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Theoretical Framework of Collaborative Design Issues

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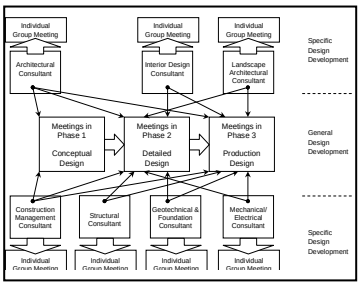
Graphical abstract



Abstract

Building's design is developing to involve complexities of engineering systems, where design process requires various disciplines of participants to solve the complex issues. Collaborative design is developed with main purpose to facilitate the integration of multiple participants in design process to produce best design. This paper presents conceptual understanding, current practices, and theoretical framework of collaborative design. Literature review builds the conceptual understanding, exploratory study through in-depth interviews to design managers and designers reveals the current practices, and grounded theory constructs the theoretical framework. The review had found three main indicators of collaborative design, and through those indicators it has been identified that collaborative design is implemented at design process. The interviews had revealed that best design is hard to be achieved although collaborative design has been applied. Through grounded theory analysis, it has been found that the lack understanding of Knowledge Management (KM) roles is found to be main issue collaborative design practices.

Keywords: Collaborative design; design management; knowledge management; collaboration

1.0 INTRODUCTION

The increasing need to develop sustainable environment by improving buildings' design [1, 2] and to generate competitive buildings' design [3, 4] are some reasons that caused design complexities [5]. Based on these circumstances, design process requires participants with diverse expertise. Collaborative design is determined as concept that can be applied in facilitating the integration of multi-participants whom involved in design process to achieve best design [6]. Based on its vital roles, collaborative design has been developed empirically and theoretically. Research in collaborative design mainly discussed about the invention of concepts, systems and tools with focus to support collaborative design process [7]. This objective related with the emerging and developing issues in collaborative design that are need to be solved through the invention of supporting systems and tools. Thus, collaborative design is developing in conjunction with the development of Information and Communication Technology (ICT). ICT has abilities in carrying the invention of systems and tools to assist the process of collaborative design.

The diversity of participants' expertise is also found in design process of high-rise building, and best design is difficult to achieve [8]. Related with the finding of collaborative design's function in facilitating the achievement of best design, Authors conducted exploratory study in order to discover collaborative design practices. Furthermore, this research has main purpose to indicate main issue of collaborative design practices that caused failures in the achievement of best design.

This research formulates three main issues. First issue concerns the implementation of collaborative design at the process of multi-disciplines design. The second issue concerns the understandings and responses of designers about collaborative design concepts and roles, and also issues that impacted the negative responses to collaborative design's roles. The third issue concerns theoretical-empirical framework of collaborative design's issues. In order to achieve the research's purposes, the methodology of this research applies literature study, exploratory study through in-depth interviews, and also grounded theory.

This paper aims to present theoretical basis and preliminary empirical studies toward understanding the implementation of collaborative design. This research accomplishes conceptual understanding of collaborative design, empirical circumstances of collaborative design practices, and also theoretical framework of collaborative design issues. The finding of this research discovers possibilities in developing collaborative design research.

2.0 COLLABORATIVE DESIGN

According to [9], there are three different endeavors that have capability to facilitate multi participants' works. The endeavors are coordination, cooperation and also collaboration. The concept of collaboration is developed in design process, which is called

collaborative design. In collaborative design development, both practically and theoretically, there are arguments about its definition. Some researchers and practices defined collaboration similar with cooperation [10]. Collaboration has different meaning with cooperation and coordination [6]. The difference related with its process and goal when it is compared with other approaches. In collaborative design, design has to be produced simultaneously by all participants during design process, from the beginning until the process is finish, while others are not. Best design as best shared-solution is the main goal of collaborative design, in which it is obtained from the integration of entire participants in design process. The difference of those three endeavors also related with the interaction of participants in finishing design [11]. The interaction in coordination is uni-direction, bi-direction in cooperation, and multi-directions in collaboration.

Based from review to collaborative design previous researches, it is found that there are three main indicators which can be used to identify the application of collaborative design. The first indicator is the involvement of multi expertise consultants with various backgrounds and expertise in design process [12]. This indicator related with the basic need to use collaborative design in facilitating the integration of multiple participants to produce best design. In order to solve issues related with design complexities and to gain best integrated solutions, design process is need to involve multiple expertise participants. The second indicator is the integration process of multiple participants and tasks that are done from simultaneous works [6]. Integration and simultaneous work are two main factors that signify the distinction of collaboration to others. This notion underlies the essential need to conceptually formulize these factors as the indicator of collaborative design. The third indicator is the appearance of tasks interdependencies between multiple design works and participants in creating design [13]. The third indicator illustrates associations between tasks, in which it indicates that design is done by all participants and the integration has been achieved s[7].

■3.0 RESEARCH METHODOLOGY

This research aims to discover the implementation and current practices of collaborative design. Literature review is used to build conceptual understanding of collaborative design. In order to carry out the current practices of collaborative design, this research uses exploratory research through in-depth interviews to 32 respondents. The respondents consist of design managers and designers whom have experiences in multi-disciplines design process of high-rise commercial buildings in Indonesia. There are three types of questions for the interviews. First questions related with the discovery of collaborative design's indicators, second questions related with definition of collaborative design and its role to multi-disciplines design process and third questions related with issues of collaborative design.

The first questions intend to discover the implementation of collaborative design. The reviews found that there are three main indicators. The indicators are the involvement of multi-expertise participants [12], the integration and simultaneously work of design process in realizing best design [6, 11], and the appearance of task interdependencies between multiple tasks and participants that indicates the achievement of integration in best design [7, 13]. Data of the first question is descriptively analyzed by using percentage measurement. In this session, respondents are also asked to describe and illustrate the process of collaborative design.

The second questions aim to discover the understanding of participants about collaborative design. There are three types of questions. First, respondents are given description of collaboration and cooperation, and they are asked to choose the appropriate description of collaboration. Secondly, the respondents are asked their responses about collaborative design's role in supporting multi-disciplines design process. And third, the respondents are asked to describe their reasons if they have doubts or negatives response of collaborative design's roles. Descriptive analysis is used to analyze collected data of understandings and responses. The results of second questions contribute to third questions and analyzed accordingly by using grounded theory analysis.

The third questions intend to discover issues and approaches in collaborative design practices. There are two kinds of questions. The respondents are firstly asked to describe the appearance of issues or difficulties during collaboration, and secondly they are asked to illustrate approaches that are mostly used to solve the issues. Grounded theory is used to analyze collected data from the third questions. Main purpose of this analysis is to discover main issues of collaborative design practices. In advance, the findings of empirical studies are synthesized by comparing with findings from literature studies.

■4.0 CURRENT PRACTICES OF COLLABORATIVE DESIGN

Three indicators of collaborative design are the diversities of participants, the simultaneously process and the achievement of best integrated design. Figure 1 illustrates quantity percentage of each indicator's frequency that has been discovered in design process. Based from results, it can be concluded that the concept of collaborative design is applied. Each indicator of collaborative design has high frequency, which indicates that respondents mostly often found those three indicators in design process. The percentages of frequency where indicators were found in design process are between 84%-94%.

The involvement of multiple expertise participants is mostly often found in design process. The purpose of this involvement is to achieve best design [12], in which it is also the purpose of collaborative design. As well described by [14], design process involves multiple participants in order to share expertise, ideas, responsibilities, and resources to produce best design. In line with the result of the first indicator (93,75%), it can be concluded that the design process has purpose to achieve best design.

The second indicator of collaborative design related with the achievement of goal and its supporting process and activities in design process. According to [3], integration of participants is important in collaborative design, in order to achieve best design as integrated solution from multi participants. Best design is also gained from simultaneous works [6]. Based on the result, the second indicator is also found in design process. The frequency of this indicator that mostly often found in design process is 90,63%.

The appearance of tasks interdependencies in design process is the third indicator of collaborative design. This indicator has correlation with the second indicator. Each task corresponds to other task in collaborative design [15]. Every task is interrelated, and there are correlation paths between tasks. The paths illustrate interdependencies between tasks in collaborative design. Based from result, frequency of the third indicator that is mostly often discovered is 84,38%. In accordance with these findings, it can be concluded that the design process applies collaborative design. The conclusion is generated from the appearance of all indicators that were found by respondents in design process. The frequencies of all indicators found in design process are high, in which the frequencies are almost 100%.

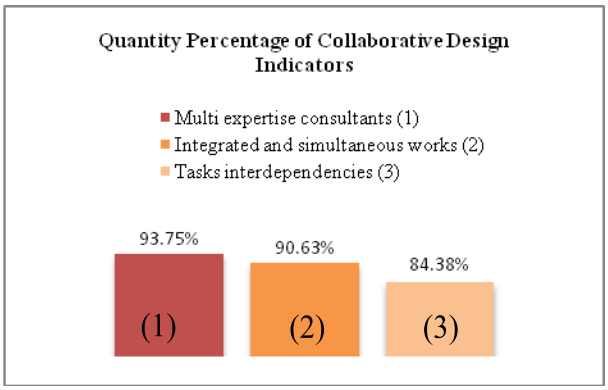


Figure 1 Quantity percentage of frequencies where collaborative design indicators were discovered at the design process

Based from the results, it can be indicated that the important aspect in collaborative design is the process itself. In supporting the collaboration, conducting meeting is necessary [16] to assist the integration process and simultaneous works. Some activities that need to be done in each process of meeting are the activities of sharing information and knowledge [17], negotiating [18], and decision making [19]. Comparable with the concept of collaborative design that was stated by [6], integration and simultaneous work of the current collaborative design practices are also facilitated by meetings. The interviews revealed that meeting has vital role in facilitating the collaboration process. The interaction model of all participants has similarities with the interaction model that is purposed by [20]. Information about the process in conducting meeting during collaborative design are synthesized and illustrated on Figure 2.

The respondents consist of design managers and designers of seven consultants, which are architectural consultants, interior consultants, landscape architectural consultants, construction management consultants, structural consultants, geotechnical and foundation consultants, and mechanical/electrical consultants. There are two main processes in developing design, which are the process of developing specific design development and general design development. Meetings conducted in general design development aim to integrate the multiple participants and works. Consultants send their delegates to present at the meetings. The delegates are mostly managers of each consultant. All invited delegates discuss the contents of design developments and make decisions of design developments. They also modify and integrate the design drawings in this process. Decisions, contents, and drawings resulted in this process are developed individually by each consultant together with their team in the process of specific design developments. Each consultant accomplishes tasks that are appropriate with each specification or tasks that have been divided in the previous meetings. Results of specific design developments from each consultant will be simultaneously developed with all consultants in the next meeting.

In collaborative design practices, there are three main phases of design developments. Phase 1 is the conceptual design phase, where consultants are involved to construct conceptual design and to determine design criteria. Phase 2 is the detailed design phase, where consultants are involved to develop design based on criteria that are produced from previous in Phase 1. Phase 3 is the design production phase, where design drawings (as built drawing) that are used as guidance for construction works are produced. Each consultant has different role in design process. Architectural consultants as well as construction management consultants are mostly involved in all three phases, and other consultants are mostly in Phase 2 and Phase 3. Meeting is essential due to its role in facilitating the integration process. All consultants' works/tasks and thoughts/perspectives are integrated through meetings that are conducted in every design development phases. The interviews reveal that the concept of collaborative design is implemented in all those three phases of the design process.

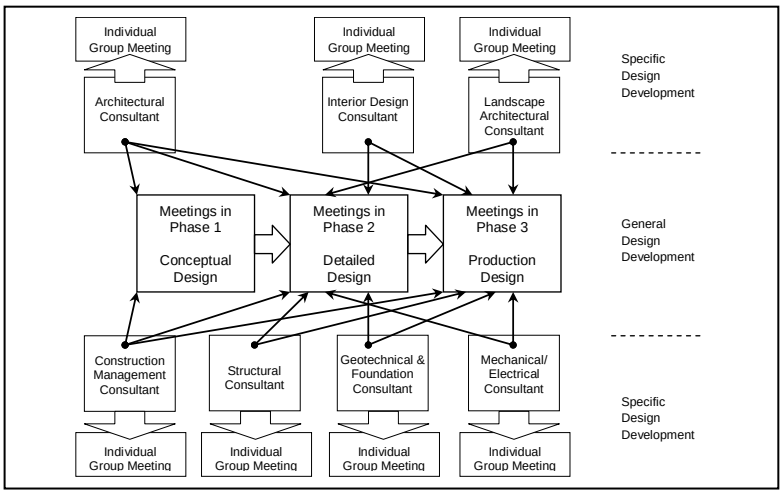


Figure 2 The involvement and interaction of participants in conducting meeting at current practices of collaborative design

5.0 COLLABORATIVE DESIGN ISSUES

The indicators of collaborative design had been discovered. In addition with this finding, respondents were then also interviewed their understanding about the concept of collaborative design. This was done with purpose to explore the perspective of designers about the process of collaborative design that was experienced by them. Respondents were asked to choose two different statements in discovering their understanding of collaborative design. One statement described the definition of collaboration, and another described definition of cooperation. Both statements are adopted from definitions that were purposed by [6, 9, 11]. The result of this study is presented on Table 1. The results discover that not all respondents understood the definition

of collaboration. Some of them (5,56%) comprehend the concept of collaboration similar with cooperation, whereas theoretically cooperation has different meaning with collaboration. It can be defined that even though collaboration were mostly found to be used as approach, some designers did not recognized that they experienced collaborative design. Even though this issue was appeared, most respondents (94,44%), defined collaboration correctly, which is suitable with the concept that are purposed by [6, 9, 11]. Besides discovering the perceptive of collaborative design, respondents were also asked their perception about collaborative design's role in supporting multi-participants' design process.

Study discovered that not all of respondents, whom understood the definition of collaboration, have positive response to the role of collaborative design in supporting multi-participants' design process. Some of them had doubt (8,82%) and negative responses (2,33%). These perceptions are driven by the presence of issues, and made some respondents are questioning the role of collaboration in supporting design process, even though most of them (88,2%) appreciate the achievement of best design through collaboration. Similar with these findings, it is also found that 50% of respondents whom did not understand about the definition of collaboration were also had doubt about its role to design process. This doubt was also resulted from the appearance of issues during the process.

There are three main aspects of issues that are developed in collaborative design research [21]. First issue is physical issues, which related with difficulties in integrating design process as a result of difficulties in conducting physical meeting. Technical issues are the second issue that are difficulties in integrating design objects due to problems in achieving shared understanding between multiple participants and modifying designs. The third issue is social issues, which consist of difficulties in integrating participants that caused best design is hard to be achieved. Based from these emerging issues, research of collaborative design is developing to find and invent systems and tools that can be applied in supporting collaborative design. Physical approaches by providing supporting media [22] can be used to overcome the appearances of physical issues in conducting physical meeting. Technical approaches through KM [23] can be applied in order to solve technical issues and support the achievement of shared-understanding between participants and also to manage the design development process. Concerning individual and team are similar with social approaches [16] that can be used to solve social issues that able to direct best design achievement.

At collaborative design practices, there are three main classifications of issues. First issue is physical issues that are difficulties in conducting physical (face-to-face) meeting. Second issue is technical issues, which are difficulties in achieving shared-understanding between participants, making decision, and managing design developments. Third issue is social issues that are difficulties in managing diverse participants. These issues are then synthesized through grounded theory analysis in order to discover main issue that caused failures in applying collaborative design. The synthesis includes discovery of empirical-theoretical gap by identifying the dissimilarities used of approaches, within in practices or proposed approaches, as presented in Table 2.

Practically, collaboration is difficult to be done because of time and place availabilities of each participant, where face-to-face meetings are difficult to be conducted. In dealing with this issue, physical approaches have been applied, by applying ICT-based tools and systems to provide virtual design process [24, 25]. This finding was also discovered in previous collaborative design researches, as well as the development of related issue. Virtual collaboration causes the appearance of divergent understandings or comprehensions about design developments that have been developed by each participant. Shared-understanding between participants is hard to be achieved, because the communications within virtual collaboration are limited [26]. Thus, the issues are developing into the requirement of systems and tools that have capabilities in managing design developments to support the mutual comprehension of design developments in collaborative design.

Table 1 The understanding and response of respondents about collaborative design definition and roles

Understanding		Response		Reasons
1. Understand	(94,44%)	a. Positive	(88,24%)	The diversity of multi disciplines participants can lead to the achievement of best design, even though it is difficult to be achieved
		b. Doubt	(8,82%)	The appearance of issues which are resulted from collaboration, such as : a. Difficulties in coordinating and integrating design developments b. Leader whom takes control result without considering all participants in making decision c. Limitation of time and place availability caused ineffective and inefficient design process d. Extra time is needed in finishing design because the involvement of various participants
		c. Negative	(2,33%)	The appearance of issues, such as : a. Difficult to develop design because of various attitudes and personalities participants b. Difficult to develop and finish design because of difficulties in modifying designs
2. Not yet understand	(5,56%)	a. Positive	(50%)	The diversity of multi disciplines participants can lead to the achievement of best design, even though it is difficult to be achieved
		b. Doubt	(50%)	The appearance of issues, regarding different perceptions between participants, which lead to difficulties in making decision and caused extra time needed for finishing design
		c. Negative	(0%)	-

Table 2 The development of issues and approaches in collaborative design pactices

No	Issues that are mostly appeared in collaborative design practices		Solutions that are used in practice (Empirically)		Solutions that were previously purposed by researchers (Theoretically)	
1	Difficulties in conducting physical (face to face) meeting	Physical Issue	a. Using ICT-based tools & systems to conduct virtual meeting. b. Negative impact: difficulties to manage design developments and achieve shared-understanding between participants.	Physical Approach	Applying ICT-based tools and systems in providing shared-workspace [22, 24, 27]	Physical Approach
2	Difficulties in achieving shared-understanding, that is: a. Impacted from virtual meeting b. Impacted from diverse disciplines of participants	Technical Issue	a. The appearance of un-effective and inefficient design process because physical meetings are still needed, although virtual meetings have been conducted. b. Using social approach through personal communication approaches to create social understanding for disputants. c. Negative impact: the appearance of conflicts and hard to gain best design as integrated solution	Social Approach	Developing and applying KM [23, 28, 29]	Technical Approach
3	Difficulties in coordinating and integrating design developments	Technical Issue	a. Manually coordinates and integrates design developments. b. Involving design manager in order to coordinate design developments c. Negative impact: time consuming; design cannot be easily finished on time; the appearance of design errors.	Technical Approach	a. Using similar or compatible software [30, 31] b. Developing systems that have capabilities to classify design developments, which have been done by each participant [32, 33]	Technical Approach
4	Difficulties in modifying design	Technical Issue	a. Using personal communications and approaches in negotiating design developments that are able to be accommodated by all participants. b. Negative impact: design developments are limited to the capabilities of participants in modifying design, therefore best design is difficult to be produced	Social Approach	a. Providing design templates [34] b. Developing systems that able to provide accessibilities for all participants in modifying design objects [35]	Technical Approach
5	Difficulties in producing or making decision; which is impacted from conflicts of different perceptions between participants	Technical Issue	a. Applying coordination as approach to integrate design developments, where leader takes control without involving others. b. Using social approach by creating social understanding to disputants c. Negative impact: unsolved conflicts made best design is difficult to be achieved	Social Approach	a. Applying KM by providing criteria in developing design [36, 37, 38] b. Applying agent in ICT-based workspace [19, 39] c. Developing integrative group decision making through Grounded Group Decision Making Model [40, 41] d. Developing decision support tool to collect and integrate various alternatives [42, 25]	Technical Approach
6	Difficulties in collaborating and integrating participants that are caused by diverse attitudes and personalities	Social Issue	a. Determining and structuring the form of design team based on experiences in working together b. Concerning leadership styles that support collaboration	Social Approach	a. Forming design team based on its experience [43] b. Considering attitudes and personalities [16] c. Organizing communications [14, 44]	Social Approach

The involvements of multi participants in design process make design developments, which can be identified as knowledge [45], are difficult to be managed. These difficulties caused issues in modifying design objects [35] and gaining similar perceptions between participants [29]. Empirically, these issues were also found together with issues in coordinating design developments and issue in making decision that caused by dissimilar perceptions between participants. These issues are categorized as technical issues [21], and becoming issues that mostly visible and matter in collaborative design practices. Based on interviews, it is found that these technical issues resolved with social approaches, which are personal communications and approaches that are mostly used by respondents in advance to create social understanding between participants. Theoretically, these are inappropriate approaches for technical issues, in which it explains the failure of best design achievement that should be gained through collaboration.

The issues have to be solved by using technical approaches that are mainly considering design objects through the application of KM, instead of social approach that is considering participants. For example is the issue of difficulties in modifying design. According to previous research, the issue has to be solved by concerning design objects and applying KM through the provision of systems that support easy access for all participants in modifying design object [35]. Other previous studies advised to provide design templates, where participants do not need to work many times for similar object in developing design [34]. But in fact, practically it was solved by concerning participants and using personal approach to negotiate the modifications which are not inconvenience to other participants. This practice is limiting the development process of design into best design, which relays on capabilities in integrating and modifying design objects.

The use of inappropriate approach was also found in treating issues of shared-understanding achievement. Basically, the issues can be avoided by managing design developments, which can be traced and also understood by all participants. There are three examples of purposed facilities of KM that can be provided to support this approach. First sample is the facility to store and record the process of design developments [23], which contains of design objects (drawings) and discussions of all participants in developing design. Second sample of facility is to provide system that able to trace or review the flows of design development process [46]. This system can be provided to achieve shared-understanding between participants [23]. System that has abilities in providing detail information of design changes is other facility that can also be applied [28, 29]. Comparable to other previous issue, this issue is practically solved by using social approaches that lead to failure in resulting best design.

Inappropriate use of social approaches is also discovered in solving the difficulties of decision making process that are caused from failure in achieving shared-understanding. Creating social understanding was used as an approach to make decision that influenced the achievement of best design. Related with this issue, KM can be applied by providing criteria of design developments [36, 37, 47], which has ability in directing the design to stay focus with goal that need to be achieved. Furthermore, agent systems can be provided in ICT-based tools and systems of collaborative design process [19, 39], with main purpose to filter suitable options in deciding best alternatives for design developments.

In collaboration, the successfulness is not only achieved from the integration of design process and design objects, participants are also necessary to be integrated [13]. Social issues that are caused by difficulties in integrating participants were also found to be important aspects in resulting best design. Teamwork [48], leadership [49], professionalism [50], and participants' behavior [16] are several social factors [21] that influence collaboration. Respondents found the appearance of these issues in collaborative design practices. Comparable with approaches that have been purposed in previous collaborative design researches, approaches that are applied at collaborative design practices have similarities. The social issues were solved with social approaches. In supporting the collaboration of multi participants in design process, design team is formed based on the experience of each participant in working together at previous design process, in which the concept of this approach is also found in [43]. Beside the formation of design team, leadership styles were also mostly concerned to be supporting factor in collaboration.

6.0 CONCLUSION

There are three main indicators of collaborative design, which are the involvement of multiple participants, the integration and simultaneous works, and the achievement of best integrated design. The concept of collaborative design is applied at design process. Main purpose of this application is to gain best design as best shared solution that is integrated from multiple participants. Best design is difficult to be achieved, even though collaborative design is applied. The difficulties are caused by the application of inappropriate approaches. Theoretically, technical issues should be solved by applying technical approach through the application of KM, but empirically the issues are solved by using social approach through personal communications and approaches. Unsuitable use of approach is caused by the lack understanding of participants about the role of KM. KM are becoming main issue of failures in collaborative design practices. Issues related with lack consideration of KM appear as main issue in collaborative design practices. In advance, research related with the awareness and application of KM and also the supports of KM to successful collaborative design are needed to be developed. It can be concluded that the designers need to improve their understanding and awareness about the essential role of KM. Further development of systems and software by implementing KM in the use of ICT-based tools for virtual collaboration is needed. This development will support the integration of design process that was failed to be achieved.

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