MODELLING OF FACTORS IMPACTING ADOPTION OF PRECAST CONCRETE SYSTEMS

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Abstract
Construction technology utilizing prefabricated concrete elements is known as a 'precast concrete system'. In Western countries, this system has been widely used in constructing bridges, office buildings and residential buildings. A precast concrete construction system provides the advantages of construction effectiveness, high levels of quality control, saving of construction time, minimisation of skilled labour, reduced manpower requirements on site, and saving in formwork requirements when compared with the traditional construction method (cast-in-place concrete). In Thailand, cast-in-place is the traditional construction system that has been mostly used to this point. Precast concrete floor slabs are the only a prefabricated elements used widely in Thailand. Only a few parties in the Thai construction market have adopted fully precast concrete systems. However, many factors have an impact on the adoption of precast concrete system. This paper presents and analyses a conceptual model that accommodates the numerous factors impacting the effectiveness of the adoption process. The results of a survey of 160 construction industry professionals in Thailand are presented and the significant factors which impact the adoption of precast concrete systems are determined through statistical analysis. The paper concludes with an analysis of the significant factors in the adoption of precast concrete elements and system.

Keywords: Precast Concrete System, Conceptual Model, Thailand

INTRODUCTION

Precast concrete elements are one of the most remarkable developments in the construction of concrete structures. In recent decades, precast concrete elements have been widely used for architectural and structural buildings. The construction method is mainly divided into two stages: manufacture of mass-produced components in a permanent construction facility, and assembly of components on the construction site. The use of precast concrete elements has increased in recent years because these precast concrete elements provide the advantages of construction effectiveness, high levels of quality control, saving construction time, minimisation of skilled labour, reduced manpower requirements on site and savings in formwork requirements. Numerous researchers have studied the adoption model within their individual fields of study. It should be noted here that although some adoption models have been developed particularly for the field of marketing, the author is not aware of any comprehensive model developed specifically for the precast concrete construction industry. This study attempts to model the various factors that influence this industry's effectiveness in adopting precast concrete elements. These factors can be broadly defined as enablers and include the product characteristics, communication channels, management support and environmental impact. The performance and interaction between these enablers influence the degree of adoption achieved. Factor analysis was used to confirm and refine grouping of significant factors.

LITERATURE REVIEW

Adoption of the precast concrete construction continues to be a key stimulant to industrialization and economic growth in developing countries, particularly in the fast-growing Asian countries such as Thailand, China, Vietnam (Prilhofer, 2007; Schultes, 1995; Yeung, 2002). In recent decades, many researchers have studied the adoption model in various areas particularly marketing, but none have targeted their study on the adoption model of the precast concrete construction industry. A literature review was undertaken in this study, which closely examined existing models developed across all industry sectors with a view to developing a conceptual model specifically designed for studying the significant impact factors of adopting precast concrete systems (Brand and Huizingh, 2008; Obra and Melendez, 2006; Wu, 2004).

Construct	**Description of variables**	**References**
Product characteristics	Construction cost Construction schedule Waste material Skilled labour Safety Pollution reduction Innovation development Complexity of construction technology	Beatty *et al*, 2001; Christensen, 2001; Gibb, 1997; Geem, 2006; Puri and Adlakha, 2003; Schultes, 1995; Waroonkun *et al.*, 1998; Yeung, 2002
Communication channels	Direct sales Sale promotion Advertisement Information Word-of-mouth	Belch and Belch, 2001; Calder and Malthouse, 2005; Kotler and Armstrong, 1996
Management support	Training Policies support	Makame, 2007; Woodside and Biemans 2005
Environmental impacts	Quality control Quality guarantee Options	Aguayo, 1990; Christensen, 2001; Roger, 2003
Level of Adoption	Awareness Interest Evaluation Trial Adoption	Roger, 2003; Wu, 2004

Table 1: *Enablers and level of adoption*

As a result of the literature review, several variables were identified and grouped as either enablers of adoption or indicators of level of adoption. The enablers were divided into four main categories: product characteristics; communication channels; management supports and environmental impacts (Table 1). The performance of these enablers contributes to the level of adoption in the construction business sector. The level of adoption, which is significantly impacted by these various factors can be divided into five degrees: awareness; interest; evaluation; trial and adoption (Table 1).

'Product characteristics' concerns how the use of precast concrete components will provide significant benefits to the investor and environment. 'Communication channels' deals with how information about the benefits of adopting precast concrete technology will be transferred to architects, engineers, project owners and other users. 'Management support' addresses the industry's policy to improve the knowledge base of customers. 'Environmental impacts' is concerned with product quality to support the customer's choice. 'Level of adoption' concerns the individual customer's satisfaction when planning to adopt the precast concrete construction system.

A conceptual model of factors impacting the satisfaction of precast concrete components has been developed (Figure 1). The relationship between the above-mentioned constructs is represented by four hypotheses, described below:

- H1: Appropriate product characteristics enhance the level of adoption;
- H2: Effective communication channels enhance the level of adoption;
- H3: Appropriate management support enhances the level of adoption; and
- H4: A supportive environment enhances the level of adoption.

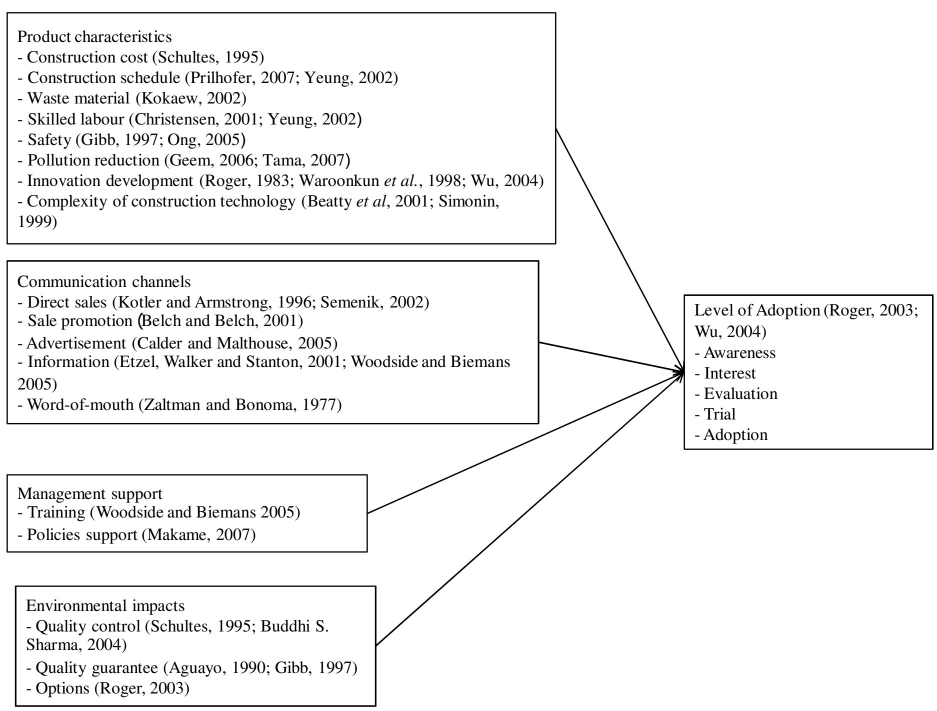

Figure 1: *Conceptual model*

RESEARCH METHOD

During April-May 2010, data collection for this study was undertaken with construction professionals in Bangkok and Chiang Mai, Thailand. The target group of respondents included design and construction professionals from construction projects involving precast concrete systems. In total, 525 surveys were distributed and 160 were returned, representing a response rate of 30 per cent which exceeds the minimum 1:5 ratio requirements for factor analysis (Hair *et al.*, 1998). The objective of this study was to refine and confirm the conceptual model, and identify the numerous factors which impact the level of adoption. Factor analysis was undertaken to summarise the information contained in a number of original variables into a small set of new factors (Hair *et al.*, 1998). Results from this analysis were used to identify the significant factors. The survey questionnaire contained two sections with a total of 29 questions representing individual variables in the conceptual model. Part 1 focused on measuring the level of adoption in the following degree: awareness; interest; evaluation; trial and adoption. Part 2 included questions relating to the enablers influencing the level of adoption, including: product characteristics; communication channels; management supports; environmental impacts. Other background information such as, years of experience, position, education, etc. was also solicited from respondents. This section was included to ensure that information was received from valid sources.

Each question in the survey required the respondents to provide a rating of the impact of enablers and the level of adoption. The question in Part 1 asked respondents for their opinion about the level of adoption, ranging from 'strongly disagree' to 'strongly agree'. Part 2 of the survey questionaire sought to ascertain respondents' perception of the factors influencing satisfication with precast concrete components, based on their experience. The scale in Part 2 of the survey questionaire ranged from 'strongly negative' to 'strongly positive' and the results were utilised for the majority of the statistical analysis because they enabled causal links between variables to be established.

DATA ANALYSIS AND RESULTS

Descriptive Statistics

Respondents were classified into five categories: designer (63%), construction manager (21%), project administration (9%), builder/contractor (5%) and project owner (2%). The respondents' level of education was classified into five levels: bachelor degree (64%), master degree (28%), diploma degree (4%), PhD degree (3%) and high school (1%). Respondent age was also noted: under 25 years (2.5%), 25-35 years (52%), 36-45 years (29.5%), 46-55 years (12%) and over 50 years (4%). The breakdown of respondents' construction experience was 0-5 years (25%), 6-10 years (27%), 11-15 years (15%), 16-20 years (28%) and over 20 years (15%).

Analysis of variance (ANOVA) was performed to ensure that respondents of different age, different education level, different positions and different length of experience could be considered as a single sample. ANOVA confirmed congeners between education levels at the 0.05 level of significance (Black *et al.*, 2000). However, when age, position and past experience were considered together, there was one variables in (use of precast concrete beam in construction) which had a significantly ($p < 0.05$) different mean value for three age groups (36-45 years, 46-55 years and > 55 years). The mean values for this variable within their respective groups suggest that respondents aged 55 years and up do not trust precast concrete beam construction, it can be describe that the construction technology was developed rapidly during 20 years ago during the period of respondents' age around 36-45 years.

Table 2 shows the mean and standard deviation value for the respondents' level of satisfaction in adopting precast concrete construction systems. The overall mean and standard deviation values for the respondents' satisfaction were 3.58 and 0.47 respectively, which suggests that all questions representing the level of respondent satisfaction in the conceptual model were understood and respondents had a high level of acceptance in adopting the precast concrete system as part of construction projects.

It was found that the respondents were highly aware of and intended to adopt the precast concrete system but when it was implemented in a construction project as part of a structural or architectural building, the respondent's satisfaction level declined slightly. This may be explained by the fact that few past construction projects in Thailand were designed to be built entirely with precast concrete elements: precast concrete is normally utilized only for the floor in Thailand. This suggests that the owners of precast concrete factories should produce a variety of products and arrange courses to promote and teach about the precast concrete products.

Level	Description	Adoption Level of Precast Concrete System		
		Number	Mean	Standard Deviation
1	Awareness	160	3.48	0.62
2	Interest	160	3.54	0.69
3	Evaluation	160	3.84	0.62
4	Trial	160	3.26	0.86
5	Adoption	160	3.76	0.64
Level of Adoption Mean = 3.58; Std. = 0.47				

Table 2: *Mean and standard deviation of adoption level*

Factor Analysis

Table 3 presents the factor loading, eigenvalues and explained variance for the final four-factors solution. The enabler variables that were significantly low on the factor loading from analysis included: making precast concrete technology comply with the traditional method (A7, 0.48) and complexity of construction technology (A8, 0.48). The enabler variables of factor loading should be appropriate for analysis by exceeding the 0.5 threshold level (Coakes, 2005; Hair *et al.*, 1998). In the final four-factor solution, factor 1 was determined to be the most important explaining 38.42 percent of the total variance, most variable loading exceeding 0.5 and the initial eigenvalue of 6.91. Factor 4 is the lowest significant of variance, explaining only 6.09 percent of the total variance with the initial eigenvalue of 1.10. Generally, factors with initial eigenvalues lower than 1 have a poor contribution to the model (Hair *et al.*, 1998).

Factor	Description	Loading
1. Product characteristics	A1 (Construction cost)	0.56
Variance = 38.42%;	A2 (Construction schedule)	0.70
Eigenvalue = 6.91	A3 (Waste materials)	0.72
	A4 (Skilled labour)	0.76
	A5 (Safety)	0.76
	A6 (Pollution reduction)	0.62
	A7 (Innovation development)	0.48
2. Communication channels	A8 (Complexity of construction technology)	0.48
Variance = 10.88%	B3 (Advertisement)	0.50
Eigenvalue = 1.95	B4 (Information)	0.63
	D1 (Quality control)	0.66
	D2 (Quality gurantee)	0.61
	D3 (Options)	0.77
3. Management support	B5 (Word of mouth)	0.59
Variance = 7.27%	C1 (Training)	0.65
Eigenvalue = 1.31	C2 (Policies support)	0.87
4. Environmental impacts	B1 (Direct sales)	0.82
Variance = 6.09%	B2 (Sale promotion)	0.61
Eigenvalue = 1.10		

Table 3: *Varimax rotated factor loading for the final four-factor solution*

Regression

The conceptual model shown in Figure 1 was tested using single regression analysis. Table 4 details the single regression analysis results from the survey questionnaire. The result obtained through single regression provides some indication on the relationship between model factors and the contribution of each factor to the predictive power of the model (Hair *et al.*, 1998; Hatcher, 1994). The higher value of R^2 produces greater explanatory power of the regression equation, and therefore a better prediction of the independent variable (Hair *et al.*, 1998). The *t* value and the significance value both explain whether the addition of the predictor variable has a significant contribution to the model. A higher *t* value suggests a higher contribution to the model.

The combination of the independent variable explained 61.2% of the variance in the level of adoption (F = 23.166, p = 0.000) suggesting that the combination of variables does a reasonable job of predicting the respondent's adoption. Two main independent effect variables including Product characteristics and Communication channels ((t = 3.904, p = 0.000), (t = 3.408, p = 0.001)), were strongly significant in the model as well as Factor 3 (Management support) and Factor 4 (Environmental impacts) were less significant in the model. Each hypothesis will be addressed in the following details.

H1 predicted that appropriate product characteristics would enhance the level of adoption. This study showed that product characteristics were significant as a predictor to increase the adoption level (t = 3.904, p = 0.000). Thus, H1 is supported.

H2 predicted that effective communication channels would enhance the level of adoption. The results show that effective communication channels did significantly enchance the level of adoption (t = 3.408, p = 0.001). Thus, H2 is supported.

H3–H4 predicted that both management support and environmental impact should lead to enhanced respondent adoption levels. These two factors were shown to be less significant in term of effect on the respondent's level of adoption ((t = 0.257, p = 0.798), (t = 0.489, p = 0.626)). Thus, H3 and H4 are only partially supported.

	Beta	*t v*alue	Sig. level
R = 0.612 R Square : 0.374 (F = 23.166) (Sig = 0.00)			
Independent Variables			
Factor 1 (including A7)	0.270	3.904	0.000
Factor 2 (including A8)	0.257	3.408	0.001
Factor 3	0.012	0.257	0.798
Factor 4	0.025	0.489	0.626

Table 4: *The single regression analysis result*

SUMMARY

This paper details a conceptual model of factors impacting adoption of precast concrete systems. The research study described herein was undertaken with the aim of examining the validity of the model factors and sub-factors, and finalising the conceptual model. Model groupings were achieved via factor analysis. Single regression analysis showed the significant relationship between each model factor to predict the respondent's adoption level. Future research will undertake a series of case studies to verify the reliability of quantified links. Recommendations is also advises herein.

RECOMMENDATION

This study on the physical factors affecting the level of adoption at the conceptual model had the objectives to develop the precast concrete system technology. Improving the physical factors are recommended in Table 5 as follows:

Component	Major factors of the problem	Recommendations for improvement
Product characteristics	- Skilled labor - Safety - Waste material - Construction schedule	- The precast concrete system should be designed to minimize the use of skilled labor in terms of production and part assembling. When compared to other construction systems, this precast concrete system will use machinery as its major tool which will result in a higher degree of safety. - The precast concrete system should be designed to reduce the construction time and to use the least construction material. The construction time of the building structure system should be reduced by at least 60 %.
Communication channels	- Options - Quality gurantee and quality control - Information	- The precast concrete system should be used as the major channel for projects with repetitive construction patterns, especially for building structure. - The precast concrete system or the precast parts must be certified by the industrial standards and its efficiency and quality be certified by a reliable institute. - Information concerning the products and the system should be publicized.
Management support	- Policy support	- The government should support the system through its policy, for example reduction of import taxes for the production machinery.
Environmental factors	- Direct sales	- Information on construction technique related to the product must be presented by the sales representatives or manufacturer directly to the designer, project manager and the contractor to promote the use of the pre-cast concrete system.

Table 5: *Recommendations for improvements of the factors*

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