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Does lean & agile project management help coping with project complexity?

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Abstract

Still, projects in the construction sector are delivered with time delays and cost overruns. One of the reasons for poor performance was assigned to project complexity. A combination of lean construction and agile project management are hypothesized as a possible solution to cope with project complexity. In this paper we aim to understand if the implicit usage of lean and agile help coping with complexity. The research was done by means of correlation analysis on data gathered from a structured questionnaire (67 responses).In total, 51 significant correlations among 255 possible relations were found. To reduce the number of variables, factor analysis was performed. Correlation analysis on the defined factors showed 8 significant correlations among 25 relations. Several lean and agile elements were shown to significantly correlate to either reducing complexity or managing complexity. It was therefore concluded that these are promising to cope with complexity and improve project performance, which is to be confirmed in subsequent research.

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Keywords: project complexity; lean construction; agile project management

1. Introduction

Poor performance, such as time delays and cost overruns, are not uncommon in construction projects and the reasons behind these problems have attracted the attention of construction practitioners and researchers (Mansfield,

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Ugwu, & Doran, 1994; Meng, 2012). Project complexity is claimed as one of the causes of cost overruns leading to poor performance and consequently project failure (Kaming, Olomolaiye, Holt, & Harris, 1997). Studies show that causes of poor performance can be divided into external causes and internal causes (Meng, 2012). External causes, which are usually beyond the control of project teams, may include adverse weather conditions, unforeseen site conditions, market fluctuation, and regularly changes while internal causes of poor performance may be generated by the client, the designer, the contractor, the consultant and various suppliers who provide labour, materials and equipment (Assaf & Al-Hejji, 2006). Hertogh and Westerveld also stress the influence of different interests of stakeholders and the way stakeholders interact (Hertogh & Westerveld, 2010). It can be argued that both external and internal causes happen because of project dynamics. Among all these efforts to find the reasons of poor performance, some scholars shed light on "the way that projects are being managed" as an important fact which could affect project performance and the successful delivery of the project (Gil & Tether, 2011; Olsson, 2006). Hertogh and Westerveld stated that the performance of megaprojects is influenced by their management (Hertogh & Westerveld, 2010). In a very recent study in 2014, Davis claims that based on the literature, project management is immature as a research field although project management processes must be in place for a project to be successful (Davis, 2014).

Apart from the importance of project management in general, differentiation in size, uniqueness and complexity of projects put emphasis on the necessity of tailored management methods. Increasingly it is argued that nowadays a pure project management approach (the traditional project management approach) is no longer effective (Hertogh & Westerveld, 2010; Priemus & van Wee, 2013). Nevertheless, most of the current project management methodologies still seem to underestimate the influence of the dynamic environment (ibid).

Based on above mentioned findings, the hypothesis of this research is that new management methodologies, Lean management and & Agile project management, can help coping with complexity. This paper explores the implicit usage of these methodologies and its influence on project complexity based on a literature review and a survey.

2. Literature review

This section provides the theoretical framework. First complex systems and project complexity are discussed, followed by the needs for improvements in project management and lean and agile project management.

2.1. Complex systems and project complexity

Projects over time have become more complex (Baccarini, 1996; Harvett, 2013; Hillson & Simon, 2007; Philbin, 2008; Williams, 1999). Van Marrewijk et al. (2008) state that large infrastructure projects are characterized as uncertain, complex, politically-sensitive and known for the involvement of large number of stakeholders (van Marrewijk, Clegg, Pitsis, & Veenswijk, 2008).

There are much efforts into defining complex systems and project complexity. Aritua et al. (2009) believe the studies on complexity is not necessarily a new challenge, but an old challenge that is being increasingly recognized in order to improving performance and understanding of management. An early definition of project complexity in construction industry was provided by Baccarini (1996). Also Hertogh and Westerveld (2010) recognize these dynamic effects. They proposed different management styles, dependent on the specific complexity in a project. Regarding complexity, Bosch-Rekveldt (2011) developed the TOE (Technical, Organizational, and External) framework to assess the complexity of engineering projects using 47 elements (Bosch-Rekveldt, 2011). This framework was used as the base for complexity assessment in this research.

2.2. Needs for improvements in project management

Project management as we know it today, or conventional project management, emerged in the 1950s in the defense and aerospace sectors. These sectors in this timeframe can be characterized as little flexible and complex (Morris, 1997). Starting in the 1990s and still growing is the awareness of the changing and dynamic project environment (Bosch-Rekveldt, 2011). It is recognized that the complex and changing context of a project makes it impossible to make reliable predictions, and instead of predicting and correspondingly avoiding changes, changes

need to be incorporated in the project (Priemus, Bosch-Rekveldt & Giezen, 2013). This asks for a broader approach, which Koppenjan et al. (2011) named the '*prepare and commit*' approach. This approach recognizes that scope changes are inevitable, due to the many unknowns and the client's learning curve, and thus acknowledges the uncertainty and complexity of many infrastructure projects (Koppenjan, Veeneman, van der Voort, ten Heuvelhof, & Leijten, 2011). Several researchers (Atkinson, Crawford, & Ward, 2006; Joana G. Geraldi, 2008; Joana G Geraldi et al., 2008; Koppenjan, et al., 2011; Perminova, Gustafsson, & Wikström, 2008) argue that project management should evolve or mature in this direction, and thus conventional project management should be combined with the *'prepare and commit*' approach. Geraldi (2008) states: '*projects demand both mechanic and organic paradigms, both order and chaos*'. With order being reflected by conventional project management and chaos by the awareness of complexity and uncertainty. Combining both approaches means that a certain degree of flexibility is needed in order to cope with complexity and uncertainty (Joana G. Geraldi, 2008; Koppenjan, et al., 2011).

2.3. Lean management and agile project management

Since the 1950s, lean production have evolved and were successfully implemented (Aziz & Hafez, 2013). Several years later Womack and Jones studied this system and started calling the philosophy behind the system: Lean thinking (Womack & Jones, 2010). Lean thinking is a method to achieve more with less. Studies into the applicability of Lean Thinking to the construction sector resulted in the formation of Lean Construction. Marhani et al. (2013) believe lean construction is excellent in managing the construction process and achieving the project's goal by eliminating waste (Marhani, Jaapar, Bari, & Zawawi, 2013). Eric Gabrial (1997) believes the lean approach to project management has worked very successfully in potentially difficult and complex areas (Gabrial, 1997).

Another development in project management was the introduction of Agile project management. The Agile approach was developed in the software industry but many other industries, including the construction industry, have also adapted the agile approach. Agile aims to increase the relevance, quality, flexibility, and business value of software solutions. This approach is specifically intended to address the problem that have historically plagued software development and service delivery activities in the IT industry- including budget overruns, missed deadlines, low-quality outputs, and dissatisfied users (Cooke, 2012). Although there is a broad range of agile methodologies, all agile methodologies share the same basic objectives including: replacing upfront planning with incremental planning that adopts to the most current information available, building in quality upfront, addressing technical risks as early in the process as possible, to minimize the impact of changing requirements, delivering frequent and continuous business value to the organization, entrust and empower staff, encouraging ongoing communication between the business areas and project team members, and increase in the client's involvement (Cooke, 2012; Johansson, 2012).

Since Agile is an umbrella name, in itself, cannot be seen as a tool. In order to describe the more practical application of the Agile idea it was chosen to focus on one of the most applied and most popular Agile methods: Scrum (Agile-Methodology, 2014). For this research it was chosen to follow the guideline for Scrum as set up by Jeff Sutherland and Ken Schwaber (2013).

3. Research design

Quantitative data was required to investigate the relation between the implicit usage of lean and agile elements to cope with project complexity. Several complex projects are used as cases. From these complex projects, team members are asked to fill out a questionnaire. In this questionnaire the participants are asked to assess the complexity of the project they are currently working on and to assess the implicit usage of Lean and Agile elements.

The data gathering is done by means of conducting a digital questionnaire. The software program SurveyMonkey was used as format for the questionnaire. SPSS was chosen for analyzing the data.

For assessing the respondents' perceived project complexity, a framework based on the earlier mentioned TOE framework was used (Blom et al., 2014). The elements were translated into seventeen statements for which the respondents were asked to assess them on a five-point Likert scale ranging from totally disagree to totally agree.

For assessing the implicit usage of Lean and Agile the distinguishing elements of Lean and Agile from literature, section 2 of this paper, were used as a basis. Selection of these elements was based on finding a proper answer to

complexity criteria extracted from literature. For these statements again a five point Likert scale ranging from totally disagree to totally agree is used. This decision was made in order to keep the survey simple and quick to fill out.

3.1. Respondents

The respondents are selected based on whether they are working on a complex project. Eventually the survey was sent to 120 possible respondents. There were 82 persons who filled out the questionnaire, yet only 67 actually completed the entire questionnaire. Therefore in the total amount of respondents is 67, resulting in a good response rate of 56%. The questionnaire was conducted in Dutch, because all possible respondents are Dutch we expected that the response would be higher and more accurate with a Dutch questionnaire.

3.2. Analysis set-up

Performing a correlation analysis for ratio variables is mostly done by means of Pearson's correlation. For this correlation a two-sided approach was adopted because regardless of the direction we looked for the relation itself not the direction of influence. The conceptual model (Figure 1) was used as starting point for this correlation analysis. The null hypothesis for this research implies there is no correlation, dependency or relation, between the complexity on the one hand and implicit usage of lean and agile on the other hand. The hypothesis to be researched implies there is a correlation, dependency or relation between the two.

Fig 1: Conceptual model

By means of a Pearson's correlation matrix all seventeen complexity statements and fifteen Lean and Agile elements were analyzed, leading to 15 x 17 matrix. Thus 255 correlations were calculated. In total 51 significant correlations were found. For this analysis a correlation is assessed as significant when $\rho \leq 0.05$.

Subsequently, factor analyses are performed in order to identify underlying variables that explain the pattern of correlations within the observed variables. Factor analysis is often used in data reduction to identify a small number of factors that explain most of the variance observed in a much larger number of manifest variables.

3.3. Results

After running the correlation analysis, in order to group the sets of variables, factor analysis was done once for complexity elements and separately for lean & agile elements. Setting the extraction value on eigenvalue and NOT on the fixed factors, and using Varimax rotation ended up to 5 distinguished factors of complexity elements and 5 distinguished factors of lean & agile elements. These factors are extracted based on the percentage of variances. In the next step the correlation analysis was done among the factors. There were 8 significant correlations among the 25 relations. Table 1 presents the results. Grey shaded boxes are those that have significant correlation.

Table 1: Correlation matrix between complexity and lean & agile factors

	Complexity 1 (technical complexity)	Complexity 2 (uncertainty)	Complexity 3 (organizational complexity)	Complexity 4 (stakeholder)	Complexity 5 (external complexity)
Lean & Agile 1 (structure & integration)	0.443**	0.205	0.594**	0.175	0.521**
Lean & Agile 2 (coordination)	0.079	0.092	0.173	0.157	0.261*
Lean & Agile 3 (planning)	0.249*	0.278*	0.325**	-0.093	0.112
Lean & Agile 4 (resource allocation)	0.147	0.195	0.196	-0.080	0.180
Lean & Agile 5 (communication)	0.226	0.120	0.431**	-0.173	0.198

**. Correlation is significant at the 0.01 level
*. Correlation is significant at the 0.05 level

4. Analysis

The first significant correlation is between technical complexity and structure & integration elements of lean and agile. Based on this significant correlation we made a number of assumptions. First, working together as one team, instead of dividing the project in several parts and merging them at the end leads to a better understanding of the overall goals of the project. Second, a more experienced project manager will advocate a project in which all team members work together. It is not assumed that the experience of the project manager will increase when all team members work together. Third, keeping the constructability of the project in mind makes that the project goals become clearer. This because in almost all cases the constructability of the project in fact makes up a big part of the goals of the project. Thus when the constructability is kept in mind, also a big part of the goals are kept in mind, and are thus clearer. Fourth, a more experienced project management is also better in taking the constructability into consideration. Fifth, using more standardization in a project could lead to an increased level of experience of the project management. Since using more standardization means that the project becomes more similar to other (previously performed) projects and which thus also means that the project management most likely already has some experience with a somewhat similar project. Sixth, cutting the project into smaller batches, or mini projects, with intermediate deliveries will lead to a better understanding of the goals of the project. For a mini project there are less goals, which can be made more clear compared to a large project where the vague overall goal mostly consists of many smaller goals. Finally, an increased level of smaller batches leads to an increased level of the project management's experience. This is meaningful because only several project managers have much experience with large projects, yet many have experience with smaller projects. Therefore cutting a large project into several mini projects with intermediate delivery will increase the level of experience of the project management.

The second significant correlation is between organizational complexity and structure & integration elements of lean and agile. This group of complexity elements consist of number of resources, contracts and communication links among them which can directly influence the technicality elements in management aspect because the work is being done by people and contractors and the communication among them influence the efficiency of the work. Based on this relation we again made a number of assumptions. First, in case all team members work together the availability of the resources increases. This because all team members also have and/or are specific resources. In case all team members work together each other's resources are better available to them compared to in case all team members work on individual projects. Second, in case all team members of the project work together as one team, the communication level will increase. Team members will communicate more easily with other team members when they truly work together, instead of them all working on their own individual projects. Third, in case the standardization usage increases the amount of readily available resources also increases. This because using more standardization also means that more standard resources are used. Since the availability of standard resources is higher compared to the availability of uncommon resources it seems plausible that using standardization increases the amount and level of readily available resources. Finally, in case the project is divided into smaller batches, with intermediate delivery and thus also a feedback moment, the amount and level of communication in the project will increase.

The structure & integration elements of lean and agile have significant correlation with external complexity which includes the environmental aspects and availability of information in proper time. The structure of the project or constructability of it has an influence on environment and vice versa. The availability of information can affect the procedure of the project especially the pace. The wrong information or vague one can cause rework or failure. Based on this relation we made a number of assumptions. First, working together as one team will increase the amount of information available. Second, in case the availability of information increases the level of taking the constructability into consideration increases.

The coordination elements of lean and agile consist of daily meetings, information circulation, tracking of performance, and monthly/weekly detail planning. This group has significant correlation with external complexity elements. Based on this relation it is assumed that visualizing information and making this information insightful at any given moment inherently leads to the fact that information is available to all team members on any given moment of the day.

Planning elements of lean and agile have significant correlation with three groups of complexity elements named technical complexity, uncertainty, and organizational complexity. By this correlation it can be concluded that proper planning can reduce uncertainty and also technical and organizational complexity can mitigate. In this relation we made the following three assumptions. First, the more experience the project management has, the more they will involve the team members in the planning process. Second, priority in tasks in planning influences the duration of the project. Looking at the significance of this correlation this does not seem very unlikely. Third, involving team members in the planning process leads to an increased level of communication. This is because involving team members in the planning process in fact is an extra and high level communication moment.

And lastly there is significant correlation between communication elements of lean and agile and organizational complexity elements. Since organizational complexity is representative of number of people, contractors, and communication links, the relation between them and communication elements in management is meaningful. It is concluded that when the number of people or contractors is increased then much efficient communication is needed to tackle complexity. In this relation we made two assumptions. First an increased level of awareness amongst the team member of who is doing what will lead to an increase in the availability of the resources. This because all team members also have and/or are specific resources. In case each team members is perfectly aware of what the other team members are doing, he is thus also aware of who entails which resources. This awareness positively influences the availability of the resources. Second, in case the awareness of who is doing what increases, the level and amount of communication also increases. This correlation in fact is inherent, the awareness of who is doing what is caused by aligning this frequently. Aligning frequently increases the amount of communication.

Based on the above mentioned assumptions and found significant correlations it is assumed that some of the lean and agile elements work in a way of reducing complexity while some others are managing the complexity (see Table 2). There are a few lean and agile elements that did not show significant correlations with complexity.

Table 2: Summary of correlation matrix

element	Statement	reduces complexity	manages complexity	unsure
Lean 1	all specialists work together in the project, instead of the project being divided into parts and merging all the parts at the end of the process	X	X	
Lean 2	all relevant alternatives are considered and worked out		X	
	the decision making process related to the alternatives is delayed as much as possible		X	
Lean 3	the constructability of the project is taken into consideration	X	X	
Lean 4	much information, like problems and corresponding action plan and the project's performance, is visualised and insightful to me at any given moment	X		
Lean 5	standardization is used in this project	X		
Agile 6	I have selected the tasks I am performing myself		X	
Agile 7	performance is tracked on a daily basis			X
Agile 8	the team or sub-team meets on a daily basis			X
	amongst the team everyone is aware of who is doing what, since we often align this	X	X	
Agile 9	the work is divided in smaller batches, which after completion are delivered to the customer so he/she can provide feedback	X		
Merged 10	I was involved in the planning process	X	X	
Merged 11	a detailed planning was not made at the beginning of the process, but a one week/month planning is made on a weekly/monthly basis		X	
	in the planning only tasks with high priority (according to the customer) and for which all prerequisites are met are included			X
Merged 12	Problems, even the smaller ones, are reported when they occur and made insightful to all team members			X

Also there are some other relations that were anticipated to be significant, but there was no significant correlation among them based on the data gathered from questionnaires. First, it was anticipated that coordination elements of lean and agile (daily basis meetings and tracking, visualized information, and decision making at the last responsible moment) has correlation with uncertainty elements of complexity. Second, it was anticipated that communication elements of lean and agile (awareness of team members of what is happening in project, and problem reporting and solving) has significant correlation with external elements of complexity (availability of information, and impact on environment). Third, diversity of stakeholders, their expectations and goals influence the project complexity. This

element of complexity can be managed by well-communication strategy which means it was anticipated that communication elements of lean and agile has significant correlation with the named element of complexity.

5. Discussion

Based on literal evidences, project management needs to evolve in some features that can fit into nowadays complex projects. Baccarini (1996) believes the construction industry has displayed great difficulty in coping with the increasing complexity of major construction projects (Baccarini, 1996). He states that certain project characteristics provide a basis for determining the appropriate managerial actions required to complete a project successfully and complexity is one such critical project dimensions (Baccarini, 1996). Cooke-Davies et al. (2008) argue that a paradigm shift is needed from the traditional project management concepts in order to deal with future project management challenges and requirements of modern practice (Cooke-Davies, Cicmil, Crawford, & Richardson, 2008). In this way, we decided to explore the usage of new-born project management methods (Lean management & Agile project management) in construction projects as a possible response to this gap.

Why a combination of lean and agile? Beside all positive aspects of lean discussed in section 2, Lean Construction has its limitations when looking at the changing and dynamic project environment. This is not only stipulated by Bertelsen (2002), but also Ward (1994) already concluded that Lean Construction does not provide a method to cope with a changing project environment (Bertelsen, 2002; Ward, 1994). This is why recent research is done into how a project could cope with this type of complexity. Agile has been put forward to fill this gap (Demir, Bryde, Fearon, & Ochieng, 2012). Even though Agile methods are currently merely applied in the construction industry, it does not mean that Agile methods are not applicable or successful in the construction sector (Owen, Koskela, Henrich, & Codinhoto, 2006). Since Agile is merely applied to construction projects, little is known about it. Yet, the interest of the construction industry on the subject is rising (Owen, et al., 2006). Since Lean Construction has its limitations related to the project environment, the construction sector is looking for (complementary) methods that do provide tools to handle this kind of complexity. But why are they searching in the direction of Agile methods? One of the main characteristics of complex systems is that they are capable of self-organisation (Bertelsen & Koskela, 2004). They do not need a detailed plan, but attention should be paid to creating a clear objective and the improvement of the reliability (ibid). This fits well with the Agile concept. Owen, Koskela, Henrich, & Codinhoto (2006) elaborately discussed the applicability of Agile Project Management to the construction sector in their paper: is Agile Project Management applicable to construction?. Agile Project Management is based on the idea that change can be transformed into added value for the costumer. The scope of the project, and a corresponding planning, are only defined as far as value for the costumer at that moment is known and can be specified. This makes it possible to deliver value on the short-term. By receiving early and recurrent feedback, continuous learning will be achieved. This will lead to a continuous evolving of the value for the costumer. This results in an end-value which satisfies the costumer's requirements at the end of the process, instead of an end-value which meets the value as defined at the beginning of the process. To see change as something positive, as an opportunity to improve customer value, a more proactive organization is required compared to Lean organizations (Owen, Koskela, Henrich, & Codinhoto, 2006).

6. Conclusion

Increasing complexity of projects needs a tailored project management methodology in order to deliver complex projects successfully. In this paper we looked at the combination of lean and agile project management as a potential answer to this problem. The lean approach has limitations in construction projects, as discussed before, but the combination of lean and agile was assumed to be a solution. Currently, agile project management is rarely used in construction projects and the aim of this research was to explore if lean and agile methodologies could be used in this type of projects to influence the performance in a positive way by coping with complexity. Based on the results of correlation analysis it was concluded that the implicit usage of lean and agile elements can help coping with project complexity. Hence the conceptual model of the research (figure 1) is confirmed, regardless of the direction of the arrows. Finding out the direction could be a topic for subsequent research.

By proving the existence of this relation, further research on how lean and agile elements can be implemented in construction projects could be a way forward to improve project performance.

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