Towards Results-Oriented Maintenance Processes at Dutch Housing Associations

Debby Goedknegt, debby.goedknegt@hu.nl
University of Applied Sciences Utrecht, The Netherlands

Pascal Ravesteijn, pascal.ravesteijn@hu.nl
University of Applied Sciences Utrecht, The Netherlands

Abstract
Maintenance of buildings, and in particular maintenance of social housing, is not executed in the most efficient manner by all related supply chain partners. The question rises whether ICT, e.g. building information model (BIM), could help improve the efficiency. BIM is perceived both as a method, which increases knowledge sharing, as well as a model that captures information during a building's lifecycle, which enables and increases cooperation between supply chain partners. The focus of this research is on improving maintenance processes through improving coordination mechanisms and improving the use of information systems. This is an explorative study based upon desk research and three unstructured interviews to verify our findings. Literature is found using keywords such as BIM, maintenance, asset management, but also through snowballing. Science Direct and scholar.google.com were the most used search engines. The interviews are held with practitioners active in the maintenance supply chain of Dutch housing associations. An electronic database search of Science direct and scholar.google.com was conducted and all eligible studies were systematically reviewed. Our search identified 43 eligible articles. The most important findings are that maintenance processes can be improved through *results-oriented maintenance* (ROM). ROM helps to define and align goals and objectives of supply chain partners. Interorganizational ICT (BIM) supports ROM with fast sharing of up-to-date information and knowledge. This benefits interorganizational communication, cooperation, and coordination, and improves maintenance of buildings.

Keywords: building information model (BIM), maintenance, results-oriented maintenance (ROM), built asset management, process management, housing association

1 Introduction

The Netherlands has a strong tradition of social housing for lower income groups. Within this tradition housing associations are a major player (Boelhouwer et al., 2014) something which dates back to the 1901 Housing Act. In the beginning, social housing was operated from the pillarization, the politico-denominational segregation. After World War II, the Dutch government managed and prescribed how, what and where to build. From the mid-1990s, the government withdrew itself and stimulated self-reliance (Van Gijssel, Gärtner, Bos, Van Dellen, & Minke, 2014). Today, the social housing system is failing, the decreasing support from society is a crucial threat to the future of the system (Boelhouwer et al., 2014). Innovation of the system, among other things by regaining commitment between the housing associations and their target population, is vital (Boelhouwer et al., 2014). The focus on core activities is, together with the first benchmark by Aedes (the national organization promoting the interests of social housing organizations in the Netherlands), the first step in the right direction.

With rental incomes just sufficient to cover the expenses for management and maintenance, more efficient cooperation with maintenance companies can lead to more efficient maintenance processes and lower maintenance costs (Gruis, 2011). It is believed by both scholars and practitioners that more efficient cooperation can be achieved with supply chain partnering, especially for housing associations. Their business environment with a portfolio of mass produced houses, built from before the 1900s until recently built state of the art houses, and their regional function makes them less sensitive to economic cycles, which enables them to offer the continuity necessary for supply chain partnering (Gruis, 2011).

1.1 Supply chain partnering in maintenance

Cooperation and contracting in the construction sector is predominantly based on mistrust; clients mistrust their main contractors who mistrust their subcontractors and suppliers (Briscoe & Dainty, 2005). It is essential that the sector implements supply chain partnering (SCP) to deliver value to the client rather than attempt to generate short term cost savings (Briscoe & Dainty, 2005). Successful implementation of SCP is hindered by a lack of understanding of the concept and its prerequisites (Eriksson & Pesämaa, 2007). However there are examples that show that when supply chain partners have developed effective systems of communication and information exchange, and have aligned their processes to benefit the project, long-term SCP has evolved (Briscoe & Dainty, 2005). Therefore, the increased implementation of SCP in maintenance processes in Dutch housing associations needs to be supported by adequate information management to effectively and efficiently coordinate actions of partners in the supply chain. Since SCP in this context is still in a development stage and many studies on SCP focus on new construction, little is known about information management challenges and potential solutions and opportunities when implementing SCP in maintenance processes.

In this research, explanations and mutual relations are sought between the organisation of maintenance, SCP and information management, using coordination theory and the building information model as methods for improving SCP and information management. The proposition of this conceptual model is that with SCP the organisation of maintenance will improve, resulting in higher quality results against lower maintenance cost. It is assumed that coordination theory gives insight in the mechanisms of SCP and that it offers valuable tools for improving SCP. Information management is perceived to be one of the key mechanisms of SCP and coordination theory. And as the building information model (BIM) offers supply chain partners the possibility to share information (and knowledge) through a joint digital model, this could help improve information management and therefore also SCP. The focus in this study is on generating ideas how these aspects relate to each other and why. This makes the nature of this research explorative (Fischer & Julsing, 2014; Kumar, 2014).

1.2 Research methodology

We will address the inefficient maintenance processes of social houses at Dutch housing associations through a literature review, identifying the knowledge gap(s) and will conclude with suggestions for possible solutions. The purpose of this literature review is to explore the present status of literature on SCP in maintenance and construction with a particular focus on Dutch housing associations. Literature is found via search engines such as scholar.google.com and Science Direct, using the keywords maintenance, housing association(s), supply chain (partnering), ICT in construction, BIM, information management, and coordination. Papers that used these terms in the title, keyword or abstract were selected for further consideration. Snowballing through the literature has been applied by searching through other paper's references. This is a relevant method since this is a first inspection search within this particular domain. It appears that the chosen research topic has no specific literature base. Most relevant literature dates from 2010, however also much cited literature from before 2010 is found relevant. A total of 119 papers were found, dating from 1989 – 2015. This amount is divided as follows: 13 papers on Dutch housing associations, 21 on maintenance, 43 on supply chains, 12 on coordination theory, 9 on information management, and 48 on BIM. The relations between these subjects are shown in figure 1, every 'x' in this

figure marks a paper on a specific topic. Further study of these papers found that not all of them are relevant to this research. Predominantly, the most recent literature has been found to describe, substructure or refute this research's issues best. However, only within their specific domain with very little crossovers. Finally 43 scientific papers, dating from 1990-2015, covering most valuable information on the constructs in our conceptual model, have been found useful for this research. Selected papers have as much search keywords as possible. In appendix A we present an overview of the papers used in this study and the topics they cover.

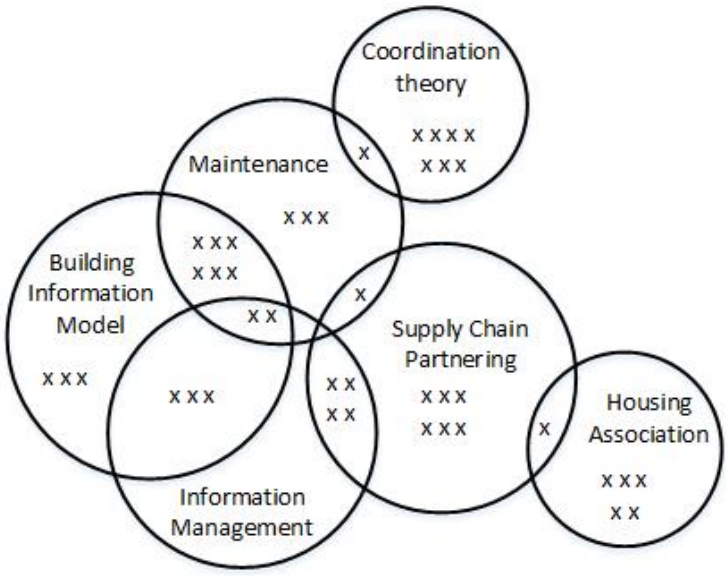

Figure 1 Conceptual model of theoretical methods (Goedknegt, 2016)

Besides literature, this research also uses informal unstructured interviews to gain insight in the current practice regarding supply chain partnering in maintenance at Dutch housing associations. This has been done to check the relevancy of this research. Informal interviews are held with two managers of a large Dutch housing association and a manager of a technical service provider in electrical engineering, climate control and ICT.

The structure of the remainder of this paper follows the conceptual model. First, existing theory on the organization of maintenance is discussed, followed by existing theory on supply chain partnering and information management. This paper ends with a synthesis of literature where the proposition is presented.

2 Organization of Maintenance

In this section general layout instructions are provided and illustrated. Dutch housing associations own more than 30% of the total housing stock (Boelhouwer et al., 2014; Gruis, 2008) and about 99% of the social rented stock (Gruis, 2008) in the Netherlands. The portfolio of houses of Dutch housing associations is very diverse. Some housing associations own houses varying from built before 1900 to those more recently constructed. According to managers of a large Dutch housing association, their portfolio lacks unity regarding: (i) construction quality; (ii) compliance with present living requirements; (iii) method of recording the construction and installation engineering information; and (iv) accessibility to and completeness of this information. As the largest client in maintenance (Bouw Research, 2013), they spend a lot of time and money on maintaining their portfolio. This is no surprise, since maintenance is part of their core business activities. Other core activities of Dutch housing associations are, according to the 2015 Housing Act (Rijksoverheid, 2015): (i) built, rent-out, and manage social houses; (ii) management of social real estate; (iii) invest in the livability of a neighborhood. In this research we use the definition of property maintenance proposed by FOSAG, the Dutch maintenance branch organization (Bouw Research, 2013): "property maintenance is the set of actions necessary to guarantee the property's user value, experienced value, technical value, and economical value during its economic life".

Maintenance can be either planned or responsive. Responsive, also corrective, maintenance is executed in response to a cause of failure or breakdown (Dreimüller, Gruis, & Snoeijs, 2013; Motawa & Almarshad, 2013). Planned, also preventive, maintenance concerns the routine maintenance based on predetermined intervals or the condition of building components (Motawa & Almarshad, 2013; Sharp, Jones, & Clarke, 2005). Traditionally, maintenance is tendered based on results of inspections, which are entered in the yearly budget (Dreimüller et al., 2013). In these traditional forms of maintenance, the housing association determines the type of maintenance, its interval and its execution through the maintenance specifications. These specifications are ambiguous about the expected quality of the maintenance work (Bouw Research, 2013). For a housing association, drawing up these specifications and inspecting the work afterwards is work not directed at core tasks, and therefore very suited to outsource to the main contractor. In addition, very often essential information such as 'as built' or 'as maintained' documentation (Volk, Stengel, & Schultmann, 2014), documentation of latest inspections, warranties, and material properties (Visser, De Boer, & Van der Voet, 2013) is incomplete or missing. This leads to ineffective processes, uncertain results, and time loss or costs increase in maintenance (Volk et al., 2014).

The heart of the problem with traditional work lies at the fragmentation of the sector (A. M. Adriaanse, 2014; Gruis, 2011; Vijverberg, Van der Krogt, & Keus, 2013). This fragmentation is threefold (A. M. Adriaanse, 2014): (i) vertical fragmentation, which is the division of the whole building process in process stages; (ii) horizontal fragmentation, which is the division of a project across different project parties; and (iii) longitudinal fragmentation, which is the division in projects with changing partnerships which hinder the knowledge diffusion across projects. The fragmentation of the sector leads to loss of information, misunderstandings, additional work and failure cost (A. M. Adriaanse, 2014; Vijverberg et al., 2013). Coordination of knowledge diffusion between the process stages, parties, and different projects is an important prerequisite for improving the maintenance process (A. M. Adriaanse, 2014). This is supported by an interview with a manager of a technical service provider in electrical engineering, climate control and ICT, who states that construction is still an industry where phases are viewed as stand-alone, and learning across stages is still not common. When one stage is finished, information is not well nurtured, and cooperation and coordination are not common. This can be overcome by changing the organizational form of maintenance from traditional into *results oriented maintenance* (ROM). In ROM, the fragmentation is eliminated. It aims at intensive and transparent cooperation between client, (sub)contractor, and advisors in order to realise an effective and efficient maintenance process where trust is an important feature (Vijverberg et al., 2013).

ROM means a big change in the way of thinking and the way things are done, but it has advantages for all supply chain partners. The client will have the security that budgets will not be exceeded and the contractor and the suppliers will experience more continuity in work through long-lasting contracts and permanent relations with clients (Bouw Research, 2013). In ROM, the housing association only performs those tasks that fit within their core business activities. They determine, together with the maintenance contractor, the final result as well as the desired functional, esthetical and technical quality (Bouw Research, 2013). Prerequisites for ROM are good communications about expectations from the client (Bouw Research, 2013), information sharing by all stakeholders (Korpela & Miettinen, 2013), a trust-based relationship between the housing association and the maintenance contractor, and effective process management (Bouw Research, 2013). With these prerequisites in place, a typical ROM relation between client and maintenance company lasts for several years (Bouw Research, 2013). Thus, because maintenance is recurring and always related to long-term activities, a one-time, project based approach of maintenance is useless (Bouw Research, 2013).

3 Supply chain partnering and coordination theory

3.1 Supply chain partnering

Supply chain partnering (SCP) is believed to lead to improvement by developing a more stable environment (Vrijhoef & Ridder, 2007). Unfortunately, several barriers, such as perceived

extra costs, traditional roles of construction partners which makes them unaccustomed to sharing knowledge across project phases, unawareness of potential benefits (Nam & Tatum, 1992), and the relatively fragmented nature of construction supply chains (Vrijhoef & Ridder, 2007), prevent integration of the supply chain (Briscoe & Dainty, 2005; Nam & Tatum, 1992). Like ROM, SCP is a different way of working in which process orientation and communication resources and skills are important features, or obstacles, to change the mind-set (Gruis, 2011). For example, when housing associations have relatively limited knowledge of contractors, it is unlikely that they will readily enter into partnering agreements (Briscoe & Dainty, 2005). Collaborative relationships evolve more effectively when not constrained by the formal aspects of contractually defined partnering relationships (Briscoe & Dainty, 2005).

When SCP is successful, supply chain partners have often developed effective and reliable systems of communication and information exchange and they have succeeded in aligning their management systems to the benefit of project delivery (Briscoe & Dainty, 2005; Eriksson, 2015). In successful SCP partners have also (i) aligned their processes and ICT systems; (ii) coordinated their cooperation; and (iii) installed successful decision-making and problem-solving mechanisms (Briscoe & Dainty, 2005). Successful supply chain integration requires a combination of formal and informal processes (Briscoe & Dainty, 2005), it means bringing things together to make it better. Gruis(2011) finds that this is exactly what it does in maintenance processes of Dutch housing associations.

Supply chains are, however, typically modelled with regard mainly to the coordination and integration of sequentially interdependent activities (Segerstedt et al., 2010). This focus on activities and the need for coordination of sequential interdependence between them may prevent the development of appropriate supply chain management models and effective supply chain practices in construction (Segerstedt et al., 2010). In addition, in every supply chain, difficulties occur. These difficulties are mostly related to the coordination of the supply chain, such as: (i) differences in the interest of supply chain members, because their work-basis is an individual firm and not the supply chain (Eriksson, 2015; Kanda & Deshmukh, 2008); (ii) conflicting goals and objectives (Crowston, 1997; Gittell, 2011; Kanda & Deshmukh, 2008); (iii) disagreements over domain decisions (Kanda & Deshmukh, 2008); and (iv) differences in perceptions of reality used in joint decision-making (Kanda & Deshmukh, 2008). These difficulties can be overcome by building long-term relationships with the supply chain partners by identifying the overall goals (Malone & Crowston, 1990), acknowledging and distributing the benefits of cooperation and coordination (Li & Wang, 2007), and implementing coordination mechanisms such as joint decision-making, information sharing, resource sharing, and implementing IT (Kanda & Deshmukh, 2008).

Therefore, the two most important issues regarding the implementation of SCP in the form of ROM are coordination and information management. These two issues are discussed below.

3.2 Coordination theory

Coordination theory provides an approach to the research of processes (Crowston, 1997), which makes this theory, although not recent, very suitable for this research on maintenance processes. This focus on processes is not common in construction, where most attention goes out to projects. According to coordination theory, actors in a supply chain face coordination problems that arise from dependencies that constrain how tasks can be performed. To overcome these coordination problems, actors must perform additional activities, called coordination activities (Crowston, 1997). These coordination activities are primarily information-processing activities, ideally supported by information technology (Crowston, 1997). Thus, coordination theory provides a useful theoretical framework for analysing the implications of information technology (Crowston, 1997). For example, information technology makes it easier to gather information about available resources and to decide which resources to use for a particular task. Also sharing information resources is easier when this information is not stored on paper but in a database (Crowston, 1997), because information is more easily accessible, shareable and available.

The mechanisms of coordination and communication are aimed at respecting and controlling the accountability of decision-making (de Blois, Herazo-Cueto, Latunova, & Lizarralde, 2011). In construction, the relations between supply chain partners are influenced by the informal mechanisms of communication and coordination, i.e. the supply chain structure. These are derived from research on procurement strategies and do not always reflect the real relations between project participants (de Blois et al., 2011). This is especially true when the procurement strategies are based on lowest price on the short term.

Coordination mechanisms in a supply chain should be tools by which every member of the supply chain can achieve more benefits (Cuenca, Boza, Alemany, & Trienekens, 2013). Furthermore, coordination also encompasses the management of interdependence between the people who perform the tasks, this is called relational coordination (Gittell, 2011). More important, shared goals, shared knowledge, and mutual respect only together enable the effective coordination of work (Gittell, 2011). Coordination mechanisms that help improve these relations in SCP are: joint decision-making, resource sharing, implementing ICT, information sharing (Kanda & Deshmukh, 2008), frequent, timely, and accurate communication, and problem solving (Gittell, 2011). Dogan et al. (2013) conclude that adequate empirical research is still lacking on the association between the effectiveness of coordination in supply chain partnerships. And while all the mentioned mechanisms are perceived important for the success of SCP, this research focusses on information sharing and ICT, and in particular on the benefits BIM implementation is assumed to have on the success of SCP, because information sharing is an important prerequisite of SCP.

4 Information management & Building Information Model

Information management and BIM cannot be perceived separately in maintenance in construction. These topics appear to be interrelated in the literature. An information management system (e.g. a BIM) is seen as an important element of the success of SCP (Verbaan, Vroom, & Ettema, 2012). Such a system offers potential benefits to operational processes as it enables fast and up-to-date sharing of information (Van der Vlist, Arno J, Vrolijk, & Dewulf, 2014). However, in the maintenance industry ICT-use (such as. BIM) is still very low despite of its benefits (e.g. lower costs structure and better operational performance) (Korpela & Miettinen, 2013; Segerstedt, Olofsson, Hadaya, & Pellerin, 2010; Segerstedt, Olofsson, Lönngren, Rosenkranz, & Kolbe, 2010; Van der Vlist, Arno J et al., 2014). The fragmented nature of the construction industry, and the different working practices, resources, and objectives of the organisations involved cause barriers to the intended use of interorganizational ICT (Adriaanse et al., 2010). Construction companies only use interorganizational IT to support those supply chain relationships that are built on trust, long-term relationships, and mutual cooperation (Segerstedt et al., 2010). Here, IT tools play a central role in SCP, because they guarantee consistent and efficient information management, and also benefit SCP in other ways (Segerstedt et al., 2010; Singh & Teng, 2016): (i) IT tools influence the relational structure of the partnership; (ii) IT tools reduce agent opportunism, coordination cost, transaction risks, imperfect information , uncertainty, and asymmetry within the partnership; and (iii) IT tools improve the performance of the supply chain.

Although the use of ICT/BIM can offer many benefits in improving interorganizational communication, cooperation, and coordination in construction projects (A. Adriaanse, Voordijk, & Dewulf, 2010), the adoption of ICT/BIM requires a change in the existing work practice (Gu & London, 2010; Straatman, Pel, & Hendriks, 2012). Benefits of ICT/BIM in construction are only found through changes in work processes (Kang et al., 2012). Implementing a BIM-based knowledge management system can help improve the performance of building maintenance operations through the improvement of knowledge sharing and communication (Almarshad & Motawa, 2012; Volk et al., 2014). Also, BIM can improve the cooperation and collaboration between team members and facilitate the mutual information exchange (Motawa & Almarshad, 2013; Straatman et al., 2012) because supply chain partners work together in the same information system and all information is readily available to all supply chain partners. Information effects include better decision-making

through the more effective collection, storage, processing and dissemination of information (Fox & Hietanen, 2007).

The vast majority of all 'life cycle cost' is part of the exploitation phase of a building. This makes BIM very interesting to housing associations (BIM Open, 2014). The main objective of a BIM is the improvement of knowledge and information sharing and communication between maintenance stakeholders (Almarshad & Motawa, 2012). A housing association should perceive the investment in BIM as being strategic, because BIM can be used to improve the performance and productivity of their maintenance processes (Almarshad & Motawa, 2012; Love, Simpson, Hill, & Standing, 2013). However, benefits will only arise from its effective use (Love et al., 2013), meaning that all information needed in maintenance, such as information of the technical equipment, is added to the model (Miettinen & Paavola, 2014). Unfortunately, this information is usually not included in 'as-built' models, it must be included in a separate way (Miettinen & Paavola, 2014). Thus the standard BIM needs adjustments or add-on tools to suit maintenance needs.

5 Synthesis of literature

Maintenance is not a one-time project-like activity, like many other activities in the construction industry. It is rather a long-term activity, well suited for implementing supply chain partnering in order to improve maintenance processes, information exchange and lower cost. ROM helps to identify the mutual dependencies between supply chain partners; both goals and objectives of supply chain partners are defined and aligned. Also, a mutual agreement on the coordination of decision-making is achieved as well as agreements on the quality and availability of information. Literature shows that the problems of traditional maintenance in a fragmented supply chain are manifold: specifications drawn up by the housing association, misunderstandings, missing and incomplete information, additional (inspection) work, high failure cost. These problems can be solved by implementing SCP, e.g. via *results-oriented maintenance* (ROM). ROM is successful when (i) the relationship between the supply chain partners is based on trust; (ii) information is shared by all supply chain partners; (iii) the mutual goals, objectives, and expectations are well communicated; (iv) ICT systems and processes are aligned; and (iv) process management is effective, meaning that there are successful decision-making and problem-solving mechanisms in place. ROM must be supported by interorganizational ICT (e.g. a building information model (BIM)), because a BIM enables fast sharing of up-to-date information and knowledge. It benefits interorganizational communication, cooperation and coordination (figure 3).

It is important to have a joint notion of the problems that occur in the existing maintenance processes. These problems can be solved by investing in information systems which will manage the opportunism of the contractor (which could be disadvantageous for the housing association) (Eisenhardt, 1989). It is only logical to connect this idea to the coordination theory. This theory states that actors in organisations experience coordination problems that originate from dependencies that hinder the execution of tasks (Crowston, 1997). Fortunately, coordination theory offers solutions to these problems, e.g. specifying the nature of relationships, mutual goals and objectives and how knowledge sharing can contribute to the execution of specific tasks that contribute to these goals and objectives (Gittell, 2011). Furthermore, mutual respect assures that actors overcome status barriers, which will otherwise prevent them from seeing and taking account of each other's work (Gittell, 2011). Thus, as maintenance is not a project but a process, problems regarding SCP in maintenance appear surmountable. The main proposition resulting from this research is:

> *Results-oriented maintenance will lead to improved maintenance processes through improved supply chain partnering and improved information management that can be reached by using coordination mechanisms and the building information model.*

Based on our study of the literature we conclude that the following elements are a prerequisite for the improvement of the maintenance processes (see figure 2): (a) Supply chain partners have a joint understanding of the mutual (inter)dependencies between all supply chain

partners; (b) Supply chain partners align their goals and objectives; (c) Supply chain partners agree on the coordination of decision-making; and (d) Supply chain partners agree on the exchange and availability of information and knowledge (regarding the maintenance processes).

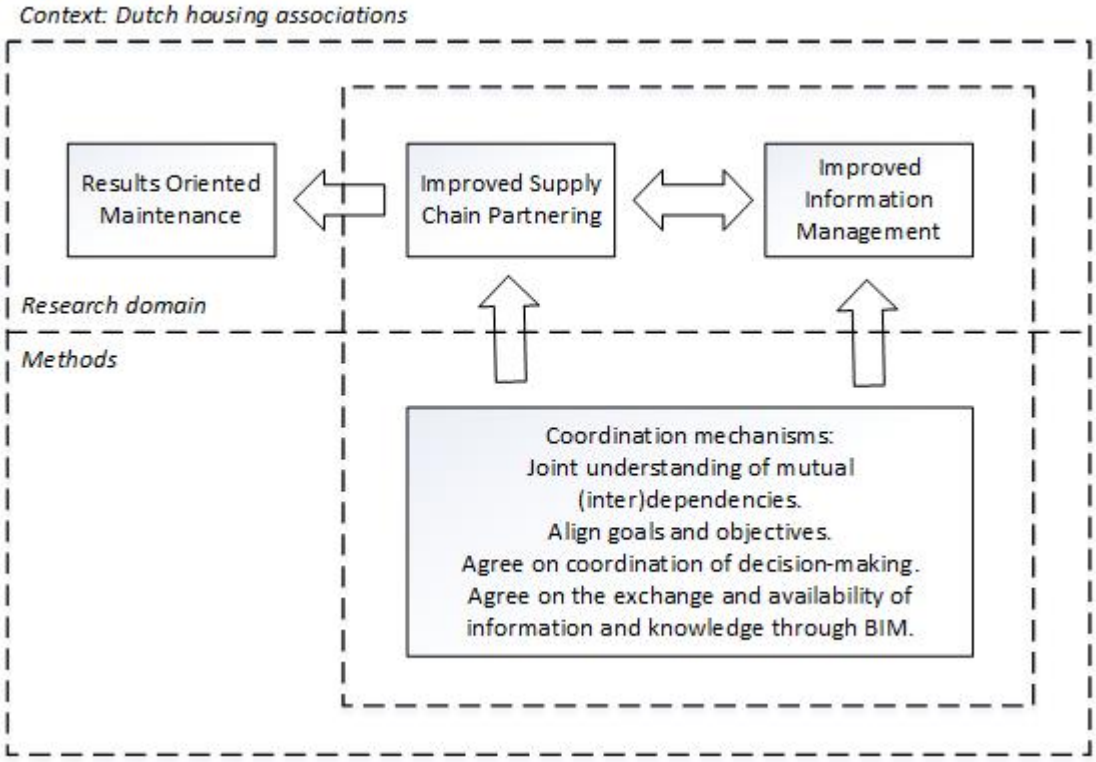

Figure 2 Research proposition (Goedknegt, 2016)

5.1 Discussion and Future research

This literature study is the rationale to subsequent future research. Although more scientific and practical research can be incorporated, this study has already shown that research regarding improving maintenance processes at Dutch housing associations is missing. Therefore research will be executed through case studies at several Dutch housing associations currently implementing results-oriented maintenance processes. With these case studies we aim to reveal whether the proposition as formulated above is correct or not, and how the different constructs in our conceptual model help improve the maintenance processes.

Acknowledgements

We would like to thank Ellen van Keeken, Beverly Pasian and Vincent Gruis for their useful comments on this paper.

References

Adriaanse, A. M. (2014). Bruggen bouwen met ICT.

Adriaanse, A., Voordijk, H., & Dewulf, G. (2010). Adoption and use of interorganizational ICT in a construction project. *Journal of Construction Engineering and Management, 136*(9), 1003-1014.

Almarshad, A., & Motawa, I. A. (2012). BIM-based knowledge management for building maintenance. Paper presented at the *CIB W078 2012: 29th International COnference,* Beirut, Lebanon.

BIM Open,. (2014,). Wat vastgoed en FM van BIM moet weten maar vooral waarom. Retrieved from http://www.bimopen.nl/blog.html

Boelhouwer, P., Elsinga, M., Gruis, V., Priemus, H., van der Schaar, J., & Thomsen, A. (2014). Wonen 6.0: Over de toekomst van de sociale huisvesting in nederland.

Bouw Research, S. (2013). Leidraad resultaatgericht vastgoedonderhoud. Retrieved from http://www.sbrcurnet.nl.www.dbproxy.hu.nl/producten/publicaties/leidraad-resultaatgericht-samenwerken-bij-investeren-en-onderhoud/titelpagina

Briscoe, G., & Dainty, A. (2005). Construction supply chain integration: An elusive goal? *Supply Chain Management: An International Journal, 10*(4), 319-326.

Crowston, K. (1997). A coordination theory approach to organizational process design. *Organization Science, 8*(2), 157-175.

Cuenca, L., Boza, A., Alemany, M., & Trienekens, J. J. (2013). Structural elements of coordination mechanisms in collaborative planning processes and their assessment through maturity models: Application to a ceramic tile company. *Computers in Industry, 64*(8), 898-911.

de Blois, M., Herazo-Cueto, B., Latunova, I., & Lizarralde, G. (2011). Relationships between construction clients and participants of the building industry: Structures and mechanisms of coordination and communication. *Architectural Engineering and Design Management, 7*(1), 3-22.

Dogan, S. Z., Arditi, D., Gunhan, S., & Erbasaranoglu, B. (2013). Assessing coordination performance based on centrality in an e-mail communication network. *Journal of Management in Engineering, 31*(3), 04014047.

Dreimüller, A., Gruis, V., & Snoeijs, C. (2013). De regie-corporatie. naar een doelmatige maatschappelijke verhuurder.

Eisenhardt, K. M. (1989). Agency theory: An assessment and review. *Academy of Management Review, 14*(1), 57-74.

Eriksson, P. E. (2015). Partnering in engineering projects: Four dimensions of supply chain integration. *Journal of Purchasing and Supply Management, 21*(1), 38-50.

Eriksson, P. E., & Pesämaa, O. (2007). Modelling procurement effects on cooperation. *Construction Management and Economics, 25*(8), 893-901.

Fischer, T., & Julsing, M. (2014). *Onderzoek doen!: Kwantitatief en kwalitatief onderzoek* Noordhoff Uitgevers.

Fox, S., & Hietanen, J. (2007). Interorganizational use of building information models: Potential for automational, informational and transformational effects. *Construction Management and Economics, 25*(3), 289-296.

Gittell, J. H. (2011). 30 new directions for relational coordination theory.

Gruis, V. (2008). Organisational archetypes for dutch housing associations. *Environment and Planning C: Government and Policy, 26*(6), 1077-1092.

Gruis, V. (2011). *Kansen bij cocreatie. samenwerk bij woningrenovatie: Openbare les 2011.* (Openbare les). Utrecht: Hogeschool Utrecht. Retrieved from http://hu.surfsharekit.nl:8080/get/smpid:45461/DS1/

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction, 19*(8), 988-999.

Kanda, A., & Deshmukh, S. (2008). Supply chain coordination: Perspectives, empirical studies and research directions. *International Journal of Production Economics, 115*(2), 316-335.

Kang, Y., O'Brien, W. J., Dai, J., Mulva, S. P., Thomas, S. P., Chapman, R. E., & Butry, D. (2012). Interaction effects of information technologies and best practices on construction project performance. *Journal of Construction Engineering and Management, 139*(4), 361-371.

Korpela, J., & Miettinen, R. (2013). BIM in facility management and maintenance—the case of kaisa library of helsinki university. Paper presented at the *29th Annual ARCOM Conference, September,* Reading. 47-56.

Kumar, R. (2014). *Research methodology.* London: Sage Publications Ltd.

Li, X., & Wang, Q. (2007). Coordination mechanisms of supply chain systems. *European Journal of Operational Research, 179*(1), 1-16.

Love, P. E., Simpson, I., Hill, A., & Standing, C. (2013). From justification to evaluation: Building information modeling for asset owners. *Automation in Construction, 35*, 208-216.

Malone, T. W., & Crowston, K. (1990). What is coordination theory and how can it help design cooperative work systems? Paper presented at the *Proceedings of the 1990 ACM Conference on Computer-Supported Cooperative Work,* 357-370.

Miettinen, R., & Paavola, S. (2014). Beyond the BIM utopia: Approaches to the development and implementation of building information modeling. *Automation in Construction, 43*, 84-91.

Motawa, I., & Almarshad, A. (2013). A knowledge-based BIM system for building maintenance. *Automation in Construction, 29*, 173-182.

Nam, C., & Tatum, C. (1992). Noncontractual methods of integration on construction projects. *Journal of Construction Engineering and Management, 118*(2), 385-398.

Rijksoverheid,. (2015). Commerciële en maatschappelijk activiteiten woningcorporaties. [Housing associations' commercial and social activities] , January 16, 2016.

Segerstedt, A., Olofsson, T., Bankvall, L., Bygballe, L. E., Dubois, A., & Jahre, M. (2010). Interdependence in supply chains and projects in construction. *Supply Chain Management: An International Journal, 15*(5), 385-393.

Segerstedt, A., Olofsson, T., Hadaya, P., & Pellerin, R. (2010). Determinants of construction companies' use of web-based interorganizational information systems. *Supply Chain Management: An International Journal, 15*(5), 371-384.

Segerstedt, A., Olofsson, T., Lönngren, H., Rosenkranz, C., & Kolbe, H. (2010). Aggregated construction supply chains: Success factors in implementation of strategic partnerships. *Supply Chain Management: An International Journal, 15*(5), 404-411.

Sharp, M., Jones, K., & Clarke, R. (2005). An investigation into inefficiency in the condition based maintenance process.

Singh, A., & Teng, J. T. (2016). Enhancing supply chain outcomes through information technology and trust. *Computers in Human Behavior, 54*, 290-300.

Straatman, J., Pel, W., & Hendriks, H. (2012). *Aan de slag met BIM; gewoon doen! handreiking virtueel bouwen.* (). Zoetermeer: Stichting Research Rationalisatie Bouw.

Van der Vlist, Arno J, Vrolijk, M. H., & Dewulf, G. P. (2014). On information and communication technology and production cost in construction industry: Evidence from the netherlands. *Construction Management and Economics, 32*(6), 641-651.

Van Gijssel, A., Gärtner, R., Bos, R., Van Dellen, R., & Minke, P. (2014). *Blue sky memo.over greenfields, de toekomst en bouwstenen voor een visie.* ().Aedes.

Verbaan, W., Vroom, P., & Ettema, M. (2012). *Nieuw krachtenveld, nieuwe paradigma's: Trendverkenning van de nederlandse bouwsector* Blauwdruk.

Vijverberg, G., Van der Krogt, H., & Keus, D. (2013). *Leidraad resultaatgericht samenwerken bij investeren en onderhouden.* (Leidraad).SBR.

Visser, E., De Boer, J., & Van der Voet, L. (2013). *BIM in beheer biedt kansen.* (). Amsterdam: Hogeschool van Amsterdam.

Volk, R., Stengel, J., & Schultmann, F. (2014). Building information modeling (BIM) for existing buildings—Literature review and future needs. *Automation in Construction, 38*, 109-127.

Vrijhoef, R., & Ridder, H. (2007). Supply chain systems engineering in construction. Paper presented at the *Proceedings CIB World Building Congress,* 14-17.

Appendix A. Literature matrix

	Topic					
Reference	Housing association	Maintenance	Supply chain partnering	Coordination theory	Information management	Building information model
Adriaanse (2014)					X	X
Adriaanse et al. (2010)					X	X
Almarshad & Motawa (2012)		X			X	X
BIM Open (2014)		X				X
Boelhouwer et al. (2014)	X					
Bouw Research (2013)		X				
Briscoe & Dainty (2005)			X			
Crowston (1997)				X		
Cuenca et al. (2013)				X		
De Blois et al. (2011)		X		X		
Dogan et al. (2015)				X		
Dreimuller et al. (2013)	X					
Eisenhardt (1989)				X		
Eriksson (2015)			X			
Eriksson & Pesämaa (2007			X			
Fox & Hietanen (2007)			X		X	
Gittel (2011)				X		
Gruis (2008)	X					
Gruis (2011)	X		X			
Gu & London (2010)		X				X
Kanda & Deshmukh (2008)				X		
Kang et al. (2012)		X	X			X
Korpela & Miettinen (2013)		X				X
Li & Wang (2007)				X		
Love et al. (2013)		X				X
Malone & Crowston (1990)				X		
Miettinen & Paavola (2014)						X
Motawa & Almarshad (2013)		X			X	X
Nam & Tatum (1992)			X			
Rijksoverheid (2015)	X					
Segerstedt et al. (2010a)			X			
Segerstedt et al. (2010b)			X		X	
Segerstedt et al. (2010c)			X		X	
Sharp et al. (2005)		X				
Sing & Teng (2016)			X		X	
Straatman et al. (2012)						X
Van der Vlist et al. (2014)					X	X
Van Gijssel et al. (2014)	X					
Verbaan (2012)						X
Vijverberg et al. (2013)		X				
Visser et al. (2013)		X				X
Volk et al. (2014)		X				X
Vrijhoef & De Ridder (2007)			X			

Table 1 Literature matrix (Goedknegt, 2016)