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Identifying the factors of trust to new seismic proofing technologies in the construction industry

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ABSTRACT

Earthquakes cause serious damages to the economy of the impacted regions. Many new methods and technologies have been introduced into the construction industry with the aim of reducing the consequences of earthquake damages and their associated repair costs. Still, the low level of trust towards these new technologies poses a significant challenge in adopting them. An enhanced understanding of the factors that affect the trust in the newly introduced Seismic-Proofing Technologies (SPTs) can play a crucial role in designing policies to leverage their adoption. This study identifies the factors of trust in adopting an innovative SPT, namely the Resilient Slip Friction Joint (RSFJ) as a representative of novel new technologies. This technology has been introduced to the New Zealand construction industry in 2016 and provides seismic energy dissipation and the ability to return the structure to the pre-earthquake position after the event in one compact package.

The data collection stage involved an online survey of three groups of respondents from the New Zealand construction industry including clients, contractors, and consultants. More than 80 responses were collected from different sectors of the industry comprising architects, structural engineers, planners, quantity surveyors and project managers. The survey questions approached the trust factors from different angles, such as organizational and project characteristics. The findings of this research can help to improve and develop a path to facilitate the uptake of new seismic proofing technologies in earthquake prone countries.

Keywords: seismic-proofing, earthquake, new technologies, trust, uptake.

INTRODUCTION

Failing to meet owners' demands has become one of the biggest concerns in the construction industry. Projects fail to meet owners' expectations of cost, time and quality [1]. New technologies, software, equipment devices, materials and methods are introduced particularly to compensate for these issues. Given the clear and global impact of seismic events over the years, the Seismic-Proofing Technologies (SPTs) and methods have been a crucial part of these innovations. SPTs address two main aims, first to maintain the life-safety criteria and second to reduce the damage and provide the possibility of post-event functionality. However, the construction industry has shown resistance to adopting these technologies and methods [2].

Several scholarly studies have been initiated to evaluate and capture the features and main reasons for this inertia towards innovation in the construction industry [2], [3] . They have provided a substantial body of evidence that confirms a lack of trust as a crucial issue in accepting the new technology, which has resulted in the overall inefficiency and quality defections. Therefore, an exploration of the factors of trust to new technology is necessary to get a clear picture of the problem and its potential solutions. An enhanced understanding of the factors can play an important role in designing policies to leverage the adoption of the new technologies. This study uses the Resilient Slip Friction Joint (RSFJ) as a case that represents the novel SPTs and explores the factors affecting the perception of construction professionals about the product and its acceptance. RSFJ is a new generation of resilient seismic technologies that is making its way to the construction industry. This technology that has been introduced in 2016 provides seismic energy dissipation and self-centering behavior in one compact package. It offers a significant damage reduction in the structural and non-structural elements and provides the possibility of immediate occupancy after the seismic event. The data for the study were collected through a questionnaire survey completed by more than 80 practicing industry members.

TRUST

The lack of trust and resistance to change are the main barriers to progressing in the construction industry. The industry is frequently pledging for change, which has been constantly reflected through the reports over the recent decades [4], [5]. There are significant indications that links these progress deficiency to the lack of trust [6]. Accordingly, trust in the construction projects has been acknowledged as a key element to the successful completion of the projects [7]–[9]. Moreover, the appropriate/inappropriate technology use and the acceptance/rejection of the technology are the main reasons significantly making the trust in technology important [10].This section gives an insight into the concept of trust in construction from different points of view.

Trust: definition and role

Trust is a complex concept with a wide variety of definitions provided, depending on the situation and problems. In an effort to aggregate the definitions, Rosseau [11] asserted trust as a disposition and attitude concerning the willingness to rely upon the actions of or be vulnerable towards a phenomenon, under circumstances of contractual and social obligations, with the potential for collaboration. Trust is also defined as "a belief that a specific technology has the attributes necessary to perform as expected in a given situation in which negative consequences are possible" [12].

Trust and the construction industry: definition and role

Davidson and Mcfetridge [13] tested three hypotheses on developing trust and adopting new technology. The hypotheses related to three potential factors that affect the technology adoption including characteristics of the individual technology, parent corporation, and the host country. They studied a sample of 1226 technology cases, which resulted in strong support of the hypotheses regarding the effects of the characteristic of the technology and its parent, and mixed support regarding the effect of the characteristics of the host country on the trust patterns. Akintoye [14] identified the complexity of design and construction, scale and scope of construction, method of construction, tender period and market condition, site constraints, client's financial situation and budget, type of client, buildability, location of project, and availability and supplies of labor and materials, as the influential factors of trust. This study collected the perspectives of contractors in the United Kingdom. Shaojie Cui et al. [15] explored the effects of market and cultural environments on trust to a technology. They studied the relative influence of two factors of the market environment, i.e., competitive intensity and market dynamism, and two factors of the cultural environment, i.e., national cultural distance and organizational cultural distance. The results indicated market dynamism as a factor with higher market-environmental influence than the competitive intensity. The organizational cultural distance was also found to be of higher cultural-environmental influence compared to the national cultural distance. Khalfan et al. [16] found three major factors influencing trust in construction projects including communication, reliance and delivery. It was found that an honest communication can guarantee a better delivery. Reliance applies when the project has to trust a development and believe it will deliver the standards as expected. The delivery needs to be functional for the client. Jafarzadeh [17] explored the effects of building characteristics and local site condition on forming a trust. Adafin et al. [18] discussed the risk aspects of trust factors through risk management, which included contract condition, procurement system, inflation, change in owner's requirement, type of cost, underestimation and type of bidding. Kai Lu [19] examined the influence of contractual control and managers' propensity to trust on the processes that foster trust in China. The examination collected survey data on 260 architect–contractor project-based relationships. The results showed that both factors positively correlate to forming a trust. Zuppa et al. [20] studied the factors that impact the establishment of trust in construction projects and the effects of trust in developing the projects in the US. They surveyed the top 400 contractors that are members of the American Engineering News Record. Their findings showed that face-to-face communication, electronic documentation, and supporting timely and adequate feedbacks help to build up trust. Adafin [21] listed eight cost factors that affect trust. The study addressed change in an owner's requirements, the complexity of design and construction, quality of information and flow requirements, availability of design information, the expertise of consultants, market condition, project team's experience of the construction type, site investigation and inadequate tender documentation as the key factors.

THE GAP IN THE LITERATURE

The above review provides an insight into the trust factors influencing the adaptation process to new methods and new technologies in construction. However, in the absence of specific research on the subject, this study evaluates the relevance of the factors to RSFJ as a representative of the new SPTs. It covers a restricted geographical scope (New Zealand) that can be expanded at further stages.

RESEARCH METHOD

To gain an understanding of the impact of the factors, which have been selected based on the literature review, a questionnaire survey was conducted with the construction field experts. The questionnaire was composed of four sections. The first section collected the demographic information, including their roles. In the second section, they were categorized based on the years of experience. The third section collected information on the field of expertise of the respondents including the type of projects (public or private section), and the type of construction (residential, industrial or commercial). The last section surveyed the position of the respondents in their organization, where they were divided into architects, structural engineers, planners, quantity surveyors and project managers with a possibility to specify any other roles that were missing from the list. A web link to the survey on the Survey Monkey website was sent to 200 potential participants. The number of responses received was 130 with 81 of them fully completed the survey.

Respondents ranked the importance of the factors on a five point-Likert scale from 'Extreme impact' to 'No impact'. The rating scale illustrated their perception about the factors (listed in Table 1), and their importance in trusting to new technology. A short explanation was provided on the RSFJ technology to ensure the clarity of the subject to the respondents.

After performing conceptual and relational analyses [22], the factors were divided into two groups including project-related and organizational-related factors. Following statistical analysis, the most imperative trust factors affecting the choice of RSFJ in a building project were determined.

Table 1. The considered trust related factors identified in the literature.

Type of client	Availability of labor
Type of cost	Availability of material
Type of project	Procurement system
Type of market	Buildability
Type of bidding	Building characteristics
Location of the project	Site access
Change in owners' requirement	Method of construction
The scale of the project	Market condition
The complexity of the design and construction	Tender period
The expertise of consultants	Inflation
Availability of the design information	Availability of material
Site investigation information	Contract condition

RESEARCH FINDINGS

A demographic analysis of the 81 valid responses indicated that 16% of the respondents were clients, 9% belonged to the category of contractors, 68% were from the consultants' background, and the other 8% consisted of surveyors, building controllers, regulator and structural designers (Figure 2(a)). The minimum working experience in the sample was five years, and the maximum was more than 20 years (Figure 2(b)). The statistical significance of the differences among the factors in each group was assessed using an independent sample t-test. As shown in Table 2 the significance of the difference was close to zero, which confirmed the homogeneity of the samples in their groups.

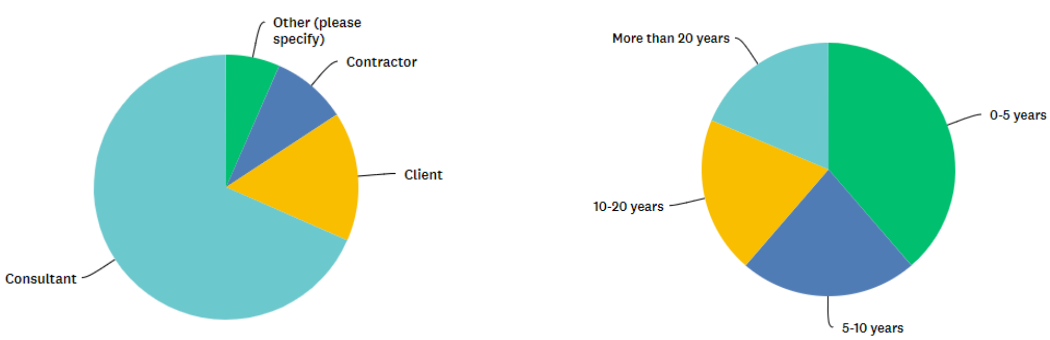

Figure 2.(a) respondants population, (b) respondents working experience

Table 2. One sample t-test result

Factors affecting trust to new methods and new technologies in construction industry	Mean	t-value	SD	Significance (2-tailed)
(I) Organizational-related factors				
Deciding as a developer	3.3	19.3	1.1	0
Deciding as an architect	3.1	22.5	0.9	0
Deciding as a structural engineer	3.8	21.2	1.1	0
Deciding as a contractor	3	16.2	1.2	0
Deciding as an owner	3.3	17.8	1.1	0
Deciding as a tenant	2.4	12	1.3	0
Deciding as a project owner when the requirements of the project are changed on the way	3.3	20	1	0
Deciding as a construction expert when the client is resistant to adopt the new technology	3.5	17	1.3	0
(II) Project-related factors				
Project type: Government	4	21.1	1.2	0
Project type: Private	3.3	21.5	1	0
Location of the project: Urban	3.2	20.4	1	0
Location of the project: Rural	2.4	16.7	1	0
The scale of the project: Large	3.6	20.5	1.2	0
The scale of the project: Small	2.7	18.5	0.9	0
The complexity of design and construction: Normal	3.3	23.8	0.9	0
The complexity of design and construction: Complicated	3.5	20	1.1	0
Type of construction: Residential	2.8	15	1.3	0
Type of construction: Industrial	3.4	18.4	1.2	0
Type of construction: Commercial	3.6	21.5	1.1	0
Site access: easy accessibility	3.1	16.8	1.2	0
Site access: hard accessibility	3	16.3	1.2	0
Lack of experience with the new technology	3.8	22.7	1.1	0
Method of construction: using the conventional construction equipment	3.3	20.6	1.1	0
Method of construction: using more advanced equipment	3.4	21.3	1.1	0
The level of expertise of the consultants in using the RSFJ	3.7	21.5	1.1	0

Table 3 presents the top ten important factors based on the ranking provided by the respondents. The next sections discuss the factors in detail in the two categorical clusters identified.

Table 3. The top ten important factors

Rank	Factors affecting the choice of RSFJ	Column 5
1	Project type: Government	4
2	Lack of experience with the new technology	3.8
3	Deciding as a structural engineer	3.8
4	The level of expertise of consultants in using RSFJ	3.7
5	The scale of the project: Large	3.6
6	Type of Construction: Commercial	3.6
7	Using more advanced equipment in the method of construction	3.5
8	The complexity of design and construction: complicated	3.5
9	The client resistance to adopting new technology	3.5
10	Type of Construction: Industrial	3.4

PROJECT-RELATED FACTORS

Figure 3 presents the results of the statistical analysis of the factors clustered in this category.

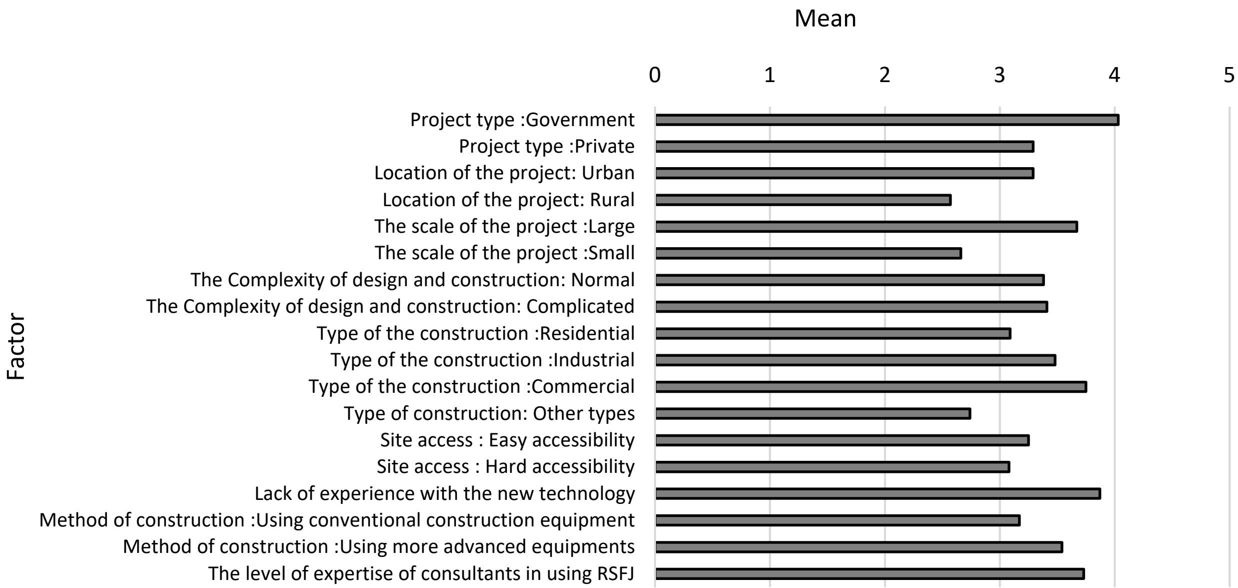

Figure 3. Project related factors

Project type, the role of government

It has been identified that the government has a key role to play in supporting the adoption of the new SPTs. Based on the regulations and standards mandated by the New Zealand government, each building is associated with a design importance level between 1 and 5. This importance level is determined depending on the risk that the building damage could impose on human life and the importance of the post-disaster functionality of the building [23]. The RSFJ provides a self-centering capability, meaning that the structure will return to its pre-earthquake position [24]. These features fit well into the requirements for the buildings with a high level of importance, which can promote the use of this product based on the regulations. Furthermore, in the majority of the cases where the government plays the role of client, the project belongs to the group of facilities that are essential to remain functional post-disaster, such as medical facilities, shelters and emergency centers. In such cases, the government can directly support the application of the new technologies such as RSFJ as a part of the construction team.

Lack of experience with the new technology

Construction industry engineers resist to change [25], and as discussed, the adaptation process to these technologies is extremely slow [25]. The survey indicated a lack of experience with the new technologies and advanced methods such as the innovations provided in seismic-proofing among the construction professionals. Accordingly, they prefer to continue with the conventional methods. Even though RSFJ has been introduced to the market in 2016 and has been used in some major projects such as the new airport terminal in Nelson (see Figure 4), it is fathomable that the industry still faces a significant restriction in their experience with this specific technology. In such cases, holding workshops and seminars can be an efficient solution to get the engineers familiar with the technology. Presenting case studies of the real-life projects that have adopted the new technology could also be effective.

The scale of the project

In large projects, the ratio of cost of technology to the overall cost of the building tends to be small. Therefore, RSFJ and similar products can better substantiate the cost-benefit analysis. Bringing the costs of post-earthquake repairs into account can encourage the initial investments on the new technologies in small to medium size projects. The initiatives should be taken in the meantime to recognize and acknowledge the importance of the new technologies and leverage the trust level.

Figure 4. Implementation of the RSFJ technology in the new airport terminal, Nelson, New Zealand

Type of construction

The foundations of national economies are on businesses [26]. Disasters such as earthquakes affect the economy by causing loss of jobs and reducing incomes. The finance business recovery and confrontation with the damages are the most significant challenges for business owners after an earthquake event [27]. Besides, the post-event business downtime can produce financial loss even higher than the cost of building repair. In such situations, protecting the commercial buildings with seismic proofing technologies such as RSFJ can minimize the business downtime. By increasing trust to these new technologies, higher adoption of the technologies will be expected that can provide a lower risk to post-disaster financial loss [28]. Simultaneously, industrial buildings are critical to remain functional during and post events [29]. The functionality of industrial facilities such as electricity providers, water providers and even internet and communication providers poses a direct and indirect influence on the economy and the society [28]. Therefore, these buildings are usually designed with a high importance level [29]. As stated, RSFJ and similar technologies can support the fulfilment of this specific requirement [24].

Method of construction

An easy installation process can promote the acceptance of technologies such as RSFJs [24]. In such cases, familiarity with the pre-fabricated type of construction will enhance the trust level to the new technology. Holding technical workshops and preparing installation guides are some alternative approaches to promote the knowledge about the installation requirements to the construction contractors. A contractor with higher experience in working with modern equipment will have a higher trust to the new technologies [30].

The complexity of design and construction

A complicated configuration may result in an easier and faster trust to the new technologies. In such cases, a design-ready pack of the technology can significantly reduce the number of efforts the designer needs to spend to meet certain seismic codes and regulations. It can promote trust and adoption levels. A simpler configuration associated with a simpler seismic design makes it more achievable for the designers without using design-ready elements [24].

Respectively, providing information on the value of using the new technologies to the designer of a simple structure can be taken as a crucial step to increase their trust to these technologies.

ORGANIZATIONAL-RELATED FACTORS

This section explains the importance of the organizational position of the decision makers (listed in Figure 5) on creating a trust to the new technologies.

Deciding as a structural engineer

For high experienced consultants that already have implemented the new technologies in the buildings, it is easier to understand the advantages of new technology compared to inexperienced competitors. The efficient knowledge transfer between those consultants that have already adopted the new technology and the potential adopters can play a crucial role in developing trust [31]. Given the importance of the role of the structural engineers in the design process of the structures [32], they are the key characters deciding about adopting a specific structural solution or new structural technology [2]. Therefore, it is imperative for them to be technically satisfied with the technology and be convinced about the cost of the technology compared to the overall value of the building. The ultimate solution can be to inform the structural engineers about the advantages of the new technologies and make them familiar with the design tools that support incorporating these new products into their design. These can be achieved through technical presentations, workshops and conference/journal publications [32].

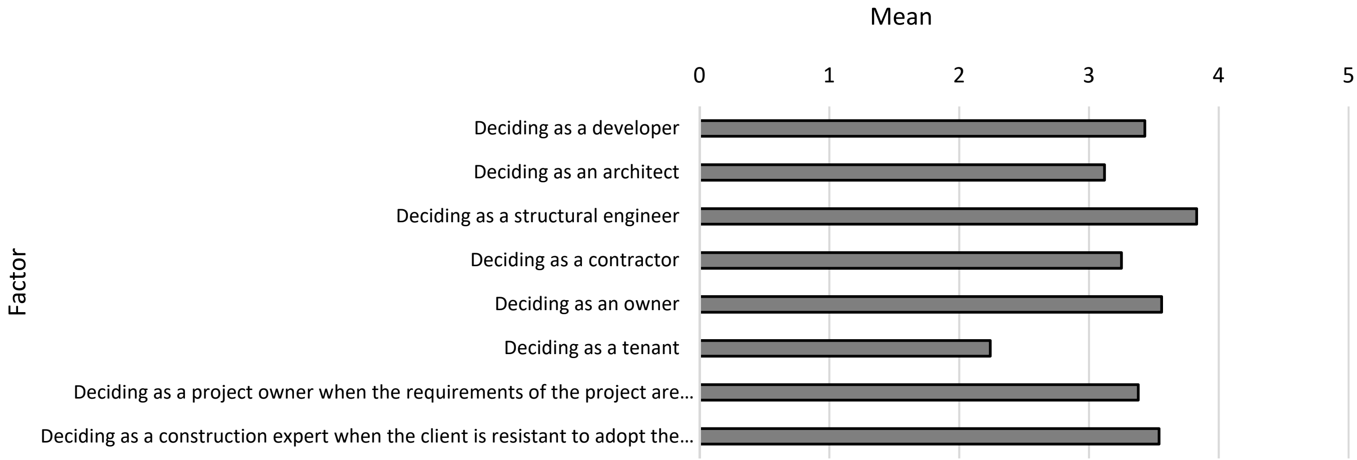

Figure 5. Organizational-related factors

Clients

Clients are typically resistant to new technologies. The main reason is the relatively higher initial cost of the technologies compared to the conventional ones. As discussed, despite the higher initial cost, the new technologies significantly reduce the post-event repair and maintenance costs, which give them an advantage compare to the conventional solutions [24]. The cost of replacing a conventional product could be much higher than its initial cost. Furthermore, if the residual deflection (post-earthquake out-of-straightness of the structure) necessitate a building re-aligned, it will encounter a considerable additional cost. In some cases, it may necessitate demolition of the building and involve a new construction that will make the case far more expensive than the use of the new technologies [33]. If the clients become more familiar with these concepts, they will be more likely to be convinced to adopt the new technologies. Thus, the observed resistance to change may reduce.

STRATEGIES TO UPTAKE THE TRUST TO THE NEW SPTS

Based on the discussions made, a few strategies can be followed to increase the trust to the new technologies:

- Most of the current earthquake design codes are using the life-safety philosophy of design. It means for the code-compliance buildings the life-safety is maintained, while the social and economic impacts of the post-earthquake damage are ignored. Therefore, incorporating a "Functional Recovery" philosophy of design into the codes could significantly aid with the uptake of the trust to the new technologies.

- Governments and the large-scale construction companies, as the leading players in the construction industry, should provide and transfer the detailed technical expertise to assist small and medium-size corporations with information about the design and installation of these novel devices. Moreover, the manufacturers of the devices or the local representatives can play a coordination role in facilitating technical assistance by providing technical or in-kind support to launch a series of training initiatives [34].

CONCLUSIONS

New methods and technologies are introduced to decrease the impact and consequences of earthquake and aftershocks. However, the low level of trust to these new methods and technologies poses a serious barrier for the adopters. Introducing new technologies into the construction industry requires basic changes in a systematic way of thinking. This research explored the factors that contribute to trust to the new seismic-proofing technologies. The analyses indicated 28 factors in two main categories that can significantly affect the uptake of the new technologies consisting of 20 project-related factors such as project type, the location of the project, the scale of the project, type of the construction, site accessibility, the level of expertise of consultants, method of construction and the complexity of design and construction; and 8 organizational-related factors dealing with the role of the decision makers. These findings can provide the technology developers with a baseline to form a pathway to improve the trust and adoption process.

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