CHALLENGES OF TRANSCENDING BIM INFORMATION FROM DESIGN PHASE TO REAL TIME ON-SITE CONSTRUCTION PHASE

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ABSTRACT

Building Information Modelling (BIM) is a revolutionary paradigm which espouses modernization and innovativeness to the conventional Architecture, Engineering, Construction and Operations (AECO) industry. Successful BIM model is enriched with information which was congregated during design phase and such information should be circulated throughout the project life cycle without disturbing its originality. Nevertheless, when the complete BIM information is transferred to the site office, the on-site personnel are not absorbing the real essence of effective BIM information for on-site construction activities. Improvements in Mobile Computing Technology (MCT) have succeeded in linking this communication gap through forms of electronic pocketbooks, personnel laptops and Personal Digital Assistants (PDA). Even though, there is a greater push from technology, site personnel are not willing to accept it and they still prefer the traditional procedure. This discloses that site personnel are not prepared to practice such technologies due to their nature of Resistance to Change (RTC). Subsequently, the aim of the research is to identify the challenges of transcending BIM information from design phase to real time on-site construction phase.

To accomplish the aim, a qualitative research approach was followed, steering semi-structured interviews. The gathered information was analysed rigorously through computer based content analysis. This topical study manifest that, all the recognized resisting factors extensively challenge the transcending of BIM information to the on-site construction phase. Hence, the research has successfully identified the challenges which barricade the transcending of BIM information to real time on-site construction phase.

Keywords: *Building Information Modelling (BIM); Mobile Computing Technology (MCT); On-site Construction; Resistance to Change (RTC).*

1. INTRODUCTION

Building Information Modelling (BIM) is a modern technology which replaces the traditional methods and adopts modernization to conventional Architecture, Engineering, Construction and Operations (AECO) projects. BIM enabled construction projects are enriched with information which should be circulated throughout the project life cycle efficiently and effectively. The project information collected in the model during design phase should be communicated to the people in the site. However, there is a gap in transferring the BIM information to the site personnel in construction projects. Thus, the research pursed to identify probable challenges that barricade the transcending of BIM information to real time on- site construction.

The paper comprehends the preliminary findings of the literature synthesis on how work force responds to a new technology through an extended model of Technology Acceptance Model (TAM) and Resistance to Change (RTC). Then, it expounds the traditional method and modern methods of communication available in a BIM enabled on-site construction. Finally, the research manifests the research findings which were collected and analysed through semi-structured interviews and computer aided content analysis respectively.

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2. BACKGROUND

Construction industry is reflected to be an information concentrated environment where information should be appropriately communicated from design phase to construction phase (Chen and Kamara, 2008). Consequently, Raj and Arokiaprakash (2016) explained that communication is the most vital aspect of success which is essential for optimum coordination in a Temporary Multi Organization (TMO). Even if, the construction communication plays an important role in project success, construction stakeholders across disciplines still rest on the traditional paper based communication methods where the collaborative effort is mostly based on the exchange in two dimensional (2D) drawings and documents (Goh *et al.,* 2014). However, Tessema (2008) highlighted that, traditional method of construction communication is considered to be an imperfect method of coordination which results in project delays and redundant tasks.

Favourably, Goh *et al.* (2014) underlined that, BIM is the best solution for problems in traditional communication method. As per Eastman *et al.* (2011), BIM can be used to reduce the number of flaws and incompatibilities of modern construction projects by providing more accurate and contemporary information to its stakeholders. Although, BIM is extensively used in the design stage, a relatively smaller number of site personnel use it in the construction phase as they are still reigned by paper based drawings (Davies and Harty, 2013). Accordingly, the site personnel in a BIM based construction project are not being able to collect all the BIM information required at the building site, even though the complete BIM information is transferred to the site office (Kerosuo *et al.*, 2015).

As a solution to the aforementioned problem, various forms of Personal Digital Assistants (PDA) in Mobile Computing Technology (MCT) have been introduced to BIM enabled construction sites which have the potential to solve these issues and allow site personnel to use BIM information at construction sites (Kimoto *et al.*, 2005). Despite the fact that, there is a greater push from technology to fill the information gap within BIM enabled construction site, most of the site personnel are not willing to accept it and still prefer the traditional paper drawings (Van Berlo and Natrop, 2015). Therefore, Kerosuo *et al.* (2015) emphasized that site personnel are not prepared to practice BIM themselves at the construction sites due to their RTC. Accordingly, Chi *et al.* (2013) stressed that, studies have not been carried out to explore the challenges related to transcending of BIM information to the real time on site construction phase. Thus, it is essential to investigate these resisting factors which barricade the acceptance of aforementioned new technology, in order to mitigate or eradicate them for the better implementation of BIM.

3. TECHNOLOGY ACCEPTANCE MODEL (TAM)

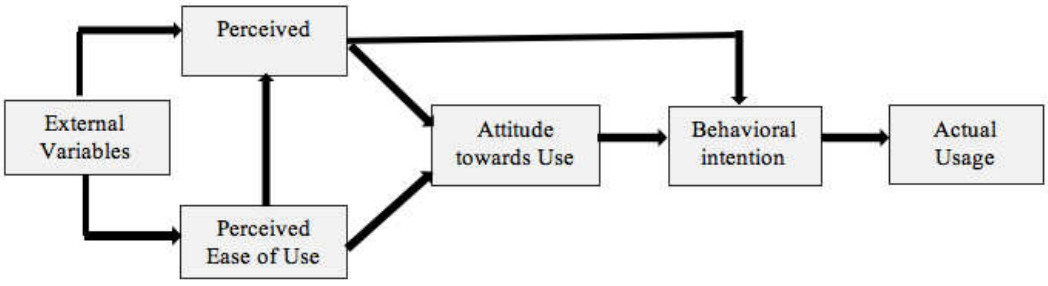

Figure 1: Technology Acceptance Model
(Source: Davis et al., 1989)

In 1989, Davis introduced the TAM which was specifically developed to investigate the effect of new technologies on its user's perception. Figure 1 illustrates the original TAM. In this model, 'Perceived Usefulness' (PU) and 'Perceived Ease of Use' (PEOU) are the primary constructs which are relevant to the acceptance of technology by an end user. According to the definitions given by Davis (1989), PEOU is "the degree to which a person believes that using a particular technology would be free from effort" (p. 320) and PU is "the degree to which a person believes that using a particular system would enhance his or her job performance" (p.320). In addition, Attitude Toward Use (ATU) is described as the assessment of the desirability of employing a novel system and Behavioural Intention to Use (BIU) is referred to a measure of the strength of one's likelihood to employ the particular system (Fishbein and Ajzen, 1975). The actual system

usage is considered to be the dependent variable of TAM which will be determined by BIU. BIU is influenced by ATU which is subjected to the behaviour of two primary determinants; PU and PEOU. Finally, both these constructs are theorized to be directly influenced by external variables.

4. RESISTANCE TO CHANGE (RTC)

According to Manzoni and Angehrn (1997), RTC is one trait of individual behaviour which critically influences for the technology acceptance within an organization. Thus, the resistance is a negative personal attitude which arises as a response to a change and effort to stop the change before or after it implement. Table 1 shows the causes for RTC which prevent an individual from accepting a new technology.

Table 1: Causes for RTC

Key	Resistance factor	Content	Ref. Code
		Individual Factors	
R1	Interpersonal relationship altered	People are having fear that new technology might disrupt their existing organizational relationships.	5
R2	Loss of self esteem	If the new technology transformed their work and its status damaging their self-esteem, they will resist to change.	9
R3	Loss of power	If the new technology alter the working process result in decrease in their existing powers, users will resist to such change.	8
R4	Loss in job satisfaction	Sometimes technological change can simplify a person's job and this may lead to less job satisfaction for them.	5
R5	Lack of knowledge and competencies	If people aware that they lack knowledge, skills and competencies required to adopt a new technology, they try to resist the implementation.	5, 7
R6	Lack of trust	People resist to change as they lack trust and are hesitant whether it can be used to fulfil their job activities.	2, 5
R7	Negative prior experience	If people have a prior negative experience with adopting new technologies, they will try to resist the new technology.	1
R8	Fear of failure	Some people are in fear of failing the technology adaptation from their birth which is known as technophobic effect. These people resist new technologies than others.	9
R9	Loosing comfort zone	People are considered as habitual creatures who do not like to escape from their accustomed things. When technology change violates their comfort zones, they try to resist it.	1, 4
		Organizational Factors	
R10	Change in work load	If, the new technology increases existing workload, such system may be rejected by new users.	1, 4
R11	Fear of redundancy/ treat to job status/ security	According to literature, people are highly afraid of adopting new technologies because they are uncertain on losing their existing position within the working environment.	5, 7
R12	Lack of training	If adequate training is not provided to workers, they become uncomfortable with technology usage and try to resist.	6, 7
R13	Lack of organizational support.	When top management does not support the workers to use the system by facilitating necessary resources and materials, they tend to resist.	7
R14	Lack of user participation	If users are not properly involved (views are not considered), they may feel that they are unimportant and try to resist.	6
R15	Lack of communication	If technology change has not properly addressed to the workers, they try to resist the new system.	4
R16	Misunderstanding	When users are not aware of the benefits of the technology, they try to resist for it.	4
R17	Change in decision making process	When implementing a new system, it will change the existing decision making process of the company which will lead to resistance again.	8

Sources: (Adapted from 1- Bagranoff *et al*., 2002; 2- Biranvand *et al*., 2015; 3- Bordia *et al*., 2004; 4- Egan and Fjermestad, 2005; 5- Landles, 1987; 6- Malato and Kim, 2004; 7- Pajo and Wallace, 200; 8- Smith and McKeen, 1992; 9 - Timmons, 2003)

5. INCORPORATING RTC IN TO TAM

According to Cheng e*t al.* (2013), in technology acceptance theory, the factors that encourage to adopt new technologies are PU and PEOU, whereas the inhibitor that obstructs the acceptance is end user RTC. Thus, original TAM can be criticized as it only considers the enablers that have influence on user's attitude but ignores the negativity of resistance to change.

However, in order to barricade this censure, many researchers have attempted to develop extension models of TAM which exhibit the influence of RTC more effectively. Nonetheless, RTC cannot incorporated directly into TAM because there is a discrepancy, as TAM shows the positive side where as RTC shows the negative side of users' nature of acceptance. Therefore, in order to incorporate RTC into TAM the original TAM model has been converted into its negative side without damaging to its original essence of theory.

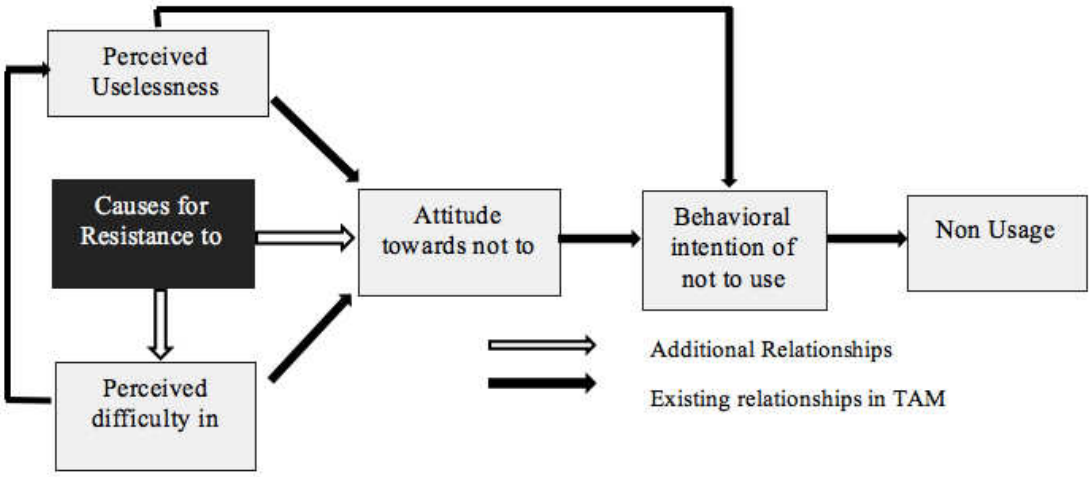

Figure 2: The Extended TAM Incorporating RTC
(Source: Biranvand *et al*., 2015; Nov and Ye, 2008)

As per Oreg (2003), people who sense more causes for RTC would discover it challenging to work successfully when a new technology is being introduced. Therefore, such users will require more effort in accepting a new technology as they have to overwhelm undesirable mental responses generated due to the new technology. Thus, Nov and Ye (2008) proved that, there is a positive relationship between RTC and perceived difficulty in use. Ultimately, such perception will inspire the user to reject the technology.

Moreover, according Biranvand *et al*. (2015), RTC has tremendous negative effect on users' attitude towards using a new technology. This emphasized that, when users' RTC is high, admittedly their attitude towards using the new technology will become low. Thus, from the above two additional relationships it is clear that RTC is an equally important component that should be incorporated in to the TAM.

6. TRADITIONAL METHOD OF INFORMATION USAGE IN BIM ENABLED ONSITE CONSTRUCTION

The traditional method of information management is still prevailing in BIM based construction sites. As per many researchers like Davis and Harty (2013) and Kimoto *et al*. (2005), traditional information management is still dominant in the forms of drawings, design information and other paper based material. Further, Mohamed and Stewart (2003) emphasized that, face to face meetings and exchange in documents like specification, technical drawings and site instructions also can be seen as methods of traditional construction communication. Accordingly, Son *et al*. (2012) confirmed that, the existing information management is mostly labour intensive and manual intrusion.

When discovering the process of existing information management, Chen and Kamara (2008) discovered that, a project manager is the main source of information in a construction project and from him information is transferred to the subsequent professionals at site such as site engineers, supervisors and other professionals. The final destination of this link is the operational level worker at the site. Thus, it is implied that the existing

information process is kind of a hierarchical process where each professional has established their own power, self-esteem and self-respect.

The construction industry has suffered from many difficulties due to traditional modes of on-site communication. According to the research carried out by Hewage and Ruwapura (2006), it was found that over 40% site personal have criticized about the lack of communication at site level due to traditional method of communication. In addition, Mohamed and Stewart (2003) identified that, only 20% of the design information is transmitted to the operational level worker in a construction site. Accordingly, Hewage and Ruwapura (2006) found that, most of the on-site construction problems occur due to this unsatisfactory communication and exchange of information within the site premises. After analysing all these facts, it can be determined that the traditional method of communication is a devastating method for the success of a BIM enabled construction project.

7. MODERN METHODS AVAILABLE TO USE BIM AT SITE LEVEL

According to the literature, there are modern methods of transcending BIM information from site office to the real time on-site construction phase. Even though, operational site personal prefer the traditional method of communication, many researchers have attempted to bridge the communication gap between site office and construction site by introducing a number of novel technological techniques, especially related to the MCT. Table 2 illustrates the modern methods available to transcend BIM information to the on-site construction.

Table 2: Modern Methods Available to Use BIM at Site

No	Methods/ Devices	Source
1	Smart Phones	Ge and Kuester (2015)
2	Laptop PC	Ge and Kuester (2015), Kimoto *et al*. (2005)
3	Ultra-mobile PC	Papagiannakis and Magnenat-Thalmann (2007)
4	Handheld PC	Ge and Kuester (2015)
5	Palm size PC	Chen and Kamara (2008)
6	Tablet PC	Ge and Kuester (2015), Van Berlo and Natrop (2015)
7	Phablets	Ge and Kuester (2015)
8	Google glasses/ Head Mounted Display	Papagiannakis and Magnenat-Thalmann (2007)
9	iHelmets	Yeh *et al* (2012)
10	Large on-site touch screens	Sacks *et al*. (2010)
11	BIM kiosks/ Information booths	Hewage and Ruwanpura (2009)

8. RESEARCH METHODOLOGY

Even though, there is a topical necessity to study the research gap, the absence of BIM in the Sri Lankan construction industry has created a real barrier to develop a satisfactory research methodology. However, by overwhelming the challenge, a qualitative research approach was adopted to achieve the research aim. In order to proceed with the qualitative approach, semi-structured interviews were carried out as the data collecting technique. Due to the non-availability of BIM in the Sri Lankan context, the interviews were carried out in construction projects where highly innovating technologies were practiced. As the sample of the research, 5 projects were selected based on their particular characteristic as per the purposive sampling method. All these 5 projects were building projects where highly innovative technologies were adopted and they all were keen and had the capacity to implement BIM. Amongst them, 2 projects already had the BIM trace as the designing part of those projects were purely carried out through BIM.

After selecting the projects, semi-structured interviews were carried out targeting 3 site personnel namely site engineer, supervisor and worker who represented the top, middle and bottom levels in the traditional site communication hierarchy. No separate validation was carried out, but the validation was made by cross examining the opinions given by respondents from another respondents who represented the same level. This cross examining validation helped the researcher to extract an exact conclusion of the critical resisting factors from each level of respondents. After collecting the data, exploratory in-depth content analysis was conducted using a computer based content analysis software namely NVivo (version 10).

9. RESEARCH FINDINGS AND DISCUSSION

There were different opinions aroused from different respondents under each resisting factor. All these opinions were considered in the analysis, since none of the opinions could be ignored as those were the opinions that persuaded the site personnel to accept or reject the technology. However, the research aim was to identify probable challenges which barricade transcending of BIM information to real time on site construction. In order to achieve the research aim, the critical causes for RTC were extracted by using the pre-determined knowledge of literature findings and validations given by the respondents.

Finally, the overall knowledge gathered from the literature study and data collection were compiled together and demonstrated as a conceptual framework as illustrated in Figure 3. This clearly demonstrates the critical resisting factors of each level of site personnel towards the acceptance of MCT which can be used to bridge the gap between site office and real time on site construction in a BIM enabled construction project.

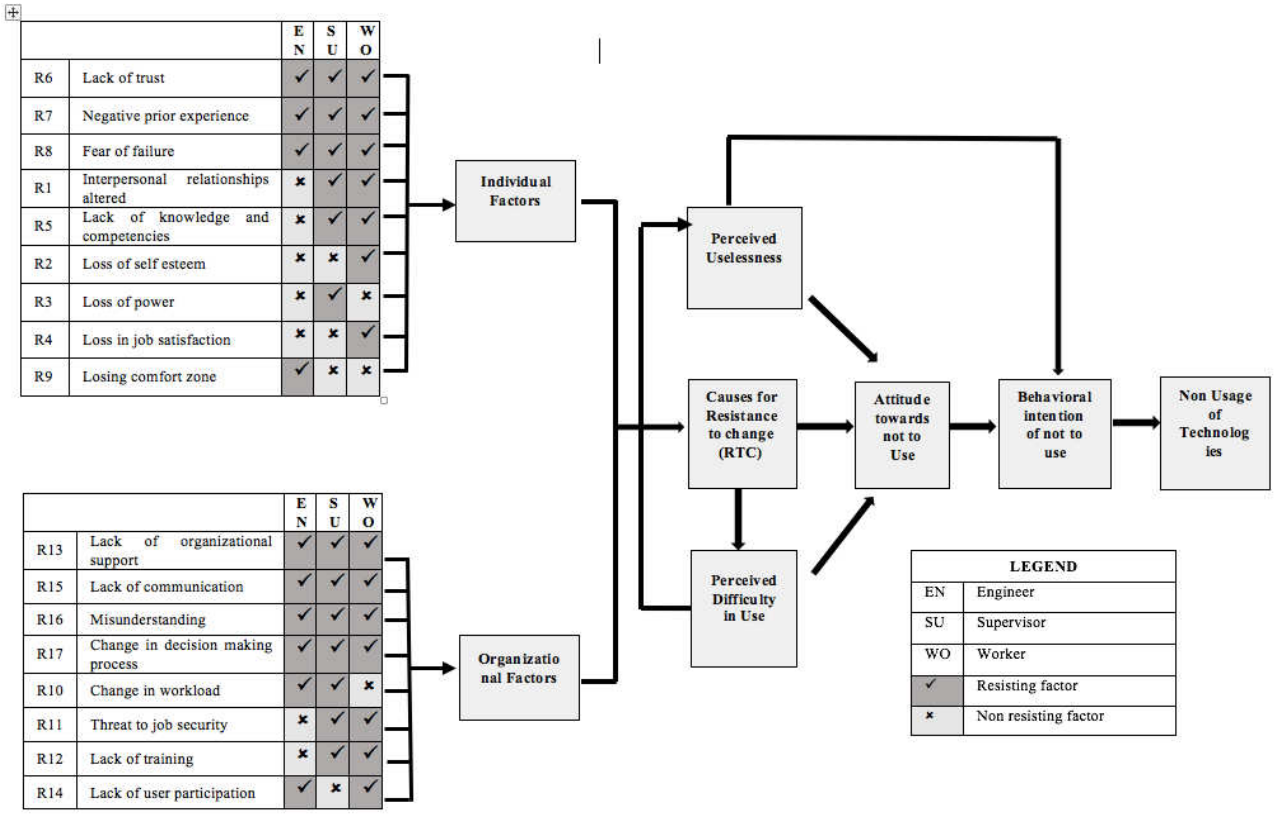

Figure 3: Conceptual Framework of Factors Effecting for RTC in BIM Enabled Real Time On-site Construction

In addition to aforementioned barriers, there were more important challenges which evolved from the opinions and reasoning expressed by the respondents under each resisting factor. The actual reasons as to why the respondents enthused to resist for MCT essentially created a new knowledge and can be expressed as an auxiliary research findings of the study. Thus, the tributary factors which evolved from the analysis can be exposed follows.

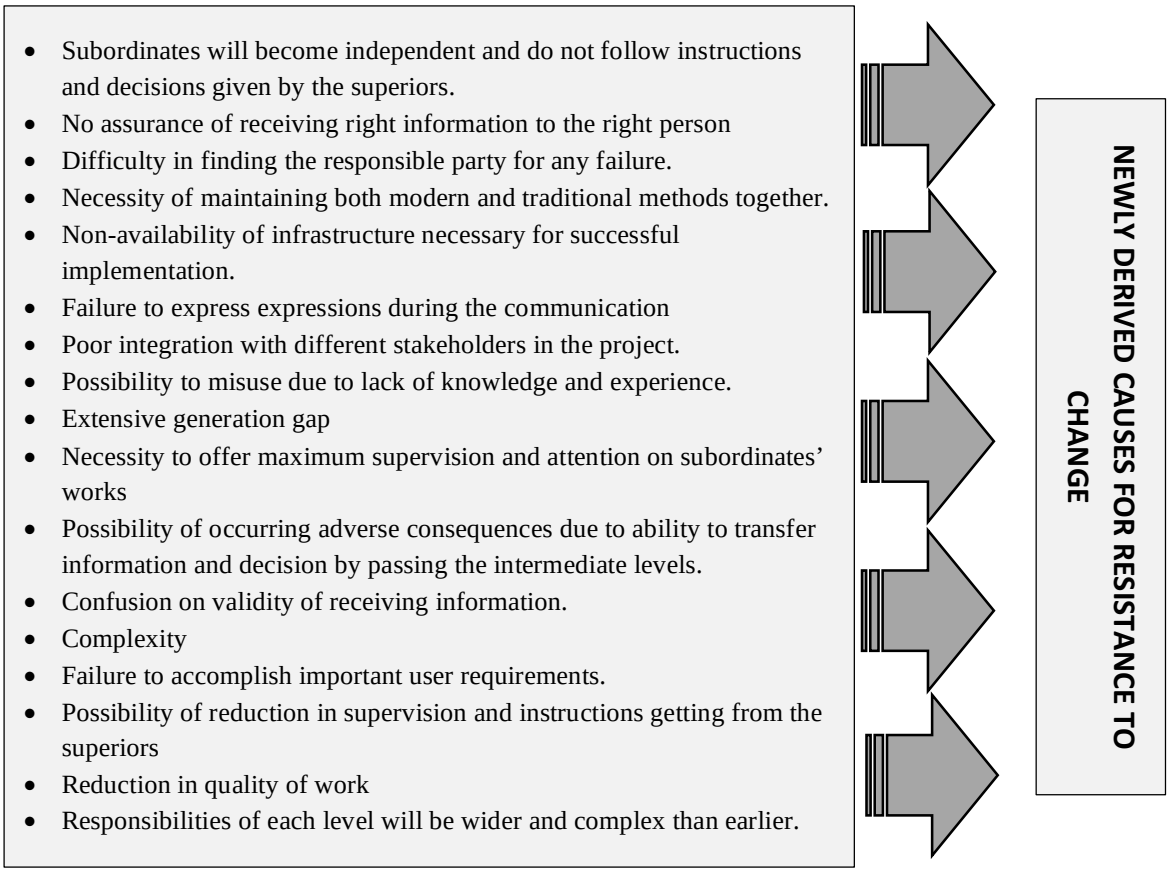

Figure 4: Newly Derived Causes for RTC

Finally, the study has successfully distinguished the challenges faced by the operational level site personnel when implementing the MCT in a construction site. These challenges inevitably create a resistance within these individuals to reject the MCT and be trapped within the traditional paper based communication. Thus, it can be indirectly expressed that the research has successfully identified the challenges which barricade the transcending of BIM information from design phase to real time on site construction. Henceforth, the research findings accomplished the established research aim efficaciously and satisfactorily.

10. CONCLUSIONS AND RECOMMENDATIONS

BIM is a revolutionary concept which has procured a series of technologies to inspire the traditional AECO industry to become a modern and innovative industry. BIM integrated with MCT has made a viable solution to bridge the gap between site office and real time on site construction in a BIM enabled construction project. Even though, such integrated solution is available, operational level site personnel still prefer to be trapped within the boundaries of traditional communication. Henceforth, the main aim of this research was to identify the probable challenges which barricade the transcending of BIM from design phase to real time on site construction.

When discovering the challenges, it was found that the resisting nature of the site personnel is the main barrier for bridging this gap. Thus, 17 causes for RTC were identified and through semi structured interviews, the resisting nature of each personnel representing top, middle and bottom levels in the site communication hierarchy were assessed. From the research findings, it was found that the most resisting party is the operational workers in the site. Subsequently, the supervisors were the second highest resisting party in the site for a technological change related to the mobile computing. However, the site engineers who were considered to be the most educated and knowledgeable personnel at the site also expressed considerable amount of resistance to such a change. Finally, in addition to the existing knowledge on causes for RTC, more auxiliary causes for RTC were identified which were evolved from the reasoning and opinions given by the respondents.

This research purely gives the recommendations to the industry practitioners who realize the necessity of transcending BIM information from site office to the real time on-site construction. There are modern methods

available to bridge this information gap, but it will require an extensive technological change within the site which will persuade the site personnel to resist. Therefore, the industry practitioners should cautiously make this transformation by implementing established change management concepts and with best organizational support.

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