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Modelling Influential Factor Relationships Using System Dynamics Methodology (Fibre Cement Buildings as a Case Study)

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Abstract

The rapid increase and the need for more sustainable buildings has led researchers and engineers to find a new way to construct buildings which can be offered more cheaply and sustainably. However, the adoption of new technology in the construction of buildings requires intense study of the influential factors that can affect the demand for new buildings. This research investigates the factors which have significant impact on demand for fibre cement technology. On the basis of questionnaire data analysis, this research process developed a model of system dynamics which showed the relationships between influential factors and demand, as well as finding new relationships between these factors. After modelling the factors of cost, advertising, education and awareness, the availability of classic buildings and specifications of fibre cement buildings are shown to be important factors in affecting demand for fibre cement buildings and vice versa.

On the other hand, factors such as population, number of couples in households, availability of building land and standard of living have an important effect on demand, while demand has no impact on these factors. Therefore, these influential factors can help construction companies and contractors to enhance the demand for their newly developed buildings. Fibre cement buildings are cheap, attractive and resistant to fire and humidity, can be assembled, disassembled and then reassembled. These features can play an important role in attracting and satisfying customers for such buildings.

Keywords: System dynamics; questionnaire; factors relationships modelling; construction management

1. Introduction

There is an increasing demand for more sustainable buildings which can offer a high standard of living. Therefore, the need for technologies in construction has been vital because new technology can offer a vast variety of materials and finishes which, in turn, produce more attractive buildings which are cheaper, more energy-efficient and require less maintenance. One of these technologies is fibre cement board which consists of natural cellulose fibre, cement and silica. This type of technology is used in many countries, such as Canada, the US and Turkey, because of the many advantages that it can offer, including being environmentally friendly, no water absorption, good heat and sound insulator and assisting in accelerating the construction of buildings because it is prefabricated and easy to assemble

(Ozge Yapi, 2007). However, the introduction of this new material in construction buildings requires an intensive study for the factors that can enhance the demand for these types of buildings. Therefore, a system dynamics approach will be developed in this research to study the factors affecting the demand for fibre cement buildings as this approach has the ability for showing the interactions between factors.

2. Research Problem

Many construction industries try to solve the problem of increasing demand for dwellings by finding new technologies for the construction of buildings in less time and at lower cost. One of these technologies is fibre cement board, but people do not like to live in such buildings. Consequently, this study will find the factors that can increase demand for these.

3. Literature Review

The literature review has been prepared in order to show the different applications of the system dynamics model. Wang et al. (2005) showed the application of SD approach in project risk management. The cause-effect relationship which is presented by causal loop diagram is used in project risk management. A simulation model of system dynamics which is based on causal loop diagram is developed to simulate the behaviour of the system that required simulation. The researcher concluded his research by citing that SD is a valuable tool because of its capability in supporting project risk management in specifying risk, risk quantification and risk reply planning. In the field of sustainable development Hjorth and Bagheri (2006) applied the SD approach to cope with issues of sustainability. The causal loop diagram has been used to show the generic viability loops related to human needs, environmental, economic and life services structures. They concluded that the SD approach helps users to improve their understanding of the relationships in the system and become conscious of their changes throughout a learning process.

In the field of construction, Balyejusa (2006) developed the system dynamics model as an application to understand the problems caused by changes in construction projects. The researcher developed a causal loop diagram that represents all critical variables and the measurements that were taken from the conceptual model. His results were that system dynamics is the best tool to deal with changes in construction. Encalada and Caceres (2012) proposed a SD model to explain the implementation and improvement of business sustainable policies and Petróleos Mexicanos (pemex). Leadership, stakeholder motivation and increasing leadership activity and external factors identified as leverage points in the model. The results of the simulation model indicate that by increasing leadership activity and levels of stakeholder motivation, the journey towards sustainability can be greatly improved whereas there is no significant impact of the external economic factors on sustainability achievement.

4. Questionnaire Design and Analysis

This questionnaire was divided into two parts. The first part was associated with the questions that related to the features of fibre cement buildings. The second part was established as a platform to explore the capability of applying the system dynamics approach.

The questionnaire was set up after studying the likelihood of factors that can affect the demand for fibre cement buildings positively or negatively. There are two reasons behind establishing this questionnaire. Firstly, it is necessary to obtain people's opinion about the features of fibre cement buildings in order to clarify the factors which are considered as an opportunity or a threat when adopting these types of buildings and the impact of these factors on demand positively or negatively. Secondly, it is a step towards supporting the use of the system dynamics approach as a technique for exploring the relationships between demand and the influential factors and vice versa.

4.1. *The relationship between the Advertisement and Demand*

Undoubtedly, the advertisement factor can play a powerful role in popularity of any products. That is because advertisements can offer many advantages so that the public can know the new products much more easily; it also leads to the creation of new customers. The most important feature of the advertisements is helping in promoting sales and this, in turn, increases the demand for the products. Therefore, a question included in the questionnaire was: If the advertisements increase, will the demand increase?

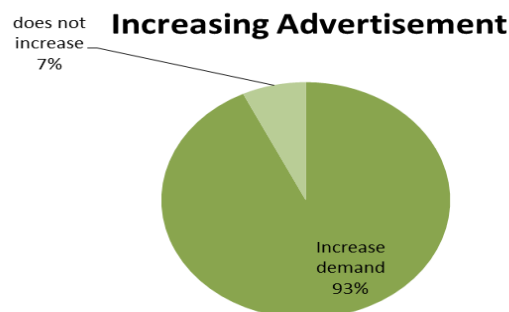


Figure 1 Effect of advertisement factor on demand

The pie chart in Figure 1 presents the results of the question mentioned above, in which a high number of positive responses elicited to this question of 93% against to 7% negative responses.

In contrast, the pie chart in Figure 2 shows the results for the question of whether the growth in demand for fibre cement buildings would reduce the need for advertisements, or not.

The feedback of this question shows a similar pattern to its opposite question because of the 82 percentage of positive replies is considered as a high proportion that makes the result of this question quite similar to its opposite question.

Increasing Demand

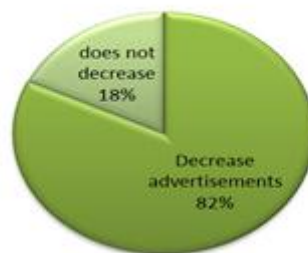


Figure 2 Effect of demand factor on advertisement

4.2. The relationship between the demand and the cost factor

Obviously, the impact of a building's cost factor on demand is considered as a fundamental issue to be aware when suggesting new types of buildings. In this research the respondents have been asked to answer this question: If the cost of fibre cement building decreases, will the demand increase?

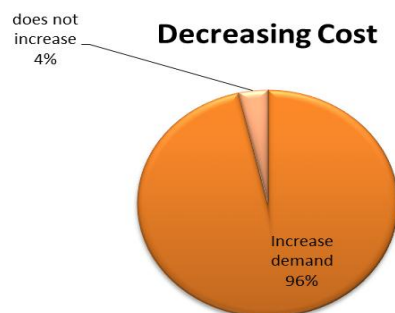


Figure 3 The impact of cost factor on demand

Figure 3 indicates the survey in which the majority of respondents answered this question positively as the percentage of positive answers was 96%. On the other hand, the other question was applied in the questionnaire in order to explore the opposite feedback of the effect of demand on cost: 'If the demand decreases on this type of buildings, will the cost increase?'

According to the pie chart presented in Figure 4, it is clear that more than 50% of respondents believe that the cost increases when the demand decreases. However, it is important to be aware about the rest of negative responses and try to investigate if there are realistic reasons for disagreement.

Decreasing Demand

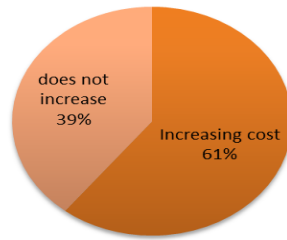


Figure 4 The impact of demand factor on cost

5. System Dynamics Model of Fibre Cement Influential Factors

The impact of these influential factors on demand and vice versa elicited positive replies from the respondents. The effects of these factors on demand and, in contrast, the demand on these factors have already been explained. However, concerning the diagram which shapes the relationships between factors and demand as a flower, there will be a trial to find a relationship among the influential factors arising from the questionnaire results.

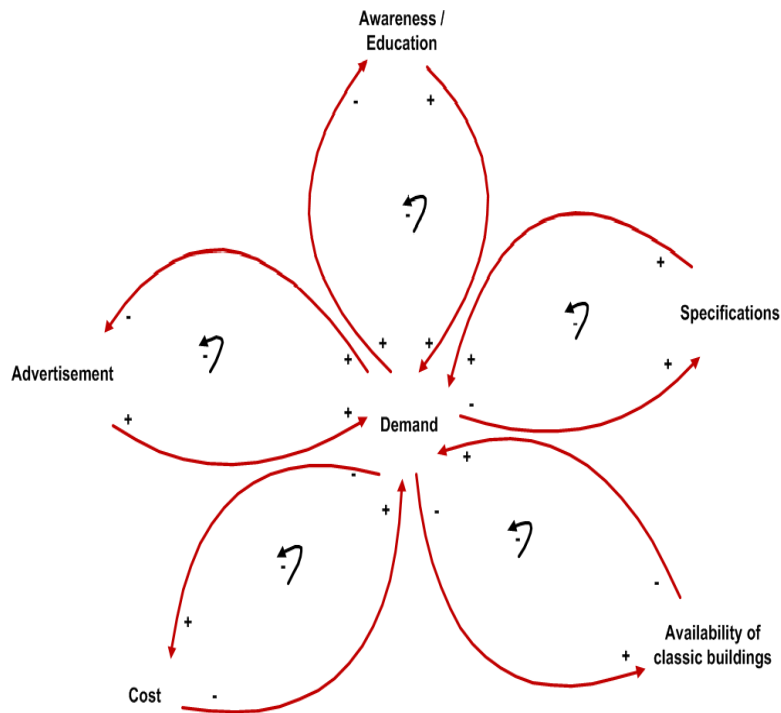


Figure 5 The flower loop diagram of the influential factors with demand

By considering Figure 5, it can be seen that when factors of advertisement, education and awareness and specifications are increased, the demand will increase for these types of building. Moreover, the respondents support the effect of these positive factors on demand

and their answers were 93% (advertisement impact), 82% (education and awareness) and 100% (specifications influence).

In contrast, the factors of cost and availability of classic buildings have the same impact on demand. This is because the decrease of these two factors (the cost of galvanised buildings and the availability of classic buildings) will lead to raising the demand for this type of prefabricated building. On the other hand, according to the questionnaire results, it appears that demand also has different powerful effects on the other factors, so that when the demand grows, the two factors which will become less important are advertising plus education, and awareness. However, factors of specifications, availability of typical buildings and cost of buildings are affected significantly by decreasing demand. Reducing the demand for these types of prefabricated buildings means raising the cost of them because of the expectation of increasing cost imposed by the supplier that lead to raising the price of the buildings. Moreover, the decreasing demand for these buildings means an increasing demand for the classic building construction and that in turns leads to the availability of more classic buildings to meet public demand. Furthermore, decreasing in demand will affect the specifications because this factor will increase as demand declines. That is because the contractor will be forced to develop the specifications for the buildings from fibre cement board and steel frame structure in order to make them more attractive and popular, so as to fulfil his targets on increasing demand for these buildings to achieve more sales and finally more profit.

6. Conclusions

This research has addressed the influential factors on demand for fibre cement buildings. It described a particular methodology in finding the influential factors. The research outcomes, activities and framework have fulfilled the research aim and objectives. The research started with a literature review which showed a variety of applications of system dynamics in different fields. The questionnaire was prepared for data collection. The data analysis was performed. The system dynamics model has proved its effectiveness when applied to show the cause-effect relationships between the influential factors and demand. The outcomes were as follows:

- It has been clarified that fibre cement buildings are superior to classic buildings.
- The increase in the factors of advertising, education /awareness and specifications will lead to an increase in demand.
- The decrease of these two factors (availability of classic buildings and costs of fibre cement buildings) will result in increased demand.
- The reduction in advertising will influence the need for more education/awareness and vice versa.

- The demand for classic buildings will drop when specifications, education/awareness and advertising of fibre cement buildings increase.
- The low cost of fibre cement buildings will minimise the demand for traditional buildings.
- The factors of increasing population, number of couples in household, availability of building land and raising the standard of living have a major impact on increasing demand. However, the demand has no impact on these factors.
- However, the influential factors vary from country to country, but most of the factors studied in this research can be considered important for influencing demand for buildings in any country, such as cost and improving specifications of buildings.

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