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Article

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Flexibility Cost and its Application for Construction Projects

Rashmi Shahu[1]

Abstract: The paper aims to develop a methodology for valuing flexibility by developing a mathematical formula for predicting future saving of cost. The work aims to evaluate flexibility in the initial design phase of projects taking examples of construction projects. Flexibility is becoming a more widely accepted aspect of project management. Although contingency theory in project management states that the unknowns are controllable, complexity theory believes that the best way to handle the unknowns would be to have a flexible approach rather than rigidity. Designing a flexible system is a method of managing uncertainty. Two case studies were considered in this research to validate the mathematical formula. This research explains three case studies of an educational institution 28 years old for explaining the concept and giving benefits of flexible design for modification / renovation work of building. Flexibility becomes inevitable for environment where the environment is dynamic. For a ready adaptation to market fluctuations it would be good to impose the condition that the building, along with its installations should be suitable for several uses. Flexibility in the initial design phase is modelled in order to know the advantage in future. The comparison between the extra cost of flexibility in the initial design phase and the discount that can be achieved in future due to this premium will help the developers in making strategic decisions. Prior research work contains various characteristics of flexible building structures but no attempt has been made to compare between the extra cost of flexibility in the initial design phase and the discount that can be achieved in future due to flexible building structures.

Keywords: Flexibility; Future Saving; Flexibility Cost

1. Introduction

Most of the early research works in the field of construction generally pointed out that construction projects once constructed are irreversible, (Zhao & Tseng 2003),. The utilization of such projects by their clients is a continuous process and a great amount of diversity in client's requirements is observed throughout functional life cycle of each building, (Davison et al 2006). The heavy, fixed and irreversible nature of construction projects makes it complicated to meet the dynamic and uncertain demands of its clients. The existing philosophy based on the competing paradigm of rigidity and flexibility of construction projects is often inadequate to address this uncertainty, (Finch 2009, Blok & Herwijnen 2005). The ontological and epistemological research literature proved to be insufficient for forming a methodology of incorporating flexibility in the rigid construction designs, (Kalligeros 2006). Flexibility of building is one such characteristic of building that influences the sustainability of existing building as well as the functional value of new building, (Shahu et al 2012a). This created a need for several researchers to dedicate their efforts in the direction of defining flexibility and its application in construction projects. Such kind of study has importance in both realistic and academic

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field. In this paper an attempt is made to identify the existing ontology based on theoretical concepts of construction projects and how a paradigm shift could be brought in by creating knowledge of flexible buildings, (Choong 2005, Finch 2009, Blok et al 2005, Saari & Heikkila 2008, Greden & Glicksman 2004, Gereadts 2008). The existing literature dominantly point out the acclimatization of buildings and bringing flexible characteristics in building designs, but lacks in justification and evaluation of flexibility cost associated with it.

1.1 Flexibility Perspectives

Project complexity is the property of a project which makes it difficult to understand, foresee and keep under control its overall behavior, even when given reasonably complete information about the project system, (Vidal et al 2010). This kind of complexity is seen in construction projects where the complete project duration itself is around 2-3 years. Most of the large construction projects are planned at least 5-6 years in advance, (Gereadts 2001). During this time, demands on the infrastructure are likely to change significantly. Changing demands may result from new forms of construction technology, changes in government regulations, change of rules in funding agencies, etc., (Arge 2005). There are many key stakeholders who are directly linked with a construction projects like project owners, users, project management, architects, consultants, and contractors, (Cowee & Schewehr 2008). With so many stakeholders playing a key role there is scope of frequent changes in the requirements of each stakeholder. Pundir et al (2008) explores the use of flexibility in managing construction projects. This creates a need of flexibility in the construction projects.

1.2 Flexibility in Construction Projects

“Flexibility can be defined as the ability to change or react with little penalty time, effort, cost or performance”, Upton (1994). This means that flexibility describes the ability of the project to cope with changes in the project definition or scope and compensate them with little influences on schedule (time), costs and quality by appropriate management policies and actions, (Volberda 1997).. Mandelbaum (1978) defines flexibility in relation to construction industry as the ability of the system to respond to change by taking an appropriate action and the inner capability of the system to function well in more than one state. This definition of flexibility of system explains that the system or organization should be adaptive in nature. Flexibility approach is laid on some of the known theoretical concepts like contingency theory, law of requisite variety and systems theory, (Paslawski 2008). This means making a system or a process more proactive so as to make contingency provisions and capability of a system to take necessary controlling actions by efficiently making adjustments to changes, (Hanna 2002). Flexibility is a property of a building that is realized to some extent in all projects, even if it had not been actually taken into account during the design phase. There are certain design characteristics of building which makes it feasible for a building for renovation work, (Blok & Herwijnen 2005). There is a need to understand these design characteristics in order to save the future renovation cost, (Shahu et al 2012 a). By using a strategy of flexibility based on the structural design of building and its installations it is possible to achieve sustainability of building with increased functional value throughout its life span. Such type of flexibility of buildings will reduce the gap between the occupant’s requirement and the building functions by making the renovation of buildings easy and less costly, (Shahu et al 2012 b).

2. Research Methodology

The present research work is explorative in nature. It explores the following research questions after the critical analysis of the research papers and field observations.

1. Will flexibility in initial building designs make renovation/modification work easy?
2. Is the additional flexibility cost justifiable?
3. Does flexibility brings future savings in cost of construction?

2.1 Research Objective

The main objective of this paper is to build up and show knowledge of how flexibility in buildings can be improved. The day to day requirement of the users is changing because of which there is a mismatch between supply and demand of construction product (building). If the building is made flexible it will be adapted in the required form and thus will fulfil the needs of its users. The purpose of paper is to find the feasibility of flexibility in the initial design structure of building and justify the additional flexibility cost incorporated at the initial design phase. The decision on whether to invest additional cost on flexibility at the initial design phase has been rationalized by preparing a mathematical formula which will give cost and benefit analysis of having flexible design.

2.2 Hypothesis

On the basis of literature and research objective the following hypotheses are framed for the research work.

1. There exists a significant difference between the net present value of the additional flexibility cost and the cost of treatment in the absence of flexibility in building structures.
2. The cost of treatment in the absence of flexibility in initial building design is always higher than the additional flexibility cost incurred at the time of initial design of buildings.

The hypotheses are discussed and investigated both in theory and by empirical studies of 30 cases of building projects. Finally the mathematical formula developed is applied to each of the case study. The study being explorative in nature the hypotheses are not tested using empirical data but investigated with the help of 30 cases of building projects.

2.3 Sample Selection

All the cases chosen for this study are identified taking care of the data required for the purpose of the research. The buildings chosen are at least 5- 30 years old and have undergone some or the other kind of changes in the build part. The 30 cases consists of 12 educational institutions, 4 hospitals, 4 hotels/ guest house, 5 residential, 5 office buildings. The three major cases chosen for implementing the mathematical formula and for explaining the theoretical concept are chosen from a 28 year old educational institution. The cases have been taken from a renowned construction company in Nagpur city, India. The cases are from Nagpur, Raipur, Shivani, Akola, Wardha and some small towns of Vidarbha region, Maharashtra. The cases show plans and designs of the construction projects that have undergone some or the other type of renovation or expansion work in the existing building.

2.4 Research Instruments

The research instruments used for collecting the necessary data for this work are case studies, interviews, and field observations.

3. Mathematical Formula for Future Savings

In order to determine that the scope of flexibility (expansion) yields to savings in future and compensate for the extra investment made at the initial design stage, the future savings are to be calculated for which the following formula was developed. The formula compares the cost associated with flexible building and a non flexible building and calculates the future savings.

$$F = P * \{[CE + CT] - CE\} - \{[Cnnpv + CNnpv] - Cnnpv\}$$

(All the cost are converted into proper cost factors considering same time interval)

Where;

CT is the cost of treatment

CE is the cost of expansion

$CNnpv$ is the net present value of additional cost incurred

$Cnnpv$ is the net present value of construction cost

P is the probability of occurrence of change/expansion in building

F is future savings

3.1 Case Interpretations Using Mathematical Formula

Considering the example of case 1 and case 2 and base year as 2005 (since the changes are done in both the buildings in 2005), the following are the values:

$CE + CT$ =1000+203 = Rs 1203 / sq ft

CE = Rs 1000 / sq ft

$CNnpv$ = Rs 64 / sq ft

$Cnnpv$ = Rs 1000/ sq ft

So applying these costs in the following formula

$$F=P*\{[C_E+C_T] - C_E\} - \{[C_{nnpv} + C_{Nnpv}] - C_{nnpv}\}$$

F = 1 {(1203-1000)}- {(1000+64)-1000}

= 203-64

F = Rs 139 / sq ft

If the value of F comes to be positive, it shows that the flexibility cost for building incurred at initial design stage is much less than the treatment cost for building. This will again depend on the probability of expansion. As the probability of expansion will increase the value of F will also increase. This formula can help to decide over the comparison between flexible and non flexible design.

3.2 Framework for Application of Flexible Building Structures:

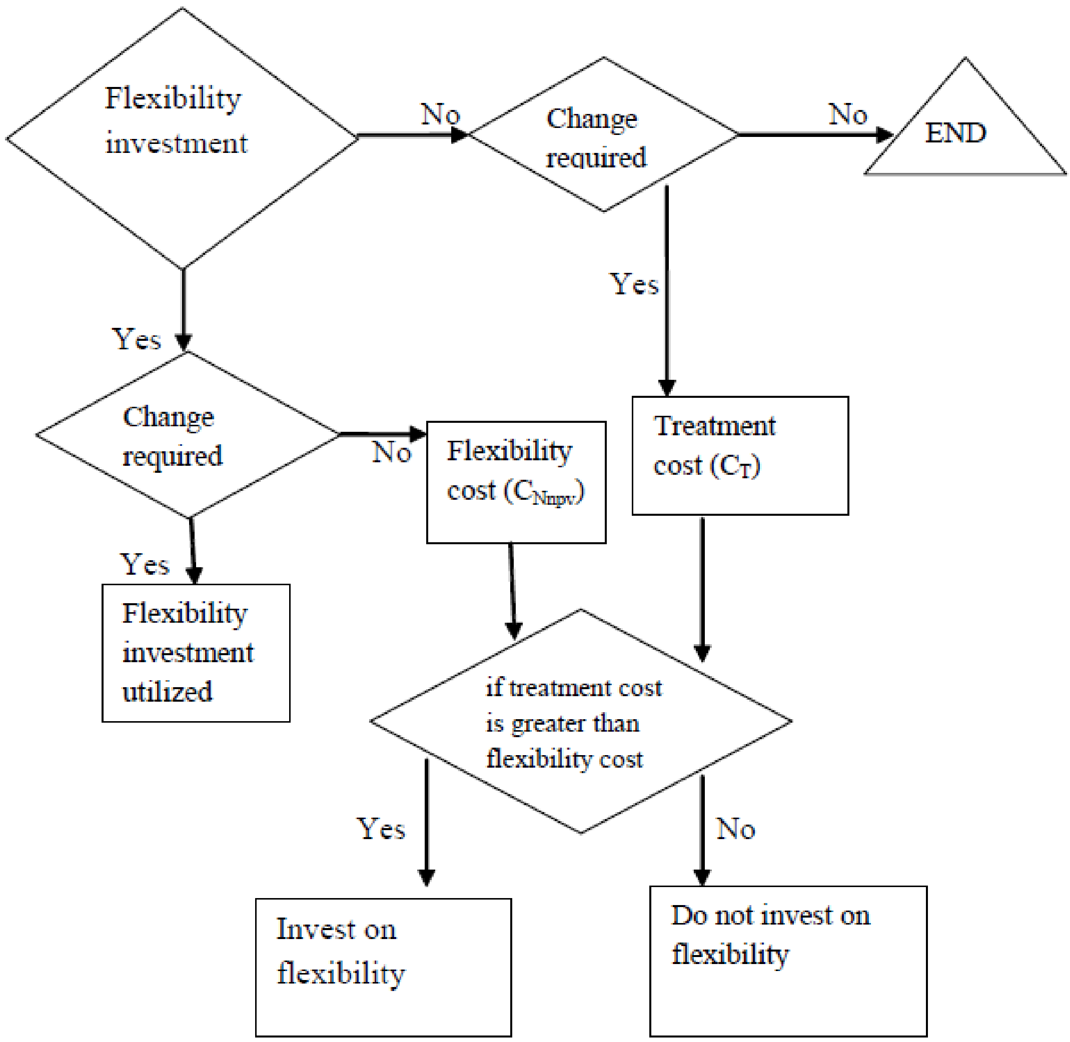

Figure 1. Proposed decision Framework for flexible cost in building structures

4. Result and Analysis of Cases

Hypothesis 1, "There exists a significant difference between the net present value of the additional flexibility cost and the cost of treatment in the absence of flexibility in building structures", was tested by performing descriptive statistics on the above data and it was observed that there is a significant difference between the net present value of additional cost and the treatment cost for different buildings as shown in table below:

Table 1. Descriptive statistics result using SPSS

Descriptive Statistics			
	Mean	Std. Deviation	N
TC	**91.50**	106.944	30
NPVADC	**40.00**	38.682	30

The hypothesis 2 , "The cost of treatment in the absence of flexibility in initial building design is always higher than the additional flexibility cost incurred at the time of initial design of buildings", was explained with the help of data from case 1 and case 2

After a careful analysis of the two major cases it was observed that it is much beneficial to leave a scope of expansion or change by investing additional cost at the time of initial construction rather than incurring heavy treatment cost later. Even though no expansion is required later, the additional investment is negligible as compared to the heavy treatment cost.

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$C_{N\ npv}$ = Rs 64 / sq ft

C_T = Rs 203/ sq ft

$$\boldsymbol{CT\ >>> CN\ npv}$$

4.1. Key Findings and Conclusion

1. The results shows that there exists a significant difference between the net present value of the additional flexibility cost and the cost of treatment in the absence of flexibility in building structures at p=0.000.
2. The cost of treatment in the absence of flexibility in initial building design is always higher than the net present value of additional flexibility cost incurred at the time of initial design of buildings, $C_T >>> C_{nNPV}$.
3. The development of the formula in finding the future savings can be useful in making comparative analysis between different construction strategies.
4. The additional cost incurred at the time of initial design structures is proved to be beneficial for saving the future rework/ expansion cost.

5. Discussion

Such Mathematical formula can help the construction industry in making comparison between the additional cost incurred for making the building flexible and the future savings gained through this provision. The future accommodation scenario can be fulfilled using this formula. The formula also considers the probability of change occurring while calculation of future savings. A building designed with such flexibility will certainly be easy to adapt in later stage. With this formula one can compare the costs and benefits of flexibility in building structures. Such formula which finds out tradeoff between the extra cost of flexibility during the design phase of building and the discount that can be achieved in future due to this premium investment will help the construction industry to take future decision.

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