layout on this important organisational process. Two from the three mechanisms have a metric that is easy to generate for CREM with a layout showing where everybody sits:

1a. (Accessibility through) Visibility $\rightarrow$ same room

1b. (Accessibility through) Placement within the room $\rightarrow$ density

2. Centrality in the building

3. Proximity in the building $\rightarrow$ same floor

But in case of placement within the room and proximity in the building, these were not the metrics with the strongest association. And for visibility, this is a dyad and not an individual metric. Studying 9453 dyads still is a lot of work, so it would be easier to use an individual metric on 138 employees. Using Depthmap to create a VGA (Visual Graph Analysis) of the individual workplaces would generate the number of visible workplaces (for visibility) and the average walking distance (for placement). Making this VGA is still relatively easy and would give more insight. On the other hand, in a simple layout it is not so hard to count the number of visible workplaces by hand, and interpret the average distance to roommates (central location or at the edges) intuitively. So unless Océ would use buildings with complicated layouts (or many buildings), using Depthmap might still be unnecessarily laborious. The centrality and proximity metrics take a lot more work, which might not be beneficial for Océ either, because these are mostly metrics with a weak association. As long as the rooms are not too large, hearing distance is less relevant.

Océ had made plans to renovate the building into an even more open layout (see Figure 7-31), because the projects were increasing in size and more equipment needs to be accommodated. The aim with this layout is to achieve more communication, an open culture, a friendly atmosphere and an inspiring work environment. All project areas with the equipment are placed in the middle of the building, with two corridors (instead of one) separating them from the office areas. The office areas have a pattern of 7.5 x 7.5 meters, which would hold a maximum of 7 employees, providing them with 8 or more $m^2$/person. The floors can be divided with flexible walls, and they plan to make compartments every 2 or 3 blocks. Unfortunately, the renovation is not implemented due to organisational changes. Projecting the results from the case-study on this new layout gives insight in the KS that should take place after the renovation program (see below), but this could not be tested.
The visibility metric with the strongest association (same room) is used well in the new plan, because with all these larger rooms more dyads will be sharing a room. The average number of visible workplaces increases as well, so it could be that more knowledge will be shared. But visibility at a certain distance might no longer be ‘real’ visibility, because the placement (hearing distance) results showed that beyond 8 meters only a few outliers of the dyads still share knowledge. So the association of room size appears to be based mostly on dyads sitting close by. Average or more knowledge was shared up to a proximity (walking distance) of 22 meters if dyads sharing a room were not included, which is exactly the size of 3 block compartments. And in larger rooms many people will have colleagues within a radius of 8 meters in all directions. The width of 7.5 meters chosen for the office areas appears to be optimal in that sense. Only people sitting close to the flexible walls might be sharing a little less knowledge and in different ways. Because of less awareness, they might have to ask more questions and will receive fewer descriptions from colleagues. These places should be allocated to people with more individual problems. A question will be whether all participants in the larger areas will feel that they share problems and thus expect more involvement of the others. The increase in visible workplace should increase the number of intentional visits. A challenge will be to minimise disturbance of KS meetings for the increased number of employees in the room.

With regard to distances in the building, the centrality of the workplace on the floor might become more relevant. Groups that need to share most knowledge should be placed at strategic points with regard to the other groups. Just like the individuals sitting at the (fewer) entrances of the office areas, because this is associated with more descriptions. It seems unlikely, that this new layout will trigger the exposure mechanism further, as the large open areas diminish the presence of room entrances. Isolating the project areas and special labs separately should not be a big obstacle for KS. The actions specifically and intentionally took place in these rooms anyway.
7.4 Face validity with Océ

The results were discussed with the CRE manager of Océ R&D and presented to the R&D accommodation steering committee\textsuperscript{13} to see how they perceived them. Also the curiosities that came forward for certain rooms were discussed to look for an explanation. The steering committee consists of the manager of each functional department in building 3G, the CRE manager of Océ R&D and an ARBO\textsuperscript{14} expert.

In general, the results on KS were considered clear and interesting and they could identify with them. Also, they felt that the CRE metrics represent building 3G correctly. They mentioned that KS at Océ does indeed take place similarly as the results from the logbooks show (e.g. many short meetings, lots of questioning, very tacit/specialist knowledge and high involvement). The fact that most KS took place between project members was what they expected, although this is not emphasized by management as the most important goal. They also value cross-functional KS a lot and try to stimulate this. Within large projects, they sometimes get complaints from project members about feeling anonymous. This might explain why not all project members shared knowledge. KS within departments takes place mostly in planned meetings, and thus is not fully visible in the results (that only deal with unplanned meetings).

The participants sitting in the smaller group offices are indeed doing more solitary work, as some of the KS indicators showed (e.g. involvement, issues addressed). They belong to projects that have more individual assignments. In some project areas no KS meetings took place the week of the fieldwork, which was unexpected. A possible explanation mentioned was that people inside work together the entire day and might not see that as a meeting/interaction, although they did talk with each other all the time.

The less dense rooms with both office workplaces and equipment showed outstanding results with regard to the 5 categories of KS activities, which were explained as follows:

- 3G59.4 mostly questions: inhabitants build test configurations so they have to deal with many questions.
- 3G32 many descriptions, few questions: inhabitants were electronics (CAD-E) specialists that write procedures and give many descriptions during the end phase of a project for the handover to production and service.
- 3G10 many questions: inhabitants work at the heart of the technical process and therefore receive (and have to ask) many questions with regard to release, reliability, robustness and production possibilities.
- 3G73 all 5 categories similarly spread: inhabitants were busy with image formation and the future, so they do many different things.
- 3G21 mostly questions: inhabitants were thinking of a successor to one of the projects and therefore asked so many questions.

\textsuperscript{13} This meeting took place February 14\textsuperscript{th} 2011, the steering committee meets 6x/year.
\textsuperscript{14} The Dutch ARBO legislation contains prescriptions and advice on safety, health and welfare of employees based on working conditions.
• 3G09 very many actions and many questions: this is a test environment so many actions take place.
The outstanding results with regard to KS of inhabitants in regular office areas were explained as follows:
• 3G55 more evaluations: inhabitants were in an early phase of their project, looking at competition and the future, and thus evaluated a lot.
• 3G70 more descriptions: inhabitants belong to the software group that deals with descriptions a lot.
• 3G05 and 3G58 more coincidental meetings: these rooms are known for the fact that people walk in and out.
• Participants at the outskirts of rooms in general perform more actions and evaluate more: when equipment needs to be placed in an office area this is done at the outskirts, with the operator nearby.

The CRE manager was content with the projection of the results on the renovation plans. This helped him with showing the added value of the new layout to general management. It is often hard to justify investments in CRE, so he also tries to emphasize on the more qualitative added values (like KS, sick leave, productivity). For this he could definitely use more visualisation techniques and ‘hard’ results as studied in this dissertation.

7.5 Conclusions
From the five mechanisms identified from literature, in this case three have suitable CRE metrics to show added value for KS. They are suitable because of an association (spearman’s rank) with the amount of KS meetings. Also they show differences in KS behaviour (shown with $\chi^2$-tests). This gave more insight in the KS activities that were used and in other KS indicators. Especially accessibility appeared to be the most important way of CRE to add value for KS in this case. For this organisation it is important who can see each other and where people are placed in a large office area. The CRE manager can use the relevant metrics to make decisions on layout matters and visualise them for general management. This is shown with a projection of the results on the renovation plans.
Chapter 8 Implications for theory and practice

This chapter compares the findings at the Océ case with the theory described on CREM, knowledge management and the expected layout mechanisms for adding value. Paragraph 8.1 relates CREM theory and the literature on the effect of CRE on KS behaviour with the results from the case study. Paragraph 8.2 does the same for knowledge management theory. The last paragraph sums up the conclusions on this comparison and translates the findings at Océ into implications for CREM. With this the 8th and last research question is answered.

8.1 CREM theory and the Océ case
This paragraph discusses the data on the layout mechanisms and their metrics from the case study in the light of the theories on the effect of layout on KS behaviour as described in Chapter 4. It will also look back at the framework of CREM theory from Chapter 2.

8.1.1 Layout mechanisms and knowledge sharing behaviour
The theories from (many different areas of) literature suggested five different layout mechanisms to influence KS behaviour, of which four were operationalised with fourteen possible metrics. These are divided over a local (co-presence) and a global (position in the building) level. Also, a distinction between individual and dyadic metrics had to be made. As discussed in Chapter 1, the methodology of this study is based on the theory of realistic evaluation. The strong influence of context on the working of a mechanism (like the influence layout might have on KS behaviour) makes it impossible to draw conclusions here on which metrics from theory are relevant and which are not outside the context of Océ. This can be different in each individual organisation, and even within the different business units within the organisation. However, it is possible to discuss whether the metrics are indeed suitable to evaluate the mechanisms that they were used for, and whether interesting metrics came forward that have received little attention in literature.

The (Spearmann) associations of the layout metrics and the amount of KS meetings at Océ varied from .46 to .13, which are at best considered to be moderately strong. Other quantitative studies on (Pearson) correlations of spatial layout with communication have also found low values (e.g. Wineman and Adhya (2007) with r-values between .12 and .17, Toker and Grey (2008) with r-values between .30 and .54). The correlation of these types of analyses cannot be expected to be as high as one finds in positivistic experiments trying to explain the exact effect of one metric on another. CRE is a supportive resource, and it cannot be expected to be responsible on its own for a high variance in the amount of KS. Other context variables (e.g. organisation structure, culture, working on the same project) will be responsible for the largest part of this variance (hence the use of realistic evaluation). But even if only 20% of the variance would be explained, this means that CREM can support and improve the primary process of their client organisation significantly, and that is their main task. Also it gives CREM insight in the relevance of metrics and the current CRE situation. A recent study (Gibler and Lindholm, 2012)
showed that up till now, CRE managers trying to align with innovation as the corporate strategy are focusing more on technology than on workplace design.

For the co-presence mechanism of accessibility all seven metrics\textsuperscript{15} indeed seem to measure co-presence. The awareness that is suggested to follow from accessibility appears to be correctly portrayed with these metrics. The Océ case suggests that accessibility is a broad term though, that can be subdivided in two different mechanisms, namely visibility and placement. The visibility metrics make it appear as if the more people in a room and the more density in this room, the more knowledge is shared. But as Boschma (2005 in: Brown, 2008) argued, too much density can result in too little openness and flexibility and thus restrict interactive learning and innovation. Also the addition of placement to plain visibility showed (at Océ) that a distance of about 8 meters appears to be a maximum to assure awareness, even when there is visibility between people. So very large rooms do not necessarily optimise KS. This distance might be different at other organisations, although it can be expected that the ability of people to be aware of others is physically limited the same way for everybody. As the distance has not been identified in previous studies as far as known, there is no proof for this thought. However, for the co-presence proximity mechanism, the metrics (walking distance, same floor) have been quantified before and show a similar type of limit. The maximum distance (proximity) for people to meet at work lies between 20 and 30 meters. This was already known in theory (Allen, 1977; Sailer and McCulloh, 2012), and is again visible in the Océ case. So perhaps 8 meter should be added to this, as a distance for the visibility mechanism. This awareness is necessary to learn by observation, for which was referred earlier to Collins, Brown and Newman (1989) for their theory on cognitive apprenticeship. It would seem that the hearing distance (generally lying between 5-10 meter according to Wenmaekers et al. (2009)) is critical for this distance. It is however hard to determine hearing distance, because it is unique for each person and each room. Of the three mechanisms that came forward at Océ, proximity was the least strong, which is similar to the results of Toker and Gray (2008), although the difference with centrality is almost negligible at Océ.

Accessibility contained both individual and dyad metrics, while proximity and meeting areas only regards dyads, and the other two layout mechanisms only regard individuals. It was interesting to see how the accessibility metrics for dyads showed similar results as the metrics for individuals. Studies on dyads are much scarcer because they imply a lot of work (138 participants at Océ formed almost 10,000 dyads).

For position in the building it is less clear as for co-presence whether all the necessary metrics have been identified. The layout mechanism ‘meeting areas’ was discarded. Océ mainly used these areas for planned meetings, whose participants are usually determined by management and organisation structure and not by CRE. So unless an organisation has specific informal meet areas, this mechanism might

\textsuperscript{15} density, position in the room, visible workplaces, compactness, same room or not, intervisibility, and being within hearing distance.
not be interesting to study. To study this effect, an organisation needs to work much more deliberately with a range of meeting places aimed to provide different conditions (Koch and Steen, 2012b). Océ sporadically used meeting areas for unplanned meetings, but (as it seems) only to avoid disturbing colleagues in crowded areas. The activity based office concepts related to the new ways of working do have many specifically designed places to incidentally sit down for a short (or longer) chat. But it has not been studied much how these types of meeting areas influence (KS) behaviour. Most research buildings do not yet have them, although the lab design handbook (Spears, 2004) does mention the importance of collaborative spaces in research facilities. In the literature on laboratory buildings and their effect on meetings the aspect was not mentioned at all.

The exposure mechanism (through the workplace position in the building) was analysed through three metrics (distance and visibility from entrance, and size of visible workspace) but it turned out to be hard to grasp. Although theory (mostly from the field of spatial network analysis) was present on the effect of exposure on interactions, the metrics used in the Océ case seemed irrelevant for KS meetings (no significant association). So in the Océ context their mechanism does not work. A reason for not finding an association could be that the three metrics used might have failed to capture exposure. For one of them, occlusivity, an alternative had to be chosen because the metric did not indicate the openness of the workplace correctly. And since Océ has no strict paths/flows of people through the open areas in the building (but only in the long corridors out of sight of the workplaces), the metrics used by spatial network academics (e.g. Penn, Desyllas and Vaughan, 1999, Brown, 2008) to relate a workplace to a flow, could not be studied here. Exposure and thus bumping into each other is a mechanism that has to be studied in more depth. For example, at Océ an analysis of the intentionality of roommates to share knowledge, showed no difference with dyads from different rooms ($\chi^2(2, N=845) = 0.26, p = .61$). So it appears that roommates do not bump into each other coincidentally more often, but also intentionally look for a certain roommate to share knowledge. It could be that this is not any different on the scale of an entire floor. Another reason, recently brought forward by Koch and Steen (2012b), is the influence of tasks on the exposure mechanism. While some need the exposure to communicate, other tasks do not require this. Perhaps the Océ tasks are an example of work that does not depend on exposure.

The centrality mechanism (with just one metric, called average walking distance to all workplaces) was the only way to show the relevance of the position in the building at Océ through an association with the number of KS meetings. Although Toker and Gray (2008) identified this mechanisms to be the strongest at their cases, here it had a weaker association with KS than several local metrics of accessibility and was almost similar to the proximity mechanism. As mentioned in Chapter 4 the evidence for position in the building supporting collaboration is rather thin, and this study could not change this. It does appear to be relevant, but not as much as other aspects.
To conclude, not all five mechanisms from theory turned out to be relevant for Océ to study effects of layout on KS behaviour. This does not mean that they will not be relevant in other types of layouts and/or contexts. With the split of accessibility in visibility and placement within a room there will be six mechanisms to consider in future studies. It is a pity that academics from the field of innovation and knowledge management disregard the physical work environment or only look at collocation in the same building. As others have showed (e.g. Becker, Sims and Schoss, 2003; Spiliopoulou and Penn, 1999) working in the same building does not automatically trigger the mechanisms of layout influencing behaviour. The effect works mainly at a more local level within the building.

Five Context-Mechanism-Outcome configurations were distinguished in Chapter 4. The results suggest the following outcome for Océ:

<table>
<thead>
<tr>
<th>Context</th>
<th>+ Mechanism</th>
<th>= Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Océ has innovation in their corporate strategy, and wants to align the CRE strategy by increasing knowledge sharing of their employees through optimisation of the building layout.</td>
<td>Visibility triggers awareness of what other employees are doing, and whether one can provide help.</td>
<td>Increased interaction and collaboration.</td>
</tr>
<tr>
<td></td>
<td>Placement within the room triggers awareness of what other employees are doing, and whether one can provide help.</td>
<td>Increased interaction.</td>
</tr>
<tr>
<td></td>
<td>Proximity triggers bumping into each other when moving around in the vicinity of one’s workplace.</td>
<td>Increased interaction.</td>
</tr>
<tr>
<td></td>
<td>Centrality within the building triggers walking over to colleagues.</td>
<td>Increased interaction.</td>
</tr>
</tbody>
</table>

Exposure does not trigger being spotted by others that are moving around.

Presence of meeting areas does not trigger their use.

Based on the analyses discussed in the previous chapter, it appears that at Océ, visibility is not only the strongest mechanism, but also the only mechanism that triggers collaboration. This makes visibility very important for them. The in-depth analysis of the KS behaviour showed that employees with more visible colleagues and dyads within visibility mentioned higher involvement and more tacit knowledge sharing. They did not differ in the KS activities that they used to share knowledge. Placement within the room is important for increased interaction only, as it showed no difference in involvement or tacit KS. The KS activities even produced an unexpected result, namely that dyads within hearing distance gave significantly more
descriptions (+questions), so that would mean more explicit KS. Exposure showed
the same unexpected result, with the exposed employees giving more descriptions.
Perhaps the KS activities are not such a good indicator of tacitness (as discussed
further on).
Proximity did not increase involvement or more tacit KS, and also showed no
difference in the KS activities used. So opposed to literature, it only increased
interaction at Océ. For centrality it was confirmed that on this more global scale,
only interaction can be increased with the layout. The exposure and meeting areas
mechanisms were not triggered at all.

8.1.2 CREM theory framework
In Chapter 2, delivering added value through CRE(M) was split in adding exchange
value (reducing costs, increasing value of assets, increasing flexibility) and use value
(increasing innovation, increasing employee satisfaction, increasing productivity and
promoting marketing and sales). A quote of Jensen (2009) was used to explain that
use value is provided by increased effectiveness leading to qualitatively different and
improved outcome. This research focused on one of the strategies related to use
value (innovation through KS) and has shown that CRE can indeed add use value
through several mechanisms. Some layout metrics showed differences in chosen KS
activities (qualitatively different outcome) and/or an association with the amount of
KS meetings (improved outcome).

This study looked at effectiveness only, but this is strongly related to the other four
organisational criteria (efficiency, productivity, flexibility and creativity). Since many
CREM departments still focus on efficiency, it would be interesting to study the
metrics and their association with costs, asset value and flexibility. A metric as
density, for example, has a clear impact on costs and is used by many CRE managers
to steer on costs. Unfortunately, the savings by increased density are hardly ever
related to possible savings through increased effectiveness in less crowded work
environments. Another example can be given with the proximity metrics. Providing
proximity to more colleagues might frustrate flexibility or demand a less generative
building (and thus lower asset value), but it could also improve productivity or
employee satisfaction. These comparative studies on both use and exchange added
values are interesting.

To be able to steer on both exchange and use values, CREM has to be at the strategic
decision table and thus up high in the CREM evolution. A taskmaster (at the bottom
of the evolution) probably will not reckon with most of the layout metrics studied
here. He focuses on engineering and technical issues, and assumes that the (internal)
client has already decided about the most effective building layout. However, the
client is not an accommodation expert, and might disregard important matters,
simply because they are not within his expertise. During the engineering process, the
taskmaster focuses his technical expertise on the way the building is constructed,
which (as shown in Chapter 2) mostly impacts the exchange value strategies. At best,
he might make some suggestions on efficiency issues (e.g. density) if available
budgets are overdrawn. The next two steps on the evolution are, the controller, who
runs a more analytical CREM department that wants to minimise building costs,
followed by the dealmaker, who is looking for standardisation of building usage. Several of the metrics studied influence the direct costs of buildings (e.g. density, workplace size, meeting areas), and should be considered by CREM on both these stages. Unfortunately, the indirect costs (which are influenced by several metrics as well) are not considered yet at these two evolution stages nor the benefits for effectiveness. Since the dealmaker wants to standardise, he must have standards for several of the metrics to be able to compare them within the client organisation. This is even more pressing for the entrepreneur stage CREM department, because it wants to benchmark with others on the external market as well. The more metrics are used and benchmarked, the more it becomes clear whether and how added exchange value is really delivered. If CREM succeeds at this and can show general management how they add (exchange) value through (a) certain mechanism(s), this might form a basis for the last evolutionary step, the strategist, and CREM’s ‘invitation’ to the strategic table. As said, only then CREM can start to really achieve alignment for the client organisation, through considering all seven added value strategies. It will be necessary to have a relevant list of CRE metrics for each strategy to start proving this added value with real estate interventions that trigger the right mechanism(s).

To be able to achieve alignment and deliver added use value, CREM has to cooperate with other business functions. That is the only way to make sure that the right needs are supported. As De Vries, De Jonge and Van der Voordt (2008) stated, output indicators of added use value “...are usually not referred to at all”. The problem is that the outcome side is not easily quantified for added use values. The other business functions will have to provide CREM with the right (measurable) aspects that CRE metrics can be related to (as done for Océ and their KS meetings). But as shown by Ramakers (2008), lists of possible corporate strategies used by academics are very diverse. And if it is not clear which needs exists, alignment of CRE is even more difficult.

8.2 Knowledge sharing theory and the Océ case
This paragraph will discuss the data on KS from the case study in the light of the theory described in Chapter 3. First, the conceptual representation of KS behaviour will be described and then epistemology in general and the relevance of realistic evaluation for this field.

8.2.1 Knowledge sharing behaviour
To look at KS behaviour, two dimensions were identified as being relevant (see figure 3.5, repeated below). The 1st dimension was an involvement dimension, with interaction at the low side and collaboration at the high side. This dimension was based on the argument of Berends, Van der Bij and Weggeman (2006), that involvement takes more time and effort of both participants of a meeting. At Océ the involvement in the meetings was high in general, because in 83% of the meetings the participants mentioned at least a medium (=3) up to high (=5) involvement. With regard to time, at Océ the duration of meetings was indeed positively associated with involvement (Spearman's rho (N = 1109) = .196, p = .000). With regard to effort, the five KS activities (behaviour) were placed on this involvement dimension, by
separating descriptions as an interaction activity from the other four KS activities as collaboration activities, as suggested by Berends (2005). Because the other four KS activities require loops in the KS process, it is presumed that they require more effort. At Océ, the mean involvement in KS meetings through descriptions was 3 (on a 5-point scale), while for each of the other four KS activities the mean involvement was 4. So both arguments for constructing the involvement dimension are supported by the data from Océ.

The 2nd dimension derived from theory was the knowledge component, indicating how tacit the shared knowledge is, without making a hard split. Based on the origination mechanisms of Berends (2005), the five KS activities were also placed on this dimension, by separating descriptions as an activity for explicit knowledge (I) from the other four KS activities to share more tacit knowledge (ESA). It was presumed, that knowledge is less tacit if it is available through more than one person and even more explicit if it is available in a non-human form. The issues addressed at Océ were tested against the alternative sources to look for confirmation of this assumption. It was significantly less often possible to consult other people or non-human knowledge sources in case of a shared problem ($\chi^2(6, N=948) = 25.63, p < .01$). It might be such a specific problem, that both these people need to bring in their own tacit knowledge. When the problem lied with the initiator only, it was significantly more often possible to also consult other people. It could be that he/she needed knowledge from a certain group of people. When the receiver was the problem owner, the sender also more often was aware of non-human sources of knowledge for the problem. This sender could be an expert in his field of knowledge, because besides taking the initiative to help others with their problems in this field, he/she also knew of relevant knowledge sources. However, the Océ data on possible alternative sources, do not confirm the dimension. At Océ most knowledge that was shared was only available through one person (77%) and hardly any knowledge
through a non-human source (4%). The non-human source answers even could not be used in a $\chi^2$-test (on the five KS activities versus alternative sources for the knowledge shared), because the cell counts were too low (<5). It was expected that descriptions would deal with knowledge that was more codified. But the $\chi^2$-test distinguishing more tacit knowledge (only this person has it) and knowledge available through more than one person does not distinguish descriptions from the rest. It is significant at the 95% threshold ($\chi^2(4, N = 640) = 10.94, p < .05$), but this is caused by the questions category. Especially when questions are asked it is more often possible to get the answer from a different person as well. So, at least part of the questioning appears to concern more explicit knowledge, but for descriptions this is not supported by the data.

After identifying the two dimensions, the knowledge creation spiral of Nonaka and Takeuchi (1995) was placed in this system. This was based on the three steps of this spiral that took place through KS within teams (externalisation), between departments (combination) or one-on-one (socialisation). At Océ 47% of the meetings took place between team members and 38% between departments (and 15% was between different teams from the same department). So 62% of the meetings took place within the department. Steen (2009) found in his case study that even 95% did, so it seems that Océ is successful in their goal to stimulate cross-functional KS. The difference between these two percentages again shows the influence of organisational context, as emphasised by realistic evaluation academics. It is not unexpected that most KS meetings are between people within close organisational proximity (through organisation structure). As Hansen (2002) explained effective KS requires a significant amount of common knowledge and a close relationship. Berends et al (2011) add that these groups form a community of practice in which their shared background enables easy KS. They also mention that the epistemic boundaries that arise because of this, hamper mutual understanding and shared meaning across group boundaries.

With regard to the involvement dimension, no significant difference in meetings between departments, between teams or within teams was found ($\chi^2(8, N = 1126) = 13.38, p = .10$). So the difference between combination and externalisation on this dimension is not confirmed. The one-on-one meetings (socialisation) accounted for 90% of the meetings at Océ, and are not different in involvement than the meetings between more people ($\chi^2(4, N = 1126) = 1.21, p = .88$). A difficulty in identifying socialisation is that not all one-on-one meetings are necessarily socialisation. The main condition for socialisation according to Nonaka and Konno (1998) was joint activities, as spending time/living in the same environment. Therefore, roommates versus dyads not sharing a room were also tested. This test did not show differences in involvement either (see Chapter 7). Despite the shown difference in involvement between descriptions and the other four KS activities, the activities do not confirm the placement of the spiral on this dimension. Even the opposite, because a $\chi^2$-test showed that within team meetings (externalisation) use descriptions significantly more often, which was linked with low involvement instead of high involvement ($\chi^2(8, N = 1379) 41.7, p < .01$). The meetings between participants from different departments show no increase in descriptions as a less involved KS activity (nor less
use of the other four KS activities). So again the difference between combination and externalisation is not confirmed. Also, again the test of roommates versus dyads not sharing a room does not show differences in KS activities either (see Chapter 7). So the placement of the spiral on this dimension is not supported by the Océ data.

The knowledge dimension is tested with the possibility to consult other sources for the same knowledge. The Océ data only partly appear to confirm the placement of the spiral on this dimension. A \( \chi^2 \)-test is significant \( (\chi^2(4, N = 949) = 17.13, p < .01) \), but this is just slightly caused by the meetings between participants from different departments. They do not share less tacit knowledge (only available through one person), but they do share more explicit knowledge (available in a non-human form). Especially the between-teams meetings (from the same department) cause the test to be significant, because more knowledge could also have been obtained from different persons. Perhaps it was the knowledge of a different team, that was necessary, and a random member of that team was consulted. It is not a strong indication of how combination and externalisation should be placed on the knowledge dimension. Testing socialisation by comparing roommates with non-roommates, the data almost confirm the placement on the dimension, but the test just misses the 95% threshold \( (\chi^2(2, N = 717) = 5.82, p = .054) \). People from different rooms have shared knowledge that also more often could have been obtained from different persons. However, the ‘roommates’ only show a slight increase in tacit (single person) KS. So it remains a bit questionable how the spiral can be placed on this dimension.

In total, it seems that the data from Océ do no support the entire conceptual representation of KS behaviour, but only the involvement dimension. Descriptions are indeed KS activities that require less involvement. This makes it a bit unexpected, that especially people from the same team use them more often to share knowledge with each other. Involvement was not different for participants from the same team, different teams or even different departments. Despite the distinction in involvement, the five categories of KS activities are not strongly valid to distinguish in tacitness, if this is interpreted by the availability of knowledge through more people and/or in codified form. People from different teams or departments only appear to slightly share more explicit knowledge than teammates or roommates.

8.2.2 Epistemology and realistic evaluation

Epistemology showed two streams that interpret and study knowledge in different ways: the objectivist versus the practice-based perspective. The data on KS meetings at Océ support the practice-based perspective on knowledge. Of the KS meetings 78% was held with the only person that could provide this knowledge, and only 4% of the shared knowledge was available in a non-human form. Apparently knowledge cannot be separated from a person as easily as the objectivists think. The five categories of KS activities let knowledge remain embedded in an activity, as the practice-based perspective emphasizes, but do offer the opportunity for using statistics, as the objectivist prefers. So they are an interesting way to bring both perspectives nearer to each other. It gives practice-based academics the opportunity to use more positivistic methods (observation, statistics) to study knowledge. And
thus might help convince objectivists of the less stringent separation of explicit versus tacit knowledge that the practice-based perspective believes in. For objectivists the KS activities might be interesting to use when studying how codified knowledge is shared during face-to-face meetings. The practice-based academics can take this a step further and use them to study the loops in the knowledge management model from Chapter 3 (see Figure 3-3). They could study whether the KS activities are suitable to study the 2nd and 3rd level of communication (resp. meaning and effect) as distinguished by Weaver (Shannon and Weaver, 1949). Especially in KS meetings with more than one KS activity, it might be interesting to see if they are used consecutively or intertwined. Also, Berends (2003) looked at the effect of the KS activities on attitude aspects of KS behaviour, which makes them even more interesting for practice-based researchers.

The fieldwork at Océ also showed that using realistic evaluation works well in studies of KS. Realistic evaluation emphasizes the influence of context on the mechanisms and outcome. And the influence of context on the outcome becomes clear when the data of Océ are compared with the observations by Berends (2003) who identified the five categories in two organisations (see Figure 8-1)). The most frequent way of KS at Océ was asking questions, while Berends observed descriptions most often and very few questions. Océ also used more actions, than were observed by Berends.

<table>
<thead>
<tr>
<th>KS activities</th>
<th>Océ Frequencies</th>
<th>Berends, 2003 Frequencies</th>
<th>Valid %</th>
<th>Valid %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptions</td>
<td>423</td>
<td>208</td>
<td>22.4%</td>
<td>41%</td>
</tr>
<tr>
<td>Actions</td>
<td>321</td>
<td>27</td>
<td>17%</td>
<td>5%</td>
</tr>
<tr>
<td>Questions</td>
<td>1067</td>
<td>67</td>
<td>56.4%</td>
<td>13%</td>
</tr>
<tr>
<td>Proposals</td>
<td>372</td>
<td>106</td>
<td>19.7%</td>
<td>21%</td>
</tr>
<tr>
<td>Evaluations</td>
<td>395</td>
<td>105</td>
<td>20.9%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2578</strong></td>
<td><strong>513</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 8-1 Two studies on KS activities compared

Placing the Océ data on two of the knowledge dimensions\(^{16}\) that Berends also used (problem orientation and initiator), it becomes visible that at Océ four different combinations constitute 80% of all meetings. Either the one with the problem initiated the meeting (me-me 19% + other-other 19% = 38%) or the problem is shared and one of the participants took the initiative (22% + 20% = 42%). In comparison with the results of Berends (see Table 8-1) a lot more shared problems were an issue during the KS at Océ (44% vs 18%) and a lot more ‘collaborative problem solving’ took place (22% vs 17%). On the other hand, less ‘pushing’ and ‘thinking along’\(^{17}\) took place (5% vs 31%). Also, at Océ the other was more often the

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\(^{16}\) The 3rd dimension (new/existing content) is not studied at Océ so cannot be compared, therefore the table sometimes holds two mechanisms in one line. On the other hand, initiating a meeting together was not studied by Berends.

\(^{17}\) Thinking along: “an interactive process between two or more participants focused on one person’s specific problem in which another person helps to solve that problem, without the contributor and problem owner having to get involved in each others’ ways of knowing” (Berends et al, 2011).
All participating organisations in both studies are industrial research companies. Comparing just two studies already shows that effects on outcome cannot be generalised to the entire population of industrial research companies. It might be the way of working in general of the employees, what differs between the organisations. In interviews with research managers at Océ, they indicated having a unique style of doing research, based on the impression of employees transferring from other research organisations to Océ. Looking at the KS behaviour data, it is clear that Océ had more shared problems and a generally high involvement, while Berends et al (2011) state that thinking along addresses problems that are not shared and without getting involved. This could explain the difference in these percentages.

8.3 Conclusion and implications for CREM
To conclude, an overview will be given of steps and considerations CREM could make to achieve better alignment with the needs of their client organisation. In Chapter 2 the strategic thinking map of Swayne, Duncan and Ginter (2006) was put forward as a method for determining strategy, which can also be used for CRE alignment (see Figure 8-2). The first important step of this alignment was positioned at the strategy formulation box in this map, where the directional strategies (for CRE and other
resources) are determined. In this research an example for the added use value ‘increasing innovation’ was given with the help of the case study of Océ. It was studied according to the thoughts of Realistic evaluation theory how this directional strategy could be implemented at Océ. The research identified the relevant layout metrics to make use of CRE mechanisms to improve KS and projected them on the new layout ideas of Océ to see what the planned real estate intervention program would achieve, according to CIMO logic as discussed in Chapter 1.

The case study showed how context is very important to correctly interpret how the outcome side (KS) is supported best: the presumptions from literature were not all confirmed by the Océ data, and comparison with a similar study on KS showed big differences in KS behaviour in similar types of organisations. Also, both in literature and in practice the definition of KS is not straightforward, so organisations should choose their own basis on which they want to study output and the effect of CRE thereupon. Only through synergy with other strategic resources (business units) of an organisation, it is possible for CREM to add both exchange and use value and aim for strategies based on effectiveness of the organisation.

This synergy depends on the position of CREM on the CREM evolution. As CREM climbs the evolutionary ladder more CRE aspects like the ones identified for layout in this research can help in showing the added value for both the softer as the more traditional (financial) CRE strategies. Hopefully this can help CREM in getting their (deserved) place at the strategic table, as a strategic resource that can do more than just aim for efficiency. In Chapter 2, many structural, installations and location aspects were identified as having a possible influence on certain added values. By only looking at the layout, this research already identified five different CRE mechanisms measured with several metrics that can be used by CREM. So if all the aspects in both tables are taken into account, CREM might end up with a long list of metrics to reckon with, depending on the CRE strategy that they are aiming for. It is a

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**Figure 8-2 Strategic thinking map for CREM (adapted from Swayne, Duncan and Ginter, 2006)**
lot of work for a CRE manager to look at all of these metrics. But as long as he does not know which ones are most relevant and which ones are not, it is not possible to shorten the list either. So far, comparative studies on such a large scale have not been done, so identification of the aspects that are most important still has to take place. And even then it is still questionable whether research results can be generalised. The strong influence of context on the way CRE adds value, became visible with this research on layout mechanisms. Each CREM department will have to look within their own ‘black box’ and see how CRE mechanisms are best implemented to support the goals of their client organisation. For one organisation the exposure mechanisms could be very important, while another will focus on visibility. The influence of context also supports the iterative nature of the strategic thinking map. Only through implementing certain metrics in a certain way, it is possible for CREM to study how they support their client organisation. But only after such studies, CREM has the knowledge to determine the right implementation.

As the case study showed, some metrics will have a larger association with the value that CREM is aiming for than others. Some of these metrics will be easy to generate and monitor, while others might take more time and effort to measure them correctly. Some layout metrics demanded automated approaches (by using Depthmap) because it was too much work to calculate them manually. A downfall of this is that only the programmer knows the computer program by heart, so the users might be stuck with the feeling that they miss the due diligence possibility of manual approaches (Brown, 2008). But for some organisations these more complicated metrics will be more suitable in determining the right solutions. This is a choice that CREM needs to make and which might very well depend on their place in the CREM evolution. Since many organisations are still climbing this ladder (especially in industry) the use of some of these metrics might still lie far in the future for them.

Once a directional strategy is chosen, the next step in the strategic thinking map calls for CREM to plan the implementation and form action plans. As Koch and Steen (2012b) have shown, implementing CRE strategy can require diving even further into the organisational context. They showed that when it is clear for the chosen layout how the mechanisms will influence KS behaviour, the placement of employees in this layout should be based on the demands of their tasks. Some tasks will require more exposure but not visibility, while others thrive in an opposite location.

This research focused on the added value of (layout related) CRE aspects, but as Frederix (2005) correctly stated, the setup and management style of the CREM department also determine which added value can be provided (e.g. being proactive, using economies of scale). So CREM has to make decisions on both these matters at this stage. Just like there is no one CRE solution for all organisations, there is also no one optimal CREM form. This depends on the chosen CRE strategy (Frederix, 2005). By studying eight cases (all large and mature multinational production companies), Frederix showed that specifically the extent of (de)centralisation of CREM and the management form (cost centre versus a separate business unit) determine whether certain CRE strategies can be used. Together with the level of outsourcing and the CREM organisational structure, these aspects
determine how much knowledge CREM has of the primary process and stakeholders of the client organisation. Frederix placed CREM departments that were run as a cost centre on a lower step of the evolution as the business unit CREM departments. A notable comment is that he placed none of the eight CREM departments at the level of strategist. A more recent study (Schelle and Baltussen, 2013) placed only six (of 23) AEX listed companies on the strategist level.

If the implementation has been planned, the CRE strategy has to be translated into managerial action (according to the strategic thinking map). Lindholm (2008) developed a model (see figure 8-3) that gives directions for each strategy on possible actions to take. As can be seen, the directions in this model are very general and CREM will have to decide how to proceed with actions. The CRE metrics studied in this research are a way of identifying how one of the directions Lindholm gave for the innovation strategy should be filled in, namely: design facilities that allow innovative processes. But they might also influence the other strategies. In Table 8-2, an example is given of how isovists and visibility graphs could be used to operationalise CRE for the other 6 strategies as well.

<table>
<thead>
<tr>
<th>CRE Metrics</th>
<th>Isovists</th>
<th>Visibility graphs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase costs</td>
<td>m²’s per workplace</td>
<td>m²’s for circulation</td>
</tr>
<tr>
<td>Increase value of assets</td>
<td>Genericness of layout parts</td>
<td>Accessibility</td>
</tr>
<tr>
<td>Increase flexibility</td>
<td>Equipment placing and its use</td>
<td>Facilities placing and their use</td>
</tr>
<tr>
<td>Increase employee satisfaction</td>
<td>Perceived workplace</td>
<td>Density and placement within a room</td>
</tr>
<tr>
<td>Increase productivity</td>
<td>Disturbance surroundings</td>
<td>Walking distances</td>
</tr>
<tr>
<td>Promote marketing and sales</td>
<td>First impression of entrance</td>
<td>Wayfinding visitors</td>
</tr>
</tbody>
</table>

*Table 8-2  The use of isovists and visibility graphs for other CRE strategies*
| **Reduce costs** | Minimize acquisition and financing costs  
| | Minimise operating expenses  
| | Create economies of scale in acquisitions  
| | Use workplaces more efficiently  
| | Conduct routine maintenance  
| | Balance between outsources and in-house services  
| | Act as a control mechanism  
| | Utilise government incentives  
| | Establish workplace standards  |
| **Increase value of assets** | Obtain current valuations of facilities  
| | Select suitable locations  
| | Manage risk associated with properties  
| | Make lease/purchase decision on a facility by facility basis  
| | Redevelop obsolete properties  
| | Create and maintain IT-system for property management  |
| **Increase flexibility** | Choose leasing instead of owning  
| | Negotiate short-term leases  
| | Create flexible workplace solutions  
| | Favour multiple use facilities  
| | Select services offices  |
| **Increase innovation** | Develop usability of the workplaces  
| | Design facilities that allow innovative processes  
| | Emphasize knowledge work settings  
| | Allow users to participate in design phase  |
| **Increase employee satisfaction** | Seek locations convenient to employees  
| | Provide pleasant working environment  
| | Provide functional workplace  
| | Provide desired amenities  
| | Respond quickly to real estate requests  |
| **Increase productivity** | Maintain facilities to accommodate optimal operations  
| | Provide environment that enhances productivity  
| | Choose convenient layouts and locations for providers  
| | Design facilities that improve the creation and delivery of products  
| | Choose convenient locations for employees in separate buildings  |
| **Promote marketing & sales** | Select locations that attract customers  
| | Provide space that attracts customers  
| | Make symbolic statement through design and location  
| | Create workplaces that support the brand  
| | Provide environment that supports the sale  |

*Figure 8-3 CRE strategies and decision making (Lindholm, 2008)*
The CRE metrics that best suit a chosen strategy can be used to benchmark the current facilities of the organisation on their appropriateness for adding value. CREM can choose from several real estate interventions to take action. De Vries, De Jonge and Van der Voordt (2008) identified five possible real estate interventions:

- Maintenance
- Functional adjustment
- Reshuffling
- (partial) Renovation
- New building.

Some of these interventions are relatively simple (e.g. maintenance, reshuffling), and can be undertaken by the client organisation with the help of their CREM experts. Other interventions take more time and effort (e.g. new building, renovation) and usually require the help of external parties. Results of an internal benchmark with the CRE metrics can be discussed in briefs with architects and other external parties, when these complex real estate interventions are necessary. Spatial dimensions, amongst other issues, are usually part of this brief and the brief also “functions as a ‘touchstone’ against which design proposals can be tested and alternatives can be compared.” (Bogers, Van Meel and Van der Voordt, 2008). As shown for the increase innovation strategy with this research at Océ, the relevant co-preseence and/or position in the building metrics that came forward can be taken up in the brief, and later used to compare alternatives, using the actual layout drawings from an architect. As Sailer et al. (2007) say, this detailed knowledge may provide architects the opportunity to design solutions that match better with the clients’ needs, and provides CREM with solid and comprehensible evidence to back up their budget discussions with general management. This is true both at the beginning of the design phase for new building, but also during later post occupancy evaluations that might lead to new interventions. Even on a small scale, a change of project of certain employees should lead to re-evaluation of the workplaces that they were allocated to. The strategic momentum box of the strategic thinking map also calls for strategy evaluation, which will help with emergent learning. The map ends with the term ‘re-initiate strategic thinking’. This should take place if the organisational strategy changes, because then the CRE strategy needs to be aligned anew, and the whole process starts from the beginning with strategic thinking, followed by the situational analysis of the strategic planning box. At that time the strategic thinking map has been followed entirely for one cycle, and a new process of (improved) alignment of CRE(M) can start.
Chapter 9 Conclusions and recommendations

This chapter first summarises the conclusions that can be drawn from this study (paragraph 9.1). Paragraph 9.2 discusses these results and how they reflect on literature and practice. In paragraph 9.3 the chosen methodologies and research choices that were made are reflected on. And last, this dissertation is concluded with recommendations for further research.

9.1 Conclusions

The second part of the question regarded Corporate Real Estate Management (CREM). CREM is best described as: “The management of a corporation’s real estate portfolio by aligning the portfolio and services to the needs of the core business (processes), in order to obtain maximum added value for the businesses and to contribute optimally to the overall performance of the corporation.” (Krumm, Dewulf and De Jonge, 2000). It can add both exchange and use value to the organisation if a CRE strategy is chosen that aligns well with corporate strategy. But to be able to add use value, coordination with the management of other company resources is essential, and thus CREM must have a strategic position within the organisation. CRE must be regarded early in the strategic thinking process, when directional strategies for the entire organisation are determined, and alignment should be continued further along the entire strategic thinking map towards the implementation. Depending on the chosen CRE strategy, different CRE aspects are important to consider when action plans are drafted and consultants and architects are hired to implement the chosen strategy into building design.

If the strategy is to increase innovation (one of the most common corporate strategies these days), CREM must support knowledge sharing (KS) behaviour to reach alignment. To influence this behaviour, building layout is very important. But a layout is hard to measure, because it is mostly described with qualitative aspects. Reliable techniques for quick pre-occupancy evaluations of designs or existing buildings are necessary. To be able to prove added value for KS, it is necessary to have suitable quantitative layout metrics, and know the underlying mechanism of the layout-effect to evaluate the effectiveness of real estate intervention programs (using Realistic Evaluation/CIMO logic).

KS must take place on different organisational levels. It is not as simple a process as just communicating codified information. Knowledge sharing is the application of a fluid mix of framed experience (E), attitude (A), contextual information (I), and skills (S) for the benefit of oneself or another person in interaction. This demands face-to-face meetings and can require several loops during the communication process. The necessary behaviour to share knowledge during meetings includes interaction and collaboration. Interaction behaviour was operationalised with KS activities like giving descriptions and reporting on explicit information in either an oral or written form. Collaboration was identified with behaviour involving proposals, evaluations, questions, and engaged actions.

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Previous studies on the effect of layout on KS behaviour, have identified five relevant layout mechanisms, which have been appointed to two different levels:

1. Co-presence on a local level, with two mechanisms (accessibility + proximity);
2. Position in the building on a global level, with three mechanisms (exposure, centrality + meeting areas).

However, these studies showed several shortcomings. When collecting data on KS, they often used perceived data from surveys, and/or only measured communication without taking into account the content of what is shared. The data collected on the layout, are hard to extend to buildings in general, because they only studied certain types of spaces or used longitudinal studies without quantifying the design correctly. Therefore, the five mechanisms have been operationalised into fourteen quantitative layout metrics. The metrics for position in the building are all related to individuals, except meeting areas which could be used by dyads (or larger groups). The co-presence metrics also relate partly to individuals and partly to dyads. So, two conceptual models have been tested to show how the mechanisms influence the amount of KS meetings.

A logbook was considered the best way to collect the necessary behavioural data, because it outperforms a questionnaire in validity, and sample surveys in precision of measurement. A test of the logbook showed that the KS items chosen to study the KS process in more depth were clear to its users. With regard to the KS that took place at Océ during the week of the fieldwork, the following came forward. On average, participants had 14 KS meetings this week with five different colleagues, which were mostly one-on-one meetings and took place at a workplace (78%) or in a project area (14%). Of the possible dyads 4% shared knowledge that week. Questions were the most common way to share knowledge (56%), but the other four KS activities also took place (+ 20%); actions mostly in the project areas. During a day, an average of 45 minutes was spent in unplanned KS meetings, with 80% of the meetings lasting up to 15 minutes. The hallway and coffee machine might be places where a lot of talking takes place, but not to share work-related knowledge in the way that was studied here. The knowledge that was shared appeared to be very tacit, because it was often (77%) available through one person only. Most meetings were intentional (72%) and concerned a problem (89% of which 44% was a shared problem). Involvement in each other’s problems was generally high (3-5 on a 5-point scale).

To obtain the CRE metrics, isovist and visibility graph analysis was used. These spatial network analyses methodologies complement the few simpler layout quantifications, to test all fourteen metrics in the conceptual models. With regard to the CRE metrics at Océ, the following came forward. On average, a participant:

- had 15 m²/workplace,
- saw 7 roommates from behind his/her desk,
- sat 8 meters from the entrance,
- had a visible rooms size of 168 m² and
- had an average walking distance of 61 meters to the other workplaces in the building.
Participants were spread over the rooms (so some were in the centre, others at the outskirts). The group offices provided their inhabitants with a more compact and smaller work area, than the larger, rectangular, open areas. 63% of the participants was visible from the entrance of the room. The meeting area mechanism was discarded, because hardly any unplanned meetings took place in a meeting area.

The CRE metrics of dyads showed that:
- 6% shared a room,
- 5.5% could see each other at their desks,
- 27% of dyads sharing a room sat within 5 meters, 69% within 10 meters,
- 61 meter was the average distance between their workplaces,
- 52% worked on the same floor.

No clear cut point for hearing distance was found, so this could not be recoded into a dichotomous variable as was originally planned.

Results showed that CRE can indeed add use value through different mechanisms. Several layout metrics showed differences in chosen KS activities (qualitatively different outcome) and/or an association with the amount of KS meetings (improved outcome). Because both the dependent variable in the conceptual models (number of KS meetings) and many independent variables (layout metrics) did not have a normal spread, Spearman's correlation had to be used to show the associations in both conceptual models. Overall, the association of the layout metrics with the number of KS meetings at Océ was not really strong. The strongest association (.460) is still considered only 'moderately strong' for Spearman correlations in general, but this is in line with other studies. CRE is a supportive resource, and it cannot be expected to be responsible on its own for a high variance in the amount of KS. Other context variables (e.g. organisation structure, culture, working on the same project) will be responsible for the largest part of this variance (hence the use of realistic evaluation). But even if only 20% of the variance would be explained, this means that CREM can support and improve the primary process of their client organisation significantly, and that is their main task. Also it gives CREM insight in the relevance of metrics and the current CRE effectiveness.

The strongest associations came forward for metrics of accessibility (co-presence) of dyads, followed by accessibility on an individual level. Accessibility was split up further into two different mechanisms: Visibility and Placement within the room (see Table 9-1). For the centrality and proximity mechanisms all metrics had significant associations too, but less strong ones (which is in line with previous studies). The exposure mechanism was not triggered at Océ. An increase in KS meetings is most likely to be caused by the visibility mechanism. But the placement within the room mechanism shows that there must be a limit to this. Very large rooms do not necessarily optimise KS. An increase in distance between dyads in a room (and decrease in density) lowered the amount of KS meetings. Beyond 8 meters only a few outliers of the dyads still shared knowledge, so perhaps this should be seen as a limit for the visibility mechanism. This distance might be different at other organisations, although it can be expected that the ability of people to be aware of others is physically limited the same way for everybody. As the distance has not
been identified in previous studies as far as known, there is no proof for this thought. It would seem that the hearing distance (generally lying between 5-10 meter according to Wenmaekers et al. (2009)) is critical. It is however hard to determine hearing distance, because it is unique for each person and each room. The centrality and proximity mechanisms show a further decrease in the number of KS meetings with distance. Dyads with more than average numbers of KS meetings had a walking distance of less than 22 meters (not counting outliers). No ideal room size limit could be found.

Several metrics correlate with each other too. But, unfortunately, Spearman correlation does not have the opportunity to do multivariate analyses and look for the unique contribution of the different metrics of a mechanism. Also, the data on dyads and on individuals cannot be run together in such an analysis.

<table>
<thead>
<tr>
<th>1a. (Accessibility through) Visibility</th>
<th>1b. (Accessibility through) Placement within the room</th>
<th>2. Centrality</th>
<th>3. Proximity in the building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyad works in the same room .460</td>
<td>Hearing distance between dyads in a room -.422</td>
<td>Average walking distance to all workplaces in the building -.183</td>
<td>Dyad works on the same floor .178</td>
</tr>
<tr>
<td>Number of visible workplaces of individual .355</td>
<td>Density in the room .181</td>
<td></td>
<td>Walking distance between dyad if not working in the same room -.132</td>
</tr>
<tr>
<td>Compactness of the workplace -.328/- .277</td>
<td>Location inside the room .168</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Table 9-1 Significant Spearman’s correlations layout metrics and # KS meetings |

After testing the association of layout metrics with the amount of KS meetings, the other descriptors of KS were studied to get more insight in what happened during the meeting. This way it became clear whether individuals and/or dyads showed different KS behaviour at a workplace with a specific level of co-presence or at a specific position in the building. It turned out that only the visibility mechanism was able to increase collaboration, and the others only increased interaction or nothing at all. The KS activities (descriptions, questions, actions, proposals, evaluations) and other KS process variables were tested with χ²-tests and showed significant differences in KS behaviour for certain values of the layout metrics. Dyads that shared a room had more shared problems, and dyads from different rooms shared less tacit knowledge (they could also have consulted someone else), and mentioned a lower involvement of others. The larger the room, the more knowledge was shared intentionally and through more cooperative behaviour. The metrics for placement within a room showed that this mechanism influenced the way knowledge was shared as well. Sitting closer to each other seems to increase awareness which prompts people to give more descriptions if this seems helpful. At a distance, it might be necessary to ask things that would otherwise have been clear by overhearing/awareness. The participants at the ‘outskirts’ of an area appear to have more opportunity there to evaluate or perform actions together; activities that
might disturb others. The centrality and proximity mechanisms showed no further
differences in KS behaviour. The exposure metrics, on the other hand, had no
association with the amount of KS meetings but did show differences in KS activities.
Participants visible from the entrance used descriptions and actions significantly
more often to share knowledge. Perhaps the visible participants are consulted more
for quick needs for a description or to help with a task or equipment issue, when
people enter the room.

The main question of this research was:

*Which quantitative CRE metrics can prove the added value of CRE for knowledge
sharing behaviour within an organisation, and how should CRE be managed to reach
alignment with corporate strategy?*

For the first part of this question, a list of fourteen quantitative CRE metrics was
developed through literature study, and appointed to five different layout
mechanisms. The exposure mechanism turned out to be hard to grasp. Although
theory (mostly from the field of spatial network analysis) was present on the effect
of exposure on interactions, the metrics used in the Océ case seemed irrelevant for
KS meetings (no significant association). Following Koch and Steen (2012b), the
influence of tasks on the exposure mechanism might be the reason for this result.
Perhaps the Océ tasks are an example of work that does not depend on exposure,
and thus in the Océ context the mechanism does not work. The strong influence of
context on the working of a mechanism makes it impossible to draw conclusions
here on which metrics from theory are relevant and which are not outside the
context of Océ. This can be different in each individual organisation, and even within
the different business units within the organisation. The study did show that the
mechanisms do exist, and that realistic evaluation and the quantitative layout
metrics that were distinguished are a valid way to study them inside an organisation.
They help CREM prove how it is adding value to the organisation. A face validity test
showed the results to be clear and interesting and Océ could identify with them.
Also, they felt that the CRE metrics represented building 3G correctly. They
mentioned that KS at Océ does indeed take place similarly as the results from the
logbooks showed. Projecting the results from the case-study on the new layout gave
insight in the KS that should take place after the renovation program is
implemented. This helped the CRE manager to discuss his plans with general
management and other stakeholders in his organisation. For the second part of this
question, the strategic thinking map was adjusted to identify the necessary steps for
aligning CRE strategies. This is discussed in more detail in the next paragraph.

9.2 Discussion and reflection on literature and practice

To be able to steer on both exchange and use values, CREM has to be at the strategic
decision table and thus up high in the CREM evolution. A taskmaster (at the bottom
of the theoretic CREM evolution) probably will not reckon with most of the layout
metrics used in this study. He focuses on engineering and technical issues, and
assumes that the (internal) client has already decided about the most effective
building layout. However, the client is not an accommodation expert, and might
disregard important matters, simply because they are not within his expertise.
During the engineering process, the taskmaster focuses his technical expertise on
the way the building is constructed, which (as shown in Chapter 2) mostly impacts the exchange value strategies. At best, he might make some suggestions on efficiency issues (e.g. density) if available budgets are overdrawn. The next two steps on the evolution are, the controller, who runs a more analytical CREM department that wants to minimise building costs, followed by the dealmaker, who is looking for standardisation of building usage. Several of the metrics studied influence the direct costs of buildings (e.g. density, workplace size, meeting areas), and should be considered by CREM on both these stages. Unfortunately, the indirect costs (which are influenced by several metrics as well) are not considered yet at these two evolution stages, nor the benefits for effectiveness. Since the dealmaker wants to standardise, he must have standards for several of the metrics to be able to compare them within the client organisation. This is even more pressing for the entrepreneur stage CREM department, because it wants to benchmark with others on the external market as well. The more metrics are used and benchmarked, the more it becomes clear whether and how added exchange value is really delivered. If CREM succeeds at this and can show general management how they add (exchange) value through (a) certain mechanism(s), this might form a basis for the last evolutionary step, the strategist, and CREM’s ‘invitation’ to the strategic table. As said, only then CREM can start to really achieve alignment for the client organisation, through considering all seven added value strategies. It will be necessary to have a relevant list of CRE metrics for each strategy to start proving this added value with real estate interventions that trigger the right mechanism(s).

To be able to achieve alignment and deliver added use value, CREM has to cooperate with other business functions. That is the only way to make sure that the right needs are supported. The problem is that the outcome side is not easily quantified for added use values. The other business functions should provide CREM with the right (measurable) aspects that CRE metrics can be related to (as done for Océ and their KS meetings). But often it is not exactly clear which needs exist, which makes alignment of CRE even more difficult. Based on literature study, two different knowledge components were distinguished (explicit and tacit) as possible knowledge outcomes. Also, it was presumed that tacit knowledge could only be shared through collaboration, which would require more involvement than interaction. And last, that KS must take place on different levels; one-on-one (socialisation), within teams (externalisation) and between teams/departments (combination). However, the conceptual representation of KS behaviour that was formed from these assumptions (see Chapter 3) could not be confirmed with the data from Océ. Only the argument for constructing the involvement dimension (interaction takes less time and involvement than collaboration activities) was supported. Descriptions were indeed KS activities that required less involvement, but did not deal with more explicit knowledge than the collaboration activities. Instead, part of the questioning appeared to concern more explicit knowledge. Also, no significant differences in meetings between departments, between teams or within teams were found with regard to involvement or the KS activities that they used. The test with a knowledge component proxy (the possibility to consult other sources for the same knowledge) just missed the 95% threshold of a significant difference too. So, there is still a lot to
study and clear up about KS behaviour, to get a clear view of what CRE should support.

As CREM climbs the evolutionary ladder more CRE aspects like the ones identified for layout in this research can help in showing the added value for both the softer as the more traditional (financial) CRE strategies. Hopefully this can help CREM in getting their (deserved) place at the strategic table, as a strategic resource that can do more than just aim for efficiency. In Chapter 2, many structural, installations and location aspects were identified as having a possible influence on certain added values. By only looking at the layout, this research already identified five different CRE mechanisms measured with several metrics that can be used by CREM. So if all the aspects in both tables are taken into account, CREM might end up with a long list of metrics to reckon with, depending on the CRE strategy that they are aiming for. It is a lot of work for a CRE manager to look at all of these metrics. But as long as he does not know which ones are most relevant and which ones are not, it is not possible to shorten the list either. Each CREM department will have to look within their own ‘black box’ and see how CRE mechanisms are best implemented to support the goals of their client organisation.

In Figure 9-1 an overview is given of steps and considerations CREM could make to achieve better alignment with the needs of their client organisation. The influence of context supports the iterative nature of the strategic thinking map. Only through implementing certain metrics in a certain way, it is possible for CREM to study how they support their client organisation. But only after such studies, CREM has the knowledge to determine the right implementation. Results of an internal benchmark with the layout metrics can be discussed in briefs with architects and other external parties, when real estate interventions are necessary. Spatial dimensions, amongst other issues, are usually part of this brief and the brief also “functions as a ‘touchstone’ against which design proposals can be tested and alternatives can be
compared.” (Bogers, Van Meel and Van der Voordt, 2008). The relevant co-presence and/or position in the building metrics can be taken up in the brief, and later used to compare alternatives, using the actual layout drawings from an architect. This way the tacit knowledge of architects on how layout influences behaviour can be made explicit and discussed with clients with less knowledge of building design. As Sailer et al. (2007) say, this detailed knowledge may provide architects with the opportunity to design solutions that match better with the clients’ needs, and CREM with solid and comprehensible evidence to back up their budget discussions with general management. This is true both at the beginning of the design phase for new building, but also during later post occupancy evaluations that might lead to new interventions. Even on a small scale, a change of project of certain employees should lead to re-evaluation of the workplaces that they were allocated to. The strategic momentum box of the strategic thinking map also calls for strategy evaluation, which will help with emergent learning. The map ends with the term ‘re-initiate strategic thinking’. This should take place if the organisational strategy changes, because then the CRE strategy needs to be aligned anew, and the whole process starts from the beginning with strategic thinking, followed by the situational analysis of the strategic planning box. At that time the strategic thinking map has been followed entirely for one cycle, and a new process of (improved) alignment of CRE(M) can start. Due to many reasons, it will never be easy to align CRE completely with all organisational goals. It is inevitable that some desires will be in conflict with each other. Also, the strategy context is so volatile that continuous adjustment should be sought, which is not financially feasible. A question is how unique and organisation really is, as most office designs are very similar. All parties involved should look for the priorities in a specific case, and try to design and make choices accordingly. In that sense, maximising added value does not have to mean reaching maximum value, but adding the value that was most important and feasible within the current context.

9.3 Reflection on research methodologies
Realistic evaluation emphasizes the influence of context on outcome, and how mechanisms might or might not be triggered to produce an outcome. The fieldwork at Océ showed that using realistic evaluation works well both for studies on KS and for studies on mechanisms of the spatial environment. The influence of context on the outcome became clear when the data of Océ were compared with the observations by Berends (2003) who identified the five categories (see Figure 8-1). Participating organisations in both studies are industrial research companies, but their way of sharing knowledge obviously differs. Comparing just two studies already showed that effects on outcome cannot be generalised to the entire population of industrial research companies. The influence of context on the mechanisms became visible by comparison with another CRE study. Toker and Gray (2008) identified the centrality mechanism to be double as strong as the other mechanisms they tested at their cases, but at Océ it had a weaker association with KS than several local metrics of accessibility and was almost similar to the proximity mechanism. So Realistic Evaluation is a good basis for these types of studies that combine spatial mechanisms and outcomes of effectiveness.
Epistemology showed two streams that interpret and study knowledge in different ways: the objectivist versus the practice-based perspective. The data on KS meetings at Océ support the practice-based perspective on knowledge. Of the KS meetings 78% was held with the only person that could provide this knowledge, and only 4% of the shared knowledge was available in a non-human form. Apparently knowledge cannot be separated from a person as easily as the objectivists think. The five categories of KS activities let knowledge remain embedded in an activity, as the practice-based perspective emphasizes, but do offer the opportunity for using statistics, as the objectivist prefers. So they are an interesting way to bring both perspectives nearer to each other. It gives practice-based academics the opportunity to use more positivistic methods (observation, statistics) to study knowledge. And thus might help convince objectivists of the less stringent separation of explicit versus tacit knowledge that the practice-based perspective believes in.

This study looked at face-to-face meetings only, which fits the chosen practice-based perspective. Among CRE practitioners, virtual cooperation still has a very low priority (Gibler, Lindholm and Anderson, 2010). But there are academics that have studied the use of technology for remote collaboration (Covi, Olson and Rocco, 1998), like email, phone and all kind of internet applications. Even some comparisons have been made between face-to-face and distant communication (e.g. Heerwagen et al, 2004). Studies looking at both forms of communication showed that ICT cannot replace the necessary face-to-face communication for KS. It has advantages (more open and democratic), but also disadvantages, for example that people communicating electronically have a hard time imagining what others are feeling (Sproull and Kiesler, 1991). It is not possible to share complex information without the feedback available by the presence of the other person (Allen and Henn, 2007). The virtual environment is an efficient space for circulating explicit knowledge, but tacit KS needs the physical space (Nenonen, 2005). Also, spontaneous face-to-face encounters have been shown to form the majority of KS meetings in organisations (Toker and Gray, 2008). Studies (Allen and Henn, 2007; Spiliopoulou and Penn, 1999) did find that people mix the media that they use, so people with more face-to-face communication also communicate more through other media. And people with little face-to-face moments, do not communicate a lot at a distance either. E-mail functions both as a substitute and as a complement to face-to-face meetings (Steen and Markhede, 2010). The knowledge management model in Chapter 3 showed that feedback is necessary to share knowledge, opposed to communication that can be one-sided. So, it seemed valid to exclude virtual KS from this dissertation.

The logbooks gave clear data on the questions that were asked. A check of how accurately the participants filled in their logbook also showed its value. While some participants did not log much but were mentioned often by their conversation partners, others logged more occurrences than their partners remembered having with them. The advantage of the logbook setup was that the ones that logged few occurrences did not have to be removed, because of the relevant information that could be gained from the logbooks of other participants. And it confirms that it provides more accurate information than perceived amounts of meetings in surveys/interviews. However, after data-analysis it also showed its limitations. The
logbooks could have been supplemented by a follow up survey. This could have gone deeper into the knowledge gathered from the logbook analyses.

As the case study showed for KS behaviour, some metrics will have a larger association with the added value that CREM is aiming for than others. Some of these metrics were easy to generate and monitor, while others took considerably more time and effort to measure them correctly. Some layout metrics demanded automated approaches (by using Depthmap) because it was too much work to calculate them manually. A downfall of this is that only the programmer knows the computer program by heart, so the users might be stuck with the feeling that they miss the due diligence possibility of manual approaches (Brown, 2008). Océ indicated that they would only use such metrics for buildings with complicated layouts or if they would start regularly monitoring many buildings. So the spatial network methodology seems unnecessarily laborious to use for evaluating these type of programs, as the layout mechanisms also have ‘easy’ metrics that can be used. These did show less strong associations with KS at Océ though. Unfortunately Spearman does not offer the possibility of studying the unique effects of the metrics that are correlated. This is a downfall of the data that were not spread normally.

In Chapter 4 the following shortcomings of previous studies were discussed:

1. They fail to study (and thus compare) all different mechanisms using rigorous methodologies. This study was the first to compare all the mechanisms (except meeting areas, which is a questionable mechanism for unplanned meetings anyway) with the same methodology and statistical analysis.

2. The outcome is measured with perceived information and measured communication without taking into account the content of what is shared. This study did not only report on frequency of communication, but also had an in depth look at KS behaviour during the meetings.

3. The outcome is related to a move with a pre-post questionnaire, without identifying whether it was (only) CRE that caused the change in outcome. This study was not longitudinal, and took place at a time that no organisational changes took place. So it measured a constant context.

4. The ways of measuring layout are questionable (types of spaces cannot be replicated due to context, and topological configuration metrics lose metric information). This study chose only quantitative metrics that can be calculated for any layout-drawing, and any workplace or room in it.

So, these shortcomings appear to have been overcome. Of course, there is always room for improvement. The last paragraph of this dissertation will therefore give recommendations for further research.

9.4 Recommendations for further research

With the split of accessibility in visibility and placement within a room there will be six mechanisms to consider in future studies. But first the context itself must be mapped in more detail, to find out which contextual issues influence the mechanisms. According to Pawson and Tilley (1997, the academics behind Realistic Evaluation), at least four contextual layers exist: the individual, the interpersonal relationships, institutional setting and the wider infrastructural system. Studies on
the mechanisms can then vary these contexts to see their influence, like organisational contexts (business sectors, countries, etc.) and different personal contexts (age, gender, tasks). With regard to the added value of layout, the building itself is a context layer as well. Shpuza and Peponis (2008; see also dissertation of Shpuza from 2006) studied floorplate shapes and the possible layouts in them. They distinguished six types of floorplate shapes (wings, bars, pavillons, compact blocks with external core, spaces with a small central core and spaces with a large central core), and found that they influence global properties of the layout used in them. My case study only looked at a ‘bar’-type building and it is interesting to study the other types as well and see whether and how the CRE mechanisms work.

Not all five mechanisms from theory turned out to be relevant for the Océ case to steer on KS behaviour. Exposure was not triggered at Océ: Roommates did not bump into each other coincidentally more often, but also intentionally looked for a certain roommate to share knowledge. The meeting areas mechanism was not relevant at Océ either. This does not mean that they will not be relevant in other contexts. For example, the case building only had very standard meeting rooms. To study this mechanism in depth, cases must be sought that deliberately use a range of meeting places to create certain conditions. Then it can be tested whether and how this mechanism works. The activity based office concepts related to the upcoming trend of New Ways of Working do have many specifically designed places to incidentally sit down for a short (or longer) chat. It should be studied how all these types of meeting areas influence (KS) behaviour. As activity based offices often have large open areas (too large according to our results), they might show different results for all mechanisms. As these offices are based on non-assigned seats, people can use different types of workplaces during the day. This will influence who they meet, and how they share knowledge with them. Exposure should be studied further as well to understand the mechanism better in more and less open layouts, and in these activity based offices.

The visibility mechanism was the strongest at Océ. But future studies in open layouts with many screens obstructing views, must show whether the visibility mechanism might be different in that context. The proximity mechanism was triggered at Océ too. But in less open layout types, proximity might show a different distance at which people still meet, so that also deserves further study. And as an office building inherently puts some people at short and others at longer walking distances, centrality and placement of employees in a layout deserve more research too, specifically focusing on which types of employees should sit where to achieve a certain outcome. Koch and Steen (2012c) showed that although the direct effect of less proximity might be fewer meetings, an indirect effect was more movement which creates more exposure for people sitting near the movement flows. So, the interrelatedness of mechanisms and side-effects that might occur should be studied further as well. A combined study of all six mechanisms will also shed more light on their relative importance.
The strongest mechanisms seem to thrive in open office layouts. More research is necessary on the disadvantages of these mechanisms for organisational innovation. As Berends et al (2011) state, unrestrained KS can create cognitive overload for individuals. How to reach a balance between awareness and interaction versus privacy and the possibility to focus? Effective collaboration needs both (Heerwagen et al, 2004) for innovation to take place. The latest US Workplace Survey by Gensler showed that “employees who can effectively focus are 57% more able to collaborate, 88% more able to learn, and 42% more able to socialize in their workplace than their peers who are unable to focus” (Hoskins, 2013). Koch and Steen (2012b) add the need to distinguish the effect of interruptions on focused work on long and short questions18. The activity/tasks might determine which mechanisms are best suited. Further studies on this matter are necessary. Besides the tasks and ability to focus, innovation also needs creativity as an individual component. Creative thought processes are influenced by the physical environment as well, and deserve more study (Kauttu, 2003; Dul and Ceylan, 2006; Martens, 2011, Van de Sande, 2012).

The literature review discussed in Chapter 2 provided Table 2-2 with a list of many CRE aspects that have an effect on one or more of the CRE strategies. This dissertation helped quantify some of the more qualitative aspects in this table, and related them to innovation. However, increased innovation is not the only possible added value of CRE(M). This study could be replicated for other use values (productivity, satisfaction, marketing & sales). And since many CREM departments still focus on efficiency, it would be interesting to study the layout metrics and their association with added exchange values too (costs, asset value and flexibility). Also, comparative studies on both use and exchange added values are interesting. A metric as density, for example, has a clear impact on costs and is used by many CRE managers to steer on costs. Unfortunately, the savings by increased density are hardly ever related to possible savings through increased effectiveness in less crowded work environments. Another example can be given with the proximity metrics. Providing proximity to more colleagues might frustrate flexibility or demand a less generative building (and thus lower asset value), but it could also improve productivity or employee satisfaction. In Table 9-2, an example is given of how isovists and visibility graphs could be used to operationalise CRE for the other strategies as well. The application of isovists/VGA to other strategies needs further research for each individual strategy, and the CRE strategies should also be studied all together. Perhaps it will turn out to be possible to combine certain strategies, because they are supported by the same layout mechanisms. This can be further extended by also including the other CRE aspects from Table 2-2 in such studies.

18 “The concept of long and short questions does not have to do with the length of the work in question but the way work can consist of small sub-tasks or longer passes of continuous reasoning, making it respond differently to interruption” (Koch and Steen, 2012c)
The strategic thinking map appeared to be a helpful framework for alignment of CRE to corporate strategies. In order to confirm this assumption, future studies must walk through the entire strategic thinking map with different CREM cases to test its usefulness. Often CRE is not considered until the strategy implementation phase of this map. But this is much too late, especially if interventions in the work environment are necessary to align better with corporate strategy. More research into the benefits of early alignment of strategies could shed more light on this issue. Also, Weber, Weggeman and Van Aken (2012) stress the importance of involving users into new product development, because they know better which job they need to perform with it. This also stresses the early involvement of CREM in strategic change programs. Further research is necessary on how CREM can best involve their client and its employees in their design processes. This involvement could have a positive effect on the adoption of the new work environment.

As a CREM academic, studying innovation and knowledge management with such depth was an interesting new perspective. Therefore, last, here follow some recommendations for academics in these fields of study. It is a pity that these academics mostly disregard the physical work environment or only look at collocation in the same building. As shown, working in the same building does not automatically trigger the mechanisms of layout influencing behaviour. The effect works mainly at a more local level within the building, so this might deserve more of their attention in future studies. For example, academics studying cognitive apprenticeship will have to start reckoning with (hearing) distances between master and apprentice(s).

The KS activities deserve further attention and clarification in future studies too. Berends (2005), combined 3 different types of questions in the ‘questions’ category, namely ‘asking a question’, ‘questioning (asking a critical question)’ and ‘asking for help’. Questioning seems a logical continuation of a meeting after a proposal has been made and also during evaluations. Asking for help during actions seems also a common combination, and questions could easily be followed by a description too (ask and answer). Asking a question appears to be a move that could stand on its own. Perhaps the category of questions should be split up in future studies. A question could be more explicit, while a critical question might be more tacit. And in KS meetings with more than one KS activity, it might be interesting to see if they are used consecutively or intertwined.

Table 9-2 The use of isovists and visibility graphs for other CRE strategies

| Increase costs | m²’s per workplace | m²’s for circulation |
| Increase value of assets | Genericness of layout parts | Accessibility |
| Increase flexibility | Equipment placing and its use | Facilities placing and their use |
| Increase employee satisfaction | Perceived workplace | Density and placement within a room |
| Increase productivity | Disturbance surroundings | Walking distances |
| Promote marketing and sales | First impression of entrance | Wayfinding visitors |
It also needs further study, which KS activities can be used to share tacit knowledge, and how much each category contributes to different types of innovation outcome of organisations. The results found were indefinite on their placement in the conceptual representation of KS behaviour in Chapter 3. It is interesting to study whether these two dimensions (knowledge component and involvement) are the only ones or that more dimensions should be distinguished to capture everything about KS behaviour. For objectivists the KS activities might be interesting to use when studying how codified knowledge is shared during face-to-face meetings. The practice-based academics can use them to study the loops in the knowledge management model from Chapter 3 (see Figure 3-3). They could study whether the KS activities are suitable to study the 2nd and 3rd level of communication (resp. meaning and effect) as distinguished by Weaver (Shannon and Weaver, 1949).

This dissertation only looked at the spatial behavioural school of knowledge management (as distinguished by Earl, 2001 and discussed in Chapter 3). Berends (2003) looked at the effect of the KS activities on attitude aspects of KS behaviour. Shaping attitude and values is the aim of the strategic behavioural school, and has not yet been studied much from the layout mechanisms point of view. The relationship between collaboration behaviour and attitude can be studied further too. Also the organisational behavioural school of Earl, focussing on creating networks and communities of practice, deserve more study, like Sailer and McCulloh (2012) have started to do. The final recommendation of this dissertation regards KS of employees with people from other organisations, institutions and government agencies. It would be interesting to get more insight in how mechanisms like proximity or centrality work at a larger scale.
Chapter 10 References


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Appendix I  Cleaning up and completing the logbook data

In the order of the logbook questions the following actions have been performed to complete the database with logbook data.

| Date:     _____ | start time: ____:____ |
| Duration: _____ hours _____ minutes |
| Who did you meet: ______________ |

The date was often a missing value. Where the right date was obvious (because the logbook is filled in consecutively during a week), the date has been added. If not, this has been left missing. The start time of the KS activities has been recoded into 30-minutes intervals to be able to make histograms of the spread of this variable.

The duration of the KS activities has been recoded into groups. This was necessary to be able to perform a $\chi^2$-test, because otherwise many cells would have values < 5. The recoding is done with a growing length of intervals, because the longer the KS activity, the less times it occurred. There were many KS activities of 1-5 minutes, which are not grouped. KS activities between 5 and 30 minutes are grouped in 10-minute intervals, between 30 and 60 minutes in 15-minute intervals, and longer than an hour into 61-90 minutes or > 90 minutes.

For Who did you meet, if the other person did not meet the conditions of the sample, the occurrence was not entered in the database. This was the case for:

- 117 occurrences with people from other buildings on the company site,
- 64 KS occurrences with missing values for the meeting partner.

Also, it was necessary to distinguish 3 groups:

- 617 occurrences with non-participants (“partner no logbook”)
- 743 occurrences that could not be matched although the partner did fill in a logbook (“no match”)
- 578 occurrences that could be matched (“match”)

For the people that did not participate with a logbook, their number of KS activities would not be as complete as for the participants. It is very likely, that these non-participants have also shared knowledge with other non-participants, which is not logged anywhere so untraceable. So this group is kept out of further analyses. The meetings with participants and the meetings with non-participants showed no relevant significant differences. For occurrences with more than 2 people, the non-participants are removed after the matching has taken place, because they might clarify whether something is a match or not. In the “partner no logbook” group, almost one third (173) of the occurrences were logged by only 12 persons, from different departments and product groups. These are active knowledge sharers, both with participants and with non-participants. They all had more than 10 meetings in
their logbooks with non-participants, but also plenty of meetings with participants (see Table 10-1).

<table>
<thead>
<tr>
<th>Initials</th>
<th>Meetings with non-participants</th>
<th>Meetings with participants</th>
<th>Department</th>
<th>Project team</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEM</td>
<td>15</td>
<td>14</td>
<td>Devt 2</td>
<td>1</td>
</tr>
<tr>
<td>DUIJ</td>
<td>11</td>
<td>7</td>
<td>Devt 3</td>
<td>10</td>
</tr>
<tr>
<td>HEG</td>
<td>11</td>
<td>3</td>
<td>Engineering c&amp;p 2</td>
<td>1</td>
</tr>
<tr>
<td>JIG</td>
<td>13</td>
<td>10</td>
<td>Engineering c&amp;p 2</td>
<td>1</td>
</tr>
<tr>
<td>JLG</td>
<td>11</td>
<td>5</td>
<td>Engineering c&amp;p 2</td>
<td>1</td>
</tr>
<tr>
<td>LVS</td>
<td>18</td>
<td>14</td>
<td>Devt 2</td>
<td>1</td>
</tr>
<tr>
<td>MHU</td>
<td>21</td>
<td>8</td>
<td>Devt 2</td>
<td>1</td>
</tr>
<tr>
<td>PJE</td>
<td>15</td>
<td>22</td>
<td>Devt 2</td>
<td>1</td>
</tr>
<tr>
<td>QDFRA</td>
<td>13</td>
<td>13</td>
<td>Software engineering1</td>
<td>3</td>
</tr>
<tr>
<td>RVDE</td>
<td>15</td>
<td>15</td>
<td>Devt 2</td>
<td>1</td>
</tr>
<tr>
<td>RVDT</td>
<td>19</td>
<td>20</td>
<td>Research</td>
<td>6</td>
</tr>
<tr>
<td>RWIE</td>
<td>11</td>
<td>7</td>
<td>Engineering c&amp;p 3</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 10-1  More than 10 meetings with non-participants

In total 578 occurrences could be matched into 274 matches (see Table 10-2). Especially meetings with many people were easy to match, but relatively there are just a few occurrences with many people. Some people forgot to mention a person when the group was large. Therefore, more matches of 7-person-occurrences could be made then originally were present in the database (the matching occurrence originally held less partners). In total, 44% (578/1321) of the occurrences could be matched. This indicates that only 59% of the meetings that took place, also ended up in the logbooks of all partners. This percentage is obtained by adding the non-matching occurrences, multiplied by the number of partners, to the matched occurrences: 578 + 2*620 + 3*88 + 4*32 + 5*2 + 6*3 -7*2= 2224 should be logged, but only 1321/2224 = 59% was logged. Participants were also asked to give the percentage of meetings that they expected to have logged, when the logbooks were collected. Comparing these percentages shows that people actually missed a lot more meetings than they thought. Of all participants, 42% indicated to have logged over 90% of their meetings, 62% over 80% of their meetings and even 76% thought to have filled in at least 70% of their meetings, while in general this was only 59%.

Table 10-2  Matching of occurrences
For the completion, 762 occurrences are added to the database:

1) For unmatched occurrences:
   - 646 with 2 persons → 646 extra occurrences
   - 43 with 3 persons → 2×43 = 86 extra occurrences
   - 6 with 4 persons → 3×6 = 18 extra occurrences

2) For incomplete matched occurrences:
   - 15 with 3 persons, logged twice → 15 extra occurrences
   - 1 with 4 persons, logged twice → 2×1 = 2 extra occurrences
   - 1 with 4 persons, logged three times → 1 extra occurrence.

To be able to recognise the duplicated occurrences, they receive the same match code but an alternative logbook code (999 for 2nd participant, 9999 for 3rd participant, 99999 for 4th participant). All data from the partners are copied to the duplicated occurrences, except source and involvement, because that is an opinion about the other person(s). These two variables are left missing. The variables own workplace and workplace of other need to be switched.

As an extra check for the validity of the matches, it was verified if the duration and start time (within the chosen 30-minutes limit) of partners showed large differences.

This had to be done with an adjusted database where the answers of partners are placed on the same line\(^\text{19}\). Of the 237 meetings with 2 or 3 persons, 88 (38\%) has no difference in duration, and for 70\% the difference was 5 minutes or less. Since there were a lot of short meetings, also the relative difference is verified: more than half (52\%) show a relative difference of ¼ or less of the duration of the meeting, and only 23\% shows a relative difference of more than half of the duration of the meeting.

For the start time, 71 occurrences (31\%) have no difference in start time, more than half (54\%) show a difference of 5 minutes or less, and only 24\% shows a difference of > 10 minutes. These results indicate that the matches, although done by hand, are very reliable. In conclusion, it seems safe to remove the occurrences with non-participants from the database. Also the matches are not of a different nature than the non-matches, so there is nothing important to conclude here.

<table>
<thead>
<tr>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptions</td>
</tr>
<tr>
<td>Actions</td>
</tr>
<tr>
<td>Questions</td>
</tr>
<tr>
<td>Proposals</td>
</tr>
<tr>
<td>Evaluations</td>
</tr>
</tbody>
</table>

The KS activities that the participants could choose from (or moves as they were called by Berends (2003)) were identified by Berends through observation of a limited number of employees. Therefore, it is important to check if these terms are

\(^{19}\) To keep this adjusted database readable, only the occurrences with 2 or 3 partners are used for this analyses, which constitute 86.5\% of the original database.
interpreted the same by all the participants. To be sure, that certain terms were not interchangeable, the meetings where partners disagreed are checked for anomalies. Certain combinations of KS activities could indicate that the participants have interpreted these terms as one and the same. Table 10-3 shows the number of differences in the chosen KS activities by all partners involved per meeting. In 31.6% of the cases, partners agreed on all 5 KS activities if they took place or not. For another 25.3%, one of the participants mentioned a second KS activity which are evenly spread over all 5 types. So for a total of 57%, there were no differences in interpretation.

<table>
<thead>
<tr>
<th>KS differences</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>0</td>
<td>75</td>
<td>31.6</td>
<td>31.6</td>
</tr>
<tr>
<td>1</td>
<td>60</td>
<td>25.3</td>
<td>25.3</td>
<td>57.0</td>
</tr>
<tr>
<td>2</td>
<td>58</td>
<td>24.5</td>
<td>24.5</td>
<td>81.4</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>12.2</td>
<td>12.2</td>
<td>93.7</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>4.6</td>
<td>4.6</td>
<td>98.3</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>1.7</td>
<td>1.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>237</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 10-3  Number of differences in the chosen KS activities by all partners

The correlations that are calculated last, check whether the disagreement about a term show any indications that a certain difference appears more often than you would expect (see Table 10-4). This would be an indication that those two terms are assigned to the same activities and thus cannot be discerned by the participants. The significant correlations are not very strong and do not appear to implicate that these terms are interpreted to be the same activity.

<table>
<thead>
<tr>
<th>Spearman's rho correlation</th>
<th>Difference descriptions</th>
<th>Difference actions</th>
<th>Difference questions</th>
<th>Difference proposals</th>
<th>Difference evaluations</th>
</tr>
</thead>
<tbody>
<tr>
<td>N= 237</td>
<td>1</td>
<td>.045</td>
<td>-.134(*)</td>
<td>.075</td>
<td>-.174(**)</td>
</tr>
<tr>
<td>Difference descriptions</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference actions</td>
<td>1</td>
<td>.064</td>
<td>.128(*)</td>
<td>-.047</td>
<td></td>
</tr>
<tr>
<td>Difference questions</td>
<td>1</td>
<td>-.094</td>
<td></td>
<td>-.168(**)</td>
<td></td>
</tr>
<tr>
<td>Difference proposals</td>
<td>1</td>
<td>.062</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference evaluations</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 10-4  Correlations for differences in the chosen KS activities
### Location(s)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Own workplace</td>
<td>(name)</td>
</tr>
<tr>
<td>Workplace of ___________</td>
<td></td>
</tr>
<tr>
<td>Meeting area ___________ (code)</td>
<td>(name)</td>
</tr>
<tr>
<td>Project room/area ___________</td>
<td>(code)</td>
</tr>
<tr>
<td>At coffee machine</td>
<td></td>
</tr>
<tr>
<td>In the hallway</td>
<td></td>
</tr>
</tbody>
</table>

If the workplaces of the KS partners of a meeting are adjacent, visible and within a normal speaking distance in the same room, the location was set to *own workplace* for both/all partners where this was not done already. Sometimes people had filled in *workplace of other* or checked both workplace boxes. Since it would be possible for them to speak with each other from behind their desks, this seemed most logical.

All *meeting area* and *project room/area* codes are checked and interchanged if necessary, because apparently some people had a different definition for these two terms. The 55 KS activities that took place in a *meeting area* or *project room/area* in a different building were not entered in the database. Over 96% of these meetings was scheduled/intentional, so these meetings were not a result of the layout anyway, but of an apparent shortage of meeting areas in the 3G building.

The answers are recoded into an extra location variable, with 6 possible values for certain statistical tests. Only in 39 (of 1148) occurrences, people have filled in 2 different locations for the same KS meeting. In those cases a choice has been made according to the following rules:

- own workplace + ..... → own workplace
  - 8 x workplace of other
  - 10x project room
  - 7x coffee machine
  - 1x hallway
- workplace of other + .... → workplace of other
  - 7x project room
  - 1x coffee machine
- Project room + coffee machine → project room
- Project room + hallway → project room
- Coffee machine + hallway → coffee machine

### Intentional or not

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduled in advance</td>
</tr>
<tr>
<td>Intentional unscheduled visit</td>
</tr>
<tr>
<td>Initiated after coincidental visual contact</td>
</tr>
</tbody>
</table>

The scheduled meetings are of a different nature than the unscheduled ones. They take place in the morning more often (42% started before 10am). Also, the
scheduled meetings are often the longer meetings (53% lasted more than a half hour), although also meetings of a few minutes were said to be scheduled in advance. The scheduled meetings account for 80% of the meetings in meeting areas, which seems obvious. Also to be expected, is the fact that they are most of the meetings with groups (they represent 71% of the meetings with 4 or more people). In 64% of the meetings the meeting was scheduled because of a shared problem, and in 82% of the meetings the shared knowledge was tacit knowledge, that only this particular person could provide.

To verify whether the partners within a matched meeting agreed about the intentionality, a $\chi^2$ test (like performed for the KS activities) was not necessary. Only in 7 meetings (3%) one of the partners chose *scheduled* and the other not. Both unscheduled types cannot be tested, because a person who is visited by someone else intentionally, could mistakenly think that this person just happened to see him and therefore came over to talk.

<table>
<thead>
<tr>
<th>Issues addressed</th>
<th>Problem of me</th>
<th>Problem of the other</th>
<th>Shared problem</th>
<th>Not problem oriented</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Issues addressed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem of me</td>
<td>5</td>
<td>33</td>
<td>16</td>
<td>1</td>
<td>55</td>
</tr>
<tr>
<td>Problem of the other</td>
<td>21</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>31</td>
</tr>
<tr>
<td>Shared problem</td>
<td>9</td>
<td>20</td>
<td>85</td>
<td>11</td>
<td>125</td>
</tr>
<tr>
<td>Not problem oriented</td>
<td>7</td>
<td>1</td>
<td>8</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>42</td>
<td>57</td>
<td>114</td>
<td>20</td>
<td>233</td>
</tr>
</tbody>
</table>

*Table 10-5  Count of answers for issues addressed*

Only 54% of the conversations took place because the partners had a shared problem. So this is not a necessary condition for KS to take place.
Verification if the partners within a matched meeting agreed about the initiator was not necessary, because 81% agreed.

<table>
<thead>
<tr>
<th>Alternative source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, non-human (e.g. book,</td>
</tr>
<tr>
<td>Yes, other person(s)</td>
</tr>
<tr>
<td>No, only this person</td>
</tr>
</tbody>
</table>

No further operations necessary.

<table>
<thead>
<tr>
<th>Involvement of the other(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listening</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

No further operations necessary.

It would be interesting to check how accurately the participants filled in their logbook. Therefore, the number of logged meetings is compared with the number of times people were mentioned as being a partner. This is only an indication, because in meetings with more than 2 people, you are mentioned by several persons compared with your 1 logged occurrence. On average the ratio logged/mentioned is 1, but the standard deviation is very high (0.74). Some people did not log much, but were mentioned often, while others logged more occurrences than their partners remembered having with them. The ones that logged few occurrences do not have to be removed though, because of the relevant information that can be gained from the logbooks of other participants.
Very few missing values remain, except for the variables source and involvement as explained above (see Table 10-6).

<table>
<thead>
<tr>
<th>Valid</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Match code nr</td>
<td>1907 0</td>
</tr>
<tr>
<td>logboek nr</td>
<td>1907 0</td>
</tr>
<tr>
<td>Océ initials</td>
<td>1907 0</td>
</tr>
<tr>
<td>Date</td>
<td>1897 10</td>
</tr>
<tr>
<td>Start time</td>
<td>1879 28</td>
</tr>
<tr>
<td>Duration</td>
<td>1875 32</td>
</tr>
<tr>
<td>Initials 2</td>
<td>1907 0</td>
</tr>
<tr>
<td>Initials 3</td>
<td>1907 0</td>
</tr>
<tr>
<td>Initials 4</td>
<td>1907 0</td>
</tr>
<tr>
<td>Descriptions</td>
<td>1891 16</td>
</tr>
<tr>
<td>Actions</td>
<td>1891 16</td>
</tr>
<tr>
<td>Questions</td>
<td>1891 16</td>
</tr>
<tr>
<td>Proposals</td>
<td>1891 16</td>
</tr>
<tr>
<td>Evaluations</td>
<td>1891 16</td>
</tr>
<tr>
<td>Whose workplace</td>
<td>1907 0</td>
</tr>
<tr>
<td>Which meeting area</td>
<td>1907 0</td>
</tr>
<tr>
<td>Which project room/area</td>
<td>1907 0</td>
</tr>
<tr>
<td>Own workplace</td>
<td>1903 4</td>
</tr>
<tr>
<td>Workplace of</td>
<td>1903 4</td>
</tr>
<tr>
<td>Meeting area</td>
<td>1903 4</td>
</tr>
<tr>
<td>Project room/area</td>
<td>1903 4</td>
</tr>
<tr>
<td>At coffee machine</td>
<td>1903 4</td>
</tr>
<tr>
<td>In the hallway</td>
<td>1903 4</td>
</tr>
<tr>
<td>Intentional or not</td>
<td>1891 16</td>
</tr>
<tr>
<td>Issues addressed</td>
<td>1899 8</td>
</tr>
<tr>
<td>Initiator</td>
<td>1886 21</td>
</tr>
<tr>
<td>Alternative source</td>
<td>949 958</td>
</tr>
<tr>
<td>Involvement of the other(s)</td>
<td>1126 781</td>
</tr>
</tbody>
</table>

Table 10-6  Missing values of logbook variables

198
Appendix II  KS at Océ

Looking at the days of the week, Monday appears to have been the most productive day in the sense of KS in general (29% of meetings) and Friday the least (13%) (see Table 10-7). The other days had an average contribution around 20%. But when comparing this data with the percentage of participants that was present at work that day, that seems to be the reason of the differences per day. Also, it is not that hard to imagine, that during the week the interest for keeping the logbook will have decreased, which might explain the relatively low frequency on Friday compared to Tuesday.

<table>
<thead>
<tr>
<th></th>
<th>KS meetings (frequency)</th>
<th>KS meetings (valid %)</th>
<th>Employees present (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>556</td>
<td>29,3</td>
<td>92</td>
</tr>
<tr>
<td>Tuesday</td>
<td>340</td>
<td>17,9</td>
<td>67</td>
</tr>
<tr>
<td>Wednesday</td>
<td>358</td>
<td>18,9</td>
<td>74</td>
</tr>
<tr>
<td>Thursday</td>
<td>392</td>
<td>20,7</td>
<td>75</td>
</tr>
<tr>
<td>Friday</td>
<td>251</td>
<td>13,2</td>
<td>68</td>
</tr>
<tr>
<td>Total</td>
<td>1897</td>
<td>100,0</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1907</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 10-7  KS & days of the week*

Friday is a significantly different day then the others with regard to the different KS activities; $\chi^2(16, N=1371) = 69.31, p < .01^{20}$. Apparently, Friday is a day of relatively a lot more evaluations and actions, and less questions or descriptions (see Table 10-8). The other days do not show any irregularities in activities, except very few proposals on Wednesday. A logical explanation does not come to mind.

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>Total</th>
<th>descriptions</th>
<th>actions</th>
<th>questions</th>
<th>proposals</th>
<th>evaluations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>394</td>
<td>74</td>
<td>34</td>
<td>199</td>
<td>38</td>
<td>49</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td>Expected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuesday</td>
<td>261</td>
<td>60,4</td>
<td>43,7</td>
<td>197,4</td>
<td>31,3</td>
<td>61,2</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td>Expected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wednesday</td>
<td>255</td>
<td>40,0</td>
<td>28,9</td>
<td>130,8</td>
<td>20,8</td>
<td>40,5</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td>Expected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thursday</td>
<td>290</td>
<td>39,1</td>
<td>28,3</td>
<td>127,8</td>
<td>20,3</td>
<td>39,6</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td>Expected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friday</td>
<td>171</td>
<td>15</td>
<td>33</td>
<td>58</td>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td>Expected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1371</td>
<td>210</td>
<td>152</td>
<td>687</td>
<td>109</td>
<td>213</td>
</tr>
</tbody>
</table>

*Table 10-8  Single KS activities and days of the week*

---

20 only interactions with one type of activity could be taken into account with this analysis, called ‘single KS activities’ from here on in this dissertation
The time of the day that the meetings started, shows an almost logical picture of a standard working day, with lunch between noon and one o'clock (see Figure 10-1). The morning shows more KS then the afternoon, with a clear peak at the beginning of the workday. To allow further $\chi^2$-analysis, the start times have been grouped into morning or afternoon meetings, with a split at 12:30. Tested against the day of the week, Fridays have even less meetings in the afternoon than the general preference for the morning ($\chi^2(4, N=1869) = 23.34, p < .01$). A possible explanation for the morning activity might be that certain start up meetings take place for that day of work. These are not planned though, because the planned meetings have been removed from the sample (these also started more often at 9:00 in the morning). There are no significant differences between morning and afternoon meetings with regard to any of the other variables in the logbooks, that could explain the busier mornings.

Looking at the mean duration of the meetings with single KS activities, actions and evaluations last longer than the rest (see Table 10-9), although all can be done during meetings of only 1 minute. The evaluations show a significantly different picture then the rest in a statistical test because they last longer. To avoid problems with the test having cells with expected counts below the requested amount of 5, duration had to be grouped into 2 large time-periods. But whether the line is drawn between meetings shorter or longer than 5, 15, 20 or 30 minutes, the test stays significant caused by the fact that evaluations are present much more than expected in the longer time-period (resp. $\chi^2 = 70.0; 61.3; 37.5; 43.6$). As the number of different KS activities increases, so does the duration (see Figure 10-2).
Table 10-9 Duration of single KS activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>descriptions</td>
<td>8</td>
<td>1</td>
<td>38</td>
</tr>
<tr>
<td>Actions</td>
<td>18</td>
<td>1</td>
<td>363</td>
</tr>
<tr>
<td>questions</td>
<td>9</td>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>proposals</td>
<td>11</td>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>evaluations</td>
<td>18</td>
<td>1</td>
<td>150</td>
</tr>
</tbody>
</table>

The shorter meetings dealt more often with the problem of only one of the participants (χ²(10, N= 1768) = 49.34, p < .01), perhaps because less evaluating took place and that takes longer.

Combining the problem orientation and initiator (see Table 10-10, it becomes visible that 4 different combinations constitute 80% of all meetings. Either the one with the problem initiated the meeting (me-me plus other-other = 38%) or the problem is shared and one of the participants took the initiative (= 42%). The meetings about shared problems were significantly more often initiated together (χ²(4, N = 1883) = 27.27, p < .01), but in absolute figures this happened only 39 times (=2%). In comparison with the results of Berends (2003, see Table 3-4) a lot more shared problems were an issue during the KS (44% vs 17%). Less pushing and thinking along took place, which is what Berends called the moves associated with a problem of the other, but initiated by me (4% vs 19%). In the case of Océ the other was usually the initiator of a meeting, when it regarded his/her problem (19%). The not problem oriented meetings were very significantly more often coincidental meetings and less intentional (χ²(3, N = 1888) = 87.27, p < .01), which is a logical outcome. On Mondays

---

21 To avoid a lot of problems in the test with expected cells smaller than 5, only the meetings up to 30 minutes are taken into account.
significantly more meetings were not problem oriented ($\chi^2(12, N = 1889) = 25.00, p < .05$). So, again, a certain type of unplanned coordinating meetings comes forward.

<table>
<thead>
<tr>
<th>Initiator</th>
<th>Count</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem of me</td>
<td>21%</td>
<td>351</td>
</tr>
<tr>
<td>Me</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The other(s)</td>
<td>46</td>
<td>2%</td>
</tr>
<tr>
<td>Both</td>
<td>6</td>
<td>0%</td>
</tr>
<tr>
<td>Problem of the other</td>
<td>24%</td>
<td>86</td>
</tr>
<tr>
<td>Me</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The other(s)</td>
<td>362</td>
<td>19%</td>
</tr>
<tr>
<td>Both</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Shared problem</td>
<td>44%</td>
<td>405</td>
</tr>
<tr>
<td>Me</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The other(s)</td>
<td>380</td>
<td>20%</td>
</tr>
<tr>
<td>Both</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Not problem oriented</td>
<td>11%</td>
<td>107</td>
</tr>
<tr>
<td>Me</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The other(s)</td>
<td>97</td>
<td>5%</td>
</tr>
<tr>
<td>Both</td>
<td>4</td>
<td>0%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>1883</td>
</tr>
</tbody>
</table>

*Table 10-10 Issues addressed and initiator*

Testing the issues addressed against the alternative sources for the knowledge that was shared, the expected results come forward; $\chi^2(16, N=1371) = 25.63, p < .01$. It is less often possible to consult other people or explicit knowledge sources in case of a shared problem. It might be such a specific problem, that both these people need to bring in their own tacit knowledge. When the problem lies with the initiator only, it was significantly more often possible to also consult other people. It could be that he/she needed knowledge from a certain group of people (perhaps a different department. When the receiver was the problem owner, the sender also more often was aware of non-human sources of knowledge for the problem. This sender is probably an expert in this field of knowledge, because besides taking the initiative to help others with their problems in this field, he/she also knows of relevant knowledge sources.

<table>
<thead>
<tr>
<th>Alternative source</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, non human</td>
<td></td>
</tr>
<tr>
<td>Yes, other person(s)</td>
<td></td>
</tr>
<tr>
<td>No, only this person</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem of me</td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>12</td>
</tr>
<tr>
<td>Expected</td>
<td>8.3</td>
</tr>
<tr>
<td>Problem of the other</td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>15</td>
</tr>
<tr>
<td>Expected</td>
<td>9.0</td>
</tr>
<tr>
<td>Shared problem</td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>12</td>
</tr>
<tr>
<td>Expected</td>
<td>18.4</td>
</tr>
<tr>
<td>Not problem oriented</td>
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</tr>
<tr>
<td>Count</td>
<td>1</td>
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<tr>
<td>Expected</td>
<td>4.3</td>
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<tr>
<td>Total</td>
<td>40</td>
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*Table 10-11 Alternative source and issues addressed*
The hallway and coffee machine mostly have coincidental meetings, which is logical ($\chi^2(5, N=1886) = 81.7, p < .01$; see Table 10-12). Without these 2 types of locations, there are no significant relations between location and intentionality. The coincidental meetings significantly more often consisted of giving descriptions and less of actions or questions ($\chi^2(4, N = 1370) = 62.3, p < .01$), so it seems more common to share explicit knowledge during such meetings than tacit knowledge. The coincidental meetings also requested less involvement of the others ($\chi^2(4, N = 1117) = 17.73, p < .01$). With a shared problem, the involvement was generally higher, opposed to meetings that dealt with one persons’ problem. Especially the not problem oriented meetings requested low levels of involvement ($\chi^2(8, N = 1123) = 45.6, p < .01$). The involvement is not related to possible alternative sources.

<table>
<thead>
<tr>
<th>Location</th>
<th>Count</th>
<th>Intentional unscheduled visit</th>
<th>Initiated after coincidental visual contact</th>
<th>Total</th>
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<tbody>
<tr>
<td>own workplace</td>
<td>577</td>
<td>215</td>
<td>792</td>
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<tr>
<td>Expected</td>
<td>568.2</td>
<td>223.8</td>
<td>792.0</td>
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<td>other workplace</td>
<td>512</td>
<td>167</td>
<td>679</td>
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<td>Expected</td>
<td>487.1</td>
<td>191.9</td>
<td>679.0</td>
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<td>meet area</td>
<td>20</td>
<td>2</td>
<td>22</td>
<td></td>
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<td>Expected</td>
<td>15.8</td>
<td>6.2</td>
<td>22.0</td>
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<td>project area</td>
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<td>75</td>
<td>273</td>
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<tr>
<td>Expected</td>
<td>195.8</td>
<td>77.2</td>
<td>273.0</td>
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<tr>
<td>coffee machine</td>
<td>37</td>
<td>44</td>
<td>81</td>
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<td>Expected</td>
<td>58.1</td>
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<tr>
<td>hallway</td>
<td>9</td>
<td>30</td>
<td>39</td>
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<td>Expected</td>
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<td>11.0</td>
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<tr>
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<td>533</td>
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*Table 10-12* Intentionality and location $\chi^2$-test

As said, the not problem oriented meetings were very significantly more often coincidental meetings and thus it is no surprise that they took place relatively often in the hallway or at the coffee machine ($\chi^2(10, N=1894)= 52.1, p < .01$; see Table 10-13). It is also noticeable that 16 (=73%) of the meetings in meet areas concerned a shared problem.
Looking at the days of the week, on Friday relatively more KS took place in the project areas ($\chi^2(16, N = 1870) = 29.6, p < .05$; see Table 10-14). This is probably caused by the fact that a lot of actions were done that day, and these often take place in project areas. Wednesday was a particularly busy day at the coffee machine, and also showed significantly more jointly initiated meetings ($\chi^2(8, N = 1876) = 18.0, p < .05$). A test between locations and the initiator is significant too, because apparently coffee machine meetings are initiated together often, but too many expected values are <5 for the test to be valid. No plausible explanation for the coffee machine preference on Wednesday comes to mind.

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<td>expected</td>
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<tr>
<td>other workplace</td>
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<td>200.0</td>
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<tr>
<td>expected</td>
<td>80.6</td>
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<tr>
<td>coffee machine</td>
<td>16</td>
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<tr>
<td>expected</td>
<td>23.2</td>
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<tr>
<td>hallway</td>
<td>13</td>
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<tr>
<td>expected</td>
<td>11.5</td>
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<tr>
<td>expected</td>
<td>550.0</td>
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Table 10-14 Location and day of the week $\chi^2$-test

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<td>expected</td>
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<td>expected</td>
<td>51.6</td>
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Table 10-13 Issues addressed and location $\chi^2$-test
It is possible to show the different single KS activities per room (see Figure 10-3). Some rooms show a very different activity pattern than others, which probably depends on the type of equipment in them.

Figure 10-3  Single KS activities per room

People from the same team initiate their meetings more after visual contact and less cross-functional meetings stem from visual contact ($\chi^2(2, N = 1891) = 14.0, p < .01$); see Table 10-15). This would seem logical, if the teams were grouped into rooms, but that is not always the case, because they are located according to project.
Even in general, being located in the same room does not significantly increase the amount of meetings initiated after coincidental visual contact. So it would seem that visual contact with a team member is more of a stimulant to start a (KS) conversation, than seeing somebody from a different team or department. Steen and Markhede (2010) formulate this as: “Perhaps we can say that people are not social in the sense of talking to just anybody: they economize their sociality.” Perhaps a reason for this is, that people from the same team have significantly more joint problems, while cross functional KS regards more problems of only one person ($\chi^2(4, N = 1899) = 12.6, p < .05$; see Table 10-16). Because of the project clustering in the buildings, people from different rooms also have more single problems and less joint problems to share knowledge about ($\chi^2(2, N = 1703) = 36.1, p < .01$).
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Summary

Only a few decennia ago, Corporate Real Estate (CRE) decisions used to be made ad hoc and at the last moment, with no overall strategy in mind or coordination with other units. But this is changing, as real estate is getting more attention from general management. It has formed its own discipline named Corporate Real Estate Management (CREM), which is best described as: “The management of a corporation’s real estate portfolio by aligning the portfolio and services to the needs of the core business (processes), in order to obtain maximum added value for the businesses and to contribute optimally to the overall performance of the corporation.” (Krumm, Dewulf and De Jonge, 2000)

CRE is a costly resource, often benchmarked with financial input indicators only. But CREM can add value to the organisation in more ways:

- Added exchange value through ‘Reducing costs’, ‘increasing the Value of assets’, and ‘Increasing flexibility’.

A focus on unit costs and building condition rather than overall costs and effectiveness will keep CREM from capturing full strategic attention. But to prove added value they need reliable techniques for quick pre-occupancy evaluations of designs or buildings. Evaluation delivers the power to justify their decisions to general management. Realistic Evaluation is a theory trying to perfect methods of evaluation, and therefore relevant for CREM research on added value and the basis for this dissertation. It tries to identify mechanisms behind the working of (CRE) programs (see Figure 0-1). For this, quantitative metrics of CRE are necessary, to prove correlation with organisational outcome metrics.

![Figure 0-1 Causation according to Realistic Evaluation](image-url)
In the modern western world, there is one added value in particular that organisations strive for these days, namely innovation. Although innovation is getting attention from both social studies researchers and CREM practitioners, the working of the mechanisms underlying the added value of CRE for innovation is not clear yet. It is not expected that CRE can stimulate innovation of organisations directly. But instead, it should stimulate innovative behaviour like knowledge sharing to stimulate organisational learning and innovation. If CREM can show general management that an investment in real estate can significantly add value through the amount of knowledge sharing, they will be more inclined to grant them the necessary budget for real estate interventions. Therefore, the goal of this dissertation is to develop and test a list of suitable quantitative metrics that can prove through which mechanism(s) CRE(M) adds value to knowledge sharing behaviour within an organisation.

**The added value of CREM**

Specific CREM departments did not come into being until the industrial revolution demanded more and more buildings to be constructed. The international expansion of many organisations was the first time that CREM was forced to show added value. The recession following in the ‘80s of the 20th century further increased general management’s attention for (the financial output of) CREM. The financial benefits of CRE (internal rental incomes and an increase of the real estate value) shrunk and CREM was forced into pursuing efficiency and still be effective in providing speedy accommodation. The competences of the CREM departments moved from highly-trained technicians to financial managers.

Since the 1990s, academics developing theory on different ways of adding value with CREM have identified many more opportunities for CREM to add value besides direct financial value. CREM can deliver both added exchange value and added use value. While exchange value lies fully within the expertise field of the CRE manager, he/she needs to tune with other business functions to be able to deliver use value (e.g. human resources, research & development, marketing & sales). To be able to coordinate with all these other business functions, CREM needs to be at the strategic table. Studies have shown that often this is still not the case.

To obtain maximum added value, the CRE strategy must be aligned with corporate strategy. In literature, there is concordance about possible real estate strategies, but studies on corporate strategies are very diverse, which makes alignment difficult and often not proven and thus not recognised. CRE alignment should be started early in the strategic thinking process, when directional strategies for the entire organisation are determined. Later, when implementing a chosen CRE strategy that can achieve alignment with the corporate goals, CREM must also know which CRE aspects can be used for each specific CRE strategy. And these aspects must be quantified to be able to measure effect. This dissertation focused on the strategy ‘increasing innovation’. With regard to innovation, two different issues can be distinguished, which both can be influenced by CRE. There is the individual’s creativity, and the knowledge sharing
(KS) between employees. This research focused on the latter: how should CRE be designed to support KS behaviour. Literature showed that layout aspects are the most important way to add value this way. But building form and layout are hard to measure because they are mostly described with qualitative aspects. So CREM cannot prove the success of the design they are advising to implement when aiming at an increase in knowledge sharing.

**Knowledge sharing behaviour**

Knowledge sharing is defined as *the application of a fluid mix of framed experience (E), attitude (A), contextual information (I), and skills (S) for the benefit of oneself or another person in interaction*. This definition complies with the practice-based perspective within epistemology, which stresses the embeddedness of knowledge in purposeful human activity. It encompasses implicitly the common distinction in most Knowledge Management literature between explicit knowledge (information) and tacit knowledge (E=experiences, S=skills, A=attitude). Looking at knowledge that way, a knowledge management model can be developed that is not linear (see Figure 0-2), unlike the objectivist perspective that is most dominant in knowledge management literature. Organisational learning takes place because of this spiralling process between individuals, teams and departments.

![Knowledge management model](image)

*Figure 0-2  Knowledge management model*

Looking at KS behaviour, many synonyms are used, like collaboration, communication, interaction and integration. But in general, a distinction can be seen between (brief) interactions and more time-consuming and interdependent collaboration. Most (objectivist) research focuses on the first level, because it is a behaviour that is relatively easy to quantify, measure, influence and change by management (planned meetings, document exchange). Collaboration has the same interactive behaviour but with more interdependence and combines this with attitudinal aspects, which are harder to measure because they are inside the human mind. Stimulating collaboration, what the practice-based perspective refers to when...
studying KS, therefore remains more of a lacuna. But as it has a more positive influence on innovation than interaction, it deserves more attention.

The tacit and explicit knowledge components are not totally inseparable. Similarly, the line between interaction behaviour and collaboration behaviour is not very clear either, because the same communication channels and activities can be used. The difference lies more in the wilfulness of actually wanting to achieve something together (involvement) or just exchanging information. Therefore, KS behaviour is represented as a conceptual 2 dimensional system: the knowledge component to share and the involvement level for sharing (see Figure 0-3). This conceptual representation is tested with the fieldwork. For this test, interaction and collaboration were operationalised with categories of identified KS moves. These moves determine the (type of) knowledge that can be shared, based on the involvement during the cooperation between persons. While interactions have been shown to help in sharing explicit knowledge, it was expected that this might not be enough to share tacit knowledge like experience, skills and attitude (ESA). Interaction activities are giving descriptions and reporting on explicit information in either an oral or written form. For more tacit KS collaboration it is deemed necessary, to share knowledge through activities involving proposals, evaluations, questions and engaged actions.

For researchers in knowledge organisations to be able to learn and share more and more knowledge (achieve organisational learning), these activities must take place on different organisational levels: both within groups as between groups. For so-called ‘combination’ (sharing explicit knowledge between groups), interaction activities should suffice. For within group ‘externalisation’, during which the individual tacit knowledge is made explicit to be shared among team members, more involved activities are a condition. For socialisation, whether within groups or cross-
functionally, a lot of involvement is necessary, leading up to the actual sharing of tacit knowledge. This can also result in attitude changes.

**Layout mechanisms**

The CRE-literature proving a positive influence of layout on any synonym of KS, has been interpreted in a content analysis to identify in more detail the layout mechanisms that might increase interaction and/or collaboration. The results of the content analysis are split in local effects (the workplace) and global effects (the building as a whole).

For the office workplace, two layout mechanisms came forward that stimulate both interaction and collaboration:

- **Proximity of employees** (the most studied and mentioned mechanism). Face-to-face interaction is obviously stimulated through proximity. People in close proximity interact more, because they bump into each other when moving around in the vicinity of their workplace. Also, working in proximity makes it easier to ask questions, perform actions and go through the repetitive team work of making suggestions and evaluating together.

- **Visual/aural accessibility**. Working in visually open layouts enhances face-to-face interaction through seeing and overhearing. If people can see each other at their workstations, they can collaborate, share tasks and ideas more easily and provide assistance, because they are more aware of other people’s need for help.

For the building as a whole, three mechanisms could be identified of which only the first one has been shown to influence both interaction and collaboration. The other two, so far, only have a proven influence on interaction:

- **Centrality**. Spaces that are centrally located and have connections to many other places enhance unplanned interaction because of their connection to well-trafficked pathways. Also it is easier (faster) to walk over to colleagues to share knowledge.

- **Exposure**. Layout controls the flows of people on a floor and who get to know each other. Because of exposure, employees sitting close to the flows of movement interact more.

- **Meeting areas**. Meeting areas are meant for interaction, and specifically designed and equipped for KS moves like giving descriptions and handing over publications. These spaces work best if they are well connected and have places to sit that do not block the other flows.

If there is one thing all these layout studies point out, it is that people are more inclined to cooperate when they see each other, whether it is for a long(er) time or when passing by. This has been referred to as ‘spatial behaviour’, distinguishing between Co-presence (number of active and/or inactive people visible) and Movement (number of people moving along a path). Co-presence is the more local spatial behaviour. The persistent results on the positive influence of proximity and
especially visual accessibility can be assigned to this spatial behaviour. The exposure and the centrality within the building relate to the global spatial behaviour of movement. Meeting areas (with local behaviour within) also generate movement (from and to the meeting) and their use is based on their placement within the floor layout. As the unit of analyses are the employees of an organisation and not the spaces itself, movement is renamed into Position in the building, which regards the movement nearby.

The studies that identified these five mechanisms have several shortcomings in their methodologies, and do not compare all the mechanisms amongst each other. When collecting data on KS, they often use perceived data from surveys, and/or only metric communication without taking into account the content of what is shared. The data collected on the layout, are hard to extend to buildings in general, because they only studied certain types of spaces or used longitudinal studies without quantifying the design correctly. Therefore, more appropriate metrics are constructed, to describe co-presence and the position in the building quantitatively. It is important, that these metrics cannot only describe the layout quantitatively, but are also close to an intuitive understanding of space. Otherwise, non-real estate people, what general management usually is, will not understand it.

The following 14 quantitative layout metrics were identified to study the five different mechanisms:

Co-presence
- Visual/aural accessibility
  1. density
  2. location inside the room
  3. how many workplaces can somebody see from their desk
  4. the compactness of the visible workplace
  5. workplaces are in the same room
  6. workplaces have intervisibility
  7. workplaces are within hearing distance
- Proximity
  8. walking distance per dyad
  9. being on the same floor

Position in the building
- Exposure
  10. distance to entrance
  11. size of the visible workplace
  12. openness of the perimeter of the work area
- Centrality
  13. average walking distance to other workplaces
- Meeting areas
  14. presence of meeting area
The metrics for Position in the building are all individual, except meeting areas which could be used by dyads (or larger groups). The co-presence metrics also relate partly to individuals and partly to dyads, so two conceptual models were distinguished to first relate the metrics to the amount of KS meetings:

- for the individual’s workplace (see Figure 0-4) and
- for the co-presence of dyads (see Figure 0-5).

After testing the association of the metrics with the amount of KS meetings in both models, several other descriptors of KS were studied to get more insight in what has happened during the meeting and to distinguish between interaction and collaboration. This way it became clear how individuals and/or dyads showed different KS behaviour at a workplace with a specific level of co-presence or at a specific position in the building.

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**Figure 0-4 Conceptual model for individual workplaces**
Methodologies for data collection

A logbook seemed the best way to collect the necessary behavioural data, because it outperforms a questionnaire in validity, and sample surveys in precision of measurement. The logbook contained two pages for personal information (e.g. days of presence at work, location of desk). The rest of the pages are identical (see Figure 5-2) and collect all the information necessary to measure KS in depth. Participants had to fill in date, start time, duration, location and conversation partners for all face-to-face meetings during which work related issues came up. This was necessary to see if all partners filled in the same conversations. This extra verification also made it possible to complete the database if some people forgot to fill in a meeting, and thus helped identify the most complete data on the amount of KS meetings. As planned meetings are less likely to be a result of the physical work environment as unscheduled conversations, the intentionality of each conversation was asked to filter out the scheduled meetings.

To study the KS process in more depth, the logbook pages contained questions on the KS activities, the initiator and the issues addressed. Also, questions on the presence of an alternative source to acquire the shared knowledge, and involvement of the other person were taken up, to test the assumptions on tacit and explicit knowledge and differences between interaction and collaboration. Besides the information gained from the logbook, the organisational structure was studied as well, to check its impact on KS before testing the conceptual models. The logbook data could be used to create two databases; one for each conceptual model. A test of the logbook showed that the KS items chosen to study the KS process in more depth were clear to its users, and that there were no major problems filling in the logbook.
To obtain the layout metrics, isovist and visibility graph analyses were used. These spatial network analysis methodologies complemented a few simpler layout quantifications, and enabled to test all metrics in the conceptual models. An isovist is defined as “the set of all points visible from a given vantage point in space and with respect to an environment” (see Figure 5-3). When isovists are placed on a regular grid, a visibility graph can be derived, which is a “graph of mutually visible locations in a spatial layout” (see Figure 5-4). An appealing side of isovists and visibility analysis is that they provide a description of space as how the user perceives it, interacts with it and moves through it, and have the potential to reveal more of the life that occurs in a space than by just studying the space itself. Especially for underlying research, isovists were useful because they describe the exact layout area that supplies visual accessibility (co-presence). Visibility graphs describe the layout of the floor as a whole from the viewpoint of exposure. Each node can be seen as a potential place for another person, which is relevant both for co-presence and position in the building. For co-presence in larger open-office spaces it was also interesting to only use those nodes that represent another person’s workplace to calculate visibility graph analysis (VGA) metrics. This was a slightly different approach of VGA which has not been taken up yet in any previous VGA study, as far as known. Several software programs have been developed to generate the metrics used in both these techniques. For underlying dissertation, the program called Depthmap (version 7.12) was used, because it could generate all metrics that are necessary for this research, and can read AutoCAD drawings.

Data description and analysis

Because past studies have shown that KS is very important in that sector, the industrial research organisation Océ Technologies was chosen as a case. At the time of the fieldwork of this dissertation, Océ research in Venlo consisted of over 1000 employees. The building with most researchers was called 3G and therefore was chosen as the subject of this case-study. It was built in 1984 and had not been renovated since. In total 269 employees had a workplace in the 3G building of which 138 participated in the study (51% response rate). Building 3G has two floors (see Figure 6-1), and has both large and small rooms, ranging from single-person rooms to open areas with up to 29 workplaces. Small lab areas without daylight are concentrated around the corridors, and a few large lab areas with less specific climate conditions are located in areas similar to the offices. All logbook data were entered in a database in SPSS, where each line is an occurrence entered by a person in his/her logbook. Before this database was used to generate DATABASE 1 and 2 (adding up the occurrences for resp. persons and dyads), several actions were undertaken to clean up the data-set and make it more complete. Several tests have been run to validate these choices. DATABASE 1 contained 138 lines, representing the participants, their workplace metrics and their indicators of KS. DATABASE 2 contained 9453 lines, representing the dyads, their co-presence metrics and the indicators of KS within each dyad.
With regard to the KS that took place at Océ during the week of the fieldwork, the following came forward. On average, participants had 14 KS meetings this week with five different colleagues, which were mostly one-on-one meetings and took place at a workplace (78%) or in a project area (14%). Of the possible dyads 4% shared knowledge that week. Questions were the most common way to share knowledge (56%), but the other four KS activities also took place (+20%); actions mostly in the project areas. During a day, an average of 45 minutes was spent in unplanned KS meetings, with 80% of the meetings lasting up to 15 minutes. The hallway and coffee machine might be places where a lot of talking takes place, but not to share work-related knowledge in the way that was studied here. The knowledge that was shared appeared to be very tacit, because it was often (77%) available through one person only. Most meetings were intentional (72%) and concerned a problem (89% of which 44% was a shared problem). Involvement in each other’s problems was generally high (3-5 on a 5-point scale). For more insight in the KS process at Océ see appendix Appendix II.

To be able to generate the Depthmap metrics, an AutoCAD drawing of building 3G with both floors was imported into the program, and a grid of 0.50 x 0.50 meters was placed over the entire layout. The accessibility metrics (1 through 7) are generated with the doors-layer turned on (which means doors are closed), because the doors between the rooms/areas were usually closed (not locked). So that is the best representation of visibility during the day. The proximity and building position metrics (8 through 14) are generated with the doors-layer turned off (which means doors are open) to get a representation of walking distances and exposure during movement.

With regard to the layout metrics at Océ, the following came forward. On average, a participant:

- had 15 m²/workplace,
- saw 7 roommates from behind his/her desk,
- sat 8 meters from the entrance,
- had a visible rooms size of 168 m² and
- had an average walking distance of 61 meters to the other workplaces in the building.

Participants were spread over the rooms (so some were in the centre, others at the outskirts). The group offices provided their inhabitants with a more compact and smaller work area, than the larger, rectangular, open areas. 63% of the participants was visible from the entrance of the room. The meeting areas mechanism was discarded, because hardly any unplanned meetings took place in a meeting area. For the density metric, eleven participants had to be treated as outliers, since their work area was much less dense because it is combined with lab area equipment.

The CRE metrics of dyads showed that:

- 6% shared a room,
- 5.5% could see each other at their desks,
- 27% of dyads that shared a room sit within 5 meters, 69% within 10 meters,
- 61 meter was the average distance between their workplaces,
• 52% worked on the same floor.
No clear cut point for hearing distance was found, so this was not recoded into a dichotomous variable as was originally planned.

A hypothesis of association with the amount of KS meetings could be used to test each metric. As the amount of KS meetings was not spread normal, Spearman's correlation was used for both models. The Spearman test uses ranks to test for association, and is valid for both linear as curvilinear relationships (not for hyperbolic but this was checked and not relevant). The five categories of KS activities (descriptions, questions, actions, proposals, evaluations) were visualised and tested with χ²-tests for possible differences in KS behaviour for certain values of the layout metrics. If a layout metric was not dichotomous nor had a logical split in categories, the test was done on low versus high halves of the participants to look for certain trends. The other KS indicators (location, intentionality, initiator, alternative source, involvement) were studied with χ²-tests as well, but only for the layout metrics with the highest association with the amount of KS meetings (and also for metrics that did not correlate with these metrics).

Findings

From the five mechanisms identified from literature, three come forward at Océ as having an association with the amount of KS meetings when studied with quantitative metrics (in order of importance):

1. Accessibility,
2. Centrality,
3. Proximity.

The 4th mechanism, ‘exposure’ was not triggered at Océ and the 5th mechanism, ‘meeting areas’ was discarded, because hardly any unplanned meetings took place in these areas. Looking at the metrics used for these three mechanisms, the first and most important mechanism ‘accessibility’ appears to include two different mechanisms. Because accessibility is used in literature sometimes for visibility and sometimes for hearing distance or other placement issues, it seemed better to split it into two different mechanisms:

1a. (Accessibility through) Visibility,
   • Same room .460
   • Visible workplaces .355
   • Compactness -.328/- .277

1b. (Accessibility through) Placement within the room,
   • Hearing distance within room -.422
   • Density .181
   • Average walking distance to visible workplaces .168

4. Centrality in the building
   • Average walking distance to all workplaces -.183

5. Proximity in the building
   • Same floor .178
   • Walking distance if not in room -.132
Overall, the association of layout with the number of KS meetings at the case organisation (Océ) was not really strong. The strongest association (.460) is still considered ‘moderately strong’ for Spearman correlations in general. But it did show that the CRE manager can add value through considering the influence of the layout on this important organisational process. CRE is a supportive resource, and it cannot be expected to be responsible on its own for a high variance in the amount of KS. Other context variables (e.g. organisation structure, culture, working on the same project) will be responsible for the largest part of this variance (hence the use of realistic evaluation). But even if only 20% of the variance would be explained, this means that CREM can support and improve the primary process of their client organisation significantly, and that is their main task. Also it gives CREM insight in the relevance of metrics and the current CRE effectiveness.

Visibility increased the amount of KS meetings. The placement within the room metrics showed that there must be a limit to the visibility mechanism, because an increase in distance between dyads in a room (and decrease in density) lowered the amount of KS meetings. Beyond 8 meters only a few outliers of the dyads still shared knowledge. The centrality and proximity metrics all showed a decrease in the number of KS meetings with a decrease in distance. Dyads with 3 or more KS meetings had a walking distance of less than 22 meters (not counting outliers) and 90% of the meetings took place within 30 meters. With regard to ideal room size, a clear limit did not come forward. The χ²-tests also showed differences in KS behaviour during these meetings. Participants that shared a room had more shared problems, while participants from different rooms shared less tacit knowledge (they could also have consulted someone else), and mentioned a lower involvement of others. The larger the room, the more knowledge was shared intentionally and through more cooperative behaviour. The metrics for placement within a room showed that this influenced the way knowledge was shared as well. Sitting closer to each other seemed to increase awareness which prompts people to give more descriptions if this seems helpful. At a distance, it might be necessary to ask things that would otherwise have been clear by overhearing/awareness. The participants at the ‘outskirts’ of an area appeared to have more opportunity there to evaluate or perform actions together; activities that might disturb others. Centrality and proximity in the building showed no further differences in KS behaviour. The exposure metrics had no association with the amount of KS meetings, but did show differences in KS activities. Participants visible from the entrance used descriptions and actions significantly more often to share knowledge. Perhaps the visible participants were consulted more for quick needs for a description or to help with a task or equipment issue, when people entered the room.

**Discussion, reflection and recommendations**

As CREM climbs the evolutionary ladder more quantitative metrics like the ones identified for layout in this research can help in showing the added value for both the softer as the more traditional (financial) CRE strategies. Hopefully this can help
CREM in getting their (deserved) place at the strategic table, as a strategic resource that can do more than just aim for efficiency. Only then CREM can start to really achieve alignment for the client organisation. It will be necessary to have a relevant list of CRE metrics for each CRE strategy to start proving this added value with real estate interventions that trigger the right mechanism(s). In Chapter 2, many structural, installations and location aspects were identified as having a possible influence on certain added values. By only looking at the layout, this research already identified five different CRE mechanisms measured with several metrics that can be used by CREM. So if all the aspects in both tables are taken into account, CREM might end up with a long list of metrics to reckon with, depending on the CRE strategy that they are aiming for. It is a lot of work for a CRE manager to look at all of these metrics. But as long as he does not know which ones are most relevant and which ones are not, it is not possible to shorten the list either. Each CREM department will have to look within their own ‘black box’ and see how CRE mechanisms are best implemented to support the goals of their client organisation. Also, CREM has to cooperate with other business functions, to make sure that the right needs are supported. A common problem is that the outcome side is not easily quantified for added use values either. The other business functions should provide CREM with the right (measurable) aspects that CRE metrics can be related to (as done for Océ and their KS meetings). Too often it is not exactly clear which needs exist, which makes alignment of CRE even more difficult.

In Figure 0-6 an overview is given of steps and considerations CREM could make to achieve better alignment. This strategic thinking map has an iterative nature. Only through implementing certain metrics in a certain way, it is possible for CREM to study how they support their client organisation. But only after such studies, CREM has the knowledge to determine the right implementation. Results of an internal benchmark with the layout metrics can be discussed in briefs with architects and other external parties, when real estate interventions are necessary. They can also be used to compare alternatives, using the actual layout drawings from an architect. This way the tacit knowledge of architects on how layout influences behaviour can be made explicit and discussed with clients with less knowledge of building design. The strategic momentum box of the strategic thinking map also calls for strategy evaluation, which will help with emergent learning. The map ends with the term ‘re-initiate strategic thinking’. This should take place if the organisational strategy changes, because then the CRE strategy needs to be aligned anew, and the whole process starts from the beginning with strategic thinking, followed by the situational analysis of the strategic planning box. At that time the strategic thinking map has been followed entirely for one cycle, and a new process of (improved) alignment of CRE(M) can start.

Realistic evaluation emphasizes the influence of context on outcome, and how mechanisms might or might not be triggered to produce an outcome. The fieldwork at Océ showed that using realistic evaluation works well both for studies on KS and for studies on mechanisms of the spatial environment. The influence of context on the outcome became clear when the data of Océ were compared with other studies. So Realistic Evaluation is a good basis for these types of studies that combine spatial
mechanisms and outcomes of effectiveness. Realistic evaluation prefers the combination of different methods of data collection. In this dissertation, the logbooks gave clear data on the questions that were asked, but in retrospect could have been supplemented by a follow up survey. This could have gone deeper into the knowledge gathered from the logbook analyses.

A face validity test showed the findings to be clear and interesting and Océ could identify with them. Also, they felt that the CRE metrics represented building 3G correctly. They mentioned that KS at Océ does indeed take place similarly as the results from the logbooks showed. Projecting the results from the case-study on the new layout gave insight in the KS that should take place after the renovation program is implemented. The CRE manager was happy with this, because it helped him show the added value of the new layout to general management. Some metrics were easy to generate and monitor, while others took considerably more time and effort. Some layout metrics demanded automated approaches (by using Depthmap) because it was too much work to calculate them manually. A downfall of this is that only the programmer knows the computer program by heart, so the users might be stuck with the feeling that they miss the due diligence possibility of manual approaches. Océ indicated that they would only use such metrics for buildings with complicated layouts or if they would start regularly monitoring many buildings. So the spatial network methodology seems unnecessarily laborious to use for evaluating these type of programs, as the layout mechanisms also have ‘easy’ metrics that can be used. These did show less strong associations with KS at Océ though. And, unfortunately Spearman does not offer the possibility of studying the unique effects of the metrics that are correlated. This is a downfall of the data that were not spread normally. But the other shortcomings of previous studies discussed in Chapter 4 appear to have been overcome.

Figure 0-6 Strategic thinking map for CREM (adapted from Swayne, Duncan and Ginter, 2006)
The data on KS meetings at Océ support the practice-based perspective on knowledge. Indeed knowledge cannot be separated from a person as easily as the objectivists think. The five categories of KS activities let knowledge remain embedded in an activity, as the practice-based perspective emphasizes, but do offer the opportunity for using statistics, as the objectivist prefers. So they are an interesting way to bring both perspectives nearer to each other. This study looked at face-to-face meetings only, which fits the practice-based perspective. Studies comparing meetings with virtual communication showed that ICT cannot replace the necessary face-to-face communication for KS. The knowledge management model in Chapter 3 also showed that feedback is necessary to share knowledge, opposed to communication that can be one-sided. So, it seemed valid to exclude virtual KS from this dissertation.

Many recommendations for further research can be distinguished. Within the main theme of this dissertation (added value of CRE for innovation), the context itself must be mapped in more detail. It is necessary to find out which contextual layers influence the outcome, so that studies can vary these and map their influence on the six mechanisms. Also, the mechanisms themselves need further research. The mechanisms from theory that were not triggered at Océ (exposure, meeting areas) must be studied more in-depth in contexts where they might be more relevant. The strongest mechanisms in this dissertation (visibility, proximity) need to be studied for consistency of their importance in other contexts which might inhibit their working. More combined studies of all six mechanisms will also shed light on their relative importance, possible interrelatedness of mechanisms and positive and negative side-effects that might occur. For example: how to reach a balance between awareness and interaction versus privacy and the possibility to focus. Last, the mechanisms should be studied further in the modern context of New Ways of Working, which is producing different layouts then have been common in the past decades.

Recommendations for the broader framework of this dissertation (as discussed in Chapter 2) are that this study could be replicated for other use values (productivity, satisfaction, marketing & sales). And since many CREM departments still focus on efficiency, it would be interesting to study the layout metrics and their association with added exchange values too (costs, asset value and flexibility). Also, comparative studies on both use and exchange added values are interesting. The application of isovists/VGA to other strategies needs further research for each individual strategy, and the CRE strategies should also be studied all together. Perhaps it will turn out to be possible to combine certain strategies, because they are supported by the same layout mechanisms. This can be further extended by also including the other CRE aspects from Table 2-2 in such studies. The strategic thinking map appeared to be a helpful framework for alignment of CRE to corporate strategies. In order to confirm this assumption, future studies must walk through the entire strategic thinking map with different CREM cases to test its usefulness.

As a CREM academic, studying innovation and knowledge management with such depth was an interesting new perspective. Therefore, last, some recommendations are given for academics in these fields of study. The KS activities deserve further
attention and clarification. Perhaps the category of questions should be split up in future studies. A question could be more explicit, while a critical question might be more tacit. And in KS meetings with more than one KS activity, it might be interesting to see if they are used consecutively or intertwined. It also needs further study, which KS activities can be used to share tacit knowledge, and how much each category contributes to different types of innovation outcome of organisations. The results found were indefinite on the conceptual representation of KS behaviour in Chapter 3. It is interesting to study whether these two dimensions (knowledge component and involvement) are the only ones or that more dimensions should be distinguished to fully capture KS behaviour.
**Curriculum vitae**

Rianne Appel-Meulenbroek (Eindhoven, 1973) joined the REMD Group in 2004 as an assistant Professor. Previously, she worked as a consultant for Buck Consultants International and for the international consultancy and engineering group DHV, advising small and large organisations on all kind of CRE issues (site selection, masterplanning, office design, programs of requirements, project management etc.).

Rianne focuses her research and teaching activities on Corporate Real Estate (CRE) management, strategy and the way building design can add value to an organisation, through productivity of employees, innovation, knowledge sharing etc. She also studies new ways of working, performance and functionality of office buildings, decision support models, and solutions for office vacancy. To do this type of research, she uses innovative methods of measuring design among which spatial network analysis techniques.

Rianne received her MSc in real estate management from the TU/e in 1999. She is a board member of VOGON (Dutch Society for RE researchers) and the European Real Estate Society ERES, and a member of Corenet (global association for corporate real estate professionals), FRESH alumni and NewWoW (platform on new ways of working). She is on the editorial board of the Journal of CRE and of CRE journal, and has published her research in Journal of CRE, Facilities, Property Management and journals focused on innovation and knowledge management.