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DERIVING A BASELINE SCORE FOR SELECTING ADAPTIVE REUSABLE PROJECTS: A QUANTITATIVE APPROACH

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ABSTRACT

Building Adaptive Reuse (BAR) has been recognized to be a viable option to deal with old building stock in spite of the trivial decision of either demolish or reuse. An objective scale to gauge the accuracy of this choice is however non-existent even there is a potential to do so. Hence, the aim of this research is to ease out this decision by developing a rational framework. A comprehensive literature survey, expert's interview and questionnaire survey was carried out. 35 experienced industry personnel participated in the questionnaire survey. The topics entailed were their exposure to BAR projects in Sri Lanka, BAR potential and drivers and barriers affecting BAR decision. Expert opinion was taken to verify the findings. In order to understand the importance level of each of the recognized factors, the Relative Important Index (RII) technique was used as the primary data analysis method. Analytical Hierarchical Process that involves pair-wise comparison, normalised comparison and consistency calculations was used to augment a baseline score in order to make the BAR decision rational. It was found that structural integrity is the highest priority acquiring 12.8% in the total factor score out of 36 globally important indices. The Overall Global Importance score has been considered in this decision making model against 5 successive adaptive reuse projects in Sri Lanka. A pass mark of 60 has to be the minimum threshold to proceed with adaptive reuse. The outcome offers a national benchmark.

Keywords: *Analytical Hierarchical Process; Building Adaptive Reuse; Relative Importance Index.*

1. INTRODUCTION

In the long run, buildings become obsolete or redundant. Continuous maintenance and restoration are needed in the building usage even if their life span extends up to decades and centuries (Langston andShen 2007). With this concern, a trend is to explore the possibility of reuse of old buildings before they fall into disrepair (Langston *et al*. 2008). The Department of Environmental and Heritage (DEH 2004) defines Building Adaptive Reuse (BAR) as "a process that changes a disused or in effective item into a new item that can be used for a different purpose". The benefit is that it gives neglected, out-dated buildings a liveliness that makes them once again attractive and useful (Campbell 1996). Almost all the historic cities now have realized that adaptive reuse of historic buildings marks a vital part of building renovation (Ball 2002). The processes of BAR is heavily contributed towards environmental sustainability through the mitigation of CO_2

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emissions (Bullen 2007). It reduces huge amounts of non-digested wastage generated through the demolition of old buildings. Adaptive reuse postures quite challenging for designers as the function changes of the buildings warrants the fulfilment of new regulatory conditions (Langston and Shen 2007). A successful adaptation is the one that respects the prevailing building and its historic background (DEH 2004). In Sri Lanka, a noticeable amount of buildings are located in Colombo, Galle Fort, Kandy as well as Jaffna and it could there be inferred that Sri Lanka has the potential of adopting BAR solutions. This arises the quest of rationality behind selection of projects for adaptive building reuse.

The aim of this research is to derive a decision making support model that enhances rationality of BAR decision. The objectives are to diagnose the factors that affect the decision making of building adaptive reuse, prioritize the most critical factors involved, develop a hierarchical order for identified critical factors that influence adaptation and augment a baseline score to make the BAR decisions, that are cogent and sensible.

2. RESEARCH METHODOLOGY

The process of decision making is dynamic so that an interpretative research would be ideal (Bullen and Love 2011; Loosemore 1999). A comprehensive literature survey was carried out using textbooks and research papers. 35 experienced industrial experts who had at least in a single BAR experience participated in the questionnaire survey. The topics entailed were the BAR potential, benefits, driving factors, the barriers affecting BAR decision. Expert opinion was taken to verify the findings. The Relative Important Index (RII) technique was used to obtain a ranking relative to the importance of such factors. RII was calculated using formula (01).

$$RII = \frac{\Sigma W \times 100}{A \times N} \qquad (01)$$

Where, W= weightage given to each factor by respondents, A= the highest weighting and N= total Number in the Responses.

The next step is the Analytic Hierarchy Process (AHP) which is a multi-criteria analysis on complex human judgments instead of analysis of mere information (Saaty 1990). This involves Pair-wise Comparison, Normalise the Comparison (deriving priority vectors) and Consistency Calculation (Ehrhardt and Tullar 2008). The decision maker expresses his preference between each pair of elements verbally according to a predefined numerical code based on its level of importance (Bayazit 2005). Accordingly, the numerical values from 1 to 9 were used to scale the responses. The ratio scales are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value.

3. ORIGINALITY AND IMPLICATIONS

While the advantages of BAR have been generally embraced hither and thither, there is no consistency among the building owners to legitimize and assess their opinions as to its worth to reuse or demolish the existing assets (Bullen and Love 2011). On the other hand, BAR process is found to have been not that widespread in Sri Lanka. There is neither BAR base nor a BAR model. The focus of this study is to establish a rational approach to make this choice.

4. LITERATURE REVIEW

Building obsolescence arises when there is an imbalance between the rate of change in market stresses and the rate at which the building stock is able to vary according to those changes (Williams 1986). According to Williams (1986), there are six types of building obsolescence; *Physical obsolescence*: relates to the condition of the building fabrics; *Statutory obsolescenc*e: occurs due to financial or technical difficulties arising from statutory requirements focussed on buildings; *Economic obsolescence*: relates to the building type demand and focus indirectly on the goods and services produced at the premises; *Functional obsolescence*: relates to the spatial arrangements of the building and its location site; *Locational obsolescence*: operational advantages related to the building location which is dependent on the market variations; *Community obsolescence*: local conflicts of interest as a result of the purpose and use of a building. Various forms of obsolescence are relative (Williams 1986). The main reason for this is, even if a building is outmoded in the context of a particular set of user requirements, it can still be renovated and used for alternative uses which can yield a high level of utility.

According to Langston and Shen (2007), physical factors can be identified and evaluated by examining the policy of maintenance and performance of a given building. Economic factors are mainly evaluated by the locality of the building. If the building is located in a business hub the economic value of the building is very high. The factors related to technology can be appraised with the building's energy consumption in operational activities (Conejos at el. 2014). Functional factors are assessed through the flexibility to change embedded in the design of the old building stock (Ellison *et al*. 2007). Social factors are often combined with the building function and the market place (Bullen 2007). Regulatory factors need to be evaluated in order to check whether the old building can meet the new existing building standards (Wilkinson and James 2009). Environmental factors can be assessed through the quality of the original design of the old building.

5. DATA ANALYSIS

Several factors impinge upon the BAR process; environmental, regulatory, social, technological, functional, economical and physical. Experts too held the same view. The sub factors which were identified through expert's interviews are given bold and italicized at last in each category for easy identification. In tracing out the existing level of involvement in the BAR practice, the questionnaire participants were requested to assign the level of importance.

The Relative Importance Indices (RII) of each sub factor was calculated to rank the most valuable factors (Table 1). The factors which were gained the RII value less than 0.6 were disregarded as they are not that significant for the BAR process (Holt 2004). The factors which the RII values over and above 0.6 are transferred for further analysis.

Table 1: Relative importance indices of factors

Main Factors	Rank	Sub Factors	RII
Physical Factors	1	Material Durability	0.967
	2	Structural Integrity	0.883
	3	Foundation	0.817
	4	Maintainability	0.783
	5	Workmanship	0.767

Main Factors	Rank	Sub Factors	RII
	6	Design Complexity	0.683
	7	**Prevailing Climate**	**0.583**
Economic Factor	1	Cost of Construction	0.933
	2	Market Proximity	0.917
	3	Touristic Attraction	0.876
	4	Transport Infrastructure	0.850
	5	Plot Size	0.783
	6	Planning Constrain	0.767
Functional Factor	1	Flexibility	0.967
	2	Structural Grid	0.917
	3	Service Duct and Corridor	0.883
	4	Convertibility	0.817
	5	Disassembly	0.783
	6	Spatial Flow and Atria	0.717
	7	**Compartmentalization**	**0.550**
	8	**Tenancies**	**0.500**
Technological Factors	1	Orientation	0.917
	2	Complexity	0.900
	3	Glazing	0.783
	4	Insulation and Shading	0.767
	5	Natural Lighting and Ventilation	0.750
	6	**Building Management System**	**0.500**
Social Factor	1	History	0.850
	2	Urban Master Plan	0.833
	3	Image	0.817
	4	Passion and Identity	0.812
	5	Landscape	0.800
	6	Aesthetic	0.783
	7	**Adjacent Building**	**0.550**
	8	**Sense of Belonging**	**0.526**
Regulatory Factor	1	Indoor Environmental Quality	0.817
	2	Occupational Health and Safety	0.800
	3	Standard of Finishes	0.783
	4	Fire Protection	0.767
	5	Disability Access	0.683
	6	**Security**	**0.533**
Environmental Factor	1	Raw Material Consumption	0.900
	2	Pollution and Biodiversity	0.817
	3	Conservation	0.800
	4	Waste Creation	0.717
	5	Cleanliness/ Good Appearance	0.705
	6	Acoustic	0.683
	7	Ecological Footprint	0.700
	8	**Community Interest**	0.567

5.1 PAIRWISE COMPARISON

A total number of 21 comparisons were considered. The average of level of importance obtained through 35 respondents is given in Table 2 in **bold**. Basically, each cell value of the comparison matrix enhances the numerical representation of the importance relationship between two main factors.

Table 2: Pairwise comparison matrix for main factors

Factors	Physical	Economic	Functional	Technological	Social	Regulatory	Envir'
Physical	1.000	**1.548**	**1.474**	**2.359**	**2.011**	**2.769**	**2.867**
Economic	0.646	1.000	**0.641**	**2.115**	**1.571**	**2.354**	**1.381**
Functional	0.678	1.560	1.000	**2.684**	**2.592**	**3.004**	**2.226**
Technological	0.424	0.473	0.373	1.000	**0.724**	**1.597**	**0.488**
Social	0.497	0.637	0.386	1.382	1.000	**1.854**	**0.561**
Regulatory	0.361	0.425	0.333	0.626	0.539	1.000	**0.456**
Environmental	0.349	0.724	0.446	2.048	1.783	2.192	1.000
Total	3.956	6.366	4.656	12.214	10.20	14.700	8.979

5.2 NORMALIZED COMPARISON

Data summarized in the pairwise comparison matrix were then transferred to normalize by dividing each comparison matrix cell entry by the sum of the respective column. Moving forward each of the row total were then calculated to derive the average of each row with the mean of the "Importance Index" of each main factor. These main factors' overall importance can also be named as main factor "Performance Score" or "Relative Weightings" (Saaty, 1990). To fill the lower triangular matrix, the reciprocal values of the upper diagonal were used (refer Table 3).

Table 3: Normalized weighting matrix for main factors

Normalized Weightings Matrix: Main Factors								Sum	Importance Index
Factor	Physical	Economic	Functional	Technological	Social	Regulatory	Envir'		
Physical	0.253	0.243	0.317	0.193	0.197	0.187	0.319	1.709	**0.244**
Economical	0.163	0.157	0.138	0.173	0.154	0.159	0.154	1.098	**0.157**
Functional	0.172	0.245	0.215	0.220	0.254	0.203	0.248	1.556	**0.222**
Technological	0.107	0.074	0.080	0.082	0.071	0.108	0.054	0.577	**0.082**
Social	0.126	0.100	0.083	0.113	0.098	0.126	0.062	0.708	**0.101**
Regulatory	0.091	0.067	0.072	0.051	0.053	0.068	0.051	0.452	**0.065**
Environmental	0.088	0.114	0.096	0.168	0.174	0.148	0.111	0.900	**0.129**
								7.000	**1.000**

5.3 CONSISTENCY CALCULATION

Being the final step in the AHP process, it is required to validate the data collected through the questionnaires and measure the consistency of judgments made by the respondents. The results are tabulated in Table 4. The Consistency Index as deviation or degree of consistency was calculated using formula (02).

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (02)$$

Table 4: Consistency calculation matrix for main factors

Consistency Calculations Matrix: Main Factors								Sum	Sum ÷ Importance Index
Factor	**Physical**	**Economic**	**Functional**	**Technological**	**Social**	**Regulatory**	**Envir'**		
Physical	0.244	0.243	0.328	0.194	0.203	0.179	0.369	1.760	7.207
Economical	0.158	0.157	0.142	0.174	0.159	0.152	0.178	1.120	7.138
Functional	0.166	0.245	0.222	0.221	0.262	0.194	0.286	1.596	7.180
Technological	0.104	0.074	0.083	0.082	0.073	0.103	0.063	0.582	7.065
Social	0.121	0.100	0.086	0.114	0.101	0.120	0.072	0.714	7.062
Regulatory	0.088	0.067	0.074	0.052	0.055	0.065	0.059	0.458	7.094
Environmental	0.085	0.114	0.100	0.169	0.180	0.142	0.129	0.918	7.135
	λ_{max} = 7.126			CI = 0.021			CR = 0.016		

Considering the space constraints in this research paper, AHP Approach for Individual Sub-Factors and their net resultant impact is not given.

5.4 Assigning Global Priorities for Sub Factors

The Overall Factor Score was calculated by multiplying each sub-factor local importance index from the importance index of their main factor category (refer Table 5). The global factor scores are listed together with their global ranking as each and every sub-factors earned.

Table 5: Global importance indices for sub-factors

Main Factor		Sub Factors			
Factor name	**Importance Index**	**Sub-Factor name**	**Local Importance Index**	**Global Importance Index**	**Global Rank**
Physical Factor	0.244	Material Durability	0.229	0.056	3
		Structural Integrity	0.324	0.079	1
		Foundation	0.167	0.041	5
		Maintainability	0.123	0.030	11
		Workmanship	0.073	0.018	26
		Design Complexity	0.084	0.020	19
Economic Factor	0.157	Cost of Constructing Building	0.226	0.035	8
		Market Proximity	0.185	0.029	12
		Touristic Attraction & Value	0.289	0.045	4
		Transport Infrastructure	0.082	0.013	29
		Plot Size	0.149	0.023	16

Main Factor		Sub Factors			
Factor name	Importance Index	Sub-Factor name	Local Importance Index	Global Importance Index	Global Rank
		Planning Constrain	0.068	0.011	33
Functional Factor	0.222	Flexibility	0.332	0.074	2
		Structural Grid	0.181	0.040	7
		Service Duct and Corridor	0.151	0.034	9
		Convertibility	0.100	0.022	17
		Disassembly	0.089	0.020	21
		Spatial Flow & Atria	0.148	0.033	10
Technological Factor	0.082	Orientation	0.322	0.027	15
		Complexity	0.218	0.018	25
		Glazing	0.111	0.009	37
		Insulation and Shading	0.229	0.019	22
		Natural Lighting & Ventilation	0.120	0.010	36
Social Factor	0.101	History	0.277	0.028	13
		Urban Master Plan	0.205	0.021	18
		Image	0.157	0.016	28
		Passion and Identity	0.171	0.017	27
		Landscape	0.084	0.008	38
		Aesthetic	0.107	0.011	32
Regulatory Factor	0.065	Indoor Environmental Quality	0.286	0.018	24
		Occupational Health and Safety	0.310	0.020	20
		Standard of Finishes	0.165	0.011	34
		Fire Protection	0.129	0.008	39
		Disability Access	0.110	0.007	41
Environmental Factor	0.129	Raw Material Consumption	0.316	0.041	6
		Pollution and Biodiversity	0.215	0.028	14
		Conservation	0.145	0.019	23
		Waste Creation	0.080	0.010	35
		Cleanliness & Good Appearance	0.095	0.012	30
		Acoustic	0.089	0.011	31
		Ecological Footprint	0.060	0.008	40

5.5 ASSIGNING BENCHMARK SCORE

Five industrial experts were requested to score between 0-100 considering the use of each shortlisted critical factor. Average of each respondent's scores is summarized in Table 6. Accordingly, the minimum total score among these BAR projects was selected as the base line score of the developed model.

Table 6: Total factor score in BAR decision making model

Global Ranking of the Factor	Selection Factors	Overall Importance Indices	Project A		Project B		Project C		Project D		Project E	
			U.F.	Score	U.F.	Score	U.F.	Score	U.F.	Score	U.F.	Score
1	Structural Integrity	0.128	81.50	10.42	76.50	9.78	52.00	6.65	60.50	7.74	73.40	9.39
2	Flexibility	0.119	72.00	8.58	67.40	8.03	66.00	7.86	55.70	6.63	81.50	9.71
3	Material Durability	0.090	75.40	6.82	85.60	7.74	66.20	5.98	84.60	7.65	72.80	6.58
4	Touristic Attraction & Value	0.073	84.60	6.20	91.50	6.71	77.70	5.70	66.50	4.88	99.00	7.26
5	Foundation	0.066	77.70	5.13	95.30	6.29	70.80	4.67	36.80	2.43	91.70	6.05
6	Raw Material Consumption	0.066	77.70	5.10	62.50	4.10	70.00	4.60	28.60	1.88	79.60	5.23
7	Structural Grid	0.065	78.50	5.11	86.50	5.63	60.80	3.95	43.50	2.83	75.70	4.92
8	Cost of Constructing Building	0.057	32.50	1.86	65.20	3.73	58.50	3.35	55.80	3.19	77.60	4.44
9	Service Duct & Corridor	0.054	62.30	3.38	33.50	1.82	70.60	3.83	73.50	3.99	81.40	4.42
10	Spatial Flow & Atria	0.053	54.80	2.91	63.60	3.37	80.40	4.26	76.40	4.05	79.50	4.22
11	Maintainability	0.048	63.50	3.07	71.50	3.46	84.60	4.09	67.60	3.27	75.40	3.64
12	Market Proximity	0.047	66.40	3.11	84.60	3.97	87.60	4.11	58.90	2.76	89.50	4.20
13	History	0.045	80.80	3.65	94.50	4.27	72.60	3.28	75.60	3.42	95.10	4.30
14	Pollution and Biodiversity	0.045	64.60	2.89	77.50	3.47	74.50	3.33	69.60	3.11	70.90	3.17
15	Orientation	0.043	68.10	2.92	83.70	3.59	71.20	3.05	58.80	2.52	72.70	3.12
	Total Score	1.000	71.15		75.95		68.72		60.35		80.64	
	Base Line Score for Successive BAR Project Selection										60%	

6. FINDINGS AND CONCLUSIONS

If the CR becomes less than 0.10, it means the used data were consistent (Saaty, 1990). As the CR value in the above matrix is 0.016, it can be inferred that the data used for developing the "Importance Indices" of Main Factors are obtained through consistent judgments. Accordingly, the Importance Indices and their individual perceptions entail a higher level of validity. Among the sub-factors the highest level of overall importance was indicated by "Structural Integrity". The first 15 highest ranking sub-factors were taken to consider and locate the Overall Importance or the Global Importance score. This was implemented on 5 different BAR projects and revealed that 60% score is the minimum threshold in qualifying a successful adaptive reuse project.

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