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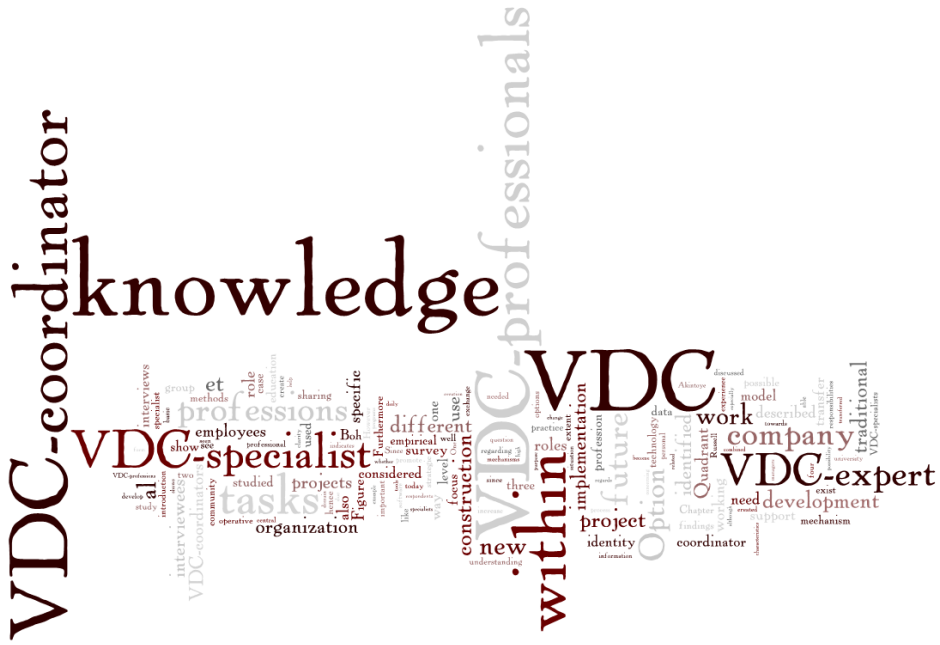

Professional roles' emergence and development due to the implementation of Virtual Design and Construction

A case study within a construction company

Master of Science Thesis in the Master's Programme Design and Construction Project Management

SIGRID GUNNEMARK & KATHARINA HEINKE

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ABSTRACT

The introduction of Virtual Design and Construction, VDC, is about to change the way of working in the construction industry. One outcome of introducing new technologies and working methods in established industries is the emergence of new professions. The main research questions for this study are: "How are professional roles, emerging from the implementation of VDC, defined?", and "How can the roles of VDC-professionals be developed in order to facilitate and support future knowledge management and increased use of VDC?". To be able to answer these questions a theoretical framework concerning knowledge management, professionalism, identity and roles is used together with a case study of a Swedish construction company. A mixed research approach was chosen, combining a qualitative method containing semi-structured interviews and a quantitative method in which a questionnaire survey was conducted. Results from the case study show difficulties to separate the today's three VDC-professionals in the company (VDC-coordinator, VDC-specialist and VDC-expert) from each other. The VDC-professionals' tasks are to some extent intersecting and no clear distinction or interface were identified in the organization today. The results further showed that the VDC-professionals today could be considered as professions, thus "a central social value", "a knowledge domain", "an education or specific training" and "the presence of a professional association" exist. Furthermore, the study concludes and suggests four different possible future development options for the VDC-professions. The four options consider how the future knowledge sharing and transfer should be organized in relation to the existence of the three VDC-professions. Finally, the empirical data combined with the theoretical framework show a tendency towards that only one or two specific VDC-professions are sufficient to facilitate and support the use of VDC in the future.

Key words: Virtual Design and Construction, VDC, professional identities, knowledge management, Building Information Modelling, BIM

Utveckling av professionella yrkesroller sprungna ur implementering av Virtual Design and Construction

En fallstudie av ett entreprenadföretag inom byggbranschen

Examensarbete inom Design and Construction Project Management

SIGRID GUNNEMARK & KATHARINA HEINKE

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Avdelningen för construction management

Chalmers tekniska högskola

SAMMANFATTNING

Introduktion av ny teknik och arbetsmetoder i etablerade branscher kan ge uppkomst till nya roller. Implementering av Virtual Design and Construction, VDC håller på att förändra sättet att arbeta i byggbranschen. Detta har varit utgångspunkten för denna studies två huvudsakliga frågeställningar: ”Hur är professionella roller, uppkomna genom implementeringen av VDC definierade?” och ”Hur kan VDC-rollerna bli utvecklade i syfte att facilitera och stötta framtida kunskapsutbyte och ökad användning av VDC?”. För att kunna besvara dessa två frågor användes akademiska teorier inom kunskapsöverföring, professionalism, identitet och roller som applicerades på en fallstudie av ett svenskt entreprenadföretag. En kombinerad forskningsansats användes, innehållande en kvalitativ del med tolv semi-strukturerade intervjuer och en kvantitativ del med en enkätstudie. Resultatet från fallstudien påvisar svårigheter att separera de tre studerade VDC-rollerna (VDC-koordinator, VDC-specialist och VDC-expert) som finns i företaget idag. VDC-rollernas arbetsuppgifter är till viss del överlappande och ingen tydlig gränsdragning var identifierad i organisationen. Vidare visar resultaten att VDC-rollerna kan anses vara professionella yrken då det finns ’ett centralt socialt värde’, ’en kunskapsdomän’, ’en utbildning kopplad till dem’ och ’närvaro av en branschorganisation’. Slutsatser från studien visar att det finns fyra möjliga alternativ för den fortsatta utvecklingen av VDC-rollerna. De fyra alternativen tar i beaktning hur framtida kunskapsöverföring ska ske och vara organiserat i relation till de tre VDC-rollerna. Slutligen påvisar de empiriska data kombinerat med den identifierade akademiska teorin att det är tillräckligt med enbart en eller två VDC-roller för att underlätta och stötta användandet av VDC i framtiden.

Nyckelord: Virtual Design and Construction, VDC, professionalism, identitet, roller, kunskapsöverföring, Building Information Modelling, BIM

Contents

Preface

This master's thesis was conducted during the spring of 2014 at a Swedish construction company. Additionally, the work was carried out related to the research project: Examing the role of experts as knowledge facilitators (Formas grant no 244-2010-283) conducted at the Department of Civil and Environmental Engineering at Chalmers University of Technology.

We would like to take this opportunity to thank our supervisor, Associate Professor Pernilla Gluch, for her support and encouragement during this spring. The discussions with her together with her insights and inputs have been highly appreciated.

Thereto we would like to thank the employees at the studied company, who answered our questionnaire survey and those who allowed us to interview them. They all contributed to our data collection, which has been the foundation for this master's thesis. We would especially like to thank our supervisor at the company for the support and the VDC manager, who provided us with necessary documentation and contacts.

Numerous of interesting factors, sub-questions and aspects outside our research question were identified during the work. This implies that the studied company has an exciting future development in regards to VDC and the VDC-professions.

Göteborg June 2014

Sigrid Gunnemark and Katharina Heinke

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List of abbreviations

APD-plan	Arbetsplatsdispositionsplan
BIM	Building Information Model or Building Information Modelling
CAD	Computer-aided design
CEO	Chief Executive Officer
CIFE	Center for Integrated Facility Engineering
CURT	Construction Users Roundtable
HR	Human Resources
IT	Information technology
SEK	Currency code of the Swedish krona
TA-plan	Trafikanordningsplan
VDC	Virtual Design and Construction
VDC-profession	Professions related to VDC including VDC-coordinator, VDC-specialist and VDC-expert
VDC-professionals	includes persons that work as VDC-coordinator, VDC-specialist or VDC-expert

English-Swedish dictionary

Business manager	Affärschef
Commission leader	Uppdragsledare
Construction engineer	Entreprenadingenjör
Construction manager	Entreprenadchef
Construction site disposition plan	Arbetsplatsdispositionsplan
Design manager	Projekteringsledare
Engineering specialist	Teknisk specialist
Engineering specialist group manager	Specialistchef
Measurement engineer	Mätningstekniker
Model coordinator	Modellsamordnare
Procurement	Inköpare
Production manager	Produktionschef
Project manager	Projektchef
Services coordinator	Installationssamordnare
Services leader	Installationsledare
Site manager	Platschef
Site supervisor	Arbetsledare
Team manager	Gruppchef
Tender engineer	Kalkylator
Tender engineer	Anbudsingenjör
Traffic plan	Trafikanordningsplan
VDC Action Plan	VDC-Handlingsplan
VDC Council	VDC-Rådet
VDC Requirement Document	VDC-Krav
VDC-Workstation	VDC-Arbetsplats

1 Introduction

The introduction of new technologies, such as Virtual Design and Construction, VDC, are about to change the way of working within the construction industry (Akintoye et al., 2012). VDC is considered to improve design quality, construction safety and management efficiency for a construction project (Xu et al., 2014). Thus, VDC is believed to facilitate the sharing of information and knowledge between different actors throughout the construction process. The use of 3D-models has changed the way to communicate and transfer information during and between the different stages of the construction process (Bosch-Sijtsema, 2013; Russell et al., 2014). Thereto the introduction of new technologies and work methods within established working environment may create new roles or professions (Jaradat et al., 2012). To organize and handle the project data and information connected to the model is not a small task, which requires management (Weygant, 2011).

A need to handle the new way of information flow and support the changed way of working was recognized by Weygant (2011), which was also acknowledged by Akintoye et al. (2012), Mourgues et al. (2007) and Russell et al. (2014), who all suggest the introduction of a new profession. Contrary to this idea there are also indicators of that the construction industry do not need the creation of new profession, instead the new way of working should be in cooperated within existing roles (CURT 2010, in (Russell et al., 2014)). Furthermore did Bosch-Sijtsema (2013) identify the creation of both a technical coordinator and a facilitator. The facilitator would manage the information and communication flow within the project whereas the technical coordinator would handle the virtual model.

A new knowledge domain may also be created through the introduction of new technology (Akintoye et al., 2012), which in turn creates new professional expertise and specialist skills. Weygant (2011) suggest the introduction of a knowledge manager as *"a hybrid of specifier, CAD manager and BIM content development"*. Although in order to utilize the possibilities of VDC it is crucial to not only educate specialists and experts within VDC but also all employees within the construction process (Mourgues et al., 2007). Basic skills regarding the use of methods and tools will become compulsory within the construction industry (Russell et al., 2014). Furthermore, Gu and London (2010) identified lack of clarity regarding roles, responsibility and distribution of benefits as major barriers for the introduction and fully utilization of VDC.

This master's thesis will focus on the identified lack of clarity regarding professions that emerge from the implementation of VDC in perspective of knowledge sharing, professional identity and further development to facilitate and support future use of VDC. The following section in this chapter presents a background concerning VDC and Building Information Modelling in order to create a basic understanding for the emergence of VDC-professions.

1.1 Background

There is a crucial need for companies to be innovative (Kodama, 2006). Furthermore Kodama (2006) realized that companies have to integrate different technologies across industries which are often related to evolutions within IT. The method of virtual prototyping, which is one innovative technology, generates benefits in the form of reduced costs and time as well as better safety and quality (Huang et al., 2007). Since this innovation arose within manufacturing it is far more advanced in this

industry than within the construction sector. However, the construction industry is about to change its way of working from 2D drawings to digital 3D models (Bosch-Sijtsema, 2013). The idea of virtual prototyping was adapted by construction industry in the form Building Information Modelling and VDC. As acknowledged by Bosch-Sijtsema (2013) it is only recently that the use of VDC has started to be applied in a large extent.

From previous research it is not possible to define BIM unanimously, since BIM can mean Building Information Model which was defined by the National BIM Standard (NBIMS) Project Committee of the Building SMART as *"a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward. The BIM is a shared digital representation founded on open standards for interoperability."* (Barlish and Sullivan, 2012). This Building Information Model holds accurate geometry and relevant data that is necessary to support design, procurement, fabrication and construction (Eastman et al., 2008). On the other hand BIM can mean Building Information Modelling which was defined by Azhar (2011) as "*a virtual process that encompasses all aspects, disciplines, and systems of a facility within a single, virtual model*". Azhar (2011) highlighted that Building Information Modelling is not only a software but also a process, since Building Information Modelling is not just the handling of the Building Information Model but also the adaption of processes and project execution (Hardin, 2011).

Initially Building Information Modelling was viewed as an instrument to create 3D models and use components instead of lines as done within 2D-CAD (Weygant, 2011). Traditionally mainly two dimensional drawings (including the width and length) are used on construction sites (Mourgues et al., 2007). In contrast the Building Information Model can visualize three dimensions (the width, length and height), plus a fourth dimension (time) and even a fifth dimension (cost) and can therefore facilitate information sharing amongst multiple project stakeholders (Akintoye et al., 2012). Within construction industry the use of these models has changed the way of communication and information transfer during the different stages of construction projects (Russell et al., 2014).

Another definition has been made for Virtual Design and Construction, VDC. According to Kunz and Fischer (2012) VDC is *"the use of integrated multi-disciplinary performance models of design-construction projects to support explicit and public business objectives"* and was designed as a model for integrating the product (typically a building or plant) so that the contractor can, based on the model, design, construct and operate (Huang et al., 2007). Additionally this definition was expanded and further explained by Kunz and Fischer (2012), who highlighted that the VDC project model emphasizes not only the product, e.g. building, but also those pieces of the project that can be designed and managed, for example the organization and the process.

Combining all three definitions (VDC, Building Information Model and Building Information Modelling) it can be stated that the Building Information Model is one part of Building Information Modelling while Building Information Modelling focuses on the building elements of VDC. Building Information Modelling is therefore a limited model since it does not take management issues into account (Kunz and Fischer, 2012).

The current use of Building Information Modelling is often reduced to clash detection as well as planning and visualization (Azhar, 2011). This seems like a natural process since the visualization of information within a model is a large change and a strong improvement compared to the traditional way of working within the construction industry (Kunz and Fischer, 2012). Additionally it allows all involved parties within the project to collaborate in a new and more effective way (Azhar, 2011; Bosch-Sijtsema, 2013). This is basically caused by the fact that visualized models are easier to understand than text-based information and can facilitate the communication between project participants (Akintoye et al., 2012) as well as project stakeholders (Xu et al., 2014). The on-going transformation in the construction industry with the introduction of virtual models together with how the models' benefits and advantages can be utilized has been the origin for this master's thesis.

1.2 Aim and Research Questions

An overall objective for this study was to stimulate a systematic administration of knowledge and efficient knowledge transfer throughout the construction process. More specifically, the purpose of this study was to describe how the VDC-professions that emerged from the implementation of VDC could be formed to facilitate knowledge management and use of VDC. Therefore two main research questions were formulated:

1. How are professional roles, emerging from the implementation of Virtual Design and Construction, VDC, defined?
2. How can the roles of VDC-professionals be developed in order to facilitate and support future knowledge management and increased use of VDC?

In order to accomplish this, the following aspects have been considered:

- The implementation level of VDC
- Required knowledge, experience and personal characteristics of the VDC-professionals
- The knowledge exchange between the VDC-professionals and the organization
- Job assignments and work tasks of the VDC-professionals
- Involvement of the VDC-professions in projects
- The organizational structure for the VDC-professions
- Attractiveness of the VDC-professions
- Future development regarding the VDC-professions

1.3 Disposition

This chapter has introduced the background to this master's thesis and presented the master thesis' aim and research questions. In the next chapter a theoretical background is presented. The theoretical background includes a literature review concerning knowledge, professionalism, identity and roles as well as challenges related to the implementation of Building Information Modelling and VDC. Chapter 2.1, Knowledge and knowledge management will in particular focus on the framework created by Boh (2007) concerning knowledge transfer mechanisms. After the theoretical background a case description is presented. The case description

presents the situation within the organization during this research period with a focus on VDC. The methodology for this master thesis is thereafter described. The different research approaches (qualitative and quantitative) are presented separately in order for the reader to get a clear perception of the chosen methodology. The methodology is followed by empirical findings in Chapter 5. The empirical findings are divided into these main themes: 'Implementation of VDC'; 'Characteristics, skills and knowledge of the VDC-professionals'; 'Knowledge exchange concerning VDC'; 'The VDC-professionals' work tasks'; 'The VDC-professionals' involvement and responsibilities in projects'; 'Organization and attractiveness of the three VDC-professions' and 'Future development of the VDC-professions'. Both the findings from the qualitative and quantitative data collection are presented together in each theme. The themes are individually divided into subsections in order to increase the comprehensibility for the reader. In the following discussion chapter, the empirical findings are discussed in relation to the theoretical background. The discussion is divided into three sections, in order to thoroughly answer the two main research questions. Finally the master thesis conclusions are presented in Chapter 7. Additionally, recommendations to the studied company and areas for further research are suggested. The last chapter gives reflections on the research process and ends this master's thesis.

2 Theoretical background

The construction industry consists of projects, in which various traditional expertise works together to reach the same goal, i.e. a building. Projects are defined as *"a unique venture with a beginning and end, conducted by people to meet established goals within parameters of cost, schedule and quality"* (Buchanan and Bryman, 2009).

Organizations that perform a majority of their business through the means of projects are often called project-based organizations (Clegg and Bailey, 2008). Sydow et al. (2004) described project-based organizations as *"a variety of organizational forms that involve the creation of temporary systems for the performance of project tasks"*. Furthermore Sydow et al. (2004) see the major goal of a project-based organization in the construction industry as the creation of outcomes by having in-house specialist staff and executing employees' on construction site. This organizational structure is confirmed by Kodama (2006) who said that the employees within project-based organizations are gathered in temporary project structures. Characteristics related to project-based organizations within the construction industry are: *"the primarily use of oral communication", "the operation on basis of material resource" and "its strong work-related and professional culture"* (Styhre, 2009). Gustavsson et al. (2012) described the construction industry as highly interdisciplinary, fragmented and temporary project organizations, process discontinues and with unique projects. Although construction is carried out in temporary projects, the organizations and project teams performing the different projects do not change to a large extent (Bosch-Sijtsema, 2013) . This also implies a degree of standardization.

Resulting from the organizational structures within construction industry and its characteristics, the construction industry is an industry that develops its knowledge by learning by doing (Styhre, 2009). This point of view is supported by other researchers who state that the gaps in flows of personnel, materials and information within project-based organizations hinder the development of routines that would support knowledge transfer and learning from a previous project (Bresnen et al., 2003). This in turn would reduce the amount of testing and repetition of mistakes. Bresnen et al. (2003) applied this to construction industry and concluded that project teams often consists of different professions that have its own knowledge base and language. Within the next chapter the basic theory about knowledge and knowledge transfer mechanism will be presented. Furthermore insights into the topic of professionalism, identity and roles will be given in Chapter 2.2. The last theory part will deal with challenges related to Building Information Modelling and VDC.

2.1 Knowledge and knowledge management

According to Nonaka (1994) knowledge is a personal 'justified belief'. Bektas (2013) stated that knowledge *"can be seen as a personal repository, with its development being shaped by the different levels of personal experience, education, culture, or personality"*. This definition is supported by Gherardi and Nicolini (2001) who said that no knowledge is 'universal or supreme'. Despite this general definition knowledge can be divided into two types of knowledge. Firstly, tacit knowledge which is *"deeply rooted in action, commitment, and involvement in a specific context"* (Nonaka, 1994). And secondly explicit knowledge (Polanyi (1962), in Boh (2007)) or like Nonaka (1994) call it 'codified knowledge' which is communicable in formal, systematic language. The proportion of these types of knowledge is

unequivocally, since eighty percent of useful knowledge is tacit knowledge (Sheehan, 2005). Which kind of knowledge that needs to be transferred to solve upcoming new problems is not clear since *"applying 'what is known' and 'what needs to be tackled' involves a tacit and partly explicit way of solving problems"* (Bektas, 2013).

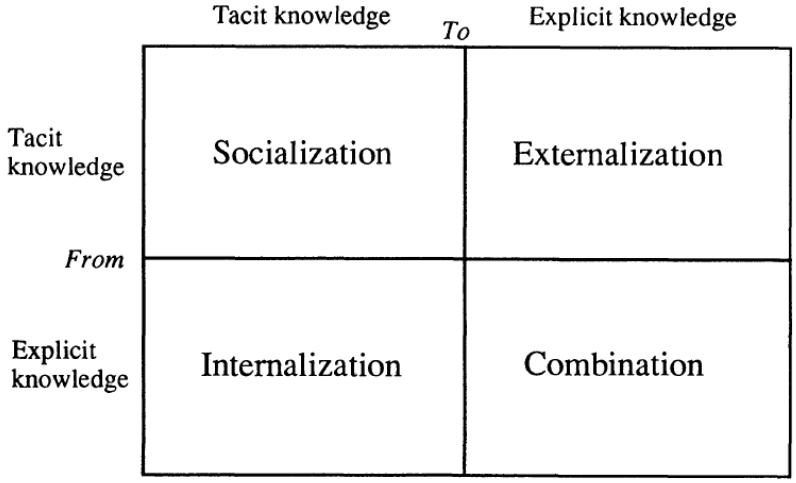

Figure 1 Modes of Knowledge Creation (Nonaka, 1994)

Nonaka (1999) defined in the paper 'Dynamic Theory of Organizational Knowledge', published in Organization Science, four different modes of knowledge creation: socialization, internalization, externalization and combination (see Figure 1) but the transfer is difficult if some kind of shared experience is missing. Knowledge creation by 'combination' describes the process when individual persons share and combine their explicit knowledge by e.g. meetings or telephone conversation. The process when tacit knowledge is transferred to explicit knowledge is called 'externalization' while the opposite process, turning explicit knowledge to tacit knowledge is named 'internalization'.

	Individualized	**Institutionalized**
Personalization	*Quadrant 1*: individualized-personalization mechanism	*Quadrant 4:* institutionalized-personalization mechanism
Codification	*Quadrant 2:* individualized-codification mechanism	*Quadrant 3:* institutionalized-codification mechanism

Figure 2 Framework of knowledge-sharing mechanisms (Boh, 2007)

Based on the two dimensions of knowledge (explicit and tacit) and using Nonaka's model as a basis, Boh (2007) developed a framework of knowledge-sharing mechanisms for managing knowledge in project-based organizations which contains four different quadrants (see Figure 2) that are determined by two dimensions. The

first dimension is defined by codification versus personalization which indicates whether knowledge can be shared since it is codified knowledge or whether it is difficult to share because it is tacit knowledge. The second dimension is the kind of mechanism that makes knowledge sharing possible at individual or at collective level and is defined by individualization versus institutionalization. *Quadrant 1* describes knowledge sharing at individual level by means of unplanned and informal communication. To use this mechanism it is necessary that individuals know from which other individuals they can get the requested information or like Moreland and Myaskovsky (2000) call it *"the knowledge of 'who knows what' in the organization"*. Technologies like email, instant messengers etc. are particularly helpful if individuals are located at different geographic places. As in *Quadrant 1* the knowledge-sharing mechanisms in *Quadrant 2* occur ad hoc but the exchange takes place through documents or artifacts containing formulated experience from individuals or groups (Boh, 2007). This mechanism can only be effective if the documents and artifacts are organized in a central and structured way and are accessible for all users within a company by using an appropriate search function. The mechanisms of *Quadrant 3* are routines and structures, in which it is defined how companies store specialist knowledge in a knowledge base. Often knowledge-management programs are used, which are made accessible for other specialists. *Quadrant 4* refers to the mechanisms which are reflected in the organizations routines and structure supporting the personal knowledge exchange. One mechanism from Quadrant 4 that can be used to transfer knowledge by human interaction is the introduction and election of experts that are available to other employees within the organization and can share their knowledge with them. This individualized knowledge transfer could also support the trust into the received information since the knowledge source is known (Sussman and Siegal, 2003). One advantage from the use of these experts is that they are often able to modify their answers and advices to the situation. Additionally they can accumulate knowledge due to their long experience and can furthermore, with help of their network, create bridges between individuals with problems and other individuals that possibly have a suitable solution (Boh, 2007). Another example for institutionalized-personalization mechanism is cross staffing which can be suitable for project-based work. Boh (2007) outlines the importance of the institutionalized-personalization mechanisms by writing:

> *"Sharing knowledge based on direct interactions between two individuals offer many advantages over trying to share knowledge by codifying the knowledge and divorcing the knowledge from a specific individual, since people are able to flexibly restructure their knowledge across different tasks. Hence, instead of trying to institutionalize knowledge sharing only by means of codification, organizations can institutionalize mechanisms to facilitate person-to-person knowledge-sharing.*

Boh (2007) concluded that, since technical solutions for codifying knowledge are often inadequate to organizational goals and the knowledge that is needed to be shared is often tacit, knowledge can be transferred extensively by personalization mechanism. Boh (2007) furthermore discovered that codification knowledge-sharing mechanism (see *Quadrant 2* and *Quadrant 3* in Figure 2) best fit organizations that deal with more standardized tasks whereas personalization knowledge-sharing mechanisms (See *Quadrant 1* and *Quadrant 4* in Figure 2) are suitable for task with a unique nature. Boh (2007) also implicated that the geographical dispersion and the size of a company play a basic role. It is much easier to find the right person with the

needed knowledge if a company is small and centralized instead of geographically spread. Therefore, in the case of project-based organizations, knowledge-sharing mechanisms are the tools that makes it possible for employees to access knowledge and information from other projects (Boh, 2007). This is greatly dependent on social patterns, practices and processes within the organization (Bresnen et al., 2003). However, project-based organizations often suffer from discontinuities in methods of organization and flows of personnel, materials and information (Bresnen et al., 2003). This was also discovered by Styhre (2009) who characterized the project-based construction industry as ruled by oral communication which involves that knowledge is mainly *"shared through storytelling and narrative accounts of experiences in the day-to-day work and not in lengthy written reports*".

Bresnen et al. (2003) argue therefore that more and more focus has to be put on investigating the influence of social communities in support or hindrance of knowledge transfer. Questioning earlier research Ferlie et al. (2005) observed that a high amount of knowledge within professional groups can result in innovation hindrance caused by boundaries between and within professions. Especially professional communities of practice may cause such effects since they develop an internal learning and change but on the other hand they are often less leaky and have low acceptance of multiple membership, which make them less fluid. This combined with social and cognitive boundaries promote knowledge and innovation to stay within this group. However, knowledge and innovation can be generated from the boundaries of these networks which can occur between disciplines, projects and existing organizations, among projects, and between project networks within and outside the organization (Kodama, 2006). Ferlie et al. (2005) suggest observing and identifying these social and cognitive boundaries between different communities of practice to ensure that knowledge management strategies can be successful. A not yet answered question within research could be if there also exist boundaries between older established professions and newer expert groups (Ferlie et al., 2005).

2.2 Professionalism, identity and roles

Since *"learning is inevitably implicated in the acquisition of knowledge, but is also implicated in the acquisition of identity*" (Brown and Duguid, 2001) the next section investigates the nature of professionalism, identity, and roles.

The word 'role' is often used to speak of a behavior that is expected from a particular social category and those roles can indicate statuses or positions in formal systems (Lynch, 2007). Tuner (1974), in Lynch (2007), recognized that role expectations, which are influencing factors of roles, can vary to a large extent. Furthermore the level of agreement upon role performance is an important dimension. Moreover roles are frequently determined by the relation to other roles or their interaction (Lynch, 2007). Since the phrase 'role' and 'role expectations' include so many factors, 'roles' is frequently used by employees to describe their practice and experience or knowledge (Simpson and Carroll, 2008). Simpson and Carroll (2008) discuss additionally that pre-defined roles exist but that the individual decides to which extent they take on and adopt the role or reject to acquire a specific role. In the case of fully acceptance and adoptions, roles can convert into identities.

Continuing, 'identity' is defined as *"the individual characteristics by which a person is recognized and known"* (Clegg and Bailey, 2008). Styhre (2012) developed this definition by describing identity as the *"totality of images of the self and norms and beliefs related to such images that guide and structure everyday practices and*

behaviors, helping the actor to cope with both demands and expectations articulated by others in the domain of practice and individual aspirations and ambitions" which is influenced by technology, physical artefacts, professional ideologies, leadership practice and stakeholders. Zunz (1990), in Brown and Duguid (2001), realized that organizations are a major influencing element regarding the construction of identity. Individuals actively strive for making sense of their work life and daily situations and by this an double-sided impact can be recognized (Gioia et al., 2010). Styhre (2012) also claims that the individual who seeks for identity is at the same time the *"very surface onto which identities are inscribed"* and identities are for this reason hard to define.

A profession is defined by Oxford Dictionary as *"a paid occupation, especially one that involves prolonged training and a formal qualification"* (Press, 2014). A related characterization was made by Mieg (2008), who considered a profession to have *"a central social value"*, *"a knowledge domain"*, *"an education in form of a university degree or specific training"* and *"the presence of a professional association"*. Styhre (2012) indicated that a specific qualification or education is enough to act like a member of a profession but that the largest part of identity construction happens in the daily practice.

Brown and Duguid (2001) found that communities of practice can offer the framework where the members build identities and that these identities are shared within these communities that are often some kind of subculture within an organization. This was affirmed by Smith (2011) who suggested that identity is "*an exclusively property of community membership, negotiated through participation*". However, individuals with the same profession within one organization do not automatically create one community of practice but maybe several small communities that can be described as a form of a network (Brown and Duguid, 2001). Brown and Duguid (2001) furthermore argue that knowledge sharing is supported by these shared identities and perceptions within communities of practice. Since individuals that are part of a community of practice simultaneously are members of the wider organization, it is possible to create a connection between organizational strategy and developments outside the organization (Brown and Duguid, 2001).

2.3 Roles emerging from the use of VDC & BIM

Akintoye et al. (2012) found that new technologies, methods and processes like Building Information Modelling and VDC require organizational adaption as well as possible creation of new professional roles. Jaradat et al. (2012) suggest that the introduction of new technologies cause a change within the understanding and practice of professional roles. They furthermore argue that this will result in the possibility and a stronger focus on the monitoring and controlling of professional expertise through these new systems and technologies. This is caused by the new specialist skills that are needed but yet not found. Xu et al. (2014) identified the availability of BIM-professionals as one of the three most influencing factors for successful Building Information Modelling adoption.

In the case of Building Information Modelling, Akintoye et al. (2012) defined the BIM-manager as the one who manages inter alia the use of virtual planning and the contribution to the model and is therefore the catalytic converter of working with Building Information Modelling. However, Russell et al. (2014) used the presented

material from Construction Users Roundtable (CURT) (2010)[1] regarding the current thoughts and trends concerning Building Information Modelling implementation, to state that the roles within a project where Building Information Modelling is used are no difference from those within traditional construction projects, but that all project participants have to invest resources to *"produce, manage, and deliver more detailed, precise, and accurate information".*

However, it has also been suggested by Russell et al. (2014) that the project engineer, in a similar manner as the BIM-manager, would be the one that manages the collaboration between the different project participants. The project engineer would as well make sure that the necessary models exist and that they include all design details for further use within the construction process. In general Russell et al. (2014) conclude that the introduction of Building Information Modelling will intensely change careers within construction and that the modifications will affect all involved parties within a construction project.

Similarly, Mourgues et al. (2007) suggested the implementation of a VDC-engineer on-site that can handle models in terms of updating and revising them. Since the situations on-site changes constantly it is most effective to have the person that updates the models on-site. This argument is supported by Weygant (2011) who said that the administration of all data is no small task and that this requires a single person who is associated with the task of organizing and managing the project data and information. Since this task exists in all project phases the question is who can execute this task and be the so called knowledge manager (Weygant, 2011). Weygant (2011) described the knowledge manager as *"a hybrid of specifier, CAD manager, and BIM content developer"*. Jaradat et al. (2012) suggest that 'document control' is not just a task but should be arranged as a new role. Bosch-Sijtsema (2013) identified two new roles emerging, one BIM-coordinator, who should manage the 3D-model and a facilitator, who would manage the information and communication flow between the project participants. Anyway, the use of these new technologies will require updated roles and descriptions of responsibilities (Russell et al., 2014).

However, the circumstances in which new roles will be necessary are not described by previous mentioned research. Gu and London (2010) favor the introduction of a BIM-manager that should *"support greater coordination in developing and maintaining an integrated BIM model".* However, they mentioned at the same time that this role will be inevitable for large scale projects.

2.4 Challenges related to VDC & BIM

Besides the probable emergence of changed or new roles or professions there are also other challenges that influence the implementation and the work with VDC and Building Information Modelling. Russell et al. (2014) found that lack of experience, resistance to change, poor information management, supposed costs and non-comparative software are challenges within the implementation of Building Information Modelling. Weygant (2011) recognized that if information is not organized in an effective way, that allows to regain data, the involved parties within the construction project will not have any use of the models.

[1] The Construction Users Roundtable® was founded by - and is driven by - many of the largest and most successful construction owners in the United States to provide the global industry a strong, singular voice to help owners effect positive, meaningful change and improvements. (http://www.curt.org/ downloaded 2014-04-23)

2.4.1 Knowledge Management

Despite the fact that communication and understanding is supported by the visualization of information, the circumstance that laborers, foremen and even superintendents lack the necessary knowledge to handle and benefit from the models make a fast implementation and active use within construction processes difficult (Mourgues et al., 2007). Xu et al. (2014) came to a similar result, identifying the lack of skills and training as an barrier to successful implement Building Information Modelling. The lack of knowledge within the construction industry (Azhar, 2011; Mourgues et al., 2007), hinder the extensive use of Building Information Modelling and VDC (Hartman and Fischer, 2008). There is not only a lack of staff who is able to work actively with applications like 3D-modelling (Azhar, 2011), but also knowledge and understanding among other professions, the ability to understand these methods and to use them in the daily work is crucial, thus basic skills will become compulsory for all employees within construction industry (Russell et al., 2014). The lack of educated people together with the lack of training was identified as hindrances for implementing Building Information Modelling to a great extent. Russell et al. (2014) suggested that there will be a need for specialists in the future that have knowledge within design, construction practices and techniques like timing of the fabrication, installation, commissioning, and startup processes. On the other hand staff within construction industry *"will need to have a high level of design knowledge to be able to fully use the technology".* Finally, Russell et al. (2014) promoted the idea to train internal staff to ensure that the implementation of the new technology is successful and encouraged to use consulting firms if needed jobs cannot be staffed with own employees.

Li et al. (2009) identified the education, within the new technology and way of working that comes along with VDC, as a major source of costs since it is necessary to unlearn the old approaches. However, the perceived cost have a undesirable effect on perceived simplicity of use of Building Information Modelling (Xu et al., 2014). Xu et al. (2014) concluded that, conversely, this means that a more negative attitude in terms of easy use towards Building Information Modelling technology can decrease the willingness to learn and integrate the new technology into operations and work routines. Gu and London (2010) suggested that the availability of Building Information Modelling professionals has a positive effect on the perceived ease of use and can therefore help to improve *"the users' perception of BIM's usefulness and ultimately constitutes an impediment to BIM technology adoption"*.

2.4.2 Standards, model ownership and information management

Xu et al. (2014) identified Building Information Modelling standards as one of the three most influencing factors of Building Information Model usage. The issue of data representation, version management and data organization was also discussed by Gu and London (2010) and identified as important issues that have to be solved when using Building Information Modelling. Furthermore a lack of trust on completeness and precision of three-dimensional models was identified as a remaining major concern (Gu and London, 2010).

Bennett (2010) identified the model management and ownership as a future challenge as well as Azhar (2011) who rose the same question highlighting that it is a legal problem concerning who is allowed and responsible for the data that is put into the model since the responsibility for the model is also connected to a great risk. He illustrated this problem by the following example:

> *"Consider the scenario in which the owner of the building files suit over a perceived design error. The architect, engineers, and other contributors to the BIM process look to each other in an effort to try to determine who had responsibility for the matter raised. If disagreement ensues, the lead professional not only will be responsible as a matter of law to the claimant but may have difficulty proving fault with others such as the engineers." (Rosenberg 2007, see Azhar (2011))*

A change regarding the responsibilities within the project will be affected due to the introduction of VDC (Bosch-Sijtsema, 2013). Weygant (2011) proposed that the responsibility of data correctness should be assigned to the owner or the facility manager. Gu and London (2010) suggested additionally that protocols, standard evaluations and validation procedures can help to solve the issue of data correctness.

3 Case Description

This chapter describes the context in which this study has been conducted. The context described is based on company specific written documents, both public and internal, as well as conversations with people that work in the company during the research period.

The studied company is one of the leading construction and property developing companies in the Nordic region with approximately 20 000 employees and a turnover of circa 60 billion SEK (year 2013). The company develops and builds residential and commercial properties, industrial facilities and public buildings, roads, civil engineering structures and other types of infrastructure divided into three business areas:

- Industrial
- Construction and civil engineering
- Development

Within the housing and property development business area, the company develops and sells residential buildings, commercial properties, offices, retail and logistics. The business areas are active through the whole construction process, from project concept, to finished product and sales.

The construction and civil engineering business area is the company's operative builder for both internal development projects and external clients. Examples of constructions are: schools, houses, roads, bridges etc. At the beginning of 2014, a major reorganization took place in the construction and civil engineering business area in Sweden, when the previous geographical regions were eliminated and replaced by business segments (see Figure 3). The five business segments are: Industrial construction, Infrastructure, Commercial buildings, Residential buildings and Partnering. This reorganization was done simultaneously to this research study.

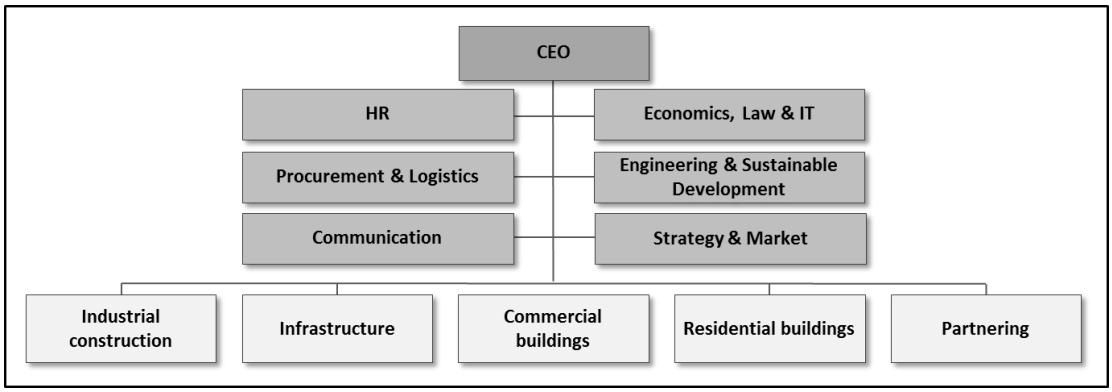

Figure 3 The company's current organizational structure

Since the beginning of 2007 the company has worked with and acknowledged VDC as a strategic opportunity to reach its objectives and goals. The executive management team has decided that all construction projects, in which the company can influence the way of working, should use VDC. The company's aim with the implementation of VDC is to integrate VDC as a natural way of working, *"business as usual"*. The implementation of VDC at the company is organizationally placed at the stab function Engineering and Sustainable Development. The VDC central strategic work group was specifically created with the purpose to implement and develop VDC.

According to the company's definition and interpretation, VDC is *"the process that uses BIM to simulate, predict and analyze the finished product"*[2]. The company further explains the difference between BIM and VDC with the help of Figure 4. The core of all systems is the 3D-model which is shown in the center of the three circles. The 3D-model is surrounded by the information management which is similar to BIM. The outer circle, which finally contains coordinated processes related to the 3D-model and the information management, is what is called VDC within the company. This indicates that VDC is considered to be the ensemble of all three circles.

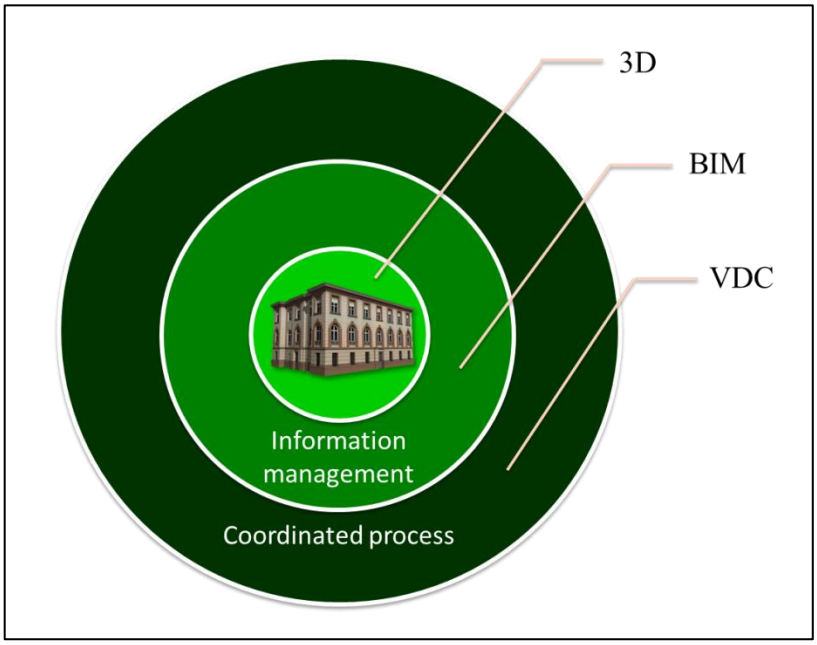

Figure 4 The company's visualization of the difference between BIM and VDC

Furthermore in company specific documents is it stated that the basis for VDC is that the information should be transferred in a systematic way, be interconnected and used between the project members in order to increase efficiency throughout the entire construction process. The company's definition and interpretation of VDC has its origin from the work done by the department Center for Integrated Facility Engineering, CIFE, at Stanford University. Thereto the company collaborates with Stanford regarding education of employees. For example, several employees from the company participated in Stanford's VDC certificate program.

The strategic way of working with VDC in the company evolved in the creation of a model coordinator role. The previous model coordinators were employed at the Engineering development department but due to a reorganization and transformation of the role, the company moved the VDC-coordinator from Engineering and Sustainable Development (the new name for the Engineering Development Department) to each operative departments. The reason was to place them closer to the construction projects. The intention was to have at least one VDC-coordinator available in each department to ensure that the departments are capable to manage their projects in regards to VDC-use. Each department should also have a VDC-

[2] The company's original definition and interpretation of VDC: "VDC är processen att med hjälp av BIM (Building Information Model/Byggnadsinformationsmodell) simulera, förutsäga och analysera slutprodukten"

specialist connected to them. The VDC-expert should not be connected to a specific department, due to that their main focus should be on development and research within VDC-areas. The introduction of the three VDC-professions was also a way to create a career path for the model coordinators, hence VDC-coordinators. Additionally it should clarify the different levels of knowledge and experience needed in order to be able to perform different work tasks and areas within VDC.

A professional network for the model coordinators was created as a possibility for them to exchange information, knowledge and experience. As the implementation and development of VDC continued, the model coordinators developed and received more work tasks and responsibilities. In the beginning of 2014, the model coordinator role had been transformed into a new profession, VDC-coordinator, and had also received more extensive work tasks and responsibilities. The two professions VDC-specialist and VDC-expert were also introduced at the end of 2013, although there were no appointed VDC-experts until March 2014.

The company's focus is on educating and informing the employees regarding how VDC affects their work. During the research period for this master thesis work there has been on-going education of employees within the company regarding VDC. One example is the compulsory manager course, which started in the autumn of 2013. The aim of the manager course was to increase the awareness of what VDC actually is, what can be done with it and promote the benefits evolving from using VDC among the managers. Hence to increase the understanding and the amount of projects that uses VDC. The company also provides other courses in different areas of VDC that are online based, as well as workshops and more traditional courses taught by a teacher.

4 Methodology

This thesis is based on a case study within the construction industry. A case study provides a detailed analysis of one specific organization and setting (Bryman, 2008). According to Bryman (2008) there is a tendency to use qualitative research method in case studies due to the possibility to collect intensive and detailed data, although a mixed research method is as well frequently used. One main issue when conducting a case study is whether or not the result and discussion has external validity, hence if it could be generalized and taken out of its context. According to Yin (2003) there are five different types of case studies: the critical case, the extreme or unique case, the representative or typical case, the revelatory case and the longitudinal case. The case study executed within this master thesis is of the representative or typical case type. The object, according to Yin (2003), for a representative or typical case "*is to capture the circumstances and conditions of an everyday or commonplace situation*". One example is to study key social processes due to the introduction and implementation of new technology in organizations.

Figure 5 shows the process of this case study. First a pre-study was performed in order to narrow the research questions and identify critical areas of VDC and VDC-professionals. The pre-study was also a way to choose the most suitable research approach for the study. In this phase, two pre-interviews, studies of internal documents regarding VDC and the VDC-professionals were conducted together with an initial literature study.

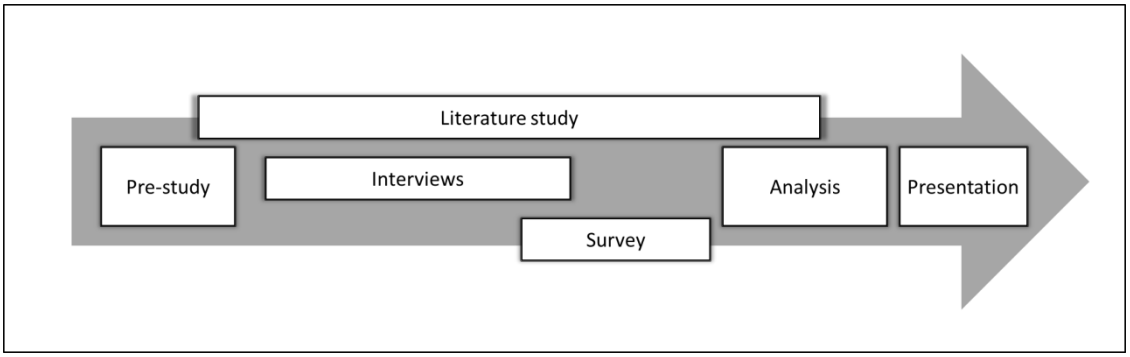

Figure 5 The case study process

As a result of the initial pre-study, a mixed research approach was developed, combining both qualitative and quantitative approaches. The main data collection began with the qualitative part through the execution of interviews. The aim of the qualitative data collection was to collect intensive and detailed data. A first analysis of the data from the interviews provided a foundation to formulate questions for the following survey (see Appendix I). The aim of the quantitative part was to be able to gather the perspective from more employees in the organization, who work together with the VDC-professionals in order to get a broader perspective to verify the results from the interview study. Furthermore the intention was to collect additional perceptions from VDC-coordinators, VDC-specialists and VDC-experts who were not part of the interview study.

Parallel to the data collection, a literature study was performed. The results from the data collection were then analyzed and further discussed in relation to the identified literature. Finally, conclusions were made and recommendations to the company

regarding the future development and implementation of the VDC-professions, together with possible further research areas, were presented.

4.1 Literature review

A literature review has been performed in order to create a theoretical framework for this master's thesis. The aim of the theoretical framework was to be able to establish the empirical findings with already performed research and to provide a context for the data analysis. The literature review was mainly based on published scientific articles and books concerning the following research areas:

- Project-based organization theory
- Knowledge and knowledge management
- Professionalism, identity and roles
- VDC and Building Information Modelling

When possible the literature has been chosen due to its focus on the construction industry or project-based setting as well as literature supporting the fundamental background in the different theoretical fields. The scientific articles and books have been found through databases and recommendations of relevant literature from the supervisor at Chalmers University of Technology. The main keyword for the search has been; knowledge, knowledge management, professional identity, roles, professionalism, construction industry, project-based organization, BIM and VDC.

The literature review was ongoing during the study, starting during the pre-study, through the data collection and the analysis of the data. The qualitative analyze software NVivo was used to structure and code the collected literature.

As mentioned in Section 1.1 Background, the definitions of BIM and VDC are many and not always similar. In this report BIM as Building Information Modelling is synonymously to VDC, Virtual Design and Construction. Hereafter in this report is BIM considered to be the Building Information Model. This definition was based on the possibility it provides to align the literature with the company's definition of VDC.

4.2 Pre-study

This case study began with a pre-study with the aim to narrow down the research area and identify critical areas of the VDC-professions. The pre-study consisted of two pre-interviews, studies of internal documentation and an initial literature review. The two pre-interviews were conducted more as a free conversation than as interviews. The first pre-interview, with the VDC manager, was conducted in Swedish, recorded and summarized but not transcribed. The second pre-interview, in which an industrial doctoral student working at the studied company was interviewed, was conducted in English, summarized, recorded but not transcribed.

The pre-study resulted in the decision to develop a mixed research approach (see Chapters 4.3 The interview study and 4.4 The questionnaire survey) and the focus of the literature was decided (see Chapter 4.1 Literature review). The result from the pre-study made it possible to identify focus areas of the study. These focus areas are: 'Implementation of VDC', 'Characteristics, skills and knowledge of the VDC-professionals', 'Knowledge exchange concerning VDC', 'VDC-professionals' work tasks', 'Involvement and responsibilities in projects', 'Organization and attractiveness of the VDC-professions' and 'Future development of the VDC-professions'.

4.3 The interview study

The purpose of the qualitative data collection was to be able to get intensive and detailed data concerning the VDC-professionals and the identified focus areas. The qualitative data was collected mainly through semi-structured interviews. Twelve interviews were conducted of which seven were with VDC-coordinators, VDC-specialist or VDC-experts and five with managers at different levels in the organization.

4.3.1 Description of the interviewees

All interviewees were chosen from a list provided by the VDC manager. The VDC-coordinators, VDC-specialists and VDC-experts were chosen based on their experience from working within the professions. The choice of managers was based on the fact that they make the decision if VDC is to be used within a project or not and to what extent. Additionally, they are superiors to the VDC-professionals in the project structures, which is why the managers' perceptions of the VDC-professionals were of interest.

In the VDC-group, five persons were VDC-specialist and two were VDC-experts and all of them have worked as VDC-coordinator or executed VDC-coordinator tasks. All seven interviewees belonging to the VDC-group have worked at the company between two to five years. Besides, three of them have worked with VDC-related tasks at other companies than the studied company. All the interviewees within the VDC-group have an educational background from university studies, either three years or more. Thereto they have experience from the design or production phase or both. Of the persons interviewed in the VDC-group three work within the housing segment, three in the residential segment and one in the infrastructure segment. Out of the twelve interviewees, five are part of the VDC central strategic work group.

Among the managers, four of them have work approximately 15 years at the company and one has worked 26 years. All the interviewed managers have an educational background from university studies, either three years or more. Of the interviewed managers, two worked as project managers, one as production manager, one as specialist manager and the last one as team manager in the design phase. All interviewed managers worked in the housing or residential business segment.

4.3.2 Data collection and analysis

The interviews were conducted with two sets of interview guides, one for the VDC-coordinators, VDC-specialists and VDC-experts (see Appendix II) and one for the managers (see Appendix III). Several of the questions were included in both of the interview guides. The reason for using two interview guides was based on the two different criteria for choosing the interviewees (working as one of the VDC-profession or deciding whether or not to use VDC), thus they were believed to be able to answer the questions from two different point of views. Thereto were some of the questions only possible to answer if the interviewee had worked as VDC-coordinator. The choice of using semi-structured interviews with an interview guide was based on the possibility it provides to create a conversation around the subject and allow for follow-up questions. Thereto is the possibility given to adapt the questions according to the interviewees answers although at the same time assure that all interviewees were asked the same basic questions from the interview guide. The formulation of the questions was open as far as possible in order to facilitate the analysis of the interviews and the interviewee could easier argue around the question and motivate

their answer. The interviews were approximately one hour long and each interviewee was interviewed individually. Three of the interviews were accomplished through telephone conference (Microsoft Lync); the other nine were conducted face-to-face. All interviews were, with permission from the interviewees, recorded and transcribed. Additional supporting notes were taken.

Additional data collection was done through observations during a two-day meeting with the VDC central strategic work group, which is responsible for the implementation of VDC in the company. Relevant data was collected through observation during the meeting and memos were taken. The aim of the presence at the meeting was to gather an understanding of how the group works with the implementation and development of VDC and in particular the VDC-professionals.

The analysis of the interviews was done with the help of the qualitative software program NVivo in which a coding of the interviews was performed. The coding was done according to the themes identified from the pre-study. The interviews were both analyzed as one group and as two subgroups, due to the two set-ups of interview guides.

4.4 The questionnaire survey

A quantitative questionnaire survey was designed to collect a more general view upon the VDC-professionals and the use of VDC. The purpose was also to verify the findings from the interviews. To collect the quantitative data a questionnaire survey was sent out to employees in the company. The focus of the survey was to collect opinions from project managers, production managers and design managers due to their position within the organization considering whether or not VDC should be in cooperated to the project and to which degree. The perspectives from employees in the production phase were of interest, due to the circumstance that they were not represented to a large degree in the interviews. Using a web based survey program, the survey was sent through email to 173 employees in the company. Due to the nature of the questions the employees that were of interest for the survey needed to have some kind of relation or connection to VDC-projects. For example, they have worked within VDC-projects, worked together with the VDC-professionals or had worked as managers for VDC-projects. The employees were identified through the following ways:

- A search in the internal address book using the word VDC
- Contact persons for projects marked by the company as VDC-projects
- The members of the previous model coordinator network
- The members of the VDC central strategic work group
- Employees identified on internal documentation and internal web sites related to VDC

Only one of the alternatives was needed to be fulfilled in order for the employees to be of interest for the survey.

The questions in the survey was based on a preliminary analysis of the interviews but also derived from the literature review (see Appendix I). The design of the survey was done with inspiration from the Likert scale, which is one of the most common techniques (Bryman, 2008). The Likert scale is a multiple-indicator measure of attitudes. According to Bryman (2008) the main advantages of using a multiple-

indicator measure are to avoid the possibility of one single factor to be incorrect interpret, thereto it takes into account that several factors can influence the specific area and that it might not be able to interpret the answer from only one statement. Furthermore, the use of a scale gives the possibility to distinguish the statements from each other in a finer manner. Bryman (2008) further highlight that it is important to remember that one concept can entail several different dimensions and that it will be interpreted in different ways by the respondents. The choice of respondents hopefully decreases this to a certain degree. The Likert scale method uses a set of arguments related to specific areas and asks the respondents to answer to which level of agreement the respondent has to several statements. In this survey a 6-point-scale were mostly used. In order to keep the surveys length to a manageable level in order to avoid that the respondents cancel the survey before completing it, the survey focus mostly on the VDC-coordinator and only to a small extent on the VDC-specialist and VDC-expert.

The survey was created and managed with the help of an online web-based survey program (surveymonkey.com). After the first invitation, engaging to participate in the survey, was sent, two additional reminding emails were sent before the survey was closed. In total 102 respondents answered the survey (59% response rate). 84 questionnaires were fully completed, giving a response rate of 49%. Three of the respondents were excluded due to the fact that they were not the right objects for the study.

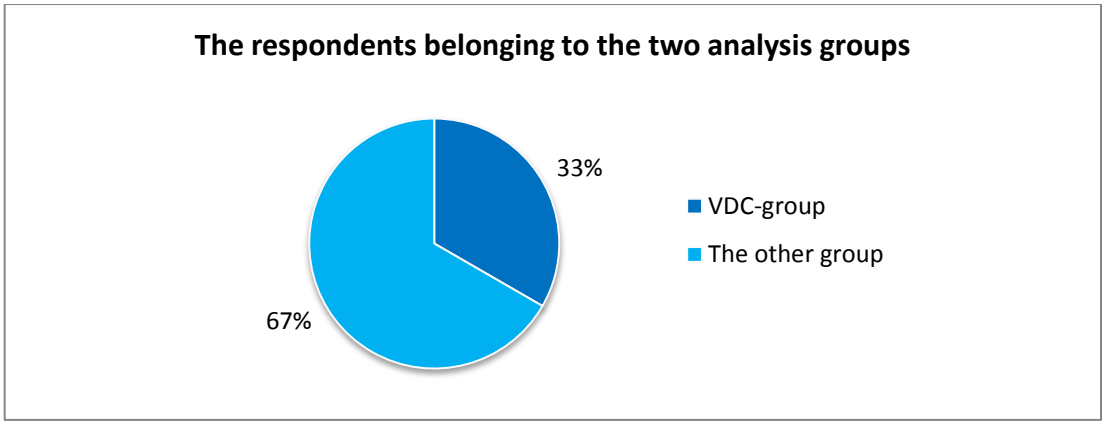

Figure 6 The division of the respondents from the survey into the two analysis groups

A frequency analysis of the survey result was done. First all the answers from the survey were viewed upon as one unit. Then a second frequency analysis was performed with a division of the survey respondents into two groups. The division was done in order to be able to identify if there was a difference between those respondents that were more deeply involved in the VDC-work and those who were not. The first group consisted of those respondents who replied to the question "Which of the following positions describe your role within a VDC-project best?" with VDC-coordinator or VDC-specialist or both, together with the respondents belonging to the VDC central strategic work group (Figure 6). The first group consists of 34 respondents of which only one did not complete the survey. Hereafter, this group will be referred to as the VDC-group in the survey context. The second group consists of the respondents that do not belong to the first group, in total 68 respondents of which 51 completed the questionnaire. The use of frequency analysis allows the use of the not completed survey answers, due to that no questions are related to or dependent on each other and only analyzed as separate questions.

4.4.1 Description of the survey population

This chapter describes the characteristics of the survey population. Out of the 102 persons that responded to the survey, the majority (36%) has worked in the company between 1 – 5 years, although 49 % of the respondent has worked at the company for more than 10 years (see Figure 7).

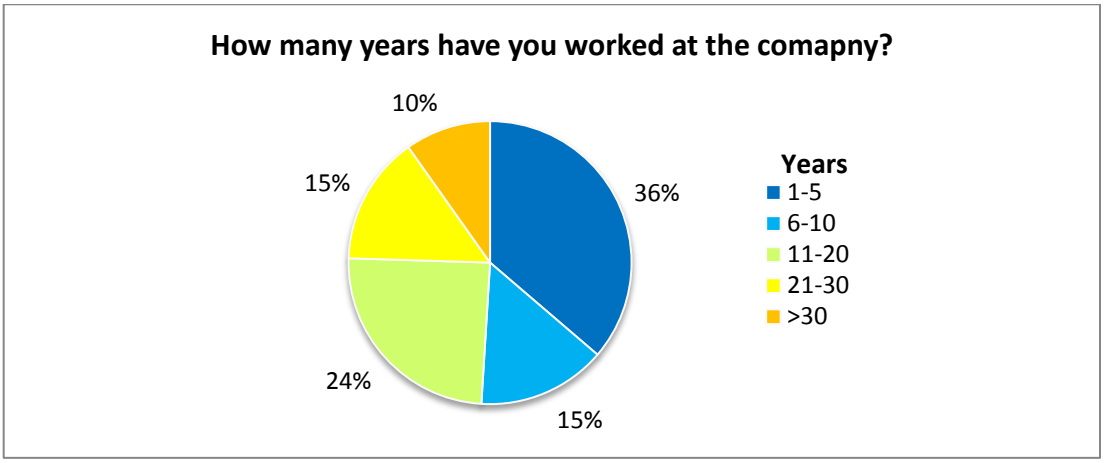

Figure 7 Response to the question "How many years have you worked at the company?", n=102

A difference was identified between the two groups when the question *"How many years have you worked at the company?"* was viewed upon separately as shown in Table 1. The majority of the respondents in the VDC-group have worked up to five years at the company, whereas the majority of the other group has worked more than ten years at the company. The question do not reflect how long total working experience the respondents have, rather it express their experience of working within the company.

Table 1 The difference between the groups in terms of years they have work within the company. The numbers represent the number of responses.

Years	VDC-group	Other	Total
1-5	22	15	37
6-10	6	9	15
11-20	3	22	25
21-30	1	14	15
>30	2	8	10
Sum	34	68	102

Two thirds (66%) of the respondents have university educations, almost equally divided between up to three years studies and more than three years. The last third of the respondents have the secondary school as their highest educational level. The educational backgrounds differ when the two groups are studied separately. In the VDC-group 38% have studied up to three years at the university and 50% have studied more than three years. The remaining 12% had completed secondary school and none of them had done any vocational training. In the other group, the majority of 43% have secondary school as their highest educational level, 3% had vocational training, and 26% had studied up to three years and 28% more than three years at university.

The current positions of the respondents are presented in Figure 8. The majority and main focus of the survey was project managers, production managers, design managers (see Chapter 4.4 The questionnaire survey). Of the total respondents, 38% belong to this group. The two other most significant groups of the respondents are construction engineers (12%) and site managers (11%). The survey was directed to employees who had worked with VDC projects and of the respondents 11 % work today as VDC-coordinator, VDC-specialist or VDC-expert according to themselves. The majority (61%) of those who said that they work as a VDC-coordinator do not work more than 25% of their time with those tasks. Only one of the respondents works 100% as a VDC-coordinator.

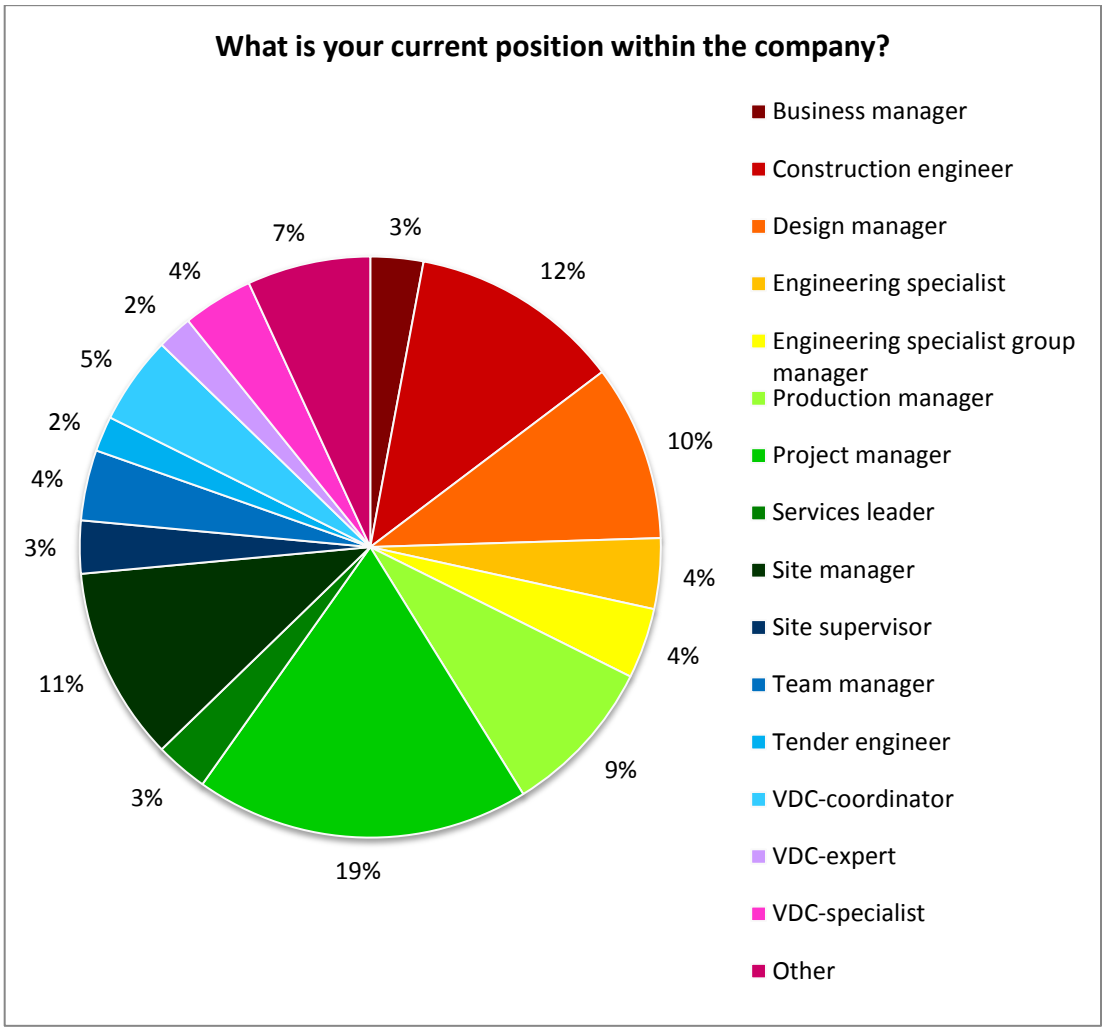

Figure 8 Response to the question "What is your current position within the company?", n=102

The respondents work in all five business segments and also the stab function Engineering and Sustainable development was represented (see Figure 9). It was possible to choose several segments in this question. The majority of the respondents are working with the construction of buildings, either residential or commercial, almost twice as many as for infrastructure and industrial construction.

The respondents were asked about what previous positions they had worked as in the company. 49,5% of the respondents have worked as site supervisor and 36,4% as site managers. The three most frequently chosen positions (site supervisor, site manager

and construction engineer) are all found in the production phase and the first design connected position is found as number four (design manager), although just followed by the construction manager which is mainly working in the production phase. When the previous positions are considered for the two analysis groups, the respondents from the VDC-group have experience from both the design and production phase. Whereas in the other group, there is an indication that the majority have experience from the production phase, for example did 41 out of 61 answer that they have worked as site supervisor and 35 out 61 as site manager in the other group.

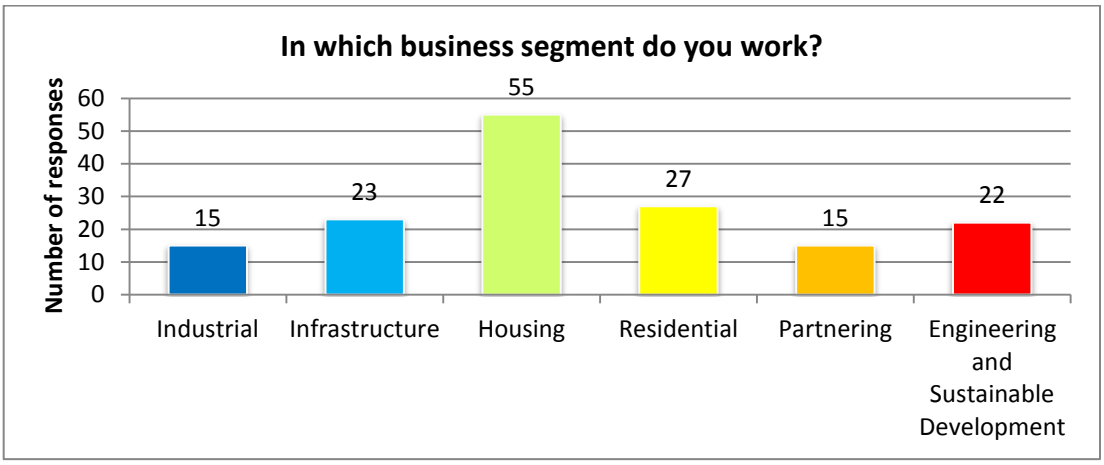

Figure 9 Response to the question "In which business segment do you work?", n=102

5 Empirical findings

In this chapter the result from the data collection is presented and analysed. The focus is on the following themes: 'Implementation of VDC'; 'Characteristics, skills and knowledge of the VDC-professionals'; 'Knowledge exchange concerning VDC'; 'The VDC-professionals' work tasks'; 'The VDC-professionals' involvement and responsibilities in projects'; 'Organization and attractiveness of the three VDC-professions' and 'Future development of the VDC-professions'. In each of the following chapters the data from the interviews and the survey are presented. In the interview context the interviewees that were asked the questions for managers (Appendix III) are referred to as managers and those that were asked the questions for the VDC-professionals (Appendix II) are referred to as the VDC-group. In the survey context the respondents are divided into two groups in accordance with the description in Chapter 4.4 The questionnaire survey. Not all results from the survey are presented in this Chapter, therefore the complete survey with results can be found in Appendix I.

5.1 Implementation of VDC

The following sections present the results in regard to the implementation of VDC within the company. The focus is on the existing definition of VDC, the purpose of the VDC-professions, the organizational awareness of the VDC-professionals and finally the current difficulties regarding the use of VDC.

5.1.1 Definition of VDC

The interviewees were all able to formulate a definition of VDC which was to high extent consistently. In general, VDC was described by the interviewees as the way of using building information models to predict, simulate, visualize and analyse the final product before it is actually built. At the same time information management in form of a central database and the simulation of construction processes was named as essential parts of VDC. A few interviewees highlighted that VDC is a wide concept which often depends on the individuals' interpretation. Furthermore the different approaches to VDC between companies and various doctrines were underlined.

The survey shows that the perception regarding VDC within the studied company is that VDC increases the companies' profitability, quality and efficiency and improves the end results (see Figure 10). The respondents do not connect VDC only to the use of 3D-models. Further there are mixed opinions regarding the existence of a clear definition of what VDC is within the company. The most spread answers were received from the claim that VDC permeates all business activities, where the majority of the answers are on the "disagree-side". Another claim with a greater spread from the respondents is that there are clear goals for the use of VDC. Considering the VDC-group's answers, the respondents' answers do not vary much and they agree to what extent the different factors are in line with the companies' view on VDC. The other group has more scattered answers. Furthermore, the survey shows that the asked employees' perception is that VDC has a positive impact on information management; the communication within projects and the number of problems that need to be solved on site. However, a strong positive influence on the work load within a project and the time planning was only seen by a small number of participants.

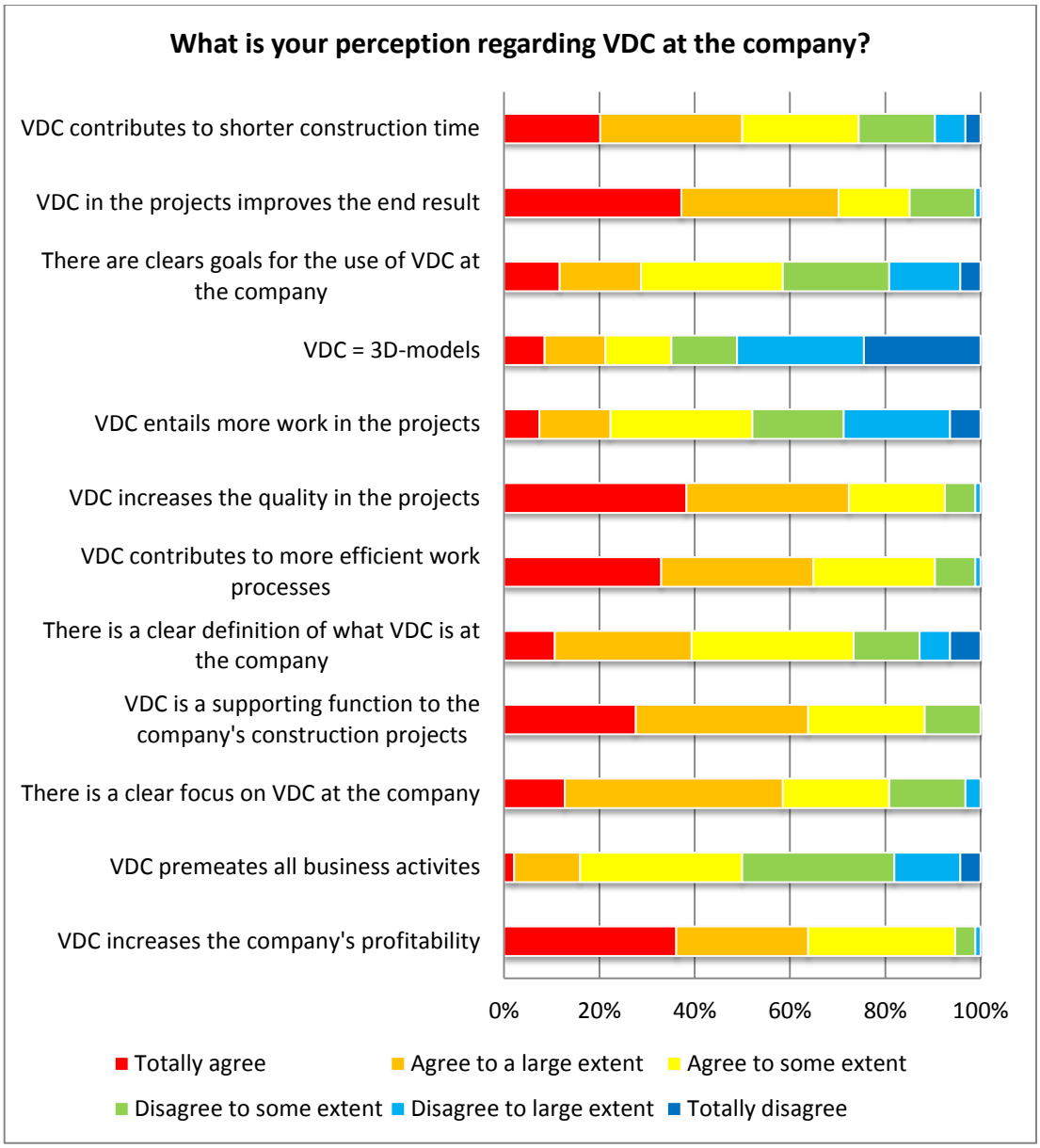

Figure 10 Response to the question "What is your perception regarding VDC within the company?", n=91

5.1.2 Purpose of the VDC-professions

During the interviews different purposes for implementing the VDC-professions were mentioned. One stated reason was that the role of the model coordinator had been unattractive due to the narrow area of work tasks and responsibilities. So this role had to be changed and modified and received a new name 'VDC-coordinator' and a more extensive area of responsibility. The necessity to have someone with specific knowledge about VDC closer to the project was an additional reason to implement the VDC-coordinator. A connected further reason for implementing the VDC-professions was the attempt to make the different VDC-professions more clear and present a way for development – both with regards to carrier as well as expertise and knowledge. This applies mainly for the roles of the specialist and the VDC-expert. The three levels of VDC-professions were also compared with a career staircase that implies the increase of knowledge and expertise. This career staircase should make the VDC-

professions more clear and standardized and show which competences the VDC-professionals have to have.

Moreover the VDC-professionals are hoped to help the company to overcome the threshold and push processes and methods within VDC forward. The VDC-professionals were described as catalysts for the implementation of VDC.

5.1.3 Organizational awareness of the VDC-professions

The interviewees that worked as one of the three VDC-professional roles knew the occurrence of three different roles and the names but had difficulties to differentiate them from each other. Four of the five interviewed managers were only aware of the VDC-coordinator or in some cases VDC-specialist. There was only one interviewed manager that was familiar with all the three VDC-professional roles.

The interviewees mentioned the often changing names of the VDC-professions and the implementation of further VDC-professions as confusing. The different roles develop and change constantly and it was described as very difficult distinguish them from each other. In addition one person may not have only one role but could be a VDC-specialist, who also undertakes VDC-coordinator's tasks. Most of the interviewees had larger difficulties to describe the difference between the VDC-specialist and the VDC-expert and some thought that these two roles are almost the same. One interviewee expressed doubts about the sense of having a role called VDC-expert. The reason for implementing the VDC-expert was to develop a possibility of career path but the interviewee sensed that the title was more dependent on the geographical placement than the educational background, knowledge and experience. The relation between the VDC-coordinator and VDC-specialist was discussed in a similar way, hence a VDC-coordinator should use the VDC-specialist as a consultant and a back-up if his/her knowledge is inadequate to the situation. Other interviewees, from both interview groups, clarified the difference between specialist and expert by saying that a specialist can consult an expert which implies a higher degree of expertise and experience. Some interviewees mentioned a competence stairs, as a metaphor for career development, as an option to differentiate between the three VDC-professionals.

5.1.4 Current difficulties with the implementation of VDC

Different challenges with the implementation of VDC were discussed by the interviewees. Three interviewees from the VDC-group mentioned that there is a need for increased acceptance and allocation of resources, especially time, to VDC-related topics. Without the allocation of resources, situations where VDC-coordinators or VDC-specialist do not have enough time to support all projects with their expertise can occur.

Furthermore one interviewee thought that the decision whether a project should use the new methods of VDC, which today is up to project managers, instead should be more clearly stated from the managerial level. Incentives from higher managerial level could than be used to increase the amount of projects that use VDC and to increase the use of VDC within projects. Today not all projects that could use VDC actually use VDC. This point of view was supported by another VDC-specialist that thinks that the whole positive effect of VDC will not be visible until the implementation is realized. A more critical point of view had one manager that highlighted that only methods and tools should be used that generate additional profit and that it is pointless to do things only because they are possible. One financial

hindrance that was mentioned was the impression that consultants want to get paid extra for executing the design in 3D, even if it means no additional work for them.

Another challenge occurs when errors exist in the models. The question was raised regarding who would be responsible if the quantities within a model are wrong and consequently calculations for purchases or proposal preparations are wrong. Building information models are not included in any contract as legally binding today. It is not only the legal part that is critical but also the effect on the employees in the company due to models containing frequently errors. If departments like calculation or purchase are not able to work with the models they could lose their trust in these new methods. The reasons for frequently wrong models were identified, for example incomplete specifications of requirements and the poor self-monitoring of architects.

Several interviewees underlined the importance of 'proactive persons'[3] to push forward the implementation and use of VDC. A high focus should be put on getting the right people to the right place or position.

In general the implementation of VDC is further ahead within the Housing and Residential department, where 70-80% of all projects already use 3D-models, while the projects within infrastructure do not use VDC to a high extent. Furthermore was a difference between the previous regions (more extensive use in southern regions while in northern parts VDC is hardly used at all) recognized.

5.2 Characteristics, skills and knowledge of the VDC-professionals

Through the combination of the interviews and the survey it was possible to create an overview of which knowledge background, personal characteristics and work experience the VDC-coordinator should preferably have according to the respondents. This overview is presented in the following chapter. Furthermore the results from the interviews in regards to knowledge, characteristics and experience of the VDC-specialist and VDC-expert are then explained in the two following sections. Since the survey focused on VDC-coordinators, no information regarding the knowledge, characteristics or experience of the VDC-specialist or VDC-expert exist from the survey.

5.2.1 VDC-coordinator

When the interviewees were asked what type of education, knowledge and experience are needed to work as a VDC-coordinator the answers mostly concerned social skills and several said that it is better to be able to handle people, to be good at communicating and being structured than to have technical expertise. The social aspects are thus of greater importance then a specific educational background or experience. Both, interviewees belonging to the VDC-group and managers, expressed that they do not see an "IT-geek"[4] with high focus on technology and technical expertise, as a VDC-coordinator. Rather they want somebody that can manage and handle different types of people and groups. The software and programs are considered as something almost everyone with an interest in VDC can learn and they further expressed that it is more difficult to get an understanding of the construction process than to handle IT-technology.

[3] Original expression "drivande personer"
[4] Original expression "datanörd"

All the interviewed in the VDC-group have a university education, although it is not something they perceived as required for a VDC-coordinator. The most frequently mentioned requirements are an understanding for VDC and the software programs that are used, together with an understanding and experience of the construction process. Furthermore all the interviewed persons from the VDC-group have experience from either the design phase or the production phase or both, which is something that the managers request for a VDC-coordinator.

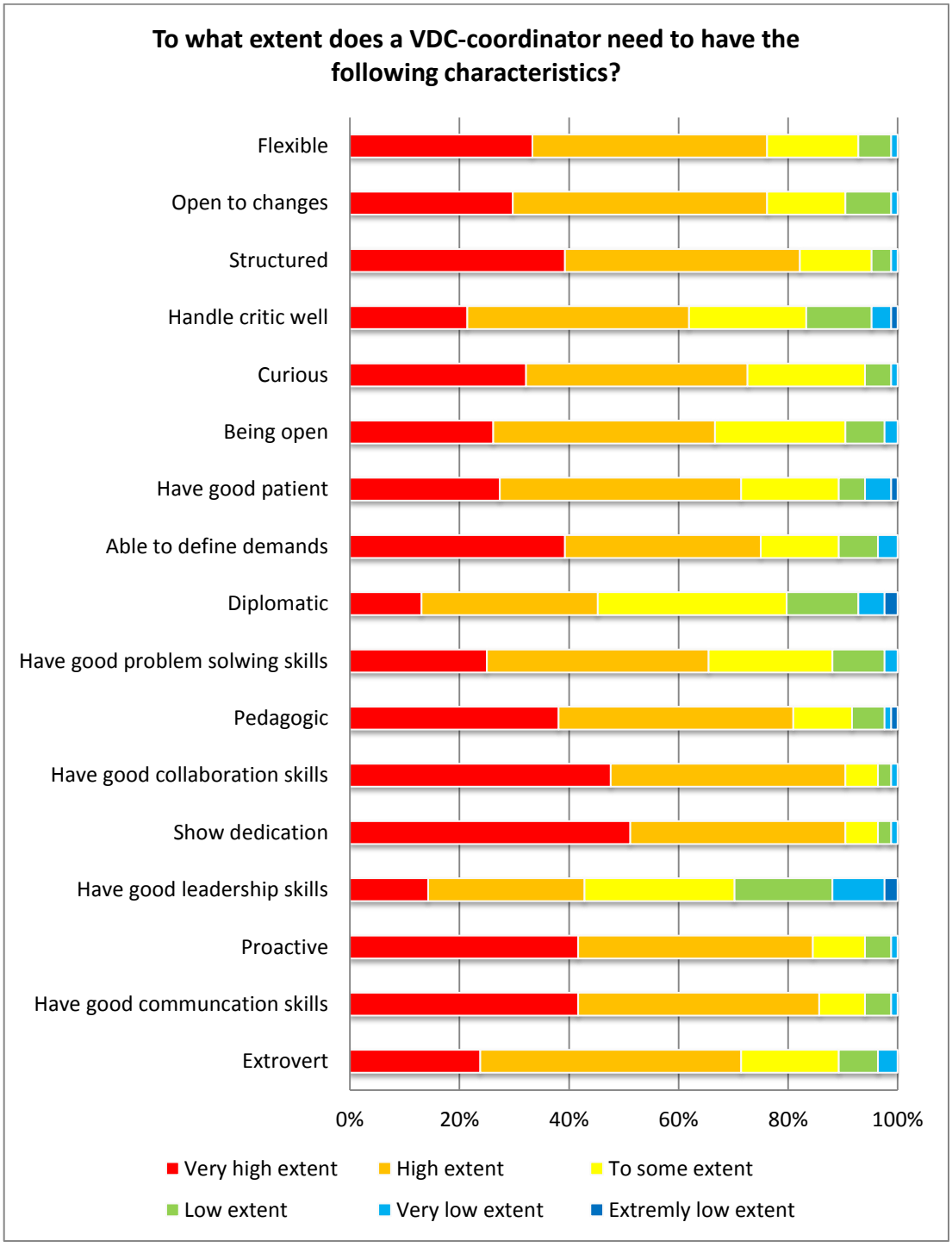

Figure 11 Response to the question "To what extent does a VDC-coordinator need to have the following characteristics?", n=84

All personal characteristics considered in the survey question "To what extent does a VDC-coordinator need to have the following characteristics?" were identified through the conducted interviews and they are all high-rated by the respondents of the survey (see Figure 11). The four highest are: *'Show dedication', 'Have good collaboration skills', 'Being proactive'* and '*Have good communication skills'*. The lowest rated are '*Have good leadership skills'* and '*Being diplomatic'*. When the result is divided into the two groups, VDC-group and the others group, it shows that each characteristic are rated higher in the VDC-group than in the other group. A further difference between the groups concerns the most high rated characteristics. The VDC-group rates '*Being pedagogic'* higher, whereas the other group rates *'Being proactive'* higher. Otherwise the groups' rates do not differentiate to a large extent from the combined result shown in Figure 11.

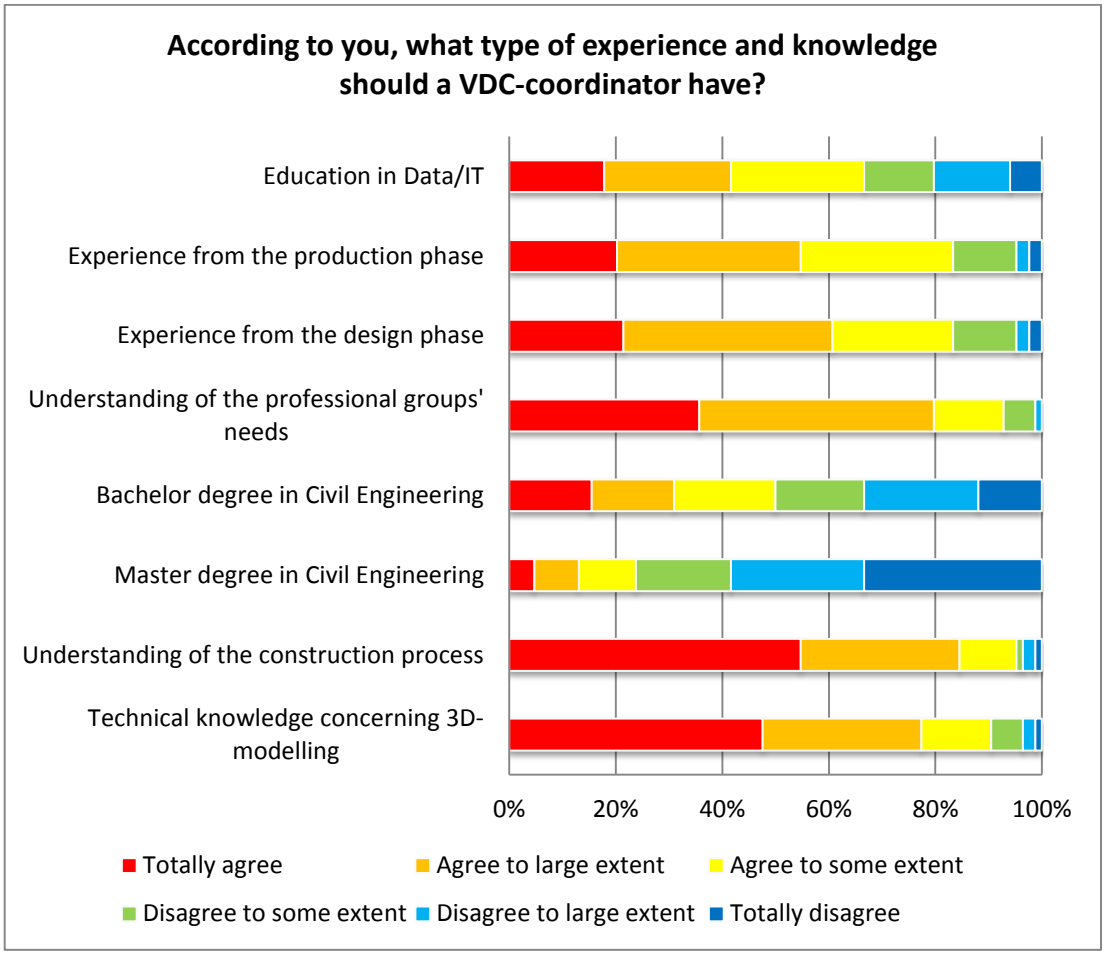

Figure 12 Response to the question " According to you, what type of experience and knowledge should a VDC-coordinator have?", n=84

The knowledge and experiences that the VDC-coordinators should have according to the survey is *'technical knowledge concerning 3D-modelling'*, *'understanding of the construction process'* and *'understanding for the involved professional groups' needs'* (see Figure 12). To have experience from either design or production or both are higher rated than a formal university education. Furthermore a master degree is lower ranked than a bachelor degree, which may indicate that it is not necessary to have a master degree. No difference between the two groups was found, both in the high and low rated factors.

5.2.2 VDC-specialist

When the VDC-specialist's knowledge, experience and characteristics were discussed by the interviewees, the focus was more on knowledge and experience than on personal characteristics. The level of knowledge and experience were often set into relation to the VDC-coordinator's. All interviewees agreed that the needed knowledge concerning the VDC-tools and methods is increased for the VDC-specialist in comparison to the VDC-coordinator. The VDC-specialist should be able to do more complex tasks with the VDC-tools. The VDC-group expressed more specific that the knowledge should be extensive and cover more areas of VDC but at the same time the VDC-specialist should have an in-depth knowledge of one or several areas. Furthermore the knowledge should concern how to use the tools and method in the most efficient way.

A higher level of understanding for the construction phases, process and involved disciplines are also required from the VDC-specialist, due to that the VDC-specialist need to be able to set the right requirements for the VDC-work in regard of both the construction process and the abilities of the VDC-tools. The interviewees consider the VDC-specialist's personal characteristics to be similar to those of the VDC-coordinator's with a focus on communicational skills, openness and observant. The managers highlight the ability to make decisions and stand for them as important for the VDC-specialist.

Several of the interviewees, both from the VDC-group and the managers have during the interviews difficulties to separate the VDC-specialist from the VDC-expert and explain how they differentiate from each other.

5.2.3 VDC-expert

When the VDC-expert is discussed the managers found it more difficult to define the VDC-expert than the interviewees belonging to the VDC-group. The VDC-expert is described as a person with high technical expertise within many of the VDC-areas, software programs and methods. Furthermore the VDC-expert should be able to interpret the development of specific parts into a more holistic view including and considering both VDC and the construction process. Hence, being more of an academic and visionary person who enjoys doing a more research oriented work rather than practical, hands-on in the construction projects. The VDC-expert is further described as a person with many years of experience from working with VDC. Two of the interviewees characterized the VDC-expert as a "classical geek"[5] with high interest and knowledge about technology, somebody that likes to think, develop and try new ideas and analyze. However, at the same time the VDC-expert's personal characteristics were considered by the interviewees to be similar to the VDC-specialist's.

5.3 Knowledge exchange concerning VDC

This chapter presents the empirical findings concerning the knowledge exchange between the three different VDC-professions and between the VDC-professionals and the other construction project members, which was investigated through the interviews.

[5] Original expression "klassisk nörd"

Knowledge management and knowledge transfer of VDC tools and methods in between the VDC-professionals do not occur in a structured manner today according to the interviewees. Although all the interviewed persons in the VDC-group express that they think that the knowledge exchange works fine today, they believed that there is a lot that can be improved. Central workgroups, such as VDC central strategic work group and two VDC development groups, has been established to develop and communicate improvements in the VDC-areas and have meetings on a regular basis. These workgroups include persons that more or less work fulltime with VDC.

Previous to the reorganization within the company a professional network, including the model coordinators (the predecessor to the VDC-coordinator), existed with the purpose to facilitate information and knowledge transfer between the model coordinators. This was done mostly on regional level but also within the whole company. According to the interviewees, the level of involvement by the previous model coordinator varied on personal level but the most variety existed between the former regions. The managers' attitude towards VDC influenced how much time and resources the former model coordinators were allowed to use for the network, which are highlighted by interviewees as a reason for the differences between the regions and why, eventually the network did not work as intended. Hence, the network was not prioritized by its members and the members' managers. In those former regions, in which the network has worked best, the participants had regular meetings, either in person or through telephone conference (Lync-meeting). During the meetings information about for example new VDC improvements and developments were shared and problems that had occurred in different projects were discussed and solved.

Today the most exchange of knowledge and information occurs in a more ad hoc way in the different offices and departments. The interviewees from the VDC-group know each other well and they know who they should contact in different matters. The knowledge exchange takes mostly place through personal contact between individuals in the same office.

> *"Yes, actually we do not have the network anymore, it is the way it is, we always transfer knowledge here in the building, those I receive help from today, who are VDC-coordinators, and that help me, we have an continuously dialog but that is the way we work and do it because it needs to function in our projects. Then you might not have as much contact with those who sit up-country for example in Stockholm, they run their race. It feels a little bit like we all do things in our own manner."*[6]

The exchange between the different offices and departments are expressed as limited and the best exchange occurs with persons they know well. An internal online forum, '*Starsites'*, exits today in which documents and work procedures can be found and exchanged and discussion regarding VDC can be held. However, this forum is strongly dependent on the activity of the users. One interviewee from the VDC-group highlighted what will happen if there is nothing new to find within the *'Starsites'*-forum:

[6] Original quotation: *Ja du, egentligen har vi ju inte det nätverket längre, så är det ju, vi överför ju liksom kunskap här i huset de som jag tar hjälp av idag som är VDC-koordinatorer och som hjälper mig, vi har ju en kontinuerlig dialog men det är ju så som vi jobbar och gör det för att det ska funka i våra projekt ju. Sen har man kanske inte så mycket kontakt kanske uppåt med de som sitter till exempel i Stockholm dom kör ju sitt race. Det är litegrann det känns litegrann så att vi gör ju på vårt sätt.*

"… if nothing happens there, no one will go in anymore and then it will die." [7]

One of the interviewed VDC-coordinators highlight the importance of knowledge exchange between the VDC-professionals and other employees in order to create an understanding for both VDC-task and the traditional way of working in the construction industry. One of the managers requests that the information exchanged during the meetings with the VDC-professionals should be more distributed to other employees in order to avoid creating "project islands"[8] in which the same problem is solved in several projects. A number of the interviewees request a new network for the VDC-professionals in order to increase the knowledge sharing and exchange of experience, especially if the number of persons working as VDC-professionals are to be increased. It should also be a way to connect the different offices and departments.

5.4 The VDC-professionals' work tasks

This chapter focuses on the job assignment and the different VDC-professionals' work tasks, identified both from the interviews and the survey.

During the interviews the interviewees in the VDC-group were asked to describe their daily work tasks and what they think that the different VDC-professionals should do. Furthermore interviewees working at management positions were asked what they expect or could imagine that the three different roles are doing. The answers to these two questions were combined and the work tasks for the VDC-professionals were differentiated and allocated to VDC-coordinator, VDC-specialist and VDC-expert as presented in Figure 13. The intersections of the three circles show work taks attributed to two of the VDC-professions, either the VDC-coordinator and the VDC-specialist or the VDC-specialist and the VDC-expert.

In general the tasks of a VDC-coordinator are more of operative nature and focus on supporting the design team as well as the construction team on-site. The specification of requirements is often described as a major task for a VDC-coordinator. Furthermore, tasks that are closely related to the use of visualization of models and their administration and handling are attributed to the VDC-coordinators' role. Some interviewees mentioned that ensuring the quality and correctness of the delivered models is also a significant task of a VDC-coordinator. It was mentioned by one interviewee that he/she had the impression that the role of a VDC-coordinator got more extensive due to the indolence of external consultants. Another interviewee said that it is imaginable that the coordinator includes two roles, one that is doing the co-ordination work and one that is executing all other tasks. The coordinators role was also termed as 'the bridge between design and production'.

Task intersections appear between the VDC-coordinator and the VDC-specialist as well as between the VDC-specialist and the VDC-expert (see Figure 13). Since the intersection affect the VDC-specialist from two sides, the VDC-specialists' role has only four tasks left that can be dedicated clearly to the VDC-specialist, all other tasks are partly occupied by the two other roles, VDC-expert and VDC-coordinator. Thereto the VDC-coordinator was assigned the highest number of work tasks, almost double the number of the VDC-expert tasks.

[7] Original quotation: " *… om det inte händer nånting där så är det ju ingen som går in längre och då dör det ju."*

[8] Original expression "projekt öar"

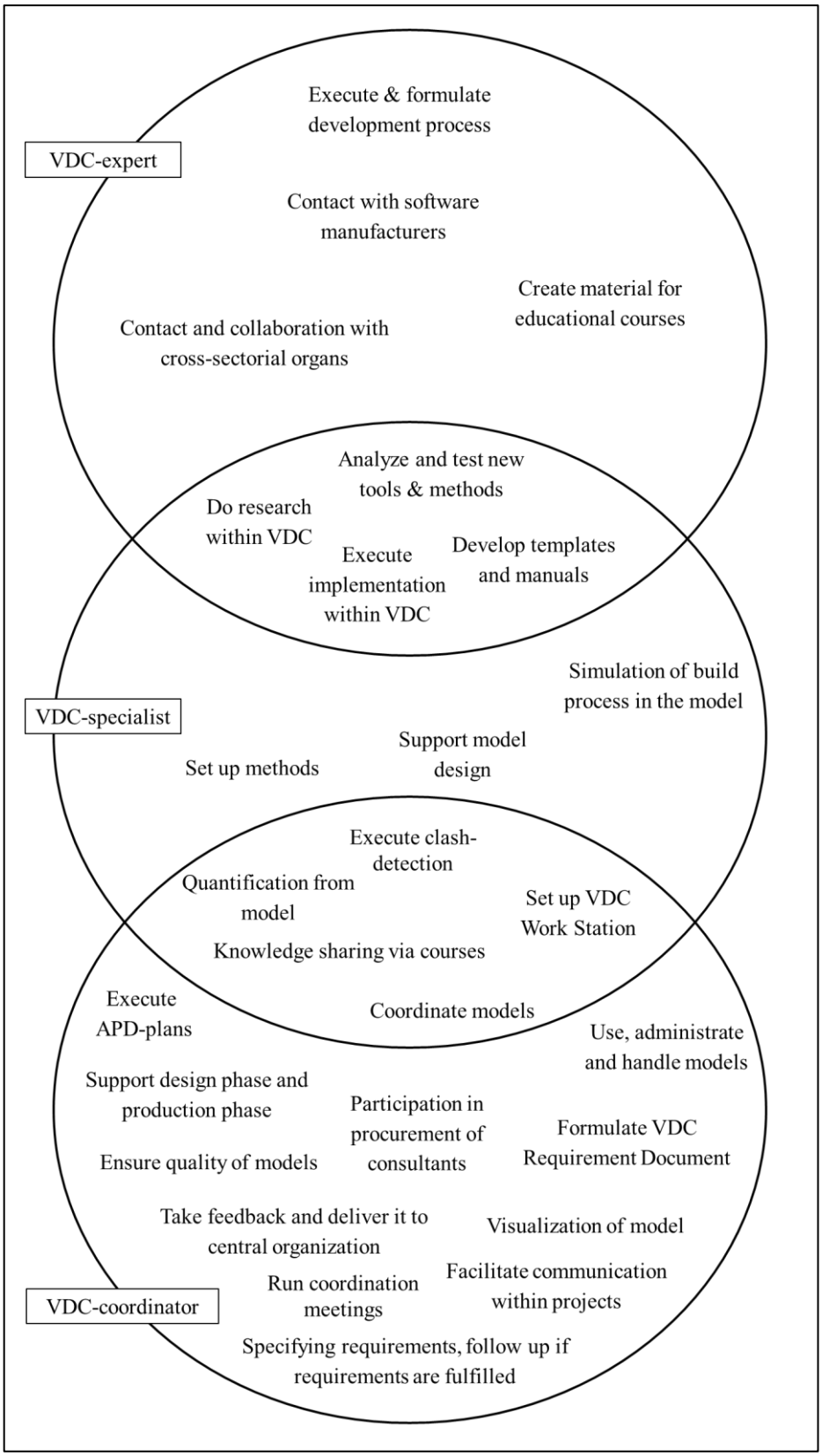

Figure 13 Work tasks assigned to the VDC-professions and their intersections

The VDC-specialists' role was defined by tasks such as formulating templates, testing new methods and tools, educate project participants, coordinating the use of VDC and supporting the department. Also the support of the VDC-coordinator was frequently

mentioned. In general the VDC-specialist should execute more complex and complicated tasks than the VDC-coordinator, like setting up VDC-Workstations on the construction site.

The tasks of the VDC-expert were described as research-orientated which includes to create and design templates and manuals, develop new methods and produce material for educational courses. The VDC-expert should also have meetings and contact with the manufacturer of software application and other participants of the industry and work in a larger scale, which includes to leave the boundaries of the own company.

The three most used applicable areas of VDC in the company today, according to the survey is; *'3D-models'*, *'Model coordination and Visualization'*, followed by creation of *'APD- and TA-plan'* (see Figure 14). *'Time planning*' and *'Laser scanning*' are the two areas that are being used to the least extent. The use of *'VDC-Workstation'*, *'Extract quantities'* and *'Setting out from model and equipment control'* received the most spread results. The division into the two analysis groups does not show a difference between them. This indicates that the view is rather unison within the company.

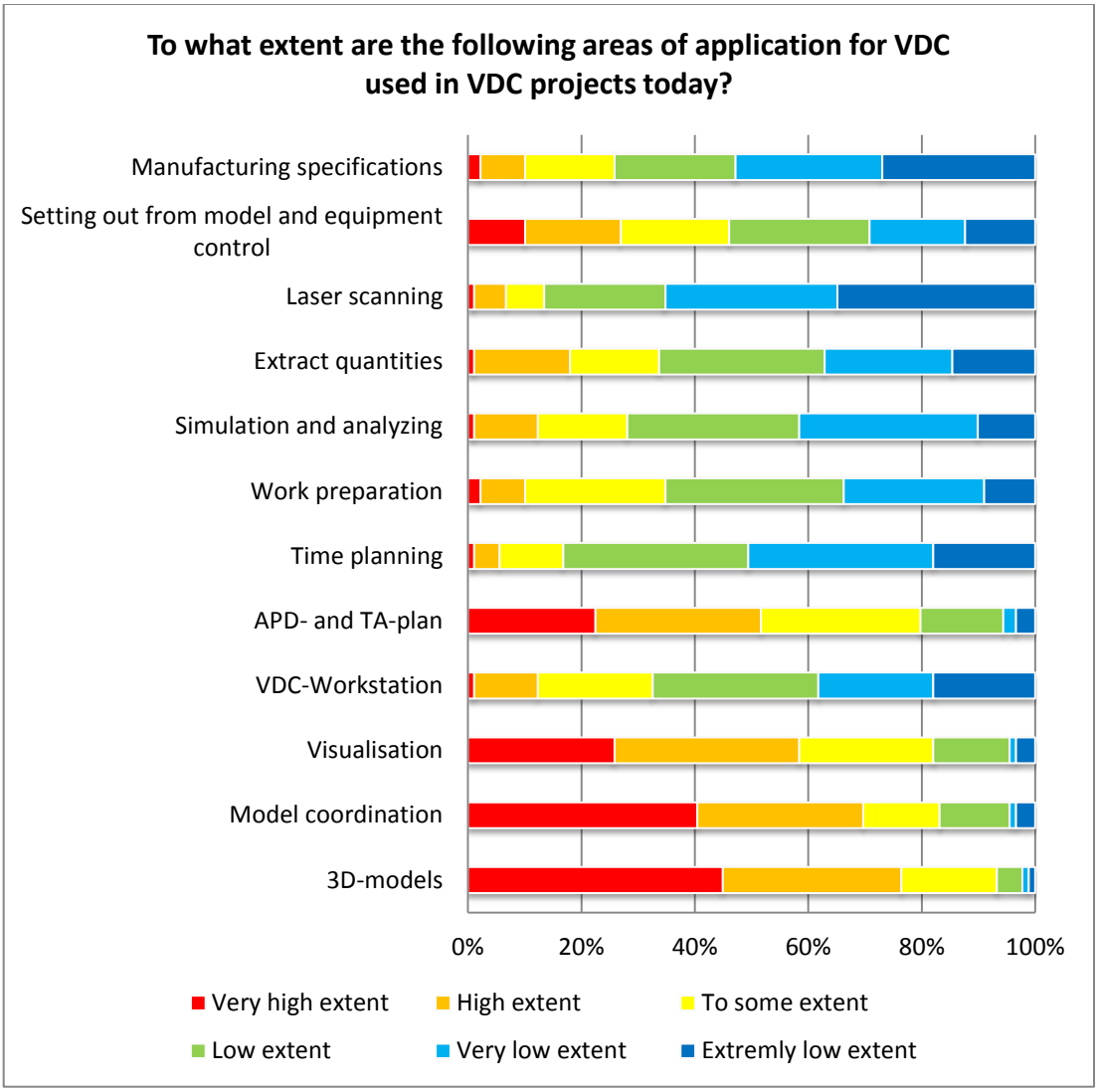

Figure 14 Response to the question "To what extent are the following areas of application for VDC used in VDC-projects today?", n=89

The result from the survey shows that there is not a unison view on whether the VDC-coordinator's tasks are clearly defined or not (see Figure 15). There is a tendency of vagueness regarding what a VDC-coordinator should do in a project. Only 2% answer that it is clearly defined to a very high extent. The result is spread but a majority disagree that it is clearly defined what a VDC-coordinator should do.

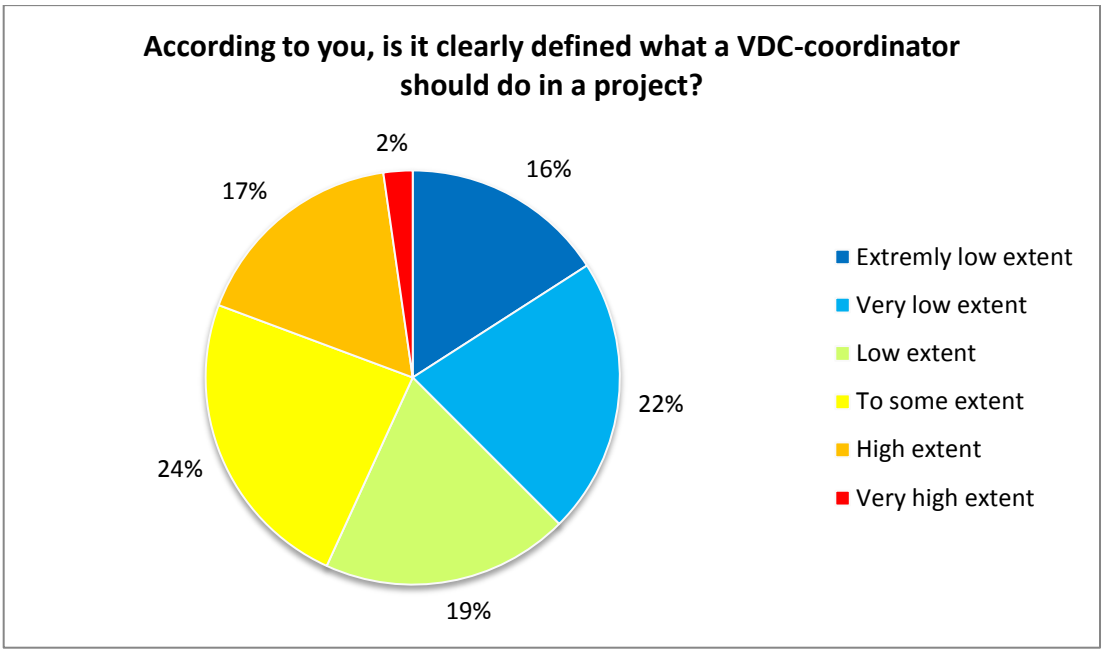

Figure 15 Response to the question "According to you, is it clearly defined what a VDC-coordinator should do in a project?", n=88

There is also a clear difference between the respondents from the VDC-group and the other group (see Figure 16) regarding the question if the VDC-coordinator tasks within a project are clearly defined. The respondents belonging to the VDC-group found it more clear defined than those belonging to the other group. At the same time there are larger variations between the answers among the VDC-group than among the other group.

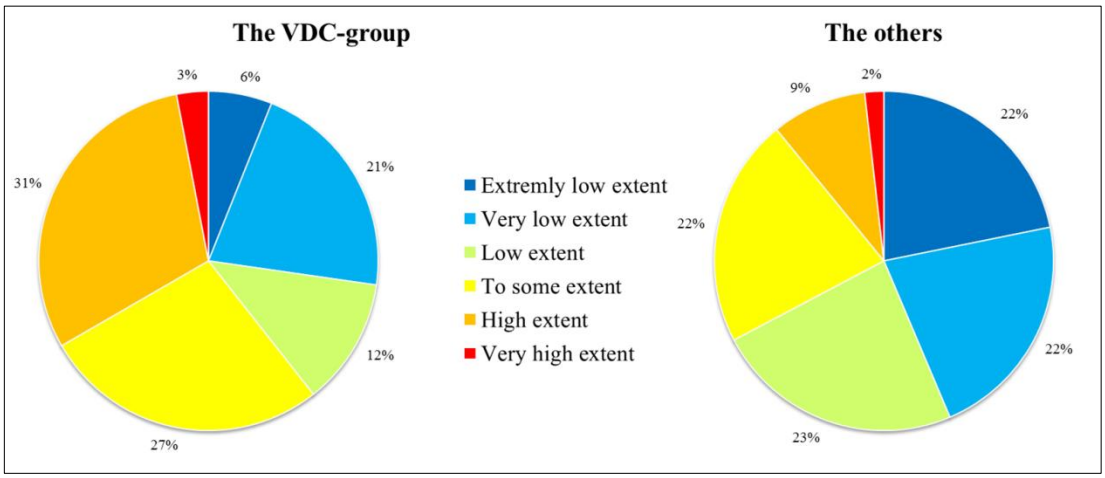

Figure 16 Differences regarding the clarity of the VDC-coordinator between the two analysis groups

According to the answers from the survey, the tasks that the most of the respondents think a VDC-coordinator should do is: *'Create and manage the coordination model'*, *'Manage VDC Requirement Document'*, *'Collocate VDC-experience from the project'* and *'Clash detection'* (see Figure 17). Other high rated tasks are *'Quality control of the model'*, *'support collaboration through visualization of the models'*. To *'facilitate communication'*, *'define metrics*' and *'simulations of work preparation'* are the lowest rated tasks according to the survey. The most disagreement among the respondents concerned whether or not the VDC-coordinator should define and manage metrics and the quality assurance of delivery to customer. The same tasks are requested that a VDC-coordinator should do when the groups are viewed independently, although the answers from the VDC-group are more united than those in the other group, which show more variation.

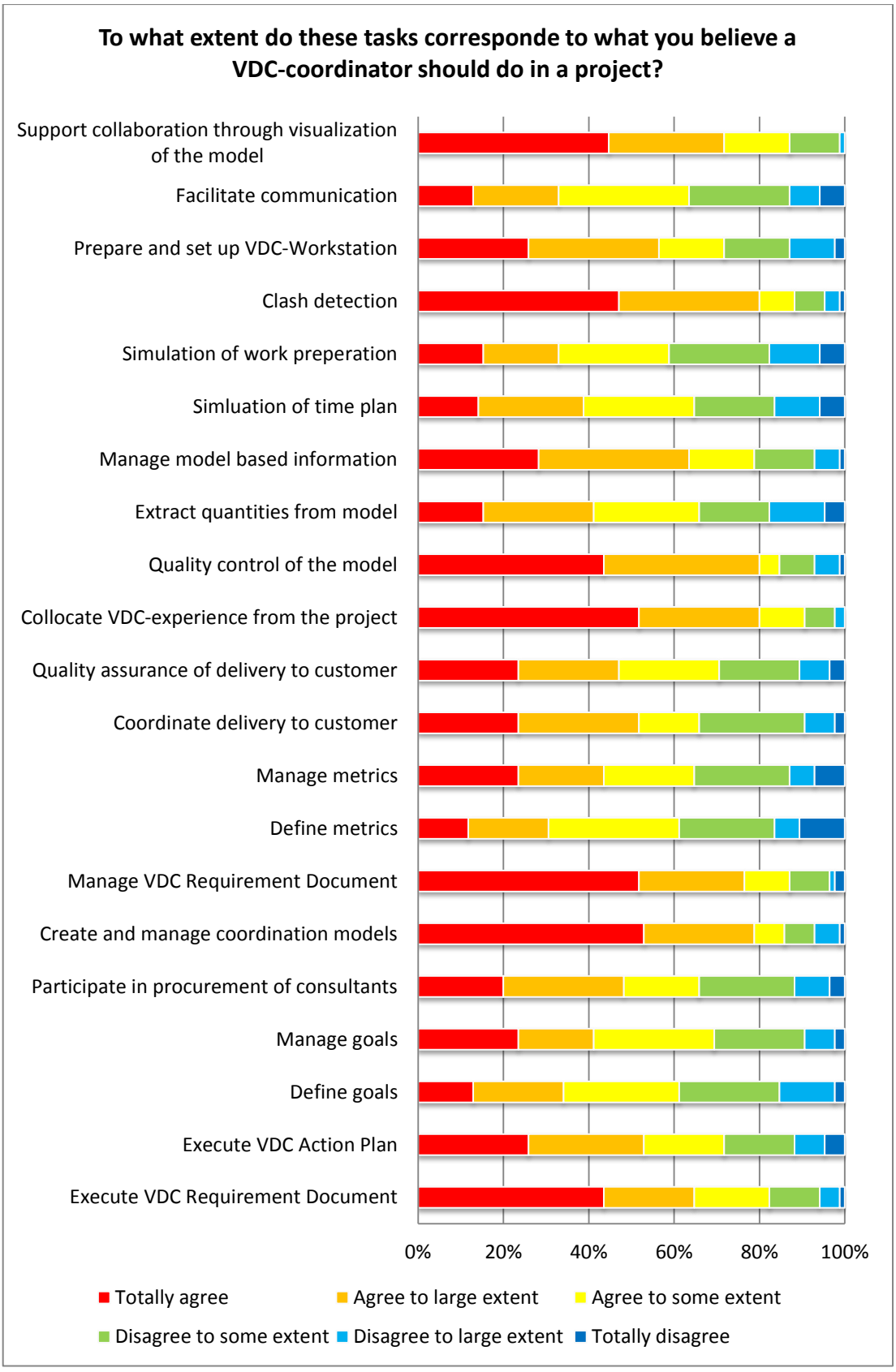

Figure 17 Response to the question "To what extent do these task correspond to what you believe a VDC-coordinator should do in a project?", n=85.

5.5 The VDC-professionals' involvement and responsibilities in projects

The involvement and responsibilities of the VDC-coordinator within projects are covered in this section. All interviewees agreed that VDC or rather VDC-coordinators should be involved in a project at a very early stage. Often it was said that it is most suitable to involve VDC-coordinators before the procurement of consultants since it should be possible to specify requirements in an appropriate way. However, another large number of interviewees mentioned the design phase as the stage where a VDC-coordinator should be involved. Subsuming there is a tendency to argue for an early involvement of the VDC-coordinator, although the interviewees are currently divided over which phase is preferable.

Earlier the VDC-coordinators got involved, according to the interviewees in the VDC-group, in best case, during the design phase. The VDC-professionals had to interlope into projects since they had not been informed about upcoming projects and have to 'chase' projects by own initiative, like the following quotations show.

> *"...earlier it was like this that we had to chase projects. When we got an indication that there was a project then we tried to run into it and introduce VDC."*[9]

> *"Well, involved or involved….I forced myself into [the projects], was I about to say!"*[10]

This was explained by the fact that the VDC-professionals had to contact the person responsible for the project instead of being contacted by i.e. the project manager. The right VDC-contact was not known by the responsible for the projects and the reorganization and the recent introduction of the VDC-professions were mentioned as reasons. Hence, the VDC-coordinators are not yet fully integrated. Furthermore, this was found to be dependent on in which of the previous regions the VDC-coordinator is active.

However from the surveys it can be said that almost all respondents (80 of 89) thought that the VDC-coordinator should be involved within the design phase (see Figure 18). Almost as many respondents (71 of 89) considered the VDC-coordinator to be active within the production phase. These two phases plus the phase 'hand-over' most of the respondents found the VDC-coordinator as the active VDC-profession. In contrast, the VDC-professional that most respondents thought to be active in early stages, hence 'sale to the external costumer' and 'tendering', is the VDC-specialist.

[9] Original quotation: *"... tidigare har det vart att vi har jagat projekten. Att när vi har fått nys om att det har vart ett projekt så vi försökt springa på det och introducera VDC."*

[10] Original quotation: *"Ja, inkopplad och inkopplad... jag slog mig in, höll jag på att säga."*

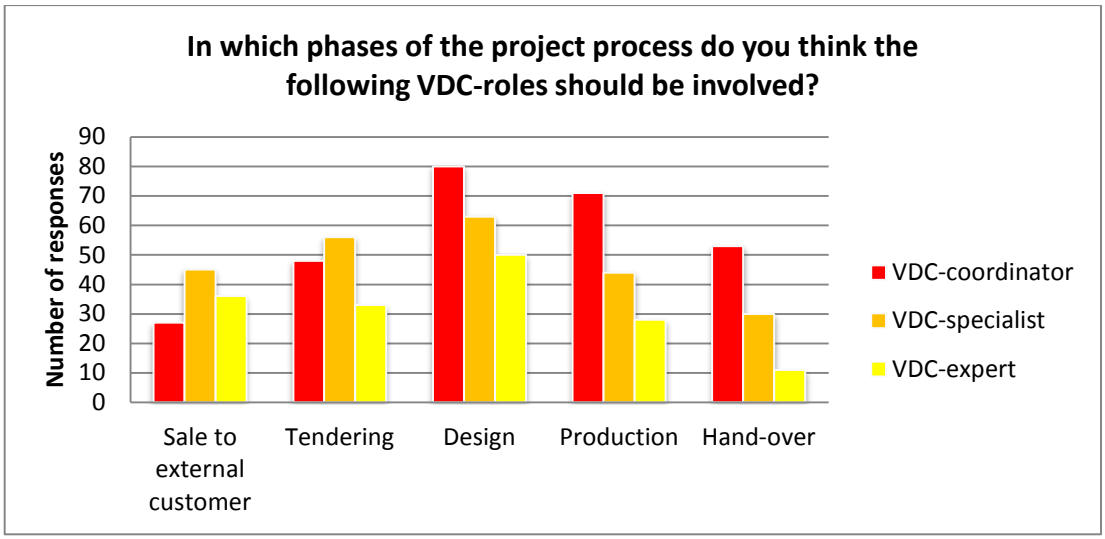

Figure 18 Response to the question "In which phases of the project process do you think the following VDC-professionals should be involved?", n=89

Today, the VDC-coordinator is most involved in the design phase of the project and almost not present at all in the sale to external customer and hand-over phase (see Figure 19). The VDC-group's perception of how involved the VDC-coordinator is in today's projects is higher than for the other group, which is also consistent in all phases. Both groups have the design phase as the phase with most involvement and sale to external customer phase with least involvement. The respondents who answered that the VDC-coordinator is not at all involved in the tendering, design and production phase, all belong to the other group.

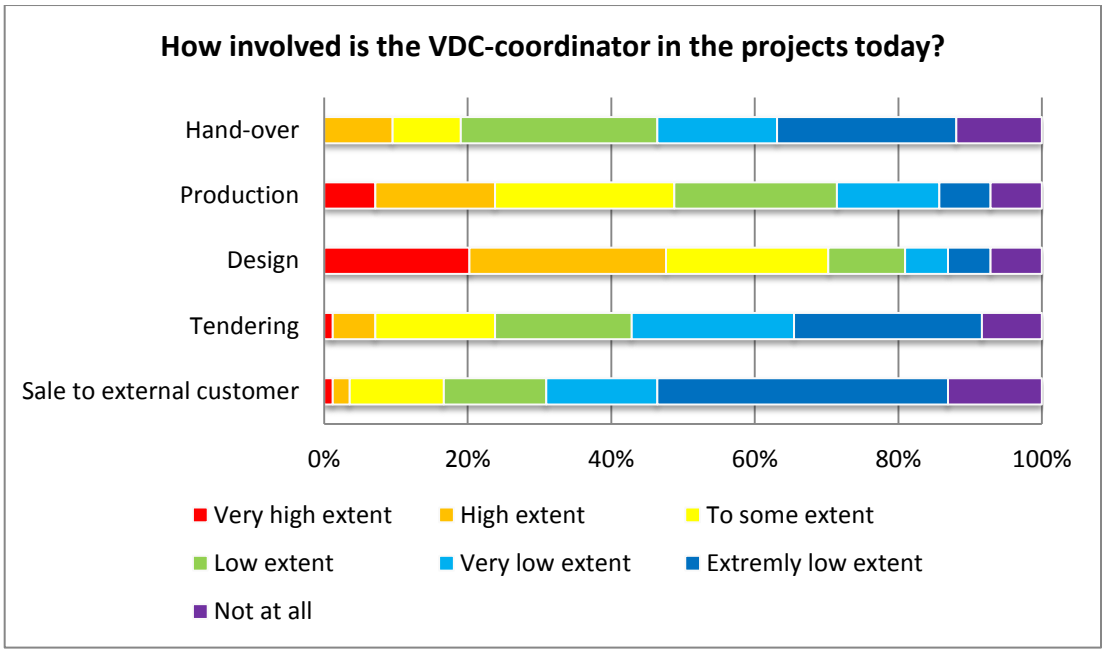

Figure 19 Response to the question "How involved is the VDC-coordinator in the projects today?", n=84

The responses from the question *"How involved should the VDC-coordinator be in the projects?"* show that compared to today, higher involvement from the VDC-coordinator in all phases is requested (see Figure 19 and Figure 20). Although the

least involvement is still in the sale to external customer phase and most involvement during the design phase. Overall the two groups' answers correspond to the total answers from the survey. Although, the respondents in the VDC-group want that the VDC-coordinator should be involved to a larger extent than the respondents from the other group.

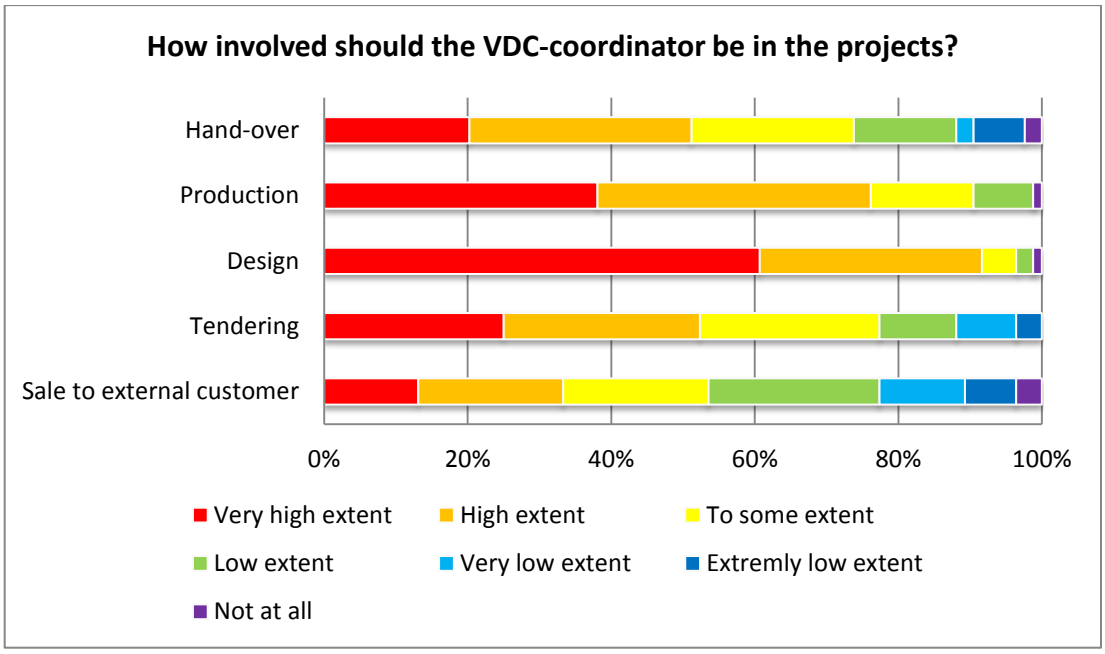

Figure 20 Response to the question "How involved should the VDC-coordinator be in the projects?", n=84

The majority of the respondents believe that the VDC-coordinators role is significant for the success of a project and only 18% think that the VDC-coordinator has 'low significant' or 'very low significant' for the success of a project (see Figure 21).

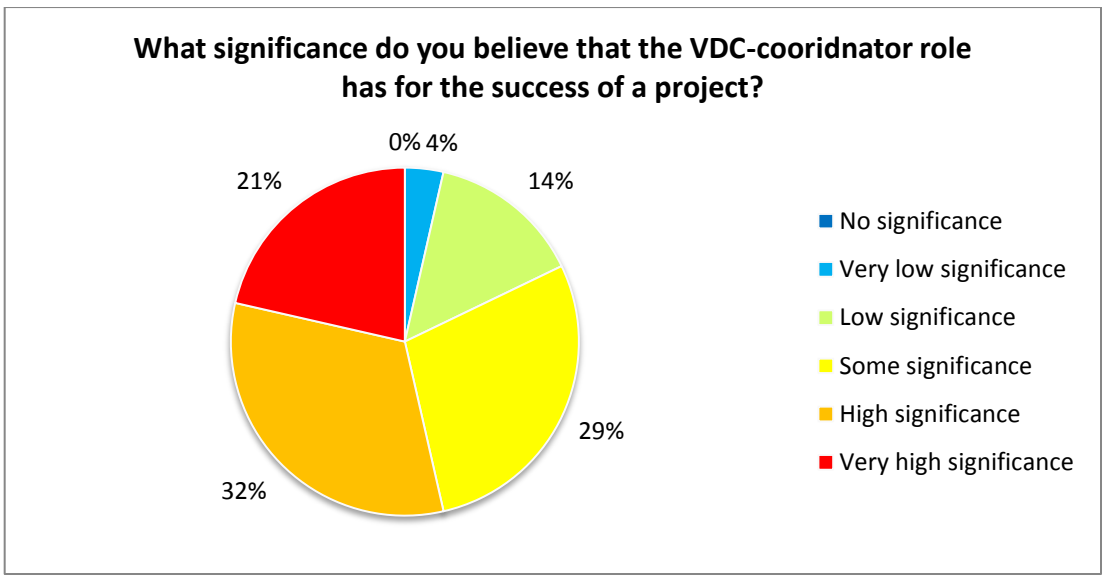

Figure 21 Response to the question "What significance do you believe that the VDC-coordinator role has for the success of a project?", n=84

The majority of interviewees had the point of view that the VDC-professionals should not have a formal responsibility for the use of VDC within projects. Since employees only should have responsibility if they are able to impact the area of accountability. Since the VDC-coordinator cannot control the use of VDC within projects, the traditional professions[11] and roles within a project should be the ones that have this responsibility (for example a project manager, production manager, design manager or a site manager within the production phase). Although the interviewees pronounced against a formal responsibility, they highlighted that work tasks imply duties and rights. Nevertheless, the interviewees considered the VDC-coordinator to be accountable for the process of specifying requirements and following up if the requirements were fulfilled by participating consultants. Furthermore the VDC-coordinator should show the possibilities with VDC and should make sure that the models work. As mentioned earlier, there is no formal responsibility and since the interviewees working as VDC-professionals tend to the opinion that a VDC-coordinator should be a project specific role, this area of responsibility could be placed at i.e. a construction engineer, site manager or project manager.

5.6 Organization and attractiveness of the three VDC-professions

This chapter deals with the organization of the VDC-professions, hence if they should be project specific roles or full-time employments, and the attractiveness of them.

The question regarding how the three different VDC-professions should be organized (as a project specific role or as a full-time employment) was discussed during the interviews. For the VDC-coordinator the majority of the interviews belonging to the VDC-group declare their self in favour of a project specific role which should work directly with the project and being part of the project team. The major reason for a project specific role were the increased effectiveness and keeping as few people as possible involved in projects. The points of view in how many projects the coordinator should be simultaneously active in varied between only one up to ten projects at the same time. The interviewees underlined that the number of projects are depending on the size of the project and the work load that is necessary to support the project regarding VDC.

The result from the survey shows that there is no unison view upon if the VDC-coordinator should be a full-time employment or a project specific role. The majority, 46%, want it to be a project specific role, and 36 % a full time employment. 17% of the respondents believe it should be a part time employment, which indicates that they would like to have the opportunity for the VDC-coordinator to do other tasks as well although at the same time have the pronounced VDC-coordinator title. When the two groups are studied, the result is almost the same. In the VDC-group 49% want it to be a project specific role and 44% among the other group.

Concerning the two other VDC-professions, VDC-specialist and VDC-expert, more clarity existed among the interviewees. The VDC-specialist should be a full-time employment and be placed in the departments within the organization. A direct connection or involvement within project groups was not deemed necessary. The same applies for the role of a VDC-expert. Although the VDC-experts do not

[11] In the context of this master's thesis, traditional professions are the already existing professions within construction projects before the introduction of the model coordinator and VDC-professions, i.e. site manager, tender engineer, service coordinator, construction engineer etc.

necessary need to be placed within the departments, instead they can be placed within the stab function Engineering and Sustainable Development.

The attractiveness of the VDC-professions within the company and in particular of the VDC-coordinators' role is considered to be influenced by a wide range of factors. Most interviewees expressed that especially the work within a topic that is under development and indicates effort within investigation and exploration makes these roles interesting. Dealing with leading-edge technologies is the core argument in this case. Besides the development of technology, the possibilities to develop personally are a further positive effect that was recognized by the interviewees. This is mainly triggered by the possibility to work within the whole process chain of construction projects and hence gain the holistic thinking within projects. This implies a great opportunity of promoting knowledge and expertise that can also be used as a fundament for a future career. Since experience from the complete project chain is important for some positions, a VDC-coordinators profession can be a suitable option to acquire this expertise. This can be seen as a possible career start, in order to become for example a design manager. However, the possibility of a clear career within VDC was more often mentioned than the possibility to take on other traditional professions. Therewith is the division into three different roles that indicates different levels of knowledge and experience a good variant to show a possible career path within VDC, according to the interviewees. Beside the existence of these three roles, a clear definition of the roles as well as a distinct work tasks, an explicit formulated area of responsibilities and plain objectives were mentioned as important aspects which positively affect the attractiveness of these professions. The interviewees agreed on the attracting effect it has to work within a topic that it is supported by the executive management and is part of a company's strategy. In addition, the fact that the tasks executed contributes to the company's profitability makes a job more attractive since it increases the feeling of involvement and participation. The support of the company's management is often reflected in the allocation of resources, like time and money, which is also mentioned as a positive influencing factor by the interviewees that promotes the desirability of these roles that are active within VDC. However, a major interest for the topic of VDC and virtual construction method is a prerequisite to find the VDC-professions attractive in general. Finally, the interviewees emphasized that varying work tasks and the possibility to use communication as an important tool within the daily work impinge positively on the attractiveness of VDC-professions.

Considering the respondents from the survey in regard to professions' attractiveness, the three most attractive factors were *'Nice colleagues'*, *'Stimulating tasks'* and *'Opportunities for personal development'* (see Figure 22). 97 respondents answered this question and all factors received similar and high rating from the respondents expect from routine tasks, which has the most spread and lowest rate.

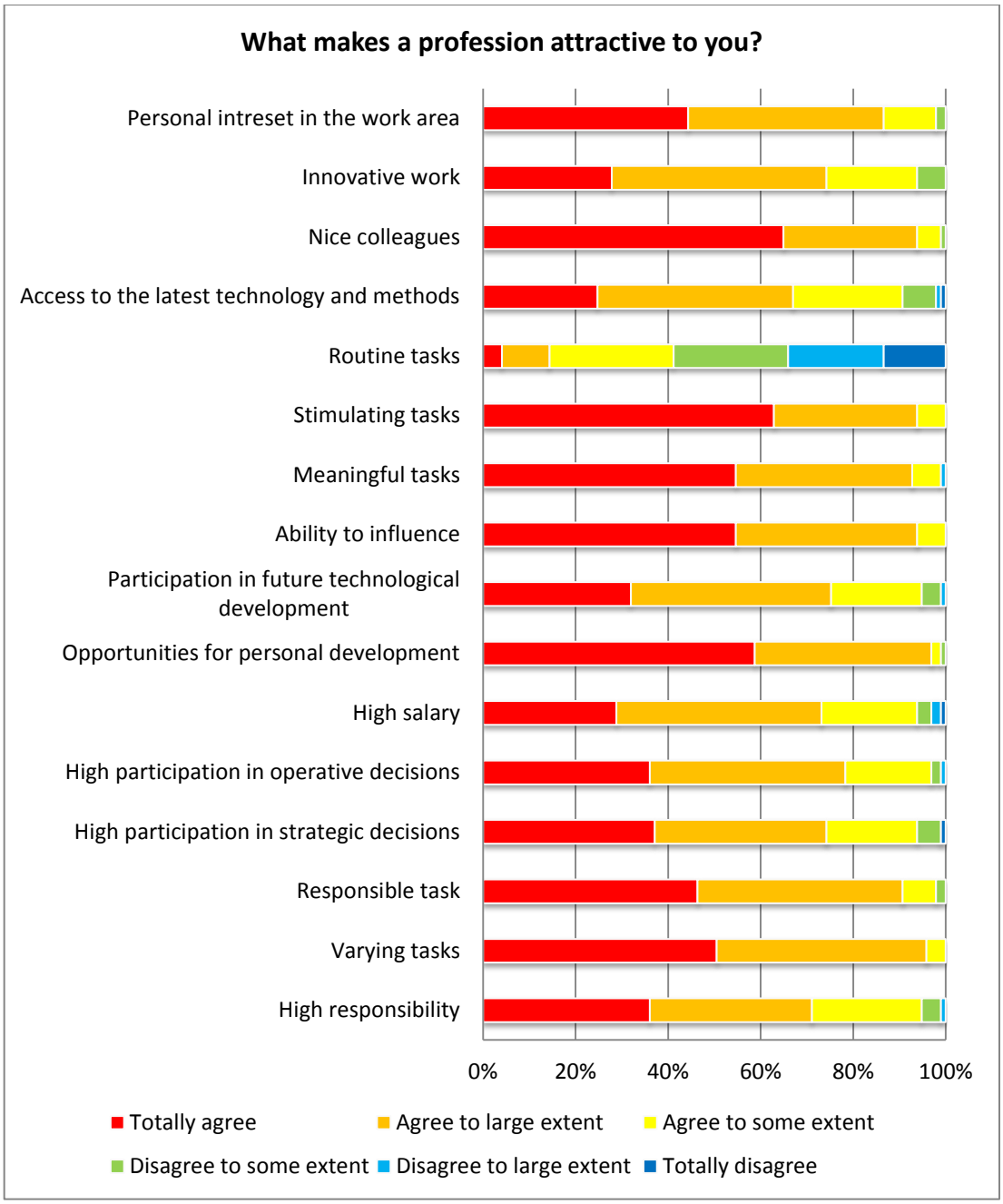

Figure 22 Response to the question "What makes a profession attractive to you?", n=97

5.7 Future development of the VDC-professions

This section presents the empirical findings regarding the future development of the VDC-professionals.

When the interviewees were asked how the VDC-professions will develop in the future a general tendency among the answers is visible. Most of the interviewees believe that there will be more VDC-coordinators in the future and that the role will have a significant importance. The VDC-coordinators will have increased their knowledge in order to support all parts of a project. How the role as a VDC-coordinator will appear in five years was not answered concordantly. Some interviewees have the opinion that the role should be appointed clearer for example by

assigning thirty percent of a job to the tasks the VDC-coordinator role require. This should help to allocate resources clearly. However, this is only the idea for short term, in particular the next five years. The interviewees that worked within VDC agreed that in longer terms the role as a VDC-coordinator will be integrated within traditional roles like design manager or construction engineer. One interviewee described this process as the trickling away of the VDC-coordinator into other type of roles. This indicates that there will not remain a clearly expressed VDC-coordinator but that the tasks related to VDC will be "business as usual" and a natural way of working for the traditional roles within a construction project. All interviewees agreed on that the VDC-coordinator role will consists of similar tasks in the future but that there will be more focus on ensuring quality. It will be easier to coordinate the models since the technique will be more implemented and advanced, therefore the realization of more complex and complicated construction will be possible. Anyway, to distinguish between project participants that work as VDC-coordinators and employees that simply use VDC as a natural way of working will be more complicated the more people learn to use the VDC-way of working. This corresponds to the survey result that shows that the majority of the respondents believe that the VDC-coordinator role will be more significant in the future (see Figure 23).

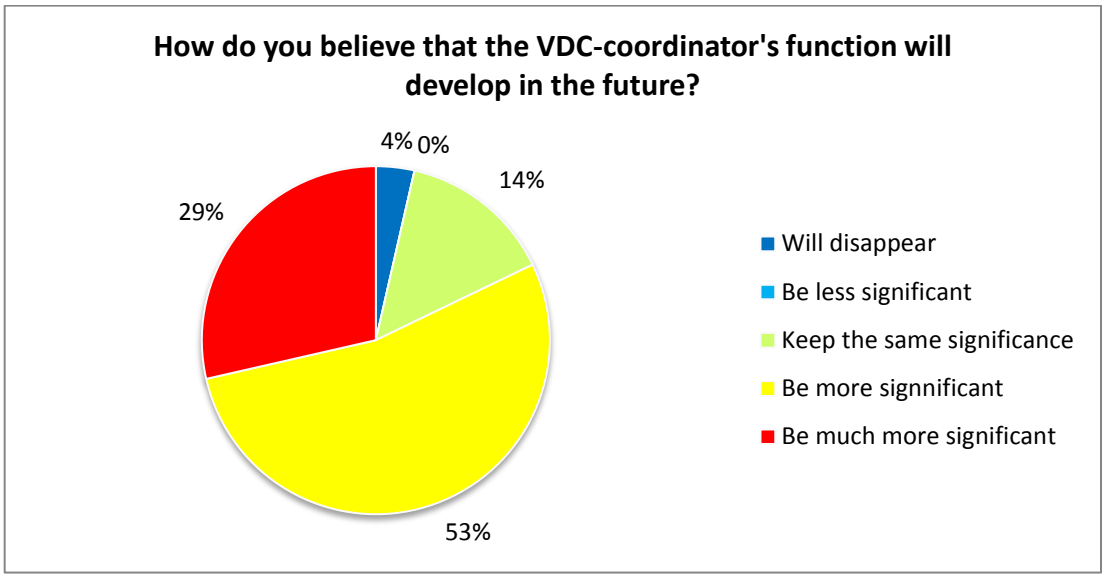

Figure 23 Response to the question "How do you believe that the VDC-coordinator's function will develop in the future?", n=84

The VDC central strategic work group use the described strategy (see Chapter 3 Case Description) and focus currently on educations of design managers and construction engineers. The design manager and construction engineer are the main targets for education since they are involved in all project phases, but since there is not always a construction engineer in every project site managers and supervisors also receive VDC-related courses. The educations should enable these traditional roles to take over the VDC-coordinator role and handle VDC-related task by their own. The main challenge is finding people that are really interested in visualization technology.

About the future development of the VDC-specialist and VDC-expert the interviewees were more unified than about the VDC-coordinator. They expressed that the VDC-specialist and VDC-expert will remain and the VDC-specialist will support VDC-coordinators if necessary but otherwise work with development and

implementation. The VDC-expert will continue with research and development of methods and tools.

Two interviewees mentioned that they think of a general transformation within the industry since younger people will grow up with these new technologies like visualisation and planning tools and will get educated within those already at university level. Therefore the effort to educate employees will be smaller for the company in a long term perspective. This transformation is accompanied by a general alteration of generations within construction industry. This will involve a lower effort convincing people about the benefits of VDC, which is often necessary today. However, one interviewee mentioned that the level of knowledge has to be increased since the tools get developed and the current expertise will be not adequate anymore the further the implementation of VDC goes.

One interviewee that works with the implementation of VDC described the current strategy of educating employees and developing VDC-coordinators as follow. The first step is to educate managers by executing courses that explain what VDC is and which tools are included. This course has to be visited by all leading positions. This should help understanding the company's strategy and enable managers to support their employees. The second step is VDC-basic courses for employees working for example as construction engineers, services coordinator, design managers or tender engineer to increase understanding and set the basic condition for a broad VDC-implementation. Additionally, positions like design managers should receive further educations in form of courses until they reach the knowledge level of a VDC-coordinator. Other professions like tender engineers receive courses adapted to their requirements. However, as one manager suggested that there will be a need to adapt and change education the further VDC will be implemented.

6 Discussion

The overall impression from the interviews and the analysis of the survey answers is that VDC as a new technology is seen as something positive and important for the studied company's future success. However, slightly different views upon the definition of VDC within the company were recognized, which seems to depend on the contingency that VDC is a wide concept which often depends on the individuals' interpretation.

Today the employees working as VDC-professionals at the studied company have to be very pro-active and sometimes even 'force' themselves and VDC into upcoming projects. This leads to a situation where VDC or VDC-professionals get involved too late. Therefore it is not always possible to use VDC in such a way that enfolds the full effect of VDC, which could increase profitability in the projects. Since the involvement of VDC often depends on the VDC-professionals, it seems that the VDC-professionals need a specific background and personality, which will be further discussed in this section. Furthermore the work tasks that were identified during the study will be discussed.

In order to achieve the company's aim with VDC, hence use VDC as a strategic opportunity to reach the company's objectives and goals, VDC has to become an established way of working within the company. The VDC-professionals were identified to be "catalysts for the implementation of VDC" and therefore their future development is of high interest.

6.1 VDC-roles and professions

The identified purposes for the introduction of the VDC-professions were *"to have the knowledge of VDC closer to the projects"*, that they should be *"catalysts for the implementation of VDC"* and *"to create a career path for the previous model coordinators, today's VDC-coordinators"*. Akintoye et al. (2012), Weygant (2011) and Mourgues et al. (2007) suggested an implementation of VDC specific roles, to handle the data and information related to the 3D-models. Since the company has worked with VDC since 2007 the company's purpose of the implementation of the model coordinator correlates with the researchers' suggestion. The implementation of the VDC-professions through the transformation of model coordinator to VDC-coordinator and the introduction of the two new professions VDC-specialist and VDC-expert can be considered as a way to further develop the model coordinator and increase the focus on VDC within the organization, hence further improve the implementation of VDC.

However, with the introduction of new roles, the roles also need to be defined. Both the literature and the findings from the interviews show that a role or profession consists of several factors which can be difficult to separate. During the interviews, the interviewees had difficulties to speak separately about knowledge, experience and personal characteristics for the VDC-professionals. The awareness of the three VDC-professions and especially the distinction between them was low among the interviewed managers, although the VDC-coordinator was known. Lynch (2007) describes that a role is often related to other roles. All interviewees related the VDC-professions to each other, especially when the VDC-specialist and VDC-expert were discussed. Additionally, it was found that there is more clarity about the VDC-coordinator than the VDC-specialist and VDC-expert. Thereto, no clear boundaries between the three VDC-professions seem to exist, see Figure 13 (in Chapter 5.4 The

VDC-professionals' work tasks) and Figure 24 (in Chapter 6.1.1 VDC-professionals' current work tasks). One reason expressed by the interviewees was the constant development of the roles and changes of names or designations. Thereto the possibility that a VDC-specialist can perform tasks related and connected to the VDC-coordinator, hence take on the VDC-coordinators 'role' within projects, creates confusion about which tasks belong to which profession.

6.1.1 VDC-professionals' current work tasks

The way to communicate and transfer information has changed due to the introduction of 3D-models and VDC (Russell et al., 2014). In turn, it creates new ways of working and new tasks, as earlier explained, new professions are introduced. The tasks connected to these new professions are visualization, virtual planning, administrations of data etc. (Akintoye et al., 2012; Azhar, 2011; Kunz and Fischer, 2012; Russell et al., 2014). These tasks correspond to the tasks mentioned during the interviews. According to Weygant (2011) the administration of data requires a pronounced single person within projects. The findings from the survey show that the VDC-coordinator should *"create and manage the coordination model", "manage VDC Requirement Document", "collocate VDC-experience", "clash detection", "quality control of the model"* and *"support collaboration through visualization"* (see Figure 17 in Chapter 5.4 The VDC-professionals' work tasks). These tasks correspond both with the tasks described in the theory and the interviewees' description of the VDC-coordinator's tasks. The tasks were described as more of an operative nature with focus on supporting the project. Figure 24 shows a further development of Figure 13 (see Chapter 5.4 The VDC-professionals' work tasks), in which regard is taken to whether the tasks can be considered to be close to the projects, hence operative, or more disconnected from specific projects and more of development, hence strategic.

As Figure 24 shows, the VDC-coordinator's tasks are found in the operative part and the VDC-expert's in the strategic. The VDC-specialist is working to some extent operative since there is an intersection with the VDC-coordinators tasks. However, the VDC-specialist also deals with strategic tasks like research and implementation, while the VDC-expert only performs strategic work. Notably is that only three tasks are identified specifically to the VDC-specialist. A reason could be the difficulties expressed by the interviewees to separate the VDC-professions from each other, which in turn indicates that no clear definition of the three professions was communicated when they were introduced. The interviewees had more difficulties to describe the interface between the VDC-specialist and the VDC-expert than between the VDC-specialist and the VDC-coordinator. Thereto the introduction of the VDC-professions was recent in time to the performed interviews within this case study, which also can influence the clarity of the professions. The survey result shows that the clarity regarding the VDC-coordinator's tasks varied among the respondents, especially if the other group is considered. Due to the emergence of the VDC-coordinator from the previous model coordinator, it indicates that perhaps confusion already existed about the model coordinator's tasks, which was transferred to the VDC-coordinator. Clarity of the VDC-professions' task are needed and requested.

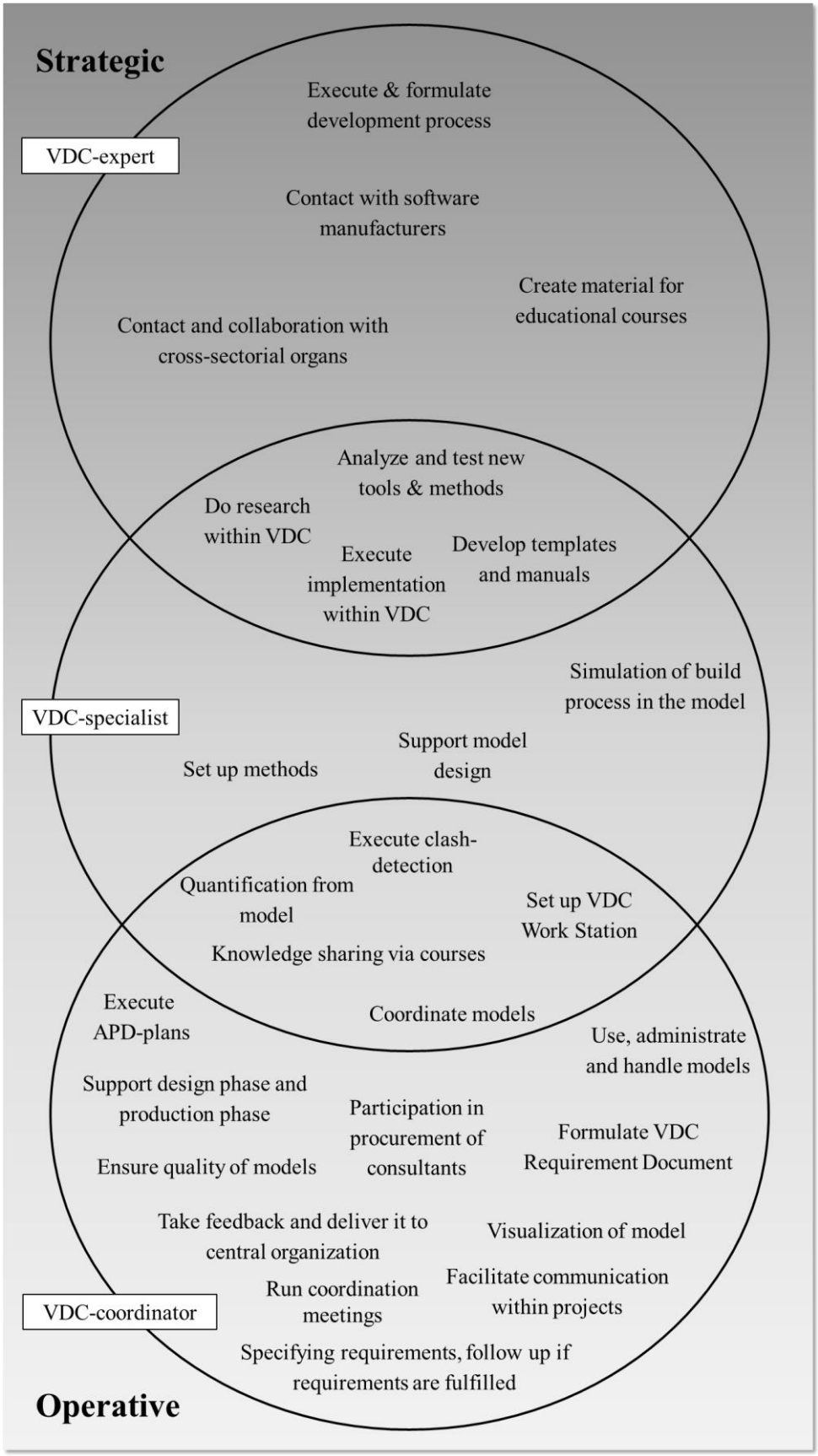

Figure 24 The VDC-professionals' tasks in regard of their either strategic or operative nature

Several of the interviewees, both from the VDC-group and managers, describe the VDC-coordinator's tasks to be more oriented towards dealing with different people within the projects than the specific VDC-technology. The focus on the VDC-technology is placed at the VDC-expert level and to some extent at the VDC-specialist as shown in the intersection between the VDC-specialist and VDC-expert in Figure 24.

6.1.2 Professions and creation of identity

If Mieg (2008) characterization of a profession is considered, a profession should have *"a central social value", "a knowledge domain", "an education or specific training"* and *"the presence of a professional association"*. The three VDC-professional roles have these four characteristics.

A central social value, that justifies a specific professional work, can be created through the support and recognition within the organization (Mieg, 2008). The studied company has put focus on VDC through involving it in their main efforts for growth of the construction and civil engineering business area. VDC should also be used in all projects, in which the company can influence the way of working. Although that the top management has highlighted VDC, it is important that the focus and support of VDC is transferred down in the organization. The support for and attitude towards VDC by the employees has an influence on the VDC-professionals' identity since the organization has a major impact on the construction of identity (Zunz, 1990 in (Brown and Duguid, 2001)). The survey results show that 82% of the respondents believe that the VDC-coordinator has high significance for the success of a project. A higher involvement of the VDC-coordinator in all phases of the construction process is also requested. This indicates that there is a positive attitude towards the use of VDC within the studied company, which is supported by the interviewed within the VDC-group and their perception and experience from implementing VDC within the organization. The empirical findings from the interviews show that the use of VDC is very dependent on individuals, both within the projects and at different management levels. One example is the former model coordinator network, which was prioritized by some model coordinators and their managers but not by others. This led to an ineffective network which stopped working and disappeared. A network, which works as a community of practice, can stimulate the members' ability to create shared identities (Brown and Duguid, 2001). Further advantages of communities of practice are the support for knowledge exchange and the possibility to create a connection between the members of the community and the organization. A community of practice created for the VDC-professionals, within the whole company, could be a possible way to reduce the identified differences between the previous regions both concerning knowledge exchange and to what extent VDC is used. Thereto establish the VDC-professionals' roles and identity, thus identity is *"an exclusively property of community membership, negotiated through participation"* (Smith, 2011) and roles can indicate behaviour, status or position in an organization (Lynch, 2007).

According to Mieg (2008) a profession should have a knowledge domain. The VDC-professionals' knowledge domain is the knowledge of VDC-methods, tools and software programs. Furthermore is an understanding of the construction process seen as required according to the empirical findings, although it might not be considered as a unique knowledge domain for the VDC-professions. The knowledge level of VDC-

methods, tools and software programs, that the three VDC-professionals should have, are illustrated in Figure 25. The basic VDC-coordinator's knowledge includes knowledge about how to use the software programs and understanding of the construction processes, which was identified both in the survey and the interviews. The VDC-coordinator only needs to have the basic coordinator knowledge whereas the VDC-specialist should have both the basic VDC-coordinator's knowledge as well as the VDC-specialist's knowledge. Both the basic VDC-coordinator's knowledge and the VDC-specialist's knowledge combined with VDC-expert's knowledge are needed for the VDC-expert. Due to that the survey focused on the VDC-coordinator, the knowledge level for the VDC-specialist and VDC-expert are identified from the interviews. The VDC-specialist's knowledge means an increased knowledge of the VDC-tools, methods and software programs. With the VDC-specialist's knowledge it is feasible to perform more complex tasks. A VDC-specialist should have knowledge of more areas within VDC, than at coordinator level, with in-depth knowledge in one or several areas. The VDC-expert's knowledge includes a high technical expertise within many of the VDC-areas of application, software programs and methods.

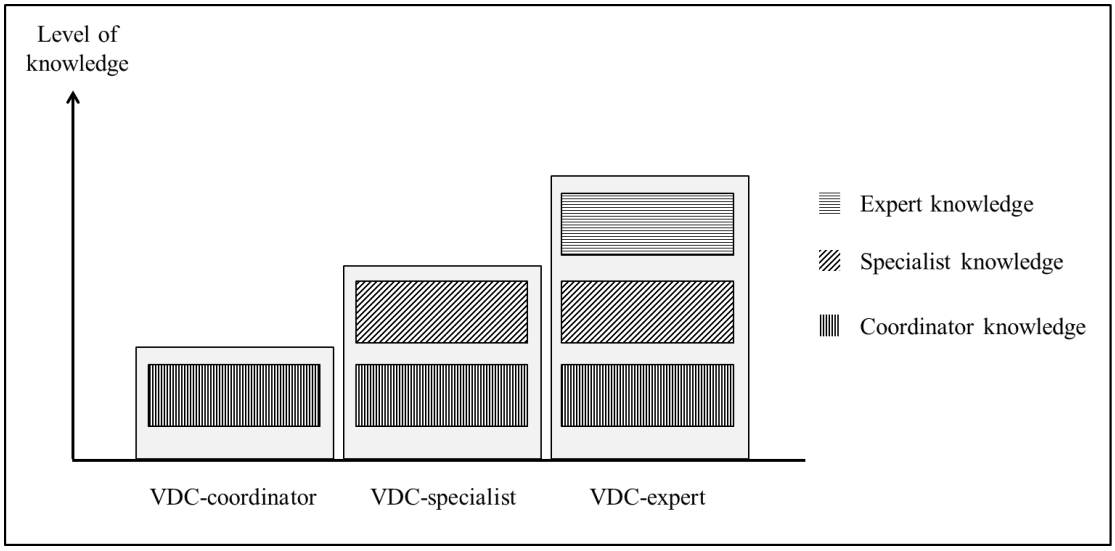

Figure 25 Level of knowledge for the VDC-professionals

The level of knowledge required is also connected to the professionals educational backgrounds and experiences, which Mieg (2008) includes in the characterizations of a profession. The interviewed from the VDC-group have all studied at the university and the survey result shows that 88% of the respondents belonging to the VDC-group have studied at a university. The empirical findings show that a university education for a VDC-coordinator is not a necessity, instead the personal characteristics are highlighted. An understanding of and experience from the construction process are considered as more important than a specific university education. The empirical findings furthermore show that the VDC-specialist and VDC-expert are considered to be more "academic" than the VDC-coordinator, which indicates the requirement of a university education. As Styhre (2012) indicated, the largest part of identity construction take place in the daily practise although education could be enough to act like a member of a profession. When the VDC-coordinator is considered, identity construction through the daily practise seems more important than identifying with a university education. Furthermore the empirical findings show that for the VDC-specialist and the VDC-expert the educational level is more important in order to construct an identity within the professions.

The experience and understanding of the construction process are in a similar way, as the level of knowledge, discussed through comparison between the VDC-professions. A basic understanding is needed to act as a VDC-coordinator, which is increased when the VDC-specialist is considered and an even higher understanding is required at the VDC-expert level. Experience from the construction phases should also increase in the same way as the understanding of the construction process. It is likewise not necessary to have experience from all phases although it is considered as an advantage. To have a holistic view is according to the interview findings needed for the VDC-expert and to some extent for the VDC-specialist. It was argued that the VDC-specialist and VDC-expert need to be able to consider the whole construction processes in their development and implementation of new VDC-tools, methods and software. The different levels of knowledge for the VDC-professionals were also used by the interviewees to describe how knowledge transfers between the professions from the VDC-expert to the VDC-specialist to the VDC-coordinator. This also indicates that the VDC-professionals can receive help and support regarding specific issues or problems that occur within the projects, for example that a VDC-coordinator receives support from a VDC-specialist. Additionally, the increase in both knowledge concerning VDC and experience enables a career path for the VDC-coordinator to become VDC-specialist and eventually VDC-expert. Combining the idea of the carrier path (from VDC-coordinator to the VDC-specialist and VDC-expert) with the described characteristics of the three different VDC-professions, the question that has to be risen whether a VDC-coordinator is capable to change and adopt personal attributes in such a way to be able to fulfil the requirements that were named for being a VDC-expert.

The general development of VDC within the construction industry (Russell et al., 2014) and certification course at Stanford University indicate a presence of a professional association. Internally, within the studied company, the creation of VDC Council, VDC central strategic work group and the VDC developing groups can be viewed upon as an internal professional association, thus it justifies the use of VDC, educate the employees and develop VDC.

Nonetheless, Turner (1974) (in Lynch (2007)) identified that the expectations upon a role and the level of agreement upon role performance as important influencing factors. It can be stated that the expectations upon the different VDC-professions vary between the different groups of employees within the company. However, the expectations on the roles have to be in unison to allow the VDC-professionals to identify their self with the role and adopt the role to such an extent so that the role can become an identity (Simpson and Carroll, 2008).

6.2 Knowledge transfer mechanisms

A lack of knowledge regarding VDC was identified by Mourgues et al. (2007) and Azhar (2011). Simultaneously, a urgent need exists to increase the understanding for the new technology and know-how within VDC to be able to implement it into the daily work (Azhar, 2011). From the interviews it was identified that the VDC-professionals are hoped to help the company to overcome the threshold and push VDC processes and methods forward. Recognizing the importance of the VDC-professions for the future development of the VDC-implementation their possible upcoming progress, also considering knowledge exchange, will be discussed in the next two sections.

Boh (2007) suggested that the characteristics of companies influence which knowledge sharing mechanism is best suitable for an individual business. The theoretical idea for knowledge-sharing mechanism and the two frameworks (see Chapter 2.1 Knowledge and knowledge management) has been combined in Figure 26. Applied to this case study, the studied company can be placed within *Quadrant 3* and *Quadrant 4*, thus the company is widely geographically spread and it is large both in terms of turnover and number of employees. However, many projects are standardized to a certain extent and do not require a high degree of innovation which supports the allocation to *Quadrant 3*. Nevertheless can *Quadrant 4* be adapted for the company because the implementation of VDC is one form of innovation and implies projects that are executed with new technology and new ways of working, hence a degree of uniqueness.

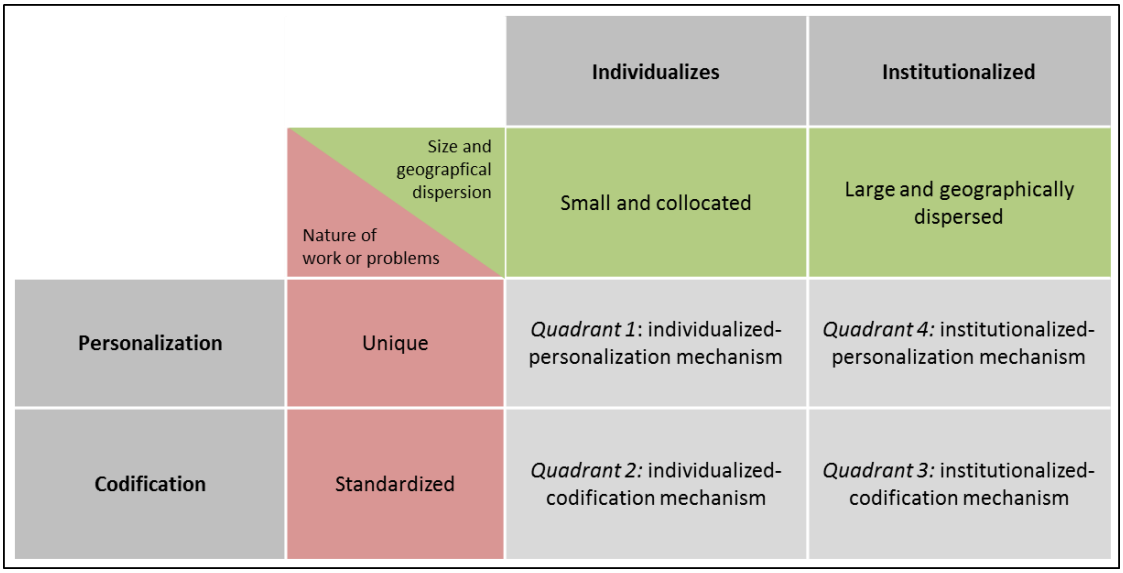

Figure 26 Framework of knowledge sharing mechanism inspired by Boh (2007)

The knowledge sharing mechanisms used in *Quadrant 3* grasp group-held knowledge and make the knowledge accessible for the rest of the organization (Boh, 2007). In the studied case, the group-held knowledge is the knowledge concerning VDC and how to work with VDC, held by the VDC-professionals. Tools that can be used to promote the knowledge sharing mechanism within *Quadrant 3* can be for example a knowledge-management program, (see Table 2). To use the knowledge sharing mechanism within Quadrant 3 a knowledge sharing base could be implemented that make the knowledge accessible for all employees within the company. This would enable the explicit knowledge to be shared, especially from the VDC-professions to the rest of the organization.

Table 2 Examples of Institutionalized knowledge sharing mechanism within the quadrants 3 and 4 (Boh, 2007)

Institutionalized-codification mechanism: *Quadrant 3*	Institutionalized-personalization mechanism: *Quadrant 4*
Knowledge-management program / data base	Create specialists Training of employees Cross staffing

One mechanism contained in *Quadrant 4* is 'to create specialists' within a topic that are not available to less experienced employees (Boh, 2007). In this case, these specialists are the VDC-professionals. The created specialists have according to Boh (2007) the advantage that they can collect and accumulate knowledge, like it is outlined in Figure 25 Level of knowledge for the VDC-professionals (in Chapter 6.1.2 Professions and creation of identity). The personalized dimension in *Quadrant 4* enable for the VDC-professionals to adapt their answers to less experienced employees' questions or specific problems. Additionally a community of practice can be used as a further source of knowledge and knowledge exchange for the VDC-professional (see Chapter 6.1.2 Professions and creation of identity). The VDC-professionals in the implementation and development groups have continual contact and meet on a regular basis, like described within Chapter 5.3 Knowledge exchange. Consequently the main focus should be on the transfer of knowledge between the VDC-professionals and the rest of the organization since professional communities of practice can create boundaries that cause hindrance of knowledge sharing.

To use VDC-coordinators efficiently for transferring knowledge they have to be available to every project if VDC should be implemented to one hundred percent. This can be a challenge within a project-based organization since the company consists of a large amount of temporary systems (Sydow et al., 2004) that are spread over a large geographical area. The choice to place the VDC-coordinators within the departments instead of the central department Engineering and Sustainable development can be seen as the first action to move towards the strategy of using VDC-coordinators as specialist in the sense that Boh (2007) defined the specialist. As the empirical data shows there is unity about the fact that there exist too few VDC-coordinators today and that they will be more significant in the future. However, the question whether a project specific role is enough to promote the knowledge transfer by using the VDC-coordinator as a institutionalized-personalization mechanism suggested by Boh (2007) has to be risen.

Since the construction industry is characterized by the fact that knowledge is mainly *"shared through storytelling and narrative accounts of experiences in the day-to-day work and not in lengthy written reports*" (Styhre, 2009) it is crucial to provide as many institutionalized-personalization mechanisms as possible. One possibility to promote institutionalized-personalization knowledge sharing is cross staffing (Boh, 2007). In the case of VDC-implementation this can be adapted by placing the VDC-coordinator into different project groups each time to help spreading knowledge. Another mechanism contained in *Quadrant 4* is the training of staff (see Table 2). Although that education of employees due to implementation of new technology is expensive, it is crucial to unlearn old methods (Li et al., 2009) in order to be able to

successfully implement VDC, hence new technology. The company has highlighted the importance of trained staff through its focus on educating the employees, both with internal and external courses.

6.3 Future development options for the VDC-professions

As Russell et al. (2014) acknowledged an introduction of new technologies requires updated roles and Akintoye et al. (2012) even suggest that new roles might be needed. The studied company has created the three VDC-professional roles due to the implementation of VDC, which is in line with both Akintoye et al. (2012), Weygant (2011) and Mourgues et al. (2007).

There might not be a need for new explicit roles to use the new technology (Russell et al., 2014). CURT suggests that the new work procedures and tasks could be in cooperated within existing or traditional professions. This raises the question whether or not the VDC-coordinator is needed in the organization as a profession or if the VDC-coordinator's tasks should be performed within existing traditional professions. How the VDC-professions will be formulated in the future is difficult to guess but there are different possibilities that seem suitable for the studied company's purpose. It is no doubt about that there will be changes and adaptions due to the implementation of a new technology (Akintoye et al., 2012) and that the status quo will not be situation in the future. A combination of the identified theoretical literature and the empirical data resulted in the identification of four possible development options, which are presented in Figure 27. The options take into account different scenarios for the organizational development of the VDC-professions and the location of the VDC-knowledge. The traditional professions are deliberately excluded in the top box showing the organization today, due to that the traditional professions do not have sufficient knowledge of VDC and explicit VDC-tasks or responsibilities in today's organization.

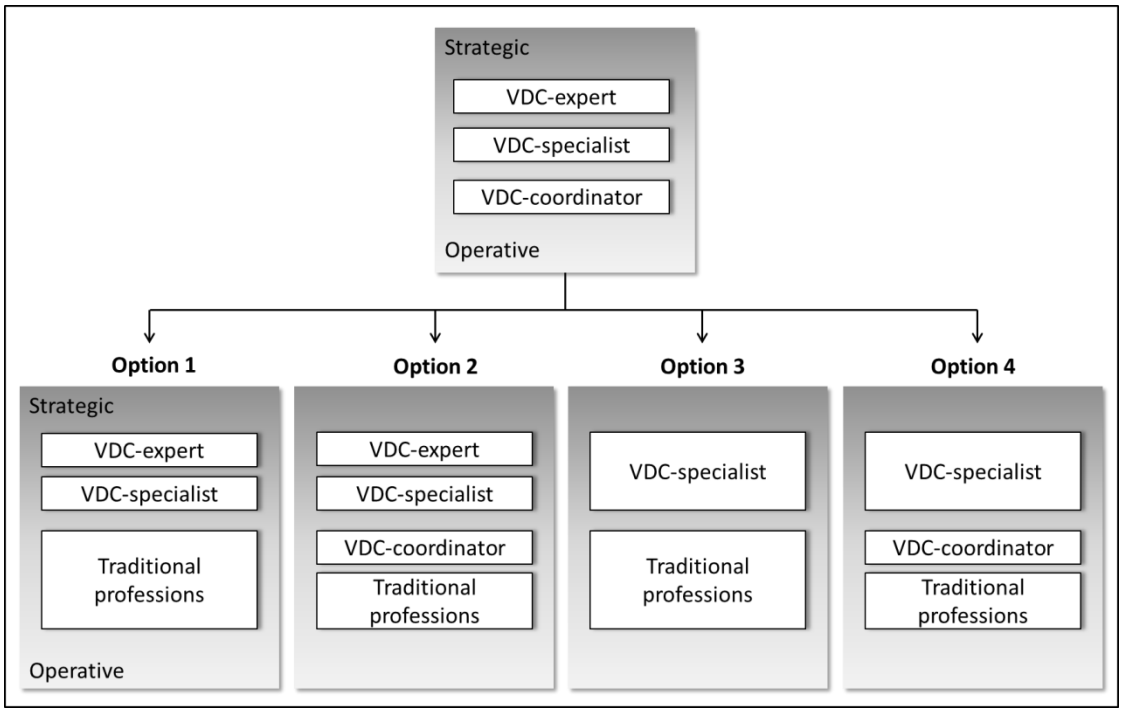

Figure 27 Future development options for VDC-professionals and professions related to VDC

At first sight, the empirical findings show no unison view concerning which form or kind of employment the VDC-coordinator should have in the future. From the survey the majority did not see the VDC-coordinator as a full-time professional employment, rather as a part-time employment or a project specific role. Furthermore there were no consistent descriptions from the interviewees regarding the future development of the VDC-coordinator and the final appearance after the completion of the VDC-implementation. However, considering the long-term development of the VDC-coordinator the interviews indicated, that the VDC-coordinators tasks will merge into traditional professions like design managers or construction engineers. Whether the profession as a VDC-coordinator should be visible by assigning the responsibility for the project's 3D-model onto one person within a project or hidden has to be discussed.

The majority of the respondents from the survey believe that the VDC-coordinator is significant for the success of a construction project and that the importance of the VDC-coordinator will increase in the future. Additionally, the result from the survey show that the majority of respondents request a higher involvement of the VDC-coordinator in all phases of construction projects than it is today. Only four percent believe that the VDC-coordinator will disappear or will be less significant. This could indicate that there is a need to keep the VDC-coordinator in the organization. The situation where the VDC-coordinator remains and the traditional professions will work more extensively with VDC is described as '*Option 2'* within Figure 27.

While *Option 1* and *Option 2* focus on the future situation within the operative work tasks, *Option 3* and *Option 4* examine the possible solution for the professions that are active within the strategic work. The majority of interviewees thought that the VDC-specialist and VDC-expert will to a great extent stay the same regarding knowledge and working tasks as well as the form of the professions. The VDC-specialist will remain working with development and implementation while the VDC-expert will continue doing research and develop methods and tools. Both, the VDC-specialist and the VDC-expert, are seen as full-time employments in the future. Anyway, the need of a separation of the VDC-specialist and VDC-expert can be questioned.

As described in Chapter 6.1.1 VDC-professionals' current work tasks , there is no clear distinction between the work tasks of the different VDC-professions and therefore the VDC-specialist currently perform both strategic as well as operative tasks. All four future options include a change for the VDC-specialist's tasks, in which the tasks will be of strategic nature instead of operative (see all four options that are presented in Figure 27).

The knowledge-sharing mechanisms within *Quadrant 3* (see Figure 26 in Chapter 6.2 Knowledge transfer mechanisms) were identified as suitable for the studied company. Which is also applicable in all options, since it makes knowledge accessible to a broader group of recipients (Boh, 2007). The mechanism can be used in form of a knowledge sharing program or a data base. In the consideration of that VDC should be part of all the company's activities, the data-base has to be accessible for all employees. These types of documents are today found in the company's intranet. Access to this type of documentation and information was considered to be of high importance by the interviewees. As recognized by (Boh, 2007) a large company as well as a project based organization makes it almost impossible to find the right person with the required knowledge and information. Therefore the storage and accessibility of the documents and information need to be central in order to facilitate

an efficient knowledge sharing. Furthermore was the importance of that the data base is constantly updated and used expressed by the interviewees. Hence the data base should help to promote the use of important and crucial documents like the VDC Requirement Document.

Another suitable way for the company to realize its knowledge transfer was identified. The VDC-coordinator can be used as a knowledge carrier, who can be seen as the created specialist described by Boh (2007). The VDC-coordinator shares knowledge with less experienced employees, in this context the traditional professions. To enable the knowledge transfer between the VDC-coordinators and the traditional professions it is essential that resources are allocated (Boh, 2007). During the interviews it was highlighted that the VDC-coordinator and VDC-specialist, who have other roles within the company simultaneously as their VDC-professional roles, do not have enough time assigned for VDC-related tasks and assignments. More time and resources were for example requested in order to support projects by answering VDC-related questions. Both these alternatives can be used during the transformation process from the current organization of the VDC-professions to either *Option 1* or *3*. For *Option 2* and *4* these alternatives are applicable in the future as well, due to that the VDC-coordinator will remain in the organization.

Regardless of which option the VDC-professions will be developed into in the future, there will still be a need to update the VDC-coordinator and/or the traditional professions about the developments of tools and methods etc. within VDC. This transfer of knowledge can then be supported by a mixture of *Quadrant 3* and *Quadrant 4* mechanisms (see Chapter 6.2 Knowledge transfer mechanisms). One possible combination of the two quadrants is to use the described data base and the mechanism 'create specialists'. These 'specialist' can in this case be the VDC-specialist and VDC-expert. They can be made available via a helpdesk function. VDC-coordinators and/or traditional professions can easily access knowledge and support when confronted with a problem during project execution.

Development *Option 1* for the VDC-coordinator

When combining CURT's point of view (Russell et al. 2014) and the empirical data a possible scenario is that the VDC-coordinator will be integrated within traditional professions for example design manager or construction engineer and hence no longer exist (see Figure 27 *Option 1*). CURT further suggests that the roles within VDC-projects are no others than within traditional construction projects but that the traditional professions need to handle the new methods by investing resources in *"produce, manage, and deliver more detailed, precise, and accurate information"* (Russell et al., 2014). The future situation would be that no VDC-coordinator exists but the tasks related to VDC will be business as usual within the project work.

To reach the future situation of *Option 1*, the traditional professions will need to develop basic skills and knowledge about VDC (Russell et al., 2014). Thus they need to be able to use the new methods and technology within their daily project work, which can be compared to the coordinator level in Figure 25 (see Chapter 6.1.2 Professions and creation of identity).

The main question will be how the knowledge transfer from the VDC-professionals to the traditional professions can be organized. Since this knowledge does not exist within this group of employees today it has to be transferred from the VDC-professionals to the traditional professions. At the same time the VDC-specialists and

VDC-experts will increase their knowledge level (Azhar, 2011) by accumulate and develop their knowledge.

The focus on training of employees, which is described as a method within *Quadrant 4* by Boh (2007) (see Chapter 6.2 Knowledge transfer mechanisms), could lead to knowledge transfer and the disappearance of the VDC-coordinator. It was identified from the interviews within the company that there exist different kinds of educational courses within different VDC-areas. Although it still seems insufficient to only focus on a limited group of employees (project managers, future VDC-coordinators and some users like tender engineers) in regards to education. Instead, the target of education should be changed from the future VDC-coordinators to the whole workforce that will work with VDC in their daily tasks. By focusing on the education of the traditional professions directly, the intermediate step through the VDC-coordinator to transfer knowledge is not necessary anymore.

If there is no need for VDC-coordinators, either because they will not be used as knowledge carriers anymore or the implementation of VDC is completed, the VDC-coordinators could either raise their knowledge level and become VDC-specialist or become a traditional profession. These two possibilities were also described by some of the interviewees.

Development *Option 2* for the VDC-coordinator

Within *Option 2* the VDC-coordinator will continue to exist in the future. This point of view is supported by Akintoye et al. (2012), Mourgues et al. (2007) and Weygant (2011), who believe that there is the need for a defined role that is responsible for managing the use of virtual planning and the contribution to the model as well as the administration of all data during the project.

In the case of *Option 2* the mechanism within *Quadrant 4* that is called 'Create specialists' can be used to share knowledge. In contrast to *Option 1* the VDC-coordinator will not disappear after the implementation of VDC but will undergo a change regarding the work tasks. Jaradat et al. (2012) suggest that 'document control' is not just a task but should be arranged as a new role. This can be arranged by assigning those tasks and responsibilities to the future VDC-coordinator within construction projects. Since some work tasks and knowledge has been transferred to the traditional professions, the extent of responsibilities for the VDC-coordinator will be limited to document control and administrating the models. This limitation of responsibilities raises the questions whether this would promote the old problem of unattractiveness of the 'model coordinator' as it was earlier described. Since the task of administrating the model is strongly dependent upon the size of a project (Gu and London, 2010) it cannot always fill a full-time employment. In this case the VDC-coordinator has to be a project specific role but clearly appointed to one of the traditional professions. As earlier described, it is important for the employees who work with VDC tasks to be up to date with different developments. If the VDC-coordinator is a project specific role, working at projects with durations of several month and even years, the question has to be risen regarding how to keep them updated. The VDC-coordinator can hardly use the knowledge about VDC every day and therefore maybe miss new developments within the technology.

The purpose to introduce the three different VDC-professions was, as the interviewees said, to present a way for development – both with regards to carrier as well as expertise and knowledge. From the surveys it was discovered that one of the three most influencing factors on the attractiveness of a job is *'opportunities for personal*

development'. This opportunity for personal development is given by *Option 2.* A further purpose of the earlier introduction of VDC-professions, especially of the VDC-expert, was to draw a clearer line between the roles dealing with VDC. Analysing the results from the empirical study, this attempt can be seen as not successful since 67% tend towards vagueness in regards to the definition of what a VDC-coordinator should do within a project. Furthermore most of the interviewees had difficulties to describe the difference between the VDC-specialist and a the VDC-expert and some thought that these two roles are almost the same. This implicates that the purpose of creating more clarity is not yet fulfilled. In the case that Option 2 is chosen a strong focus should be put on the clarification of the different VDC-professions in regards to work tasks and responsibilities.

Development *Option 3* for the VDC-specialist and VDC-expert

Within *Option 3* the operative tasks are assigned to the traditional professions. Thus *Option 3* is a variant of *Option 1*, but in contrast to *Option 1* there is no VDC-expert in the organization. Instead the tasks and responsibilities are assigned to a larger group of people called VDC-specialists, which means that the both professions VDC-expert and VDC-specialist are combined. The knowledge transfer between the different VDC-professions and traditional professions can be executed like it was described for *Option 1*, although the knowledge from VDC-specialists and VDC-experts will be combined in the future VDC-specialists.

By combining the both professions VDC-specialist and VDC-expert within one group it is possible to avoid uncertainty caused by too many different professions and vagueness of the border between them. Furthermore clarity is supported by having one group of professionals that work with VDC-topics and one group of professions that 'use' VDC in an operative way, hence within project work. The profession within the future group 'VDC-specialist' will fulfill the demands for an attractive role in regards of stimulating tasks and the possibility to focus on a topic that the employee is really interested in. Since the amount of work tasks will increase (including both work tasks from the former VDC-specialist and VDC-expert) it would be necessary that the future VDC-specialists concentrate and assign their self to one or several areas within VDC.

The group of professionals working with VDC (future VDC-specialists) can form a distinct community of practice. The benefits identified by Brown and Duguid (2001), Kodama (2006) and Smith (2011), in particular are shared identities which support knowledge exchange and the generation of innovations, which make the community of practice an attractive solution to develop and promote VDC. A problem with communities of practice can be that the knowledge stick within the community and is not transferred to other parts of the company (Ferlie et al., 2005) which is not desirable, especially when implementing for example new tools within VDC.

A drawback of Option 3 is clearly the missing career path or the obvious opportunity for personal development, which was highly appreciated both by the interviewees as well as the survey participants.

Development *Option 4* for the VDC-specialist and VDC-expert

Option 4 is a combination of *Option 2* and *Option 3*, the VDC-coordinator will exist in future but the VDC-specialist and VDC-expert will be merged into one profession called 'VDC-specialist'. This combines the advantages of *Option 2 & 3*. The community of practice represented by the future VDC-specialists can help to promote

innovation, knowledge exchange and strong identities. Furthermore the limitation to two VDC-professions, the VDC-specialist and the VDC-coordinator, helps to create clarity about work tasks and responsibilities but still provides the possibility of personal development to a certain degree and makes a career path visible. As it was described in Option 2 the VDC-coordinator will experience a change of responsibilities and can be designed as Jaradat et al. (2012) and Gu and London (2010) suggested.

7 Conclusions

The aim of the study was to describe and define the professional roles which emerged from the implementation of the new technology VDC. Furthermore the possible further development of the VDC-professions to facilitate and support future knowledge management and increased use of VDC was defined as a target of the master's thesis. The framework of knowledge sharing mechanism as presented by Boh (2007) as well as theory concerning professionalism and identity in regards to the technology VDC were presented and used to explore the status quo and present a fundament for the following empirical data collection. The following conclusions for the two research questions were drawn.

How are professional roles, emerging from the implementation of Virtual Design and Construction, VDC, defined?

The implementation of the VDC-professions can be considered as a way to further 'develop the former model coordinator', 'increase the focus on VDC within the organization', 'improve the implementation of VDC', 'clarify the different VDC-professions' and 'offer a career path within VDC'. The current VDC work tasks were identified to be separated into the three different VDC-professional roles and presented in Figure 17 in Chapter 5.4 The VDC-professionals' work tasks. The figure shows that large intersections between the VDC-professions exist. Therefore the results indicate that no established boundaries between the three VDC-professions seem to exist. However, a division between strategic work tasks (VDC-expert) and operative (VDC-coordinator) could be identified (see Figure 24 in Chapter 6.1.1 VDC-professionals' current work tasks). In the current situation the VDC-specialist executes strategic as well as operative tasks. Combining all findings regarding knowledge, characteristics and experience for the VDC-coordinator, the question has to be risen whether there are persons that can fulfill all the requirements that are requested. Especially if the VDC-coordinator is considered to professionally develop as the intended career path and eventually become a VDC-expert, since the characteristics and work tasks of the VDC-expert has a clear distinction to the VDC-coordinator's.

Both the literature and the findings from the interviews show that a profession consists of several factors which can be difficult to separate. However, all the VDC-professionals have the four characteristics for a profession defined by Mieg (2008) and can therefore be seen as professions. Nonetheless, the expectations upon professions and roles have to be in unison to make it possible to shift from a profession to an identity (Simpson and Carroll, 2008). The fact by which the VDC-professionals are defined, either by their knowledge and experience or by the work tasks they accomplish, plays an important role for the construction of the identity and thus for holistic implementation of the VDC-professionals as accepted professions within the company.

How can the roles of VDC-professionals be developed in order to facilitate and support future knowledge management and increased use of VDC?

The future development of the VDC-profession was divided into four different possible solutions. The organizational structure as well as the advantages and disadvantages for each solution are presented in Table 3 Advantages & disadvantages of the different development options for the VDC-professions.

Table 3 Advantages & disadvantages of the different development options for the VDC-professions

	Option 1	Option 2	Option 3	Option 4
Organizational structure				
Advantages	● Possible career path ● Educational focus on all employees	● Possible career path ● Clear assignment of responsibility to VDC-coordinator within projects	● High clarity ● Full use of community of practice ● Educational focus on all employees	● High clarity ● Full use of community of practice ● Possible career path ● Clear assignment of responsibility to VDC-coordinator within projects
Disadvantages	● Difficult to differentiate the VDC-expert/VDC-specialist ● No clear responsibility for models within projects	● Knowledge is spread to many places ● Lack of clarity between VDC-professions	● Knowledge can stick within community of practice – innovation hindrance ● No clear responsibility for models within projects ● Lack of career path	● Knowledge can stick within community of practice – innovation hindrance

Using the framework from Boh (2007) different mechanism for knowledge sharing were identified that suit the companies characteristics, hence institutionalized-codification mechanisms as well as institutionalized-personalization mechanisms. Diverse instruments that can be used exist within these two mechanisms. Firstly, the implementation of a knowledge-management program or a data base to serve all employees within the company with knowledge regarding VDC. Secondly, the creation of specialist, like the VDC-professionals, that can act as knowledge carrier and help supporting the knowledge transfer within the company. Thirdly, focus on training of employees within the area of VDC to enable the company to use the full potential of VDC and complete the implementation. Finally, adopt cross staffing in the form of using experienced employees or VDC-coordinators to spread knowledge from project to project. These four mechanisms are not fully used within the company

today, thus there is no functioning knowledge management data base and education is focused on a restricted group of employees.

Having presented the different development options and knowledge sharing mechanism the final questions to answer is: Should the VDC-coordinator be used as a knowledge carrier or should the VDC-coordinator be a profession that fulfills the demand formulated by research? Hence be a new profession within projects that deals with information and data management along with the responsibility for the visualization model or be a knowledge sharing mechanism. The authors' point of view is to use the VDC-coordinator as a knowledge carrier as well as a profession within project work. Therefore the most suitable future developments in regards to the VDC-professions within the studied company are *Option 3* and *Option 4* from Table 3 since these two options provide the most advantages combined with controllable disadvantages.

8 Recommendations and suggestions

Based on the results from this research we suggest that the company develop the VDC-professions in line with *Option 3* and *Option 4* from Table 3 (see Chapter 7 Conclusions). Therefore the authors recommend a further exploration and consideration of the two alternatives for the VDC-professions' future. Both options combine the VDC-specialist and VDC-expert within one profession called 'VDC-specialist'. The authors question the value of the VDC-expert as a separately communicated profession. By having two VDC-professions that have quite similar work task (which are described by the extensive intersections between these two professions, see Figure 13 in Chapter 5.4 The VDC-professionals' work tasks) or at least related work areas, confusion and vagueness are created. It not only seemed difficult for managers to draw a clear line between the VDC-specialist and VDC-expert but also for the interviewed VDC-professionals as well. Therefore the fusion of VDC-specialist and VDC-expert into one profession 'VDC-specialists' is recommended. Although the differentiation provides a more extensive career path within VDC, it does not justify the confusion that is generated by implementing two professions. Furthermore the combination of VDC-specialist and VDC-expert into one profession can support the full use of positive effects of a community of practice since all employees working with quite similar work task can identify their self with this community and can strengthen their identity. *Option 3* can be favored in regards to a high clarity since there exist only two different groups: 'VDC-specialists' and 'traditional professions'. However, there exist no clear allocation of responsibility in respects to data, information and the building information model within projects. This can be solved by clearly assigning this area of responsibility to one person within the project. Another benefit which supports the company's strategy to make VDC to 'business as usual' is the focus on educating a broader group of employees, hence the traditional professions.

Option 4 seems a suitable solution as well, because it combines the benefits from the community of practice with a clear assignment of responsibility in respect of data, information and the building information model within projects to the VDC-coordinator. Additionally a career path can be shown by having at least two different professions within VDC, hence the VDC-coordinator and the VDC-specialist.

In the authors point of view, a decision between these two options is not necessary, thus both can be used in the future. The two options can be used to define in which circumstances there is a need for a VDC-coordinator. Since the administration and information management effort grow as the size of the project increases, *Option 4* will be suitable for large projects since the VDC-coordinator can be a full-time employment when enough workload exists. In the case of smaller projects *Option 3* can be applied and thus a VDC-coordinator is not necessary. Using *Option 3* implies that there is no clear career path. However, by using the two options within the company the career path can officially be provided, although it is not applicable for all projects. Anyway, the work tasks assigned to the future VDC-coordinator and VDC-specialist have to be redefined and adapted to the chosen final situation. This involves deciding which factors will be decisive when defining the professions. Is the knowledge background and experiences determining or do work tasks decide which profession an employee belongs to? This question has to be considered when formulating the future professions and responsibilities.

The mentioned cross staffing as a knowledge sharing mechanism could help the company to overcome the geographical differences in regards to VDC-implementation. Since the implementation degree seems to depend on proactive individuals, those individuals could be placed at geographical regions where the implementation is at a lower level. The same applies for the different business segments. The extensive use of the community of practice and a possible network could be another alternative to decrease the differences between the previous regions. To be able to use these effects it is required to allocate resources in form of money and time to the network and the employees engaged within VDC.

One issue that was identified during the study is the process of involving VDC and VDC-professionals into projects. From the empirical data within this study it seems that there is no common way to decide which project should be executed by using VDC neither how nor when these methods or VDC-professionals are involved. Therefore a standardized process has to be formulated and implemented. However, how this process can be designed is a question of further examination within the studied company.

9 Further research

Some issues and research aspects were identified during this study, although they were not the focus of the study, hence included in objective and purpose. Therefore it will be necessary to consider and study these emerging queries in future research.

From the literature the question, which was also mentioned during two interviews, was identified regarding which party within a construction project should be responsible for the correctness of the model and project data which is used during all construction phases. Weygant (2011) described that this profession and thus the responsibility should be assigned to the owner or the facility manager. Some interviewees from the studied company stated that they had the impression that the role of a VDC-coordinator got more extensive due to the indolence of external consultants and that many tasks that consultants should execute are done by the company instead. Since the legal problem of model management and ownership was identified by earlier research (Azhar (2011); Bennett (2010); Russell et al. (2014); Weygant (2011)) as well as an economic and legal problem during the case study within the studied company, it should be a point of focus for future research and investigation. Since this question involves all parties within the construction industry the main tasks of investigating this issue should be academic research.

10 Reflections on the research process

During the time period when this master's thesis was conducted a reorganization within the studied company took place, where the previous geographical regions were eliminated and replaced by business segments. This organizational change was accompanied with uncertainty and temporarily lack of clarity which can have influenced the views of the interviewed persons and survey respondents. Therefore the results of this study have to be read and interpret with this factor in mind. Furthermore the studied VDC-professionals and their professions were analyzed when they still were continuously implemented and changed, see Chapter 3 Case Description. As these processes were on-going simultaneously as this study, new information communicated and the on-going development in regards to VDC and the VDC-professions within the company can have changed the interviewees and respondents points of view and opinions. Therefore this study can only give information from one point in time.

The limitation of time for this study is another factor which influenced the amount of interviewed persons in the company and thus the quality of the collected data. This applies especially for the number of interviewed managers. With a more extensive time period more managers and from more different levels within the company would have been possible to interview. In general, the issue of choosing the right people to interview for a qualitative data collection always needs to be considered. The choice of interviewees will affect the result and might create a bias in the result that will not represent the whole view of the company's perspective upon the VDC-professionals. Consequently, in general, the results are hard to generalize. However, the authors believe that the collected data about the VDC-professions have external validity in terms of adapting the VDC-professions in other construction companies that implement VDC, although roles always have to be adapted to the existing situation and context.

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APPENDIX I – Survey questions with answers

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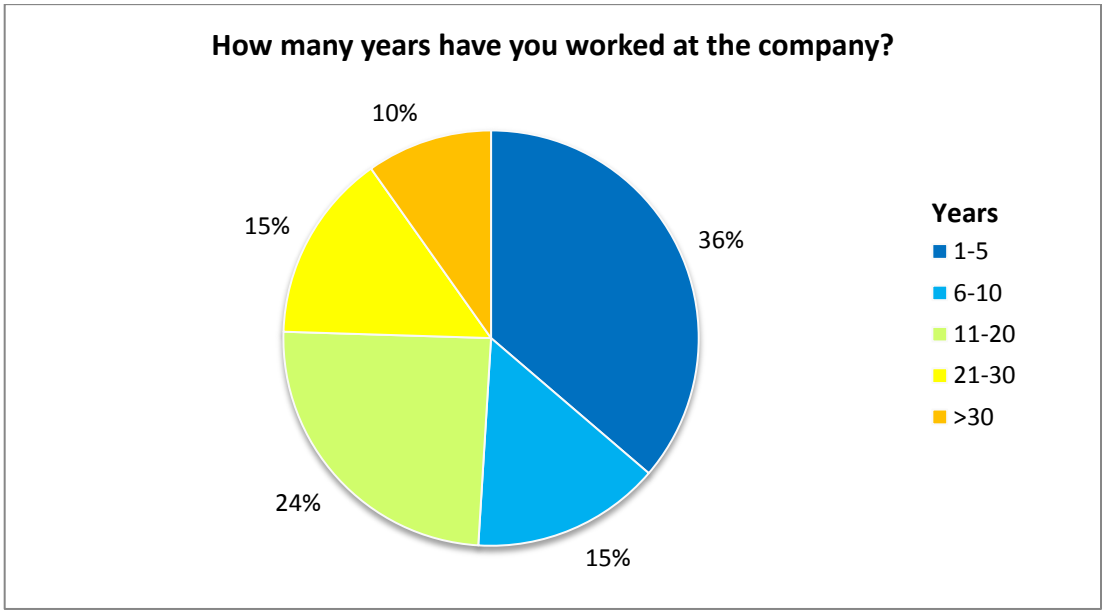

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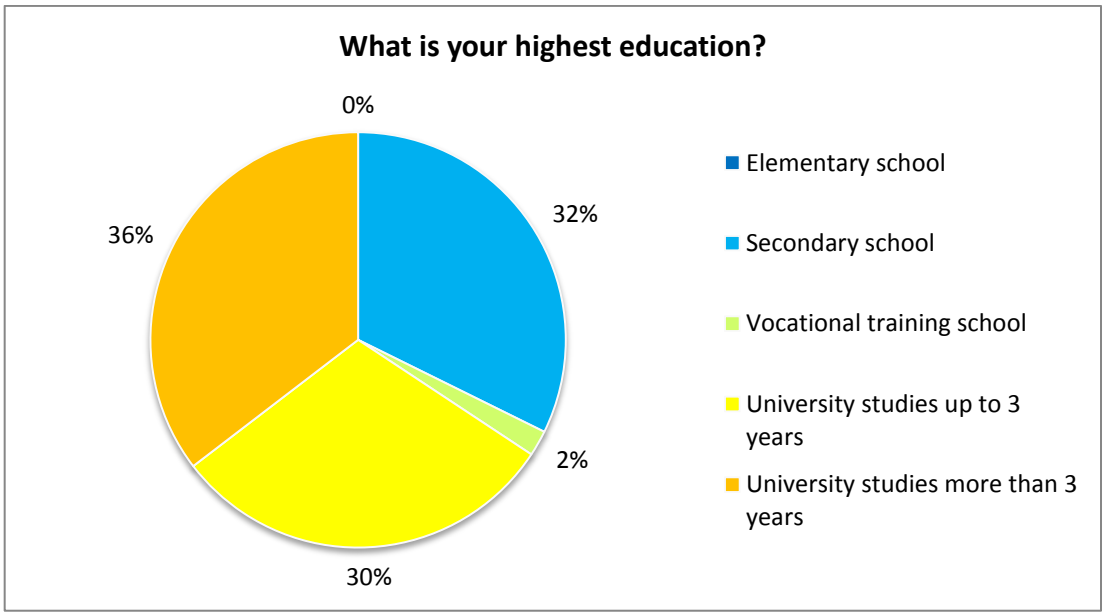

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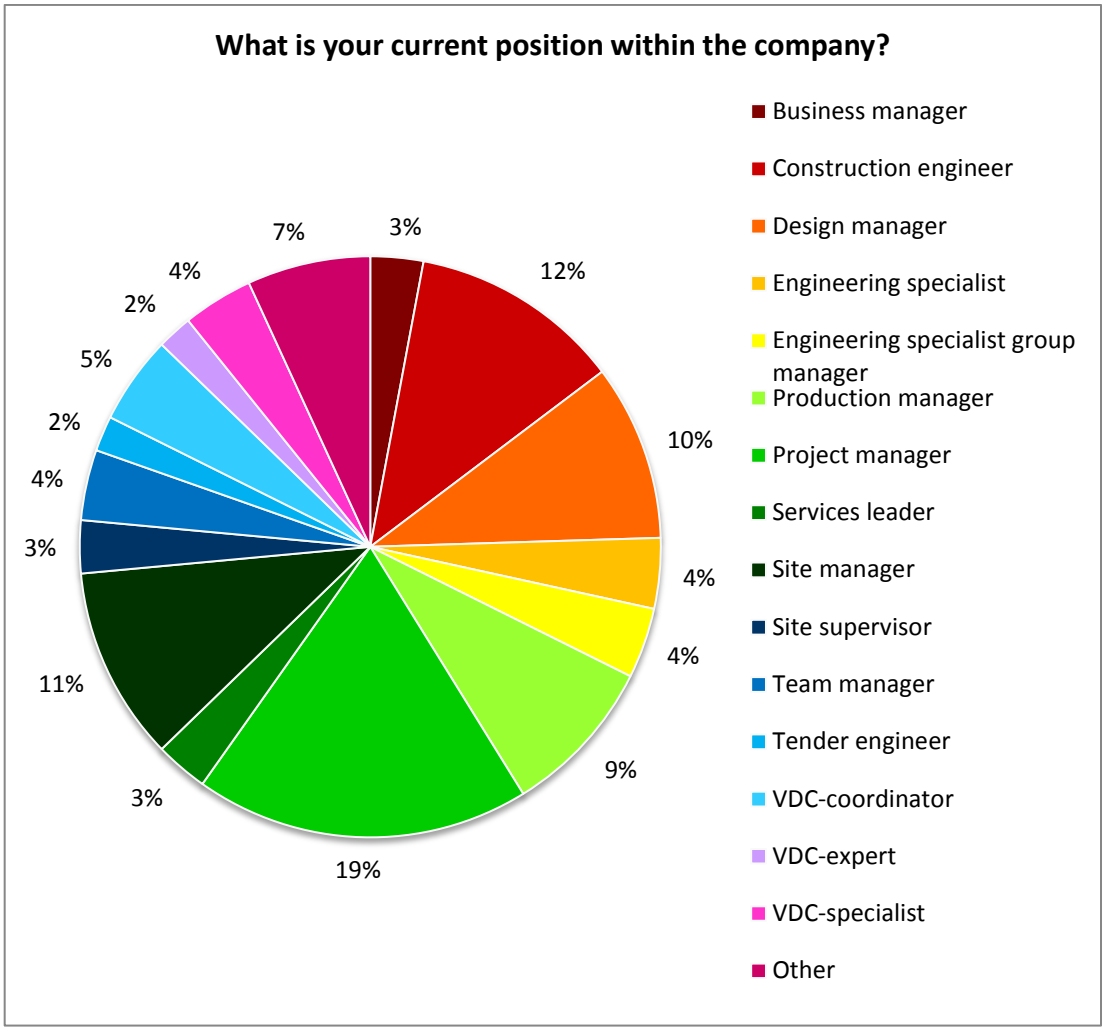

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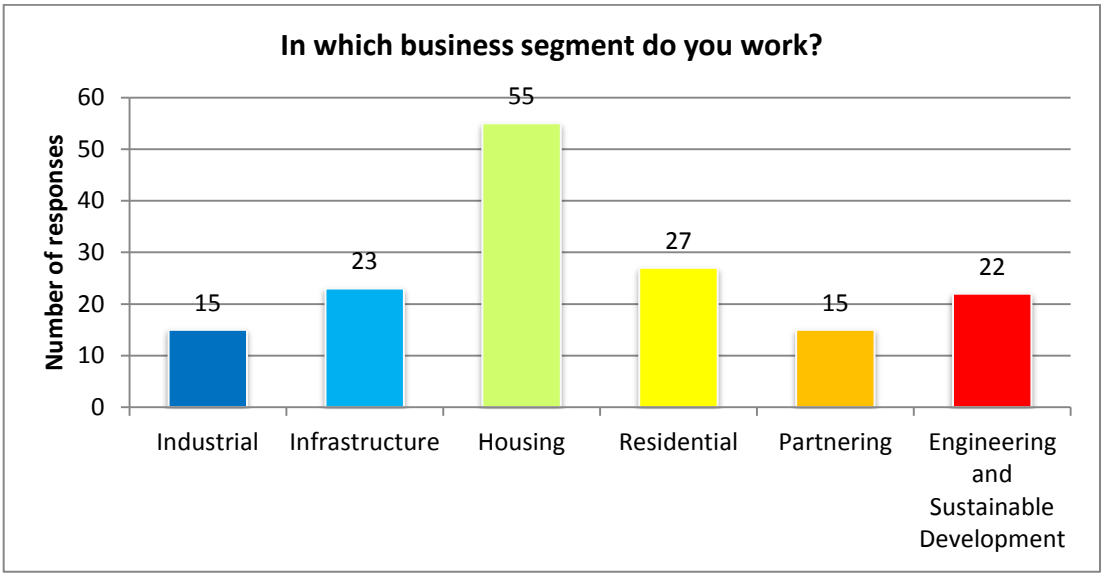

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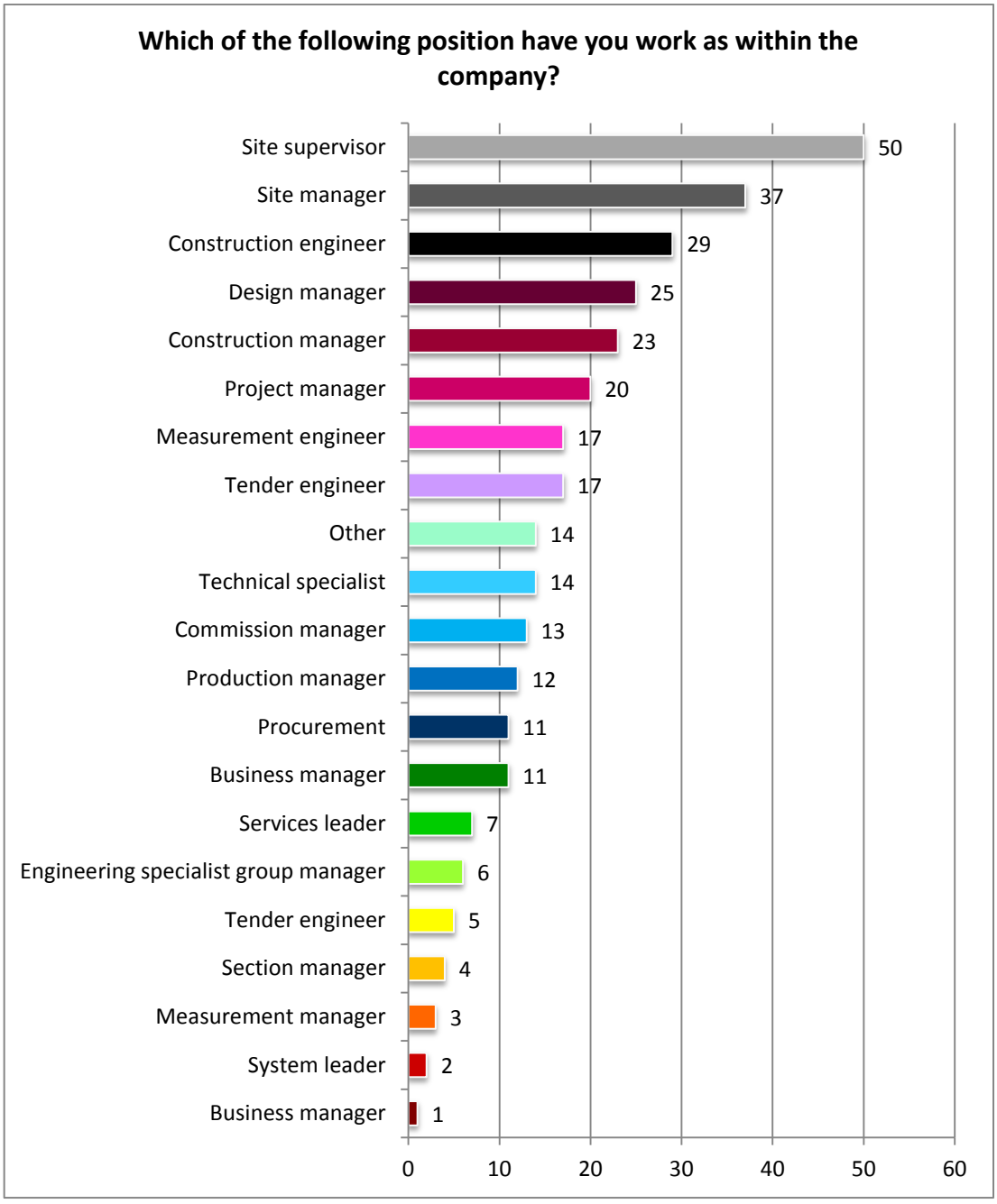

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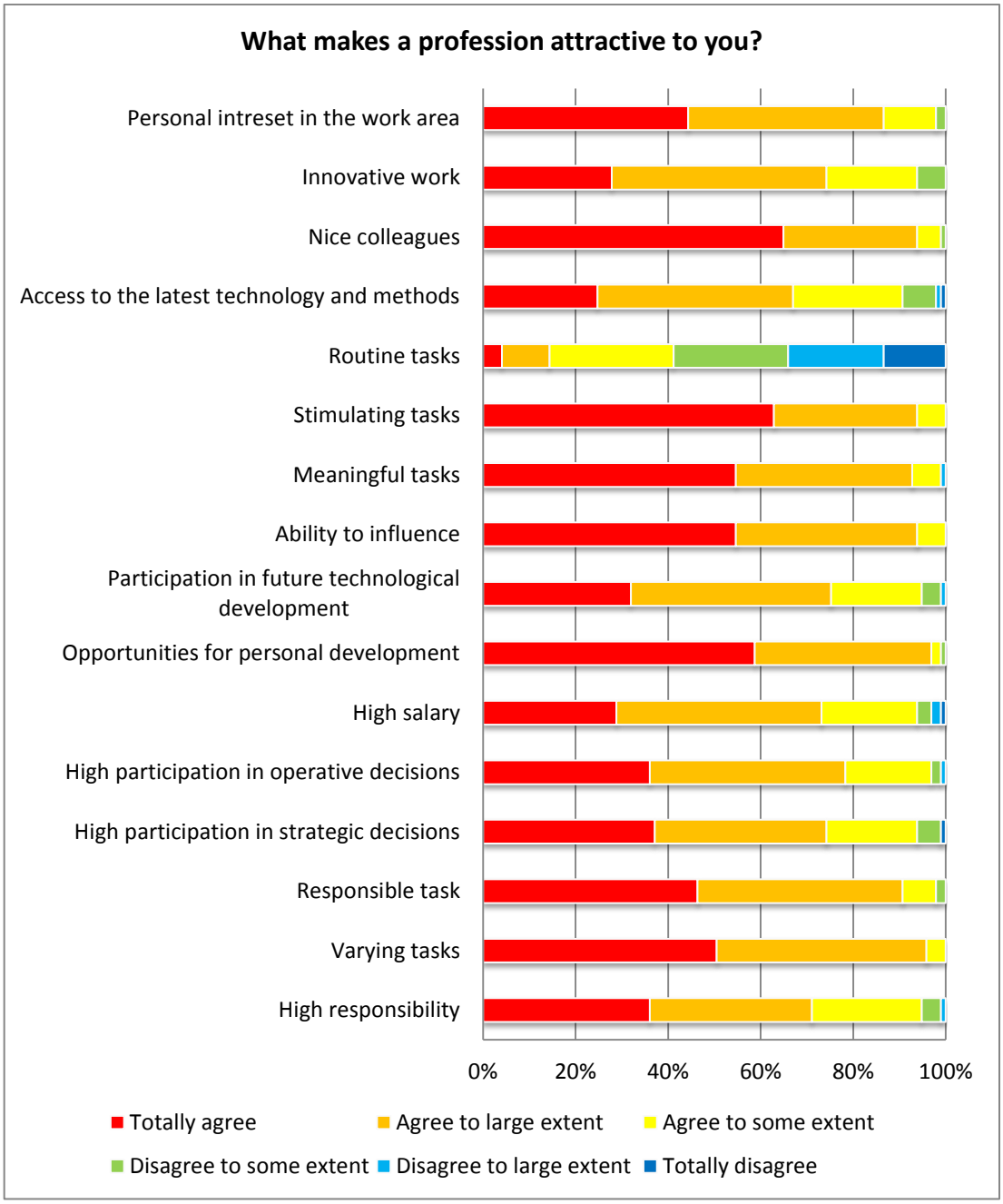

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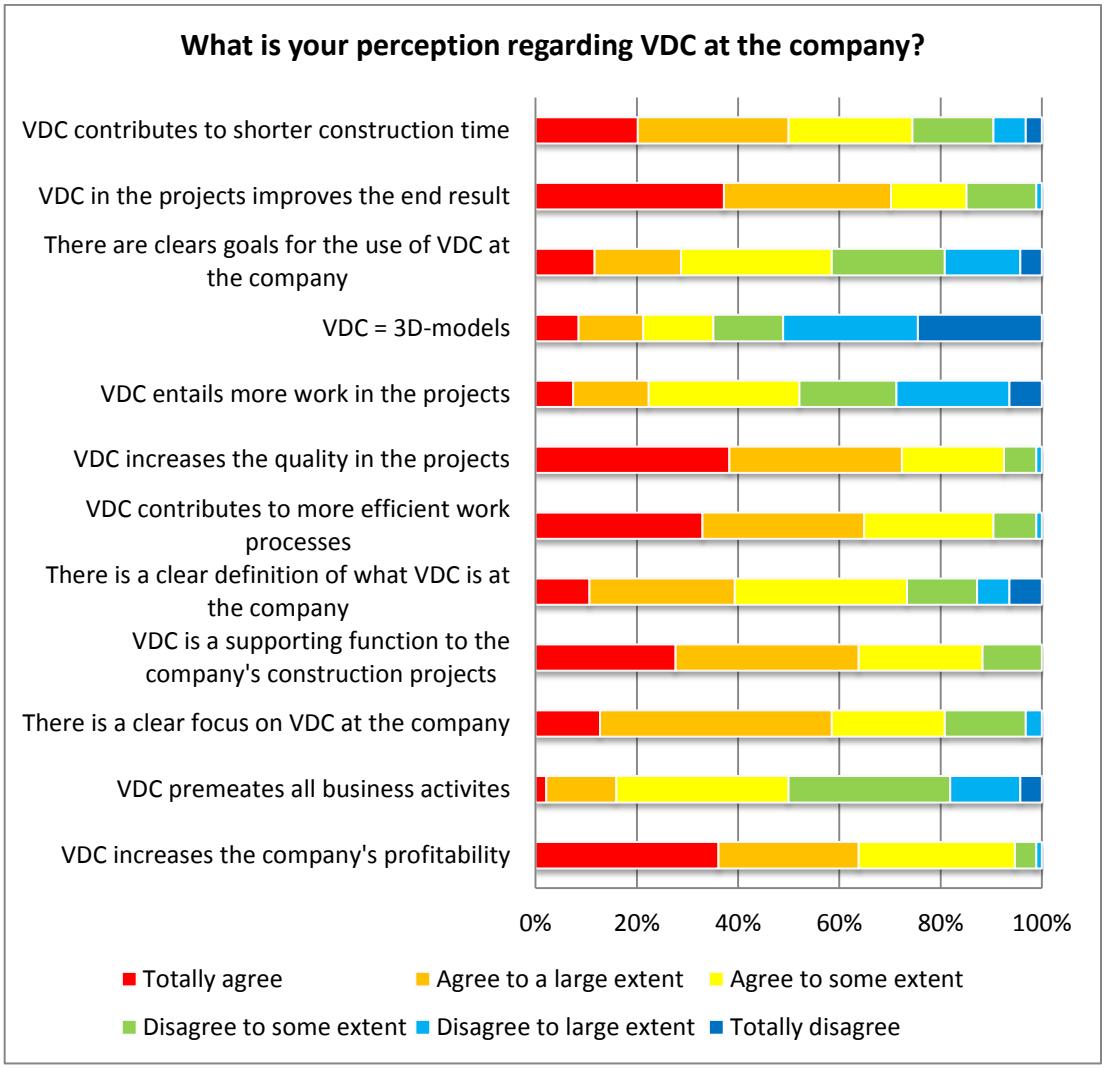

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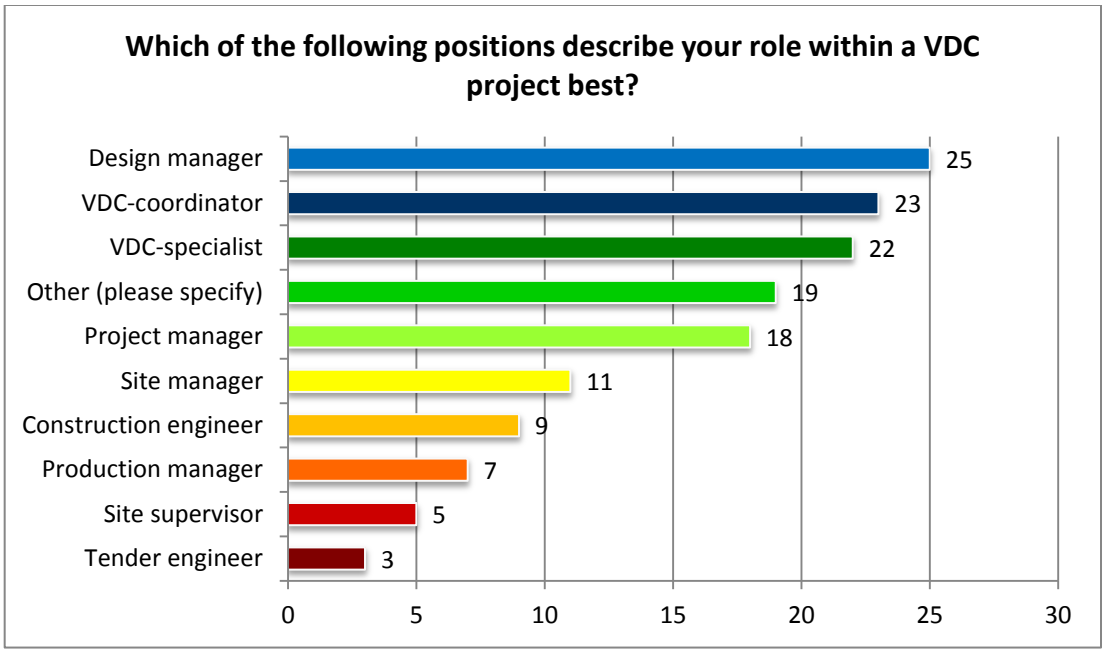

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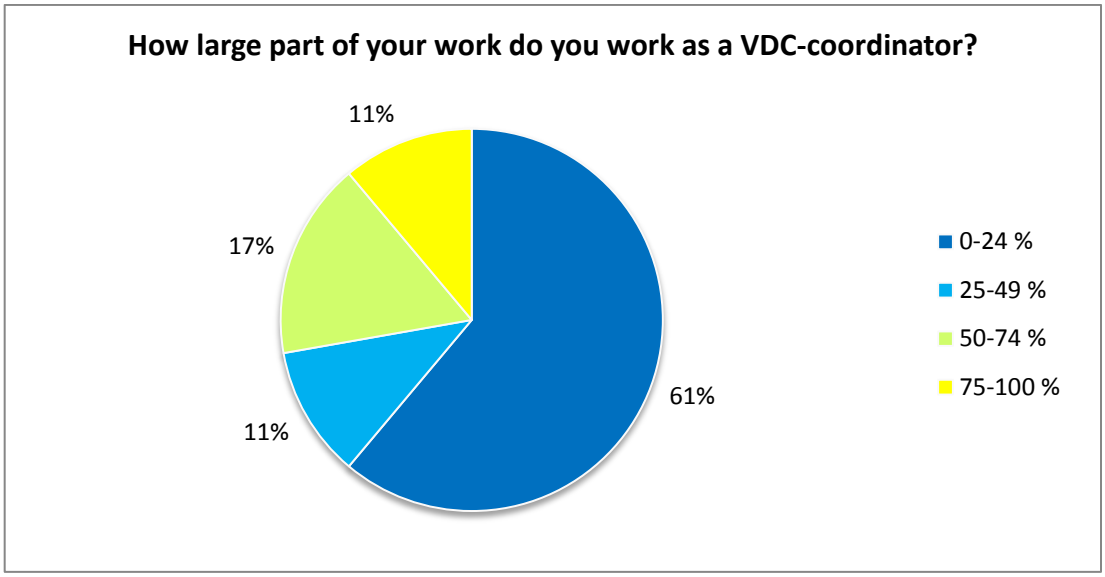

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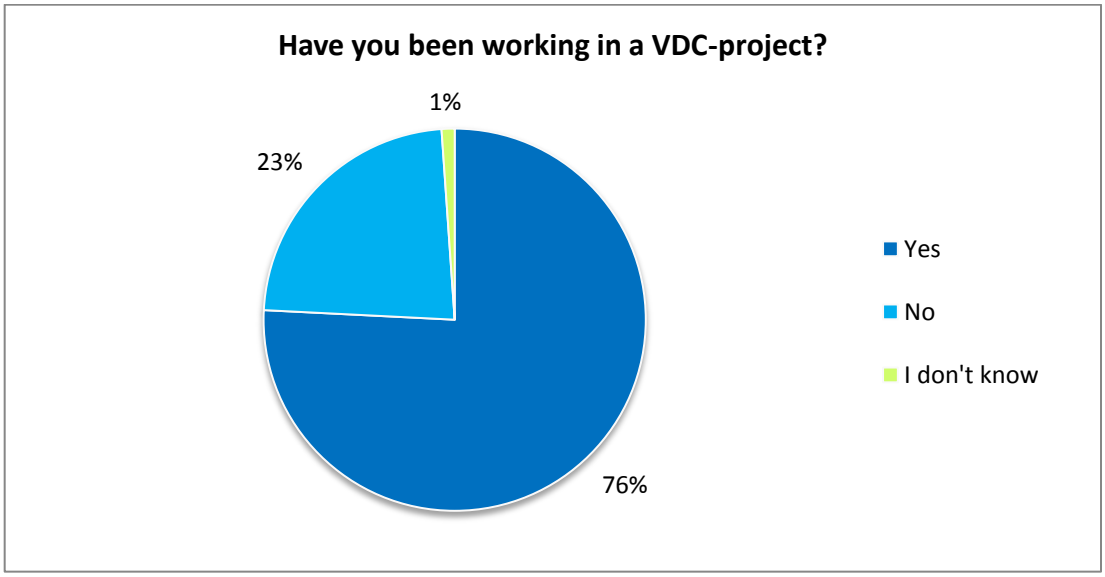
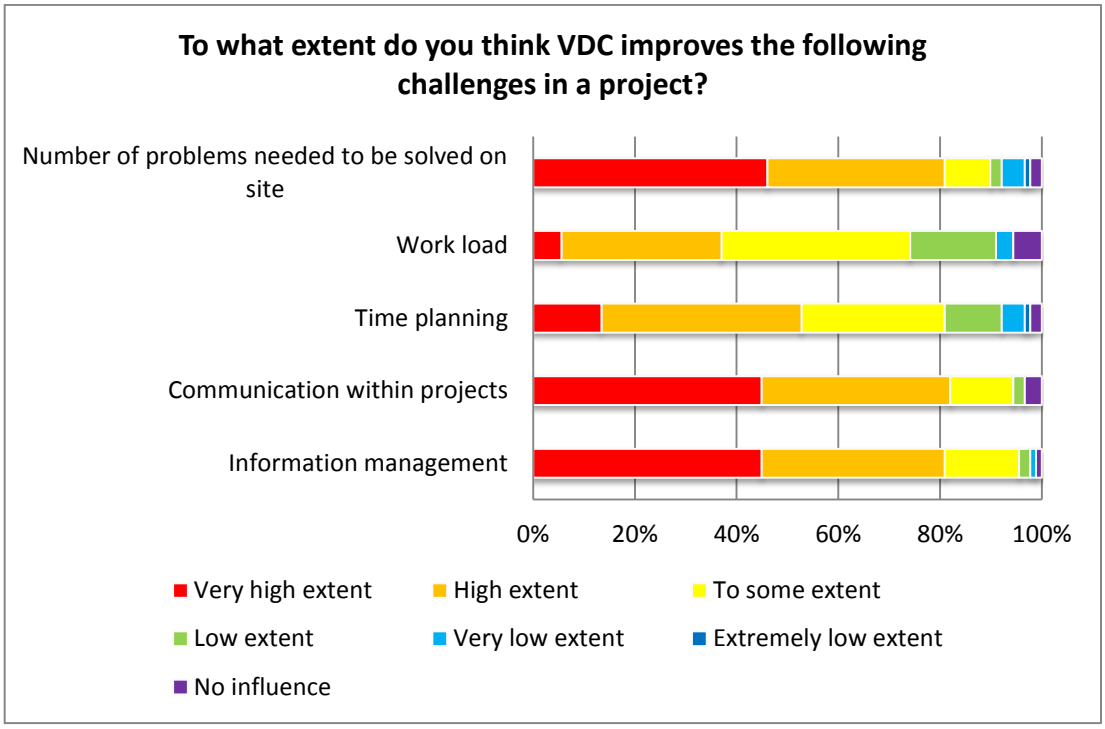


Question 11, n=22

Why have you not been involved in a VDC-project?

Individual answers with free text.

Question 12, n=89



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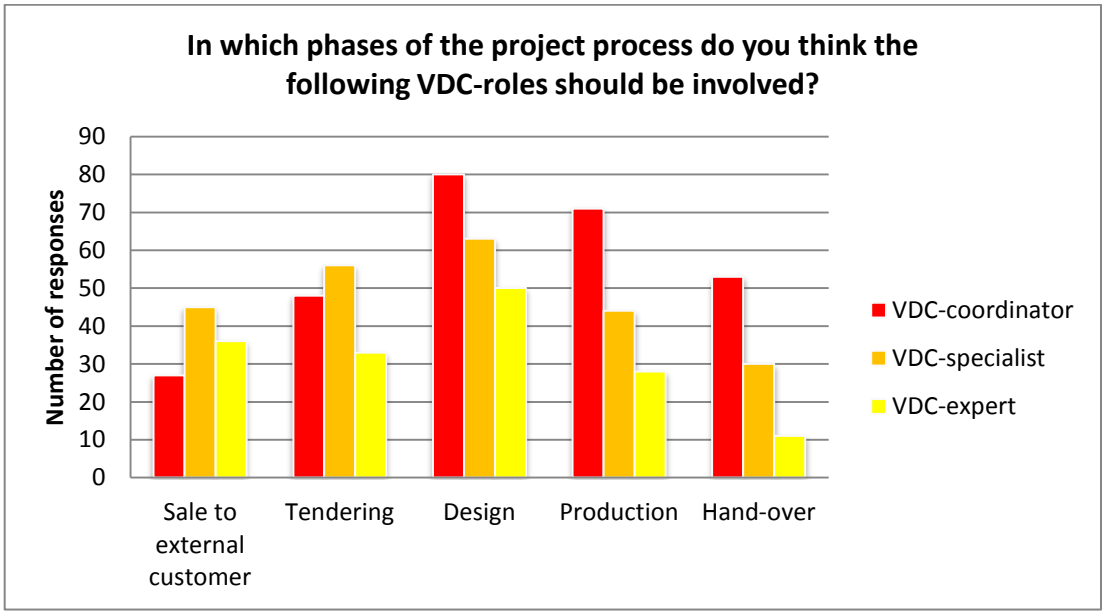

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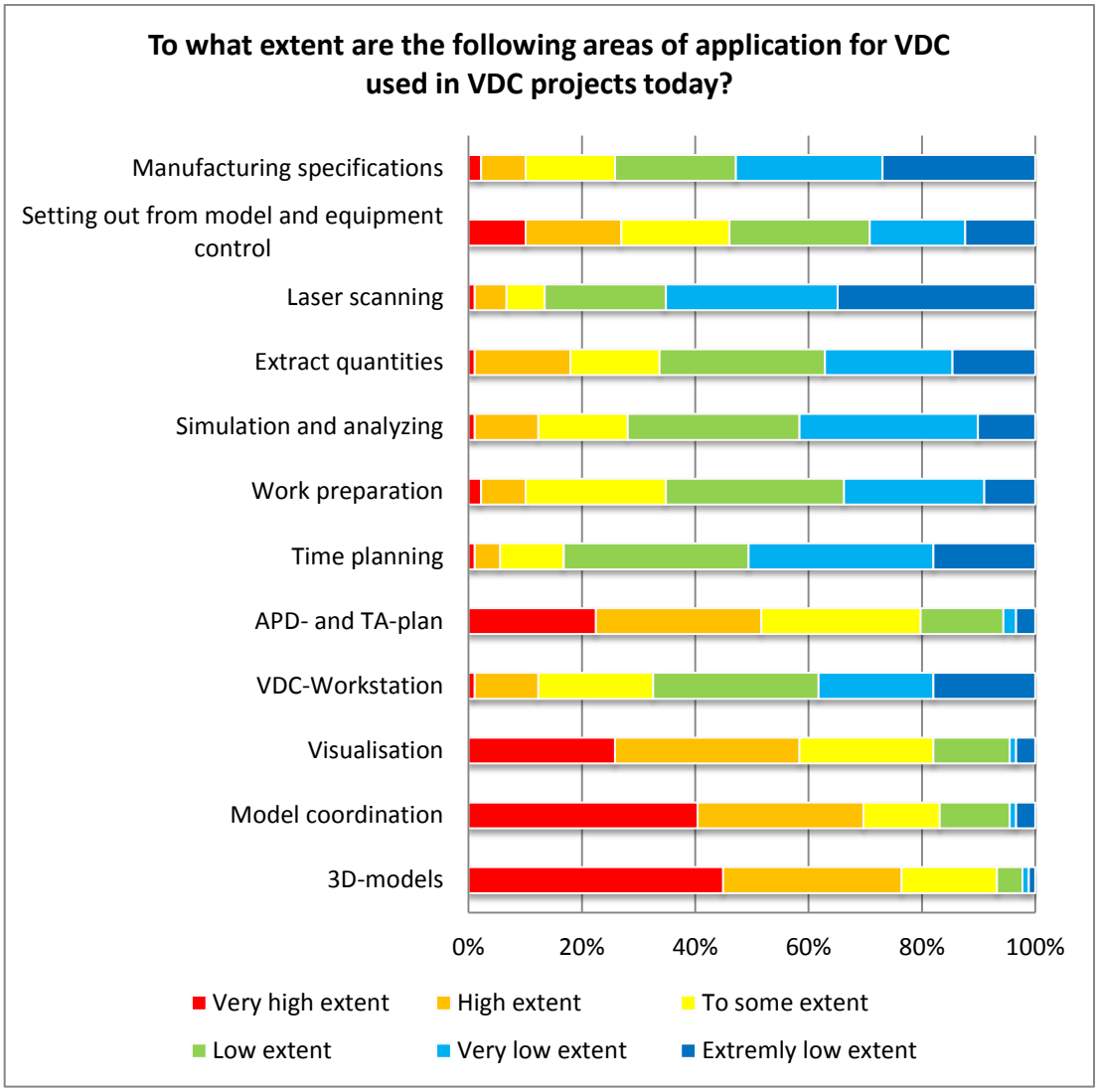

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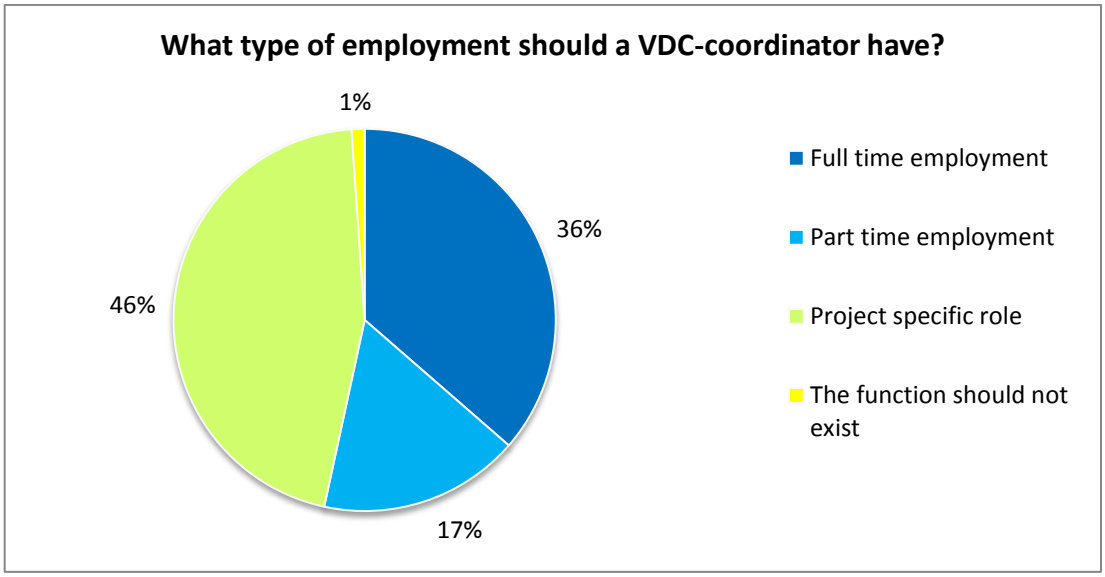

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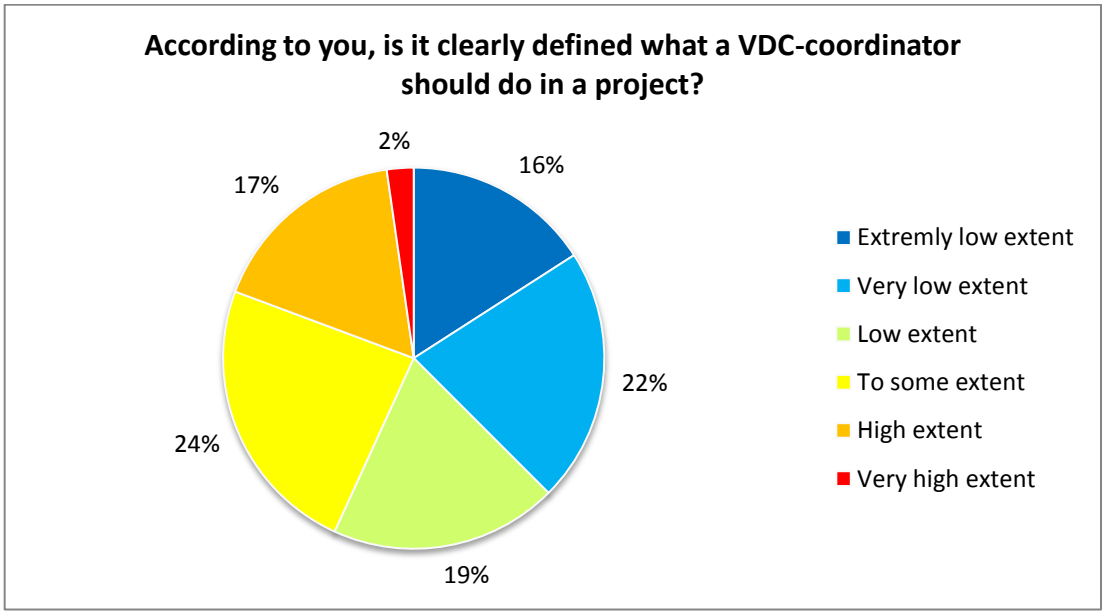

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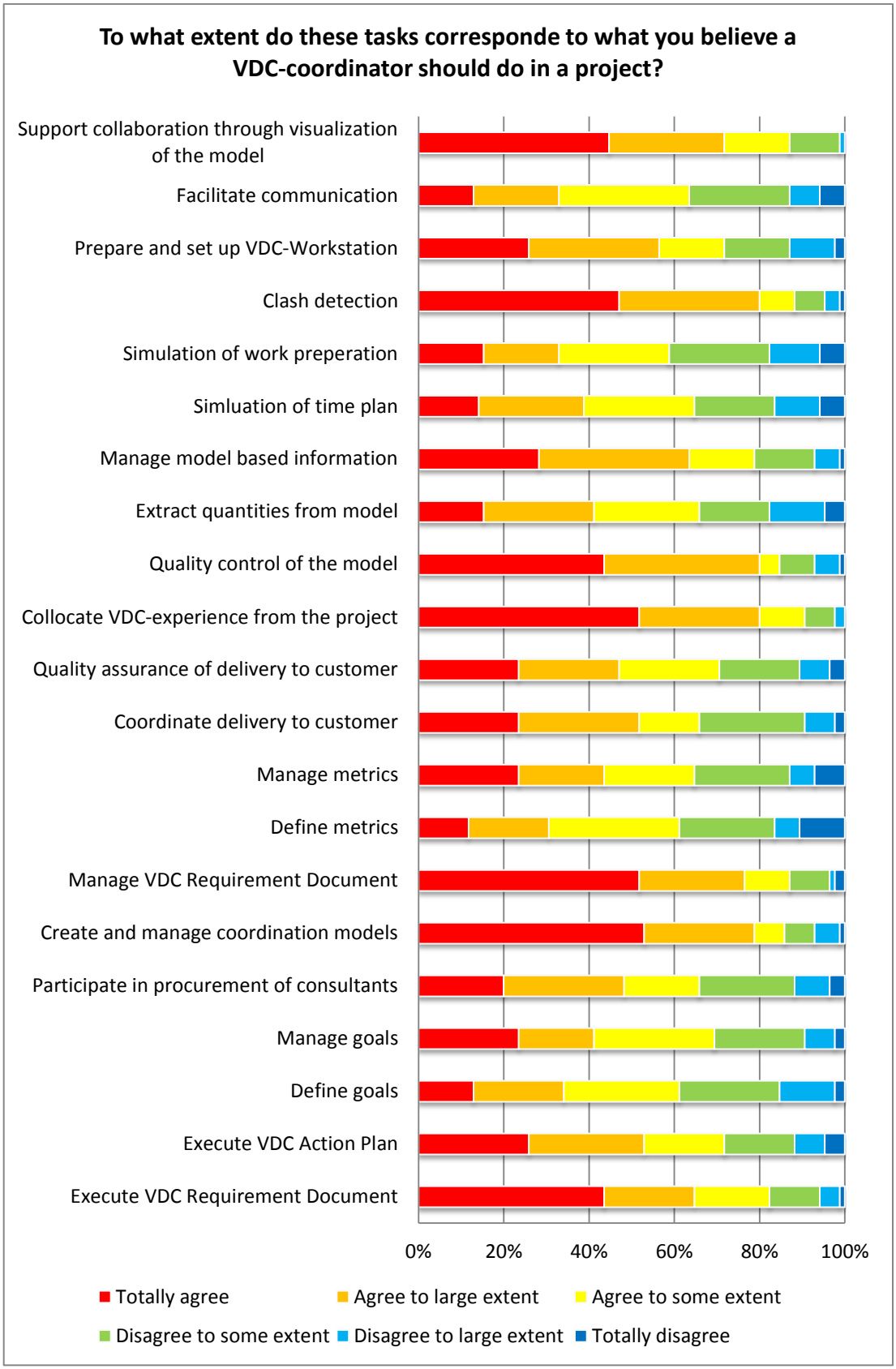

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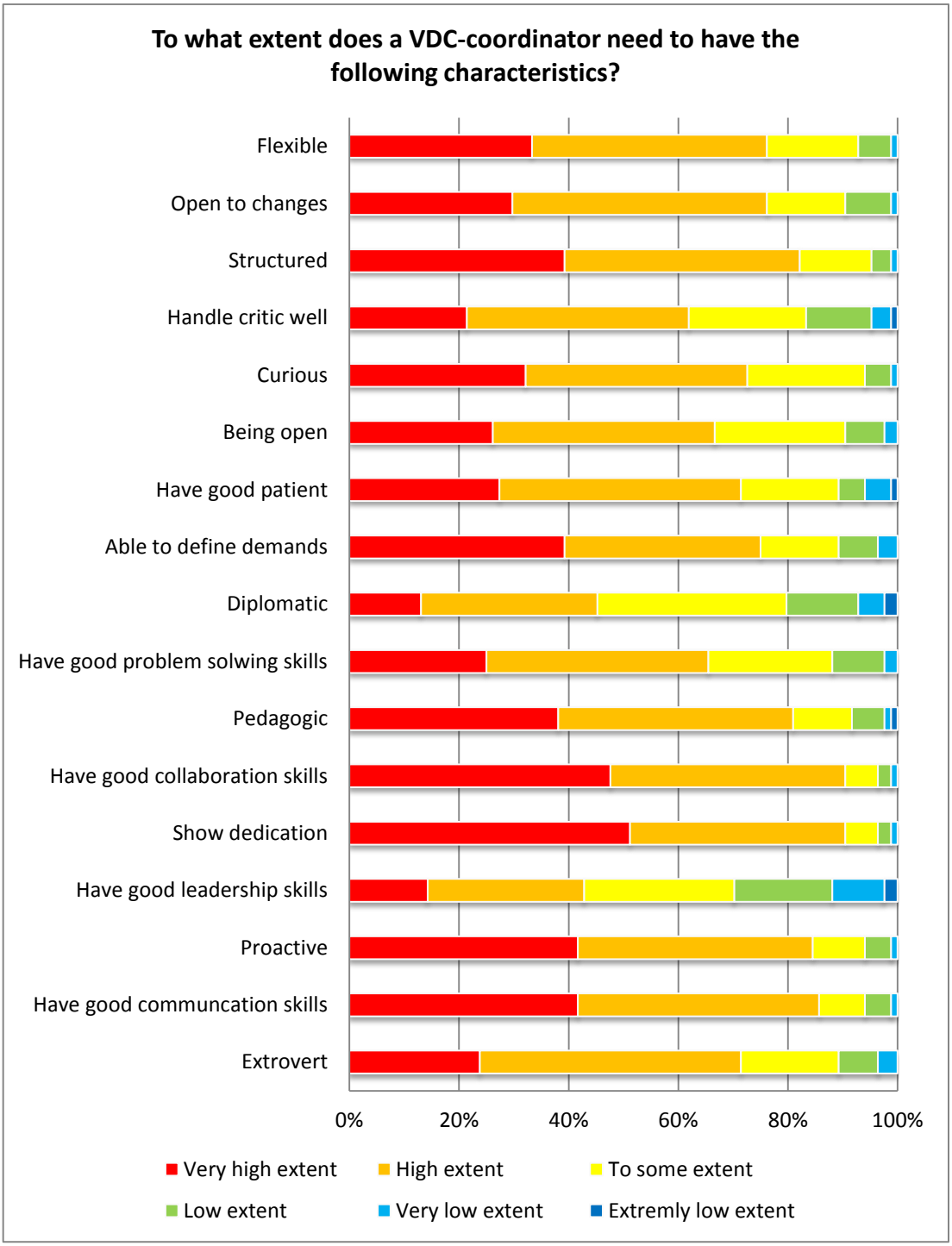

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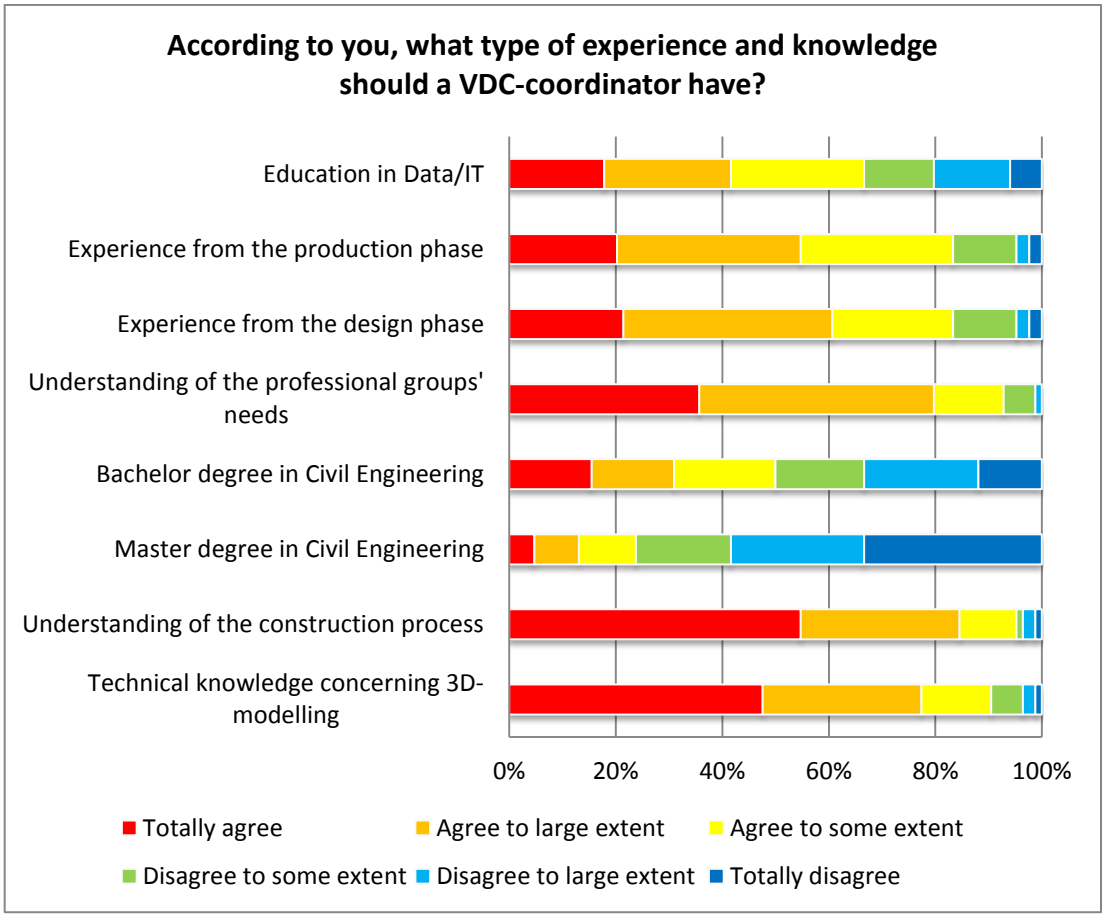

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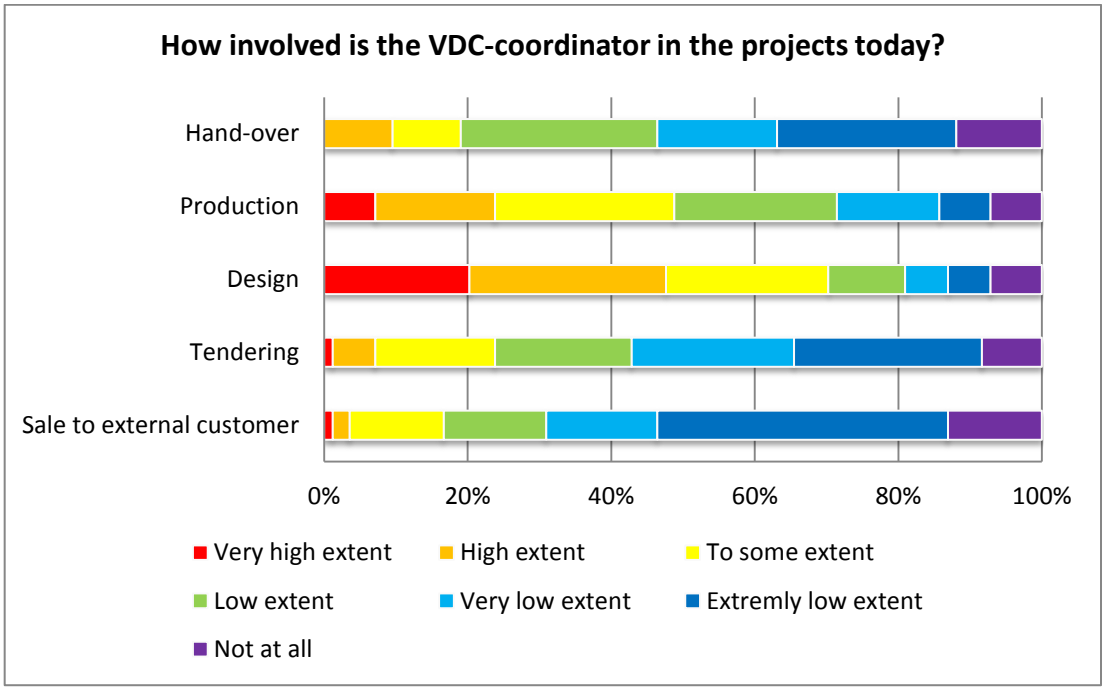

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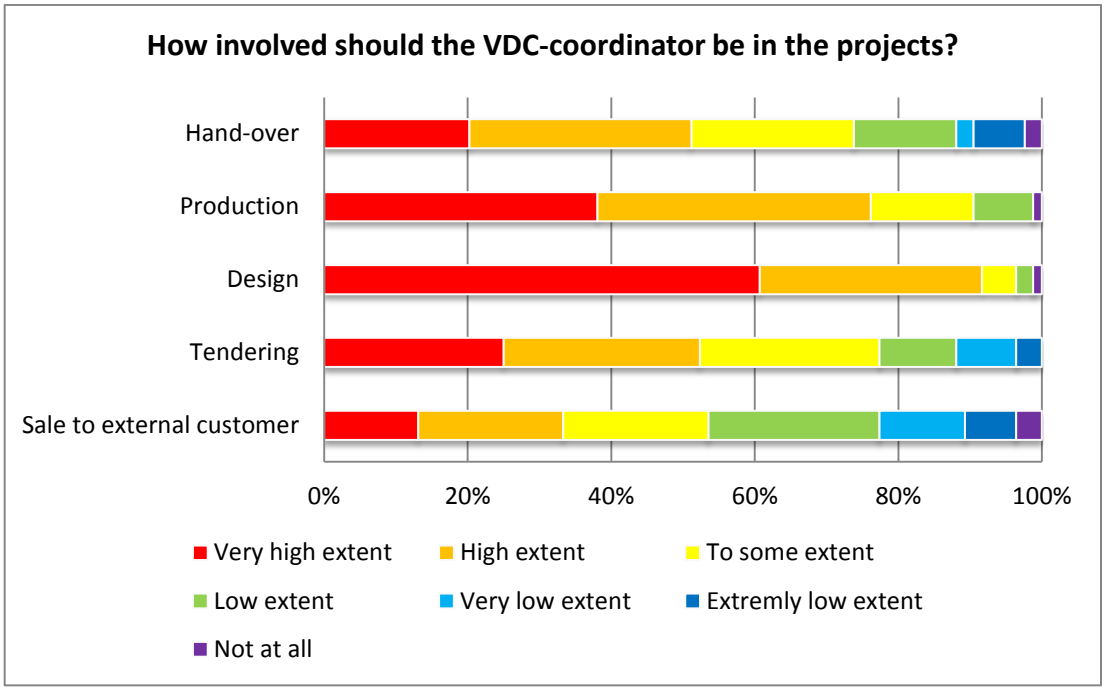

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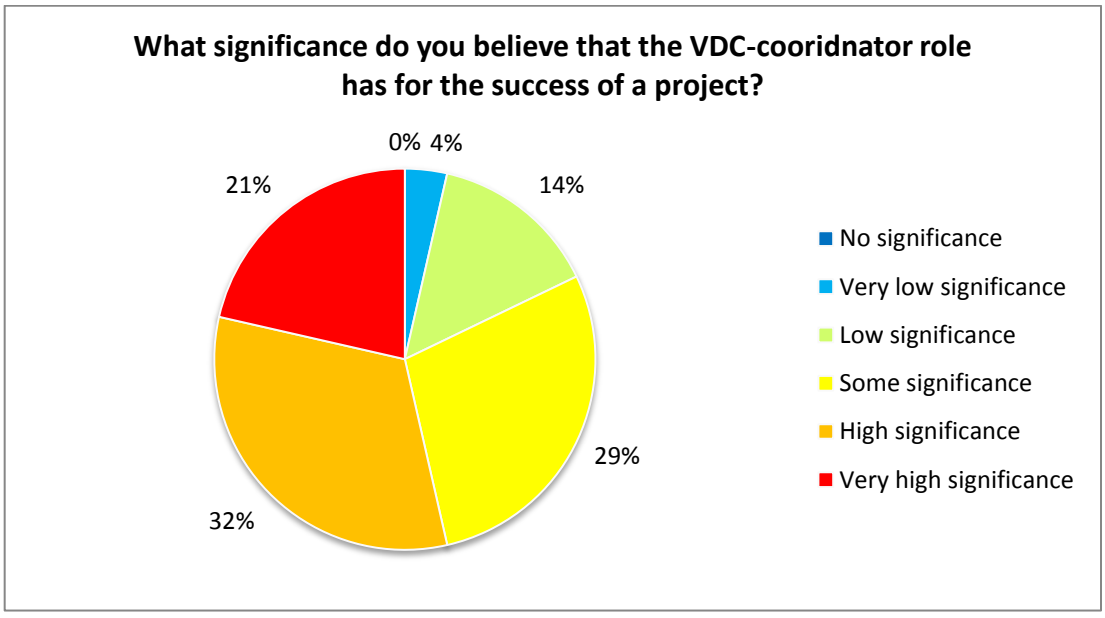

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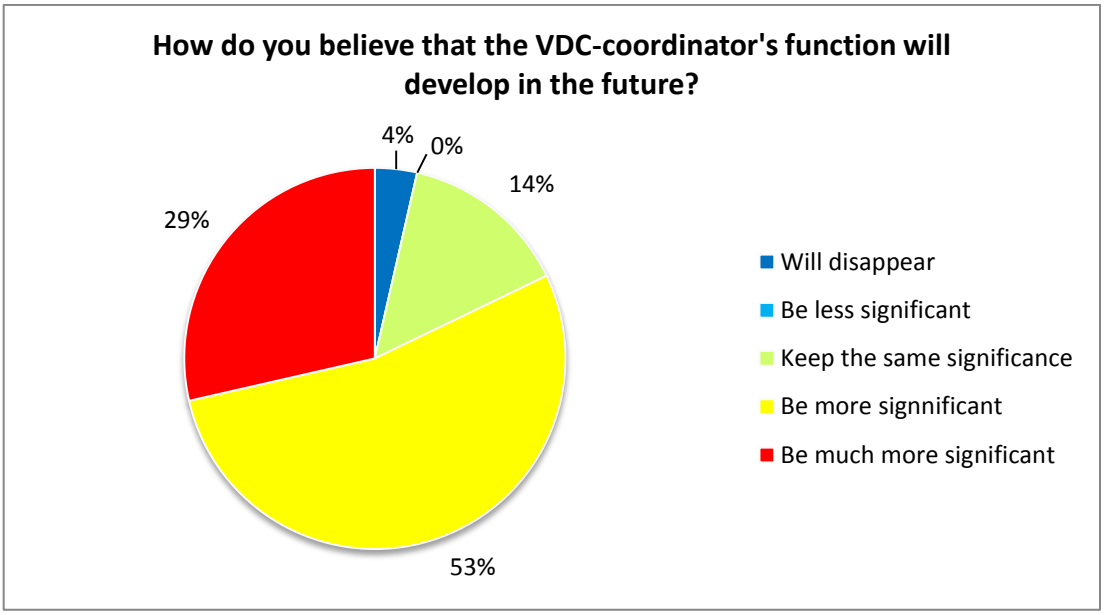

Question 24, n=27

How do you believe the future development of the VDC-coordinator will look like?

Individual answers with free text.

Question 25, n=18

Do you have any additional comments regarding VDC and the VDC-profession?

Individual answers with free text.

APPENDIX II – Interview guide for the VDC-group

”Bakgrund”

Berätta lite om dig själv

Vilka arbetsuppgifter har du inom företaget?

Hur har din karriärväg på företaget sett ut? Hur länge har du haft ditt nuvarande uppdrag?

Hur länge har du jobbat med VDC/som VDC-koordinator?

”Personen”

Vad innebär VDC för dig?

I vilket skede blev du involverad som VDC-koordinator i ditt senaste VDC-projekt?

Vilka uppgifter/aktiviteter gjorde du under sista projektet när du var VDC-koordinator?

Hade du något specifikt ansvarsområde?

Hur mycket anser du de färdiga mallarna och beskrivningar för VDC-arbetet används samt på vilket sätt används de?

Hur tycker du det fungerar att kombinera dina normala arbetsuppgifter med uppgifterna som hör till VDC-koordinatorsrollen?

Vilken roll brukar du ta på dig inom en grupp?

”Rollen”

Har du kännedom om de tre VDC-rollerna Koordinator, specialist och expert?

Anser du att VDC-rollerna är mer involverade i någon eller några faser av ett byggprojekt? Om ja, i så fall i vilka och varför?

Vilka arbetsuppgifter anser du att en VDC-koordinator/specialist/expert ska ha inom ett projekt?

Hur tycker du att ansvar för VDC och användning av BIM i produktionen ska fördelas?

Vad anser du är syftet med rollen som VDC-koordinator/specialist/expert?

Vilka färdigheter (kunskaper) anser du att en VDC-koordinator/specialist/expert ska ha?

Vilka egenskaper (personlighet) anser du att en VDC-koordinator/specialist/expert ska ha?

Vad anser du gör/skulle göra rollerna inom VDC intressanta?

Vad anser du gör/skulle göra rollerna inom VDC attraktiva?

Anser du att det finns ett behov av VDC-rollerna?

“Kommunikation och kunskapsutbyte”

Hur och var, anser du, sker utbytet av kunskap mellan VDC-koordinatorer?

Hur skulle du beskriva din relation till övriga VDC-koordinatorer/specialist/expert?

Vad för support känner du inom organisation för din roll som koordinator?

APPENDIX III – Interview guide for the managers

”Bakgrund”

Berätta lite om dig själv

Vilka arbetsuppgifter har du inom företaget?

Hur har din karriärväg på företaget sett ut? Hur länge har du haft ditt nuvarande uppdrag?

Hur länge har du jobbat med VDC?

”Personen”

Vad innebär VDC för dig?

Vilka uppgifter tilldelades VDC-koordinatorn i ditt senaste VDC-projekt?

Vilken roll inom gruppen brukar VDC-koordinatorerna ta på sig? Exempelvis i senaste VDC-projektet.

”Rollen”

Har du kännedom om de tre VDC-rollerna Koordinator, specialist och expert?

Anser du att VDC-rollerna är mer involverade i någon eller några faser av ett byggprojekt? Om ja, i så fall i vilka och varför?

Vilka arbetsuppgifter anser du att en VDC-koordinator/specialist/expert ska ha inom ett projekt?

Hur tycker du att ansvar för VDC och användning av BIM i produktionen ska fördelas?

Vad anser du är syftet med rollen som VDC-koordinator/specialist/expert?

Vilka färdigheter (kunskaper) anser du att en VDC-koordinator/specialist/expert ska ha?

Anser du att dagens koordinatorer/specialister innehar dessa färdigheter?

Vilka egenskaper (personlighet) anser du att en VDC-koordinator/specialist/expert ska ha?

Anser du att dagens koordinatorer/specialister innehar dessa egenskaper?

Vad anser du gör/skulle göra rollerna inom VDC intressanta?

Vad anser du gör/skulle göra rollerna inom VDC attraktiva?

Anser du att det finns ett behov av VDC-rollerna?

“Kommunikation och kunskapsutbyte”

Hur och var, anser du, sker utbytet av kunskap mellan VDC-koordinatorer?

Hur skulle du beskriva din relation till VDC-koordinatorer/specialist/expert?