ICT as a Tool to Support the Collaborative Design Process

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Abstract. The implementation of new management concept and practice such as collaborative design has the potential to make design project less fragmented, improve design quality and reduce design duration. Thus, the influence of ICT in supporting the collaborative design practice is important to be acknowledged. This study evaluates the differences between traditional and collaborative design approach, the requirement of collaborative design process and the potential benefits of ICT in supporting collaborative design. In this study, the respondents from the construction industry with experience in design have been interviewed for valuable information on ICT in their daily design and tools that are required for collaborative design, questionnaire survey are also distributed among the consultants so that we get a better picture of how ICT affects their design. ICT proves to be vital part in supporting the collaborative design process with certain requirement needed for it to be productively implemented.

Introduction

Information and communication technology (ICT) innovations are offering the construction industry new ways for enhancing communication, coordinated effort and information management process that never been heard before in the industry. Notwithstanding, the larger part of construction business procedures are still vigorously based upon conventional method for communication and management, for example, up close and personal meetings and the exchange of paper documents as technical drawings, specification and site instructions, and over-the-wall engineering. This is because of various conservative practices, and industry influence that governs the way industry do things, thus influencing the degree of adoption of IT and new practices in everyday operation.

Construction industry is facing with the ongoing challenge of changing and improving current work practices in order to focus more on client requirement produce high quality result and satisfy consumer demand through adoption of ICT as an integral part of the design integration process. Other than that, the execution of new management concept and practices, for example, collaborative engineering has positive effects such as make construction project less fragmented, improve project quality, lessen project duration and reduce project cost [1]. In this manner, the components of impacting ICT utilization in supporting the collaborative design approach are examined in this study so we can know the roles of ICT when used in the organization, such as enhancing the management procedure with new design concept [2]. This part presents the examination framework of this study, which outlines the issue foundation, issue explanation, study point and target, extent of study, significances of study and research philosophy.

The design of buildings requires the integration of many kinds of information into an elegant, useful, and durable data such as stated previously [5]. A collaborative design process includes the active and continuing participation of users and community members, code official, building technologist, contractors, civil engineers, mechanical and electrical engineers, structural engineers, specifications specialists, and consultants from many specialized fields. This is because one of the factor that delays a construction project are caused by fragmented design team that demands more time when a problem arises, to meet, to discuss, to propose solutions and lastly to amend the problem [5].

According to Malaysian Treasury Secretary-general, Dr Wan Abdul Aziz stated that projects with 30% or three months' behind schedule are categorized as 'sick project' [4]. When a delay of a project is no longer be tolerated by the client, the project ultimately will be scraped and abandoned. According to numbers released by Ministry of Housing and Local Government, about 115 abandoned housing projects are recorded since 1990 until June 2008 [3]. The best construction projects resulted from effective and planned collaboration among all stakeholders throughout the building's life cycle. Thus the need for a fast and reliable means of communication to support the concurrent design process between the various professionals from unique background to collaborate effectively and to improve efficiency in a construction project, this study is to identify the role of ICT to support the collaborative design process in current environment and how it is effects their work performance

The main aim of this study is to evaluate Information Communication Technology (ICT) in supporting collaborative design concept. Meanwhile, the three main objectives are:

i. To evaluate the differences between traditional method of design and modern collaborative design concept.
ii. To establish the requirement to support collaborative design.
iii. To identify the potential benefits of ICT in supporting the collaborative design.

Previous Studies

Traditional Design Approach Within the construction industry, similar tendencies and problems to that of the manufacturing industry also occur, with the attendant setbacks and disadvantages. Here, based on the client brief, the architect produces an architectural design, which is given to the structural engineer, who on completing the structural design passes the project to the quantity surveyor to produce costings and bill of quantities. On completing this work, the project is then passed on to the contractor who then takes responsibility for the construction of the structure [6]. This scenario which is akin to the 'over the wall' syndrome, is shown in Figure 1

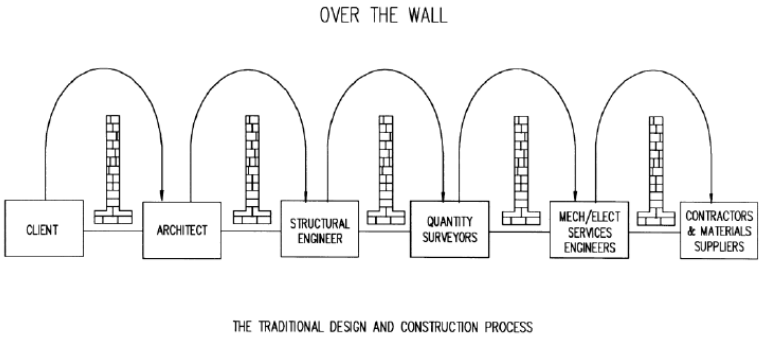

Figure 1: The over the wall approaches

Disadvantages of traditional design approach

- Key disadvantages prevalent with this approach include:
- fragmentation of the different participants in the construction project;
- fragmentation of design and construction data;
- occurrence of costly design changes and unnecessary liability claims;
- lack of true life-cycle analysis of the project;
- Lack of communication of design rationale and intent.

To address these issues, there is urgent need for a shift in paradigm within the construction industry. This should involve the adoption of new business strategies, with the aim of integrating the functional disciplines at the early stages of the construction project (Figure 2). This will ensure that all the life-cycle issues affecting the construction project are addressed early in the project life-cycle. In this regard, a framework is being developed based on the concepts and principles of

concurrent engineering to support the integration of these disciplines. This framework represents the focus of this study [6].

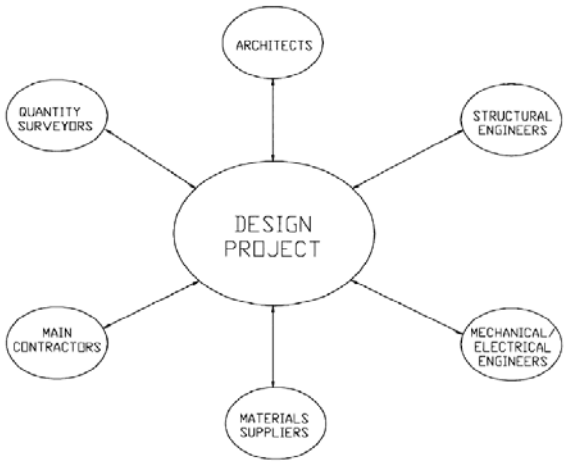

Figure 2: A typical project team

Collaborative Approach In the context of the construction industry, the above definition, can be modified thus: ''*Concurrent engineering attempts to optimize the design of the project and its construction process to achieve reduced lead times, and improved quality and cost by the integration of design, fabrication, construction and erection activities and by maximizing concurrency and collaboration in working practices*'' [1].

An examination of the various definitions given to concurrent engineering generally points to the following key issues:

- need for proper analysis and establishment of customer requirements and specifications;
- need for improving and maintaining the quality of a product;
- integration of the design of the product and associated manufacturing (construction) and production processes;
- consideration of all life cycle issues (both upstream and downstream) which affect product design;
- resolution and management of trade-offs and conflicts in the early stages of design;
- reduction of product lead times and product costs;
- Paralleling the design process.

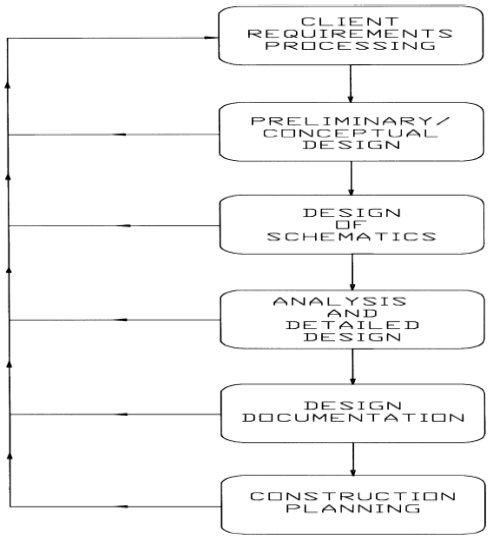

Figure 3: The concurrent lifecycle design and construction design model

Methodology

Data Collection The collected data have to be synchronized with the objectives that had been identified earlier in this study. The data should be more focused on the topic of the study in order to achieve the objectives that had been identified. The data which had been collected previously can be classified into two components which are primary and secondary data.

Data Analysis After the data had been successfully gathered, it will be analysed and the result will be presented in charts and tables as in Table 1. The result of the data analysis will be evaluated and compared with the objectives of the study that have been set to look through whether the objectives was achieved or not.

Table 1: Methodological Objective Chart

#	Objective	Methodology	Data/Output
1	Evaluate differences between traditional and collaborative design method	Literature Review Interview	• Differences Between CD & TD: Definitions Characteristics of flow • Establish the process flow for traditional approach and collaborative design process • The stakeholder involves in different phases in design process • The requirement for TDP vs CDP • How do TDP and CDP differs in terms of organizational structure
2	Establish requirement to support collaborative design environment	Literature Review Interview Questionnaire Survey	• Requirement to support Collaborative design • Requirement to support Collaborative design • Software/hardware that is essential to support collaborative design • Requirement needed to support collaborative design process
3	Identifying potential benefits of IC in supporting collaborative design	Literature Review Interview Questionnaire Survey	• Benefits of using ICT in design • What IT tool can be used and what are their function • In what way IT tools support Collaborative design • Benefits of using ICT in collaborative design • Potential benefits of ICT in design • Level of usage of ICT related tools

Average Index (AI) Average index is adopted for classification of the average index to identify the level of significance on the requirement to support collaborative design environment. The average index is compute as:

$$\text{Average index} = \Sigma a_i x_i / \Sigma x_i$$

Where: a_i = Weighting given to each factor by frequency of respondent

x_i = Number of respondents

There were five categories of skill rating which represent the feedback of the respondent and the application rating scale of average index in questionnaire would be:

Table 2: Rating Scale for Average Index

1.00 ≤ Average Index ≤ 1.50	Least Agreeable
1.51 ≤ Average Index ≤ 2.50	Slightly Agreeable Agree
2.51 ≤ Average Index ≤ 3.50	Moderately Agreeable
3.51 ≤ Average Index ≤ 4.50	Agreeable
4.51 ≤ Average Index ≤ 5.00	Strongly Agreeable

Data Analysis

Differences of Traditional Design Approach and Collaborative Design Approach Referring to Table 3 and 4, we can see that the definition and organization structure of collaborative design and traditional design differs in terms of approach, goals and collaboration.

Collaborative design has the characteristics of knowledge creation and integration between designer from different disciplines and functions, communication between the designer about both the design content and the design process, and the creation of shared understanding about both the design content and the design process. In contrast, traditional design has the characteristic of being sequential, a project is designed and then all the designer adds their input to the design in a sequence of activities, the different steps are done one after another, with all attention and resources focused on that one task, and once the first step is completed, the engineering team will move ahead to the second stage of the project.

Table 3: Literature Review on Definition

Author	**Definition Of Collaborative Design**
Khan (1996) [11]	Collaboration as an effective, volitional, mutual/shared process in which two or more departments work together, have mutual understanding, have common vision, and achieve collective goals.
Chiu (2002) [10]	Collaborative design is an activity that requires participation of individuals for sharing information and organizing design tasks and resources
Buijs, J., and Valkenburg, R., (2005) [12]	Collaborative design is the process in which actors from different disciplines share their knowledge about both the design process and the design content. They do that in order to create shared understanding on both aspects, to be able to integrate and explore their knowledge and to achieve the larger common objective: the new product to be designed.
Stalk, G & Hout, T (1990) [13]	The sequential model for design definition is that the product is designed and then all the functions add their input to the design in a sequence of activities, with the process being repeated until a satisfactory result is output from the last function
Mip Group (2012) [14]	Sequential engineering is the term used to describe the method of production in a linear format. The different steps are done one after another, with all attention and resources focused on that one task. After it is completed it is left alone and everything is concentrated on the next task.

Table 4: Interview Analysis on Difference of Organization Structure and Process

Question	**Respondent 1**	**Respondent 2**	**Respondent 3**	**Respondent 4**	**Respondent 5**
How do traditional design approach and collaborative design approach differ in terms of organizational structure?	T - Different companies, working together on a project, but only pass on the design sequentially. C -- can have one corporation that employ multi discipline staff	T – Multiple consultant, pass on the design C – Multiple consultant/ one multi discipline consultant work on one design project	T – Multiple consultant, one project C – Multiple consultant/ one consultant, working on one project	T – Multiple consultant, design is passed between them C – Multiple consultant/ one multi discipline consultant design collaboratively	T – Multiple consultant, design is transferred C – Multiple consultant/ one multi discipline consultant work on one design project together

Are you familiar with the concept of collaborative working environment? Can you explain what is your understanding of collaborative design process	Yes, a CDP is when all the design party discussed and proposed solution for a design project together, design together	Fairly familiar, CDP is when multi discipline design professional works together on a design project	Fairly familiar, CDP meaning designer working together	Familiar, CDP is when you have all designer working together on a design	Very familiar, CDP is when on a single design project, you have all the designer working together designing

Requirement Needed to Support a Collaborative Design Environment Referring to the Table 5 and Table 6, all the respondent agreed with the requirement needed that were listed. Basically, the top two requirements that were chosen by the respondents are having clear team goals/objectives, and having good communication network.

One of the requirements to support a collaborative design process is a clear team goals/objectives. Based on questionnaire survey, 19 out of 30 respondents strongly agreed with this particular requirement. An effective collaborative design process requires the design team being on the same page and has a clear common objective throughout the design process so that the work process doesn't stray away from the original client's requirement. The difference background of the design team prompts them to have a common goal, so that they can make suitable design decision based on the project requirements. In contrast, with the traditional approach, the common goal was to finish their part of the design and pass it on to other designer, without giving their professional advice on the direction of design and sharing solutions.

It is proven that a good communication network is required for a collaborative design process. A multi-modal communication facility such as speech, text, and sketching, preferably with means for conference possibility to communicate with more than one person at a time. Data exchange between modes should be quick and easy to use such as Avaya, Telegram, Yahoo! Messenger and ICQ as stated by H.H Achten (2002) [7]. The collaborative design environment should function in such a way that a participant who uses it is aware of the presence of other participants. This puts special emphasis on how participants can contact each other through the use of the communication network, and how they can keep track of each other's activities and comments on their work.

Table 5: Analysis on Requirement for Collaborative Design Environment

Requirement	**1**	**2**	**3**	**4**	**5**	**Total**	**Average Mean**	**Level of Agreement**
Clear team goals/objectives	**0**	**0**	**0**	**11**	**19**	**30**	**4.63**	**Strongly Agreeable**
Information sharing	0	0	1	15	14	30	4.43	Agreeable
Communication quality	**0**	**0**	**2**	**13**	**15**	**30**	**4.43**	**Agreeable**
Shared problem solving	0	0	0	21	9	30	4.30	Agreeable
Good Communication environment	0	1	3	14	12	30	4.23	Agreeable
Ability to compromise	0	0	3	19	8	30	4.17	Agreeable
Team satisfaction	0	0	2	18	10	30	4.27	Agreeable
Task inter-independence	0	1	4	15	10	30	4.13	Agreeable
Cooperation	0	0	2	15	13	29	4.41	Agreeable
Communication network	0	0	1	14	15	30	4.47	Agreeable
Circulation of Information between peers	0	0	3	16	11	30	4.27	Agreeable
Functional Openness	0	0	4	19	7	30	4.10	Agreeable
Mental Health	0	1	5	11	13	30	4.20	Agreeable
Stress Management	0	0	5	12	13	30	4.27	Agreeable

Table 6: Interview Analysis on Requirement of Collaborative Design

Question	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5
Requirement for traditional design process and collaborative design process to work smoothly	T – Quality Communication C–Common objective	T – Good Communication C – Information Sharing	T – Clear information Transfer C – Same goals	T – Ability to Compromise C–Information Sharing	T – Quality Communication C–Information Sharing
From your experience, what is needed for collaborative design team to work properly? In terms of support platform	communication and networking software/hardware, common language	Fluent using design software, common language, Teleconference, BIM	Conference hardware, Messaging app, email	Mobile phone, Conference hardware, Email	Teleconference, WhatsApp group, Email, BIM, Same language

Tools Required for Collaborative Design Environment Referring to the Table 8 and Table 9, all the respondent fairly agreed on the tools required that were listed. Furthermore, the top two tools that were chosen by the respondent are modern project management technique, and integration of CAD and other design tools.

From the questionnaire survey, the main tool required for a functional collaborative design environment is a modern project management technique. Collaborative design approach is different from traditional approach; hence it requires a different project management technique.

The integration of Computer Aided Drawing (CAD) with other design software such as Orion, Staad Pro and BIM such as Revit are vital for a collaborative design environment. This is because in engineering design, most designer communicates with technical drawings, graph and data sheet besides verbal communication. The CAD is mostly common language in the engineering field. In a collaborative environment, these designer will discuss and share their drawings with other designer, making CAD integration between design software crucial for the continuity of the design process.

Table 7: Rating Classification for ICT Tools

1.00 ≤ Average Index ≤ 1.50	Least Required
1.51 ≤ Average Index ≤ 2.50	Slightly Required
2.51 ≤ Average Index ≤ 3.50	Moderately Required
3.51 ≤ Average Index ≤ 4.50	Required
4.51 ≤ Average Index ≤ 5.00	Strongly Required

Table 8: Analysis on Tools Required to Support Collaborative Design

Tools	Frequency						Average Mean	Level of Requirement
	1	2	3	4	5	Total		
Teleconference	0	5	5	18	2	30	3.57	Required
Physical meeting room	0	2	4	13	11	30	4.10	Required
Virtual meeting room	1	3	9	15	2	30	3.47	Moderately Required
Integration of CAD and other design tools	**0**	**0**	**3**	**18**	**9**	**30**	**4.20**	**Required**
Modern project management technique	**0**	**0**	**1**	**15**	**14**	**30**	**4.43**	**Required**
New collaborating technology	0	0	4	18	8	30	4.13	Required
Office sharing between design team	0	1	4	14	11	30	4.17	Required
Work from home	4	6	7	11	2	30	3.03	Moderately Required
Virtual Prototyping	0	1	7	13	9	30	4.00	Required
Integrated Database	0	0	3	19	8	30	4.17	Required
Frequent Meeting	1	0	12	11	6	30	3.70	Moderately Required

Table 9: Interview Analysis on Tools Supporting Collaborative Design

Question	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5
What technological tools that is used in collaborative working environment and how do they function? (e.g. apps, software, gadget etc.)	Design Software's --input their design into the project. Conference -- a meeting can be done without the need of everyone to be at one place physically.	BIM, AutoCAD, Revit --Information transfer. MS project-- keeps trace of design progress and plan work time.	AutoCAD – Information documentation and transfer. Email – communication purposes.	WhatsApp- Communication capability. AutoCAD- Information documentation and transfer.	BIM—Design integration. WhatsApp—Communication capability MS Project—Project management.
In what way, would you say ICT support collaborative design process?	Conference capabilities over long distance, information sharing	Communication bridge, Information sharing, Fast transfer	Information display, Conference capability, Information gathering from databases	Real time information transfer, Common design language	Information transfer, Conference capabilities, Design integration, Cloud storage

The Level of Usage of ICT Related Tools Referring to the Table 10, all the respondent fairly agreed the usage level of usage of ICT related tools in collaborative working environment. The top two ICT related tools as agreed by all the respondent is the internet, and mobile phones.

From the questionnaire survey, the main ICT related tools as agreed by respondent is the internet, which enables discussion and collaboration within design party. This is true because Information & Communication Technology (ICT) provides opportunities for designers in dispersed locations to communicate, share and collaborate on their design projects to achieve a common objective, according to Hossain, L. and Wigand, (2004) [8]. Furthermore, the internet acts as a bridge for communication, which is the core for a collaboration process to occur smoothly and efficiently.

This in turn proves that ICT is crucial for a collaborative design environment, which communication is the basis of it as stated before. According to Nussbauma et al, (2009) [9], ICTs can support group discussion within a constructivist model of knowledge building and is achieved by moderating the contribution of individuals and ensuring there is an exchange of views that leads to consensus building within the collaborative group. Meaning that ICT plays a vital role in collaborative design environment by enabling each designer to input their knowledge and decision into the project, thus contributing to the progress of the project collaboratively.

Table 10: Analysis on level of usage ICT related tools in collaborative design

Statement	Agreement Level
I uses emails, calls and SMS on my phone to discuss work details outside the office	97%
I uses tele-conferencing in work meetings (at least once)	40%
I uses software to design and collaborate with my colleagues	90%
I uses video conferencing in work meetings (at least once)	46%
I require the internet to do my design and communicate with colleagues	97%
I prefer virtual meeting (using virtual reality) compare to face to face meeting	33%
I uses social media to communicate with colleagues	90%

The Potential Benefits of ICT in Supporting Collaborative Design Referring to Table 11, all the respondent agreed on the potential benefits of ICT in supporting collaborative design. The top two benefits of ICT are integrated design software simplify their work and make designing easier, and ICT help reduces their design time.

Based on the questionnaire survey, the benefits of ICT has on work performance is integrated design software simplify work for designer and make it easier compared to manual design. This is because software is created for the purpose of simplifying and easing the human user, and helping them with their task. Design software are designed so that they are easy to use, integrated databases

such as building codes, design criteria, measurement format and design analysis all in one place. This software also produces output data that can be exported to other software, and vice versa.

ICT help reduces their working time in design by using software because of the face pace of information transfer, it reduces the waiting time and prompt fast decision making in design. Furthermore, the software is very fast in calculation and can produce output within mere seconds, making calculator obsolete. This makes working time in design shorter than before.

Table 11: Analysis on benefits of ICT in supporting collaborative design

Effects of ICT tools on performance	Frequency						Average Mean	Level of Agreement
	1	2	3	4	5	Total		
Help reduces time in design work by using software	0	0	2	12	16	30	4.47	Agreeable
Design software simplify my work and make it easier	0	0	1	10	19	30	4.60	Strongly Agreeable
ICT tools reduces cost of work	0	1	4	12	13	30	4.23	Agreeable
ICT tools increase my productivity	0	0	4	11	15	30	4.37	Agreeable
ICT tools increase my motivation	0	1	9	14	6	30	3.83	Agreeable
ICT tools increase my performance	0	0	4	18	8	30	4.13	Agreeable
ICT facilitate me in managing my work plans	0	1	3	15	11	30	4.20	Agreeable
I can keep track of work progress from office by communication tools	0	0	3	17	10	30	4.23	Agreeable
ICT improves overall of my work	0	0	3	15	12	30	4.30	Agreeable
I depend on ICT tools to complete daily task	1	1	9	11	8	30	3.80	Agreeable

Conclusion

The first objective of this study has been achieved by the in depth study on the literature review. With the understanding from literature review, researcher was able to create an interview questionnaire and questionnaire survey that can produce sufficient data for this study. From the understanding of the concept of traditional and collaborative design process through literature review, it showed that collaborative design is different from traditional design in terms of definition, flow of design and organization structure.

Based on the questionnaire survey and interview, majority of respondents agree with the requirements needed to support the collaborative design process for the second objective of the study.

These are the four main requirements found for collaborative design to work in Malaysia:

I. Clear team goals/ objectives
II. Proper communication network within design team
III. Information sharing between designers
IV. Good Communication Quality

Based on the questionnaire survey and interview, majority of respondents agree with the tools required for a functional collaborative design environment.

These are the four main tools required to support collaborative design in Malaysia:

I. Modern project management technique
II. Integrated design software
III. Shared office by design team
IV. Integrated database

The study reviewed the level of usage of ICT related tools in enable the collaborative design process. The four most used ICT related tools are:

I. Internet
II. Mobile phones
III. Design software
IV. Social media

For the third objective of the study, based on the questionnaire survey, majority of respondents agree with the benefits of ICT has on their work performance in supporting collaborative design.

These are the four main benefits ICT has on their work:

I. Design software simplify their work and make it easier
II. ICT help reduces the time needed in designing
III. ICT tools increases their productivity
IV. ICT tools reduces cost of work

This showed that ICT not only plays an important role in supporting collaborative design, but also has positive impact on the work performance of the designers. Although collaborative design is beneficial, it is still a new concept in the Malaysia construction industry. With the implementation of design and build procurement, we hoped that this design method is adopted more profusely.

Reputation loss is difficult to quantify and commonly neglected in the consequence assessment. It is dependent on time and perceptions. This paper endeavored to identify the factors of stakeholders' perceptions that result in pipeline operator reputation loss. The AHP approach was adopted to prioritize the reputation loss factor. The results show that the factor contributing to the highest priority value is B1 (loss of customer confidence). The AHP method is capable of identifying contributors to reputation loss. Thus, better risk assessment of pipeline damage due to corrosion will be achieved with the inclusion of reputation loss in the consequence assessment. Hence, decision making in pipeline repair, inspection, and maintenance will be improved as well as the company's annual profit margin.

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