GATHERING END-USER INFORMATION AND KNOWLEDGE IN BIM-BASED INFRASTRUCTURE PROJECTS

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ABSTRACT

Improving customer orientation has been identified as one of the major challenges in the AEC industry. A number of reports have highlighted the need for a change, greater efficiency and stronger client focus on the construction industry. Customer orientation refers to the idea that a project is only successful if it meets the needs of its intended end-users. This could only happen if customer and end-user information is connected with the project for its whole lifecycle. In the house building, where the customer is usually known beforehand, service-related tools has been developed to capture end-users needs in the different phases of the project. However, Infrastructure projects differ from house building projects in the several ways, for example, end-users are presenting a big audience and the ownership of the projects are typically public authorities. These characteristics, together with the basic features of the project management, makes difficult to exploit past experiences to the future projects. One of the major strengths in the building information modeling (BIM) is that it enhances collaboration between the team members and allows the mutual channel for information exchange. However, there is lack of knowledge how end-user and stakeholder information and requirements can utilize and gather in the systematic manner from the design phase to the maintenance phase and for the infrastructure life cycle. In a present, it is widely noted that research system in this area has been found tangled and ineffective. In this sense, BIM could be also an effective tool for gathering, storing and utilizing end-user requirements, information, and knowledge.

Keywords: Infrastructure, transport, BIM, end-user, feedback

1. INTRODUCTION

The importance of customer orientation has highlighted widely in the construction industry. Although industry has been lagged behind other industries in measuring end-users needs and developing operational methods for delivering products and services in a customer orientation manner. Infrastructure projects are complicated and every project is unique. The main stakeholders of the projects change with each passing project, which means that new interrelationships are created all the time. Short-term interdependencies do not support satisfaction, commitment, and confidence between the project parties. In many cases, this has impaired the project delivery.

In the former way of thinking, infrastructures are seen as structures instead of services. An operational environment that is based on structures does not fully support the customer's commitment to the project delivery. Thouse fundamental characteristics of construction projects make it difficult and challenging to make use of experiences and end-user feedback in future projects. They also complicate the evaluation of the project outcome and emphasize the need for developing an effective and efficient evaluation system where end-user´s feedback has a significant role as a co-creator.

Construction is an information and knowledge driven industry. Construction firms are increasingly be-ing challenged by high-cost pressure, shortened project cycles and increasing competition. In the construction, individuals and the knowledge they create are the most critical features for improving business performance and ultimately for collective learning (Ribeiro, 2009). The infrastructure project could be depicted as an information-based organization, because of the great amount of information related to the projects and the information is used and utilized many participants in the project coalition. According to Drucker (1989) to build successful information based-organization, it requires clear, simple and mutual goals and the feedback system, which enables the comparison of achieved results and demands, which has been set. Further to Druckers statement, building infrastructure that serves end-users ability to achieve their objectives, with satisfied experiences, the development of the built environment must be based on setting end-user oriented goals and utilizing versatile end-user feedback. The challenge is then how to transform this information to knowledge on existing and future projects in the construction.

It is stated that Building Information Modeling (BIM) is transforming the way the built environment is being created (Smith and Tardif, 2009). However, studies connected to BIM have been so far concentrating on storing, linking and exchange the project based technical information. We argue that BIM could be also exploited by gathering end-user information through the whole project lifecycle, which benefits all participants and stakeholders.

Although infrastructure projects are complicated and multifaceted entities, the outcome of the infrastructure projects exists at the same reason as any other products and services – to fulfill needs of its end-users. Therefore the product development of the infrastructure projects could be approached and adapted by several methods from other service-oriented industries.

However, there is a lack of studies concerning end-user´s satisfaction and experiences of the infrastructure and the knowledge of this important entity is at the very early evolutionary stage. Formerly, performance measurement in the construction was based on hard measures, such as cost, schedule and quality, which highlight production orientation in the construction (Kärnä, 2009). Traditional performance measurement tools are too simple for measuring a construction project (e.g. Dainty, 2003) and they no longer meets the demands of the today's business environment. Therefore, it is natural that end-users satisfaction has been highlighted as one of the major key performance indicator (KPI) indicating success of the construction project (Pinto and Rouhiainen, 2001). Alongside with other soft measurement tools e.g. the satisfaction level of various stakeholders uses subjective opinions and personal judgment of the stakeholders (Chan and Chan, 2004).

The objective of the research is to create the multidimensional framework, which could be use to gather and utilize end-user information and knowledge in the different stages of the infrastructure projects from design to maintain and operation the lifecycle of the infrastructure product. This information is linked to the building information model (BIM). The framework is consists of process description e.g. when, what and whom end-user information and knowledge are gathered. It also represents measurement indicators for evaluating user experiences. The results of the study are the first step in the larger Finnish research program RYM-SHOK, which is concentrating on developing building information modeling in the Finnish construction industry.

2. END-USER EXPERIENCES AND INFRASTRUCTURE

End-users' satisfaction and customer orientation have received a lot of interest in recent years in the construction industry. At the same time, attention has been paid to creating performance evaluation methods and tools for measuring the usability of buildings (e.g. Leaman and Bordass, 2001). In the early design phase the development of the project brief should highlight to the client organisation, the importance of involving project users in the briefing process and understanding their requirements, culture and traditions (Othaman et al. 2004). After the completion of the construction project, the best-known of the methods is post-occupancy evaluation which has been used to identify and evaluate critical aspects of building performance systematically (Preiser, 1995). However the Post Occupancy Evaluation (POE) method is focusing on building as an object, without taking into account the interaction between space and user experience.

The focus of the end-user orientated construction branch should be on recognizing and fulfilling the end-users' needs. This demands systematic approach for collecting and using feedback of the user for development of the design and construction processes and for supporting the user's needs (Kärnä et al. 2010). In this user-centric approach, users of the infrastructure are seen as co-creators in the infrastructure processes. The assumption is that the co-creation adds the value, instead of traditional processes where users are seen as passive players. Users are part of the enhanced network and co-developers of the personalized experiences (see Prahalad and Ramaswamy, 2000). So far, end-user issues has been concentrated on the house building and there is a lack of proper information how end-user can create value to the project in the infrastructure projects.

Pinto and Rouhianen (2001) emphasizes that client acceptance as fourth criteria of project success in addition to traditional triple constraint (time, cost, performance) has some obvious benefits in the construction: it refocuses corporate views outside the organization towards the customer, it recognizes that the final arbiter of a successful project is the marketplace and it requires project teams to create an atmosphere of openness and communication throughout the development of the project.

The usability of the built environment focuses on the user perceptions of the ease and efficiency with which they can use the constructed infrastructure. Alexander (2006) states that, user experience encompasses all aspects of the end-user´s interaction with an organization, its services, its products and its facilities. For example, usability of the built environment depends both on the physical environment and how the environment is used (Blakstad et al. 2010). Usability is not only an attribute of the built environment, but also concerns the users´s experiences, use and satisfaction. Users experiences is also dependent on the context of the use, at least some extent.

The user experience is one of the key concepts to describe the relationship between user mode and its services. Since the user experience is personal and multi-dimensional, it can never be completely planned. User Information constitutes the raw material, which is the collection of the state of the user experience may be factors to understand and predict. To ensure that this raw material can be accessed, we should understand what factors are associated with the user experience.

The first step to understand end-user experiences and gather feedback is defining the role and status of the end-user in infrastructure. The recent study (Manninen, 2011) argues that approach to assess the outcome in the field of infrastructure needs to be developed towards the user-orientation. In the present approach the end-user is communicating loosely with a few stakeholders (e.g. with the client). The study address that there is remarkable difference if the user is in the center (user centric approach) or in the participatory role in the infrastructure processes (Figure 1). The user centric approach might still keep the user as a passive actor and as a target of different stakeholders. The participatory approach is focusing more on improving the communication between different stakeholders. This is proved to be the significant factor from many perspectives, e.g. the gathering of user feedback and the simulation of user in the infrastructure.

The customer experience can be measured through robust tools. This is also suggests e.g. Kärnä et al. (2010), who argue that because of the multi-dimensional and process nature of the usability, it should be explored by versatile methods. This can be done by evaluating customer satisfaction survey results or qualitative methods, where simulation is in the core of the end-users experience. In general, qualitative (diagnose information) and quantitative (indicative information) approaches should be seen to complement each other.

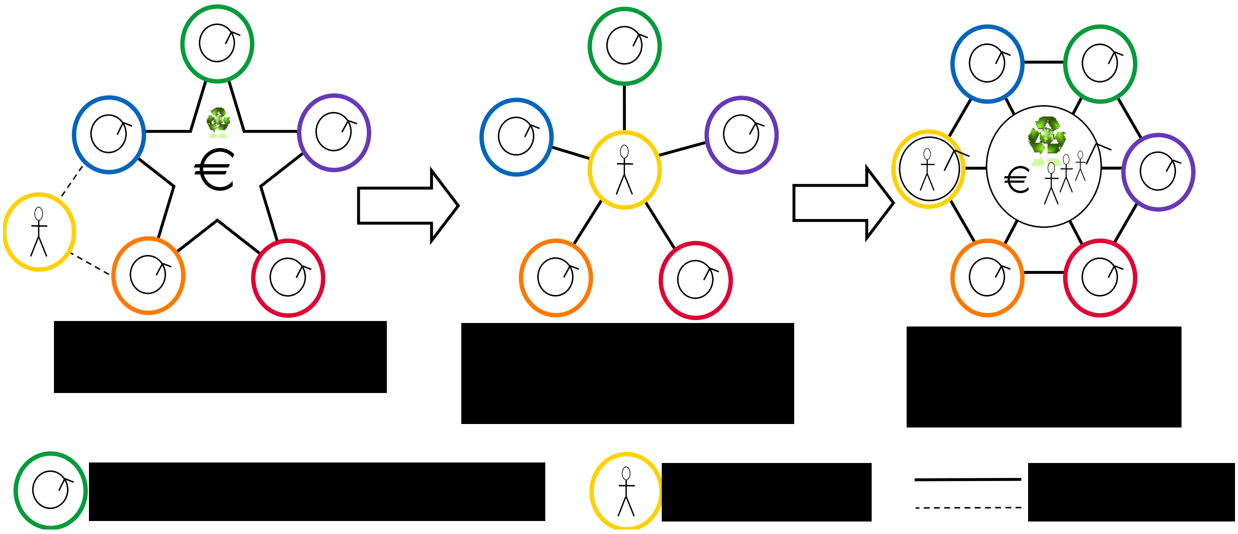

Figure 1. Towards the participatory approach (Manninen 2011).

The service perspective highlights, that the built environment, including infrastructure such as roads and traffic, is seen as a platform for work and life, and the efficient use of the built environment can be supported by services (Manninen, 2011). In this viewpoint of the participatory approach, users of the infrastructure are seen as co-creators in the infrastructure processes and co-developers of the personalized experiences. The assumption is that the co-creation adds the value and improves commitment, instead of traditional processes, where users are seen as passive players (Prahalad and Ramaswamy, 2000).

The participatory approach enables multidisciplinary optimization between different factors. In theory, user centric approach disregards factors such as life-cycle costs and environment when structures and services are provided hypothetically without economic and environmental boundaries. In the participatory approach, all valid factors can be optimized and set at the right level. In this mean, participatory approach will develop substantially Value for Money (VfM) aspect and its qualitative criteria.

In this context, the concept of Value Management (VM) is important. In shortly Value Management ensures that the construction process generates the value wanted by the client. As most of the product value is defined through the design, the Value Management during construction mainly looks after the process related value such as timeliness, dialogue with the owner, users and other stakeholders, public relations and good neighbourship (Bertelsen and Koskela, 2002).

Hines et al. (2006) have investigated product lifecycle management (PLM) in the lean construction context. One of the main results of their study was that, the existing technical product development literature lacks an of focus on the human aspects of product development. Their study also divides customers as two dimensions: (1) The external buyer or end-user of the product; and (2) The internal buyer or end-user of the process under consideration. When, the PLM team is developing new products it will not only focus on the needs of the external customer (Customer 1) but also on those of the internal customer (Customer 2). This will help ensure not only satisfied external customers but also an aligned product strategy and an effective organization.

Value generation and management is the overall progression from concept to detail design through to construction and occupation. In an overall project sense, the value definition is at the start of the project often through the designers and consultants (Perera et al. 2010). Similarly, Salvatierra-Garrid and Pasquire (2011) stresses wider perspective when exploring value in the construction. They argue that the concept of value from LC perspective has been associated with on-site activities at production level, where value generation is linked to the satisfaction of customer requirements; and the impact on society is missing from the literature as current practices aim at satisfying only end-users and/or clients´ requirements. As a result, current perspectives should be extended to consider the impact caused by construction projects to society as a whole. In the infrastructure projects, impacts on society have a significant role, because typically infrastructure projects are ranging from a wide geographical area.

3. FEEDBACK AND BIM

The actors in the field of construction and real estate business need versatile and systematic end-user information data to develop their operations which influence in the maintain phase and the whole lifecycle. In the light of this study, after the model has been tested into the real infrastructure environment, the framework will be implemented into Building Information Modeling (BIM). In this assessment, the BIM is a human activity that ultimately involves broad process changes in construction rather than type of software (Eastman *et al.* 2008). Laiserin (2007) offers a broad, holistic definition to BIM, which also support the objectives this study: *'BIM is a process of representation, which creates and maintains multidimensional, data-rich views throughout a project lifecycle to support communication…, collaboration…, simulation…, and optimization…'.*

Manninen (2009) has shown in his studies that information flows between infrastructure projects parties are at the unsatisfying level. For instance, he argues that designing stage dialogue between the customer and designer can be poor which lead to misunderstandings and the discontents relationships. The basic problem in the designing process is that customer can't delivery theirs requirements and demands to the designers. According to Manninen's studies utilization of the building information modeling (BIM) in the infrastructure sector can improve project parties´ cooperation. As such, the cooperation improvement is based on progressive project briefing and visualization of plans.

The building information model (BIM) comprises ICT frameworks and tools that can support the integrated collaboration based on the life-cycle design approach. A basic premise of BIM is collaboration by different stakeholders in different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder (Sebastian, 2011). BIM can enhance end-user orientation in several ways. Most importantly, the end-user information is available for all parties in the project coalition. Secondly, it forces all parties to take account end-user information in their operations. Thirdly, BIM and its applications can produce understandable and usable input data and information for the end-user (e.g. visualizations and simulations). This is remarkable change for the present project communication which is based on technical 2D drawings and documents.

In general, 4D tools are emerging as a construction planning technology that addresses some of the challenges and it the great potential to improve the visualisation of construction and design. 4D will be used throughout all phases of facility design, construction and lifecycle engineering of a project. However, its utilization and implementation in the industry are still at the evolutionary stage. Nine 4D-based key performance indicators were developed Three performance indicators consistently perceived as being highly significant at site process level are time, safety and client satisfaction (Dawood and Sikka, 2008).

According to Integrated Project Delivery Guide (2007) there are several feedback flows, which can consider being important for gathering end-users feedback. In a phase of conceptualization feedback on building systems relative to achieving project performance goals, which is the response by design consultants. In a criteria design phase owner should facilitate end-user group reviews and feedback to team regarding revisions. Also the prime designer must confirm end-user experiences of building as it relates to project goals. In a close out, both the owner and designers should work on end-user needs and requirements to use the BIM for lifecycle benefit and collect and analyze post occupation evaluation (POE) feedback. Othman et al. (2004) have been introduced the concept of dynamic brief development (DBD). The central principal of their model is feeding back the client organisation and the design and construction team with the learned lessons and comments of the facilities management team and end-users in order to enhance the performance of the briefing process in future projects.

Ballard (2000) has argued that feedback is one essential feature of Lean Project Delivery System (LPDS). He states that `*feedback loops are incorporated at every level, dedicated to rapid system adjustment; i.e. learning*`. Simply stated, feedback is a prerequisite for learning in construction both at the project level and on the company level. By well-timed feedback it is possible to prevent problems from developing or at least enable quick problem solving. Through effective feedback systems organisation can foresee changes in the business environment and could adapt to these changes beforehand (Kärnä & Junnonen, 2005).

In order to gather end-user experiences and link this information to BIM-model, the following stages must take under consideration:

I. Identification of stakeholders connected to the end-user experiences in infrastructure and identification of feedback flows between them
   a. To whom feedback should be given?
   b. What is the role of the stakeholder in connection with the project?
II. Determining systematic of collecting feedback
   a. Which are the main processes affecting to the development of the infrastructure?
   b. How is the flow of collecting feedback functioning?
III. Explore content of feedback surveys
   a. What is the content of each feedback survey?
   b. Which factors affect to the user experiences of the infrastructure?

An output of content determination includes creation the content of each measurement indicator. Table 1 shows an example of the main content of the surveys for the phase of road-in-use. The main indicators have been categorized in four classes: (1) usability, (2) functionality, (3) safety and (4) serviceability, which are presented in the first column of the Table. As the indicators are usually very complex, each of the indicators consists of multiple parameters, which are evaluated by the end-user.

Table 1. User experiences´ performance measurements with descriptions.

Measurement indicator	**Indicator description**	**Target**
Usability	*Comfort* *Accessibility* *Satisfaction*	Ensure services which meet end-users soft indicators needs and requirements
Functionality	*Fluency* *Speed / time* *Traffic flows* *Interruptions*	Decrease users' operation costs (fuel consumption) and environmental impacts. Ensure functional and fluent service.
Safety	*Traffic accidents* *Prevention*	Provide safety service. Increase functionality indirectly
Serviceability	*Navigation* *Accuracy of information* *Service points (additionals)*	Increase level of the service.

4. THE FRAMEWORK OF GATHERING USER EXPERIENCES

In the light of this research, the conceptual framework was developed to capture the essential stages when and how user experiences are measured. In the BIM based construction environment, gathering end-user information and knowledge includes four main stages (Figure 2). According to the framework, attention to the end-users covers all phases in the project lifecycle and not just briefing as is generally the custom, which are also suggested e.g. Dewulf and Van Meel, (2002) and Pemsel et al. (2010).

Before design, in the pre-design stage, requirements and needs of the end-users are collected into the model. By this collected information and knowledge the model processes put out functional and qualitative requirements which are the formalized baseline for the design stage. The formalized requirements are noticed for the end-user for the revising purposes. The basic tools gathering the end-user information and knowledge at the designing stage are visualizations and simulations. The feedback and comments of the end-user are gathered and used as design control elements. At the third and fourth stages, construction and operation/maintenance stages, the outputs of the model are a communication deliveries and satisfaction surveys. Communication deliveries at these stages consist e.g. of newspaper ads and internet pages. The feedback of the end-users during construction, operation and maintenance is exported to the model and exploit for the well-being point of view.

All four main stages concern the user experiences of performance measurement. Before design, the client presents functional and quality requirements which are conducted from end-users' requirements and needs. Consequently, client gather end-users' requirements and needs, process them, divide them into the functional and qualitative factors, and present them to the design. In the design stage, the performance measurement factors are tested by visualizations and simulations which ensure that design solutions really meet end-users' requirements and needs. The role of the performance measurement at construction and operation/maintenance stage is monitor and judge what is service level of the infrastructure.

It is noted that managing the participation of end-users throughout a project requires that a number of difficulties have to be overcome. The difficulties found in practice are principally making end-users see a greater and longer-term perspective of their situation and overcoming social and cultural barriers among participants as a means to understanding real needs.

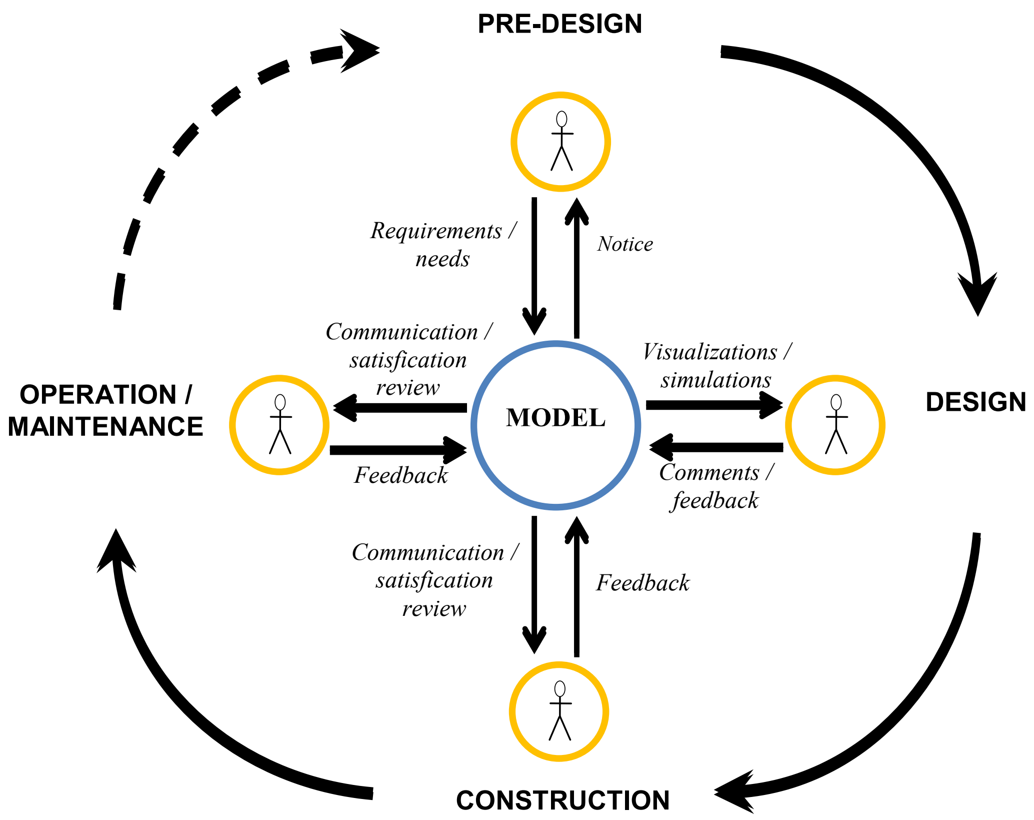

Figure 2. Framework for end-user information and knowledge gathering in BIM based infrastructure life-cycle.

5. CONCLUSIONS

This study has presented a model and a framework whereby the main actors in the field of construction obtain extensive information about the infrastructure and roads as interfaces and platforms for usability experiences as well as users' evaluations regarding the various stages of road acquisition. Furthermore, the paper introduces a user feedback systematics that meet the needs of developing user orientation in the field of infrastructure and links it to building information modeling. This information could be utilized in different stages, from the early design to the use of the project. Next the user-experience indicators will be tested in the workshops and piloted in the on-going projects.

In general, the development of the usability of the built environment requires that the focus is on user experiences and on processes how the user involvement can be supported. The canvas of the paper is to understand the requirements of the infrastructure end-users and transfer them to the customer requirements and finally transform then to the structures in the field of infrastructure. In addition, it can produce information for programming the project, guiding the designing, for the design itself and as a selection criterion of design solutions in order to provide user interfaces and platforms for user experience. In the framework the lifecycle of the whole project is strongly emphasized and the focus of each stage should be on end-users needs.

This paper depicted preliminary study how end-user information could be measured in the BIM context. In the light of this study there is lack of operational models, how user related information could be measured in the infrastructure projects, what the specific indicators are and how this information could be linked to the building information model. More systematic operational models are needed and developing usable interfaces as a measurement tool are strongly emphasized. The approach also strongly emphasizes utilizing soft measurement tools, such as end-users satisfaction to compliment traditional hard measurements which are traditionally expressed in terms of costs, schedule and quality.

The user experience performance measurement indicators presented in this study offers a guidance, which items should be concentrated, when simulating road projects or in the phase of post occupancy evaluation. Indicators were categorized in the four classes, which were usability, functionality, safety and serviceability. They can be also direct to different operational and maintenance functions: traffic control and telematics, traffic engineering/devices and traffic structures.

The framework for end-user information and knowledge gathering in BIM based infrastructure life-cycle was finally introduced to describe in which phase of the lifecycle information is collected and which kind of information is needed. In the framework feedback flows and content of the flows were presented. This information can be used various actors in the project lifecycle to improve their performance and to learn from the end-users feedback.

In the infrastructure projects, impacts on society have a significant role, because typically infrastructure projects are ranging from a wide geographical area. According to Salvatierra-Garrido and Pasquire (2011) underline the need of an expansion of current value perspectives moving from a local context (project level) to a global context (society). This emphasise the importance of value management also from the end-users perspective and product-lifecycle management.

Next step of the study is to develop performance indicators for stakeholders and create it-based platform which enables information linked to BIM. As a basis of the it-based platform Finnish feedback system PROPAL-is going to be used as a one of the information channel. PROPAL is a common Finnish feedback system, which serves all the main parties in the construction. It enables multipurpose benchmark comparisons and it could be flexibly adapted to different projects and forms of implementation. Companies can benefit by using common feedback system e.g. perceiving needs for development and targeting operations, improving cooperation and operations through openness and mutual learning and developing customer orientation (Kärnä, 2009).

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