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Case Report

Factors Influencing the Potential of Building Adaptation in India

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Abstract: Buildings are susceptible to completing the service life after their long usage. However, early completion of building service life is always been a challenge to the construction industry and warrants a thorough analysis. India has enormous scope for building adaptation that is built in the modern era due to various factors such as completion of service life, the demand for functional changes, carbon footprint reduction, and strengthening resilience. All the above reasons can be improved by adopting the method of building adaptation of the existing old buildings. To know the need and degree of the building adaptation the factors both quantitative and qualitative are to be analyzed to know the BAP (Building Adaptation Potential) of a building before making a decision for a project. The methodology adopted in the paper is a survey of existing buildings and identifying the key factors to make a decision on adoption potential. The weighted mean has been identified to showcase the significance of each factor.

Keywords: Building Adaptation, Adaption Potential, Building Resilience, Sustainable Development, Service Life

1. Introduction

Building adaptation is a method to improve the building capacity of the building to cater to resilience to various vulnerabilities, improve functional usage of the space, and incorporate features of sustainability such as reducing the energy consumption for whole life, reducing carbon emission, increasing the life of the existing building [3, 6, 8, 11]. India also there is a lot of policies which are been implemented by the government to achieve the goals of climate change and sustainable use of buildings and resources, and also due to changes of factors which affect the vulnerability of the building such as any intervention near the building after some years or improved vulnerability atlas which may have now incorporated new improvised maps for the disaster resilience needs of the areas such as what happened in Gujarat earthquake. [1]

There are lot of buildings in India which are in need of building adaptation but government or individual cannot take a clear decision which one to select first for building adaptation, to know this researchers have suggested a methodology to quantify the need and degree of building adaptation of a building based of various physical quantitative factors [5] to know the Building Adaptation Potential (BAP) still even after using this method the building adaption projects are tending to fail because of considering only the quantitative factors [9] then further research is been done in order to incorporate the qualitative factors also to this method of calculating the BAP of a building [7], but there are not classified into various categories and interdependency of those factors are not been considered till now, and in Indian context there is no detail study in incorporating these qualitative features in the calculation of Building Adaptation Potential (BAP), this papers intends to formulate a methodology to analysis a buildings BAP in consideration of both qualitative and quantity factors to know the actual success potential of the building adaptation of a project in the terms of both user perspective and the institutions.

2. Literature Study

Any work done to a building that goes above and beyond maintenance in order to improve its capability, function, or performance is referred to as "building adaptation" [4]. Building adaptation refers to a variety of building-related operations that enhance current building conditions and increase buildings' useful life [10] “any intervention to adjust, reuse, or upgrade a building” [4], this open definition includes the scope of building within the same use adaptation or across the use typology adaptation and also involves minor to major work for the building adaptation. In the context ‘adaptation’ refers to modification to buildings but not to the normal maintenance repairs. Studies have been done to identify the factors influencing the Adaptation of the building and through literature they are been classified into 6 major categories as reported in [12]. The six major categories are [12].: 1. Economic; 2. Physical; 3. Location & Land use; 4. Legal; 5. Social; 6. Environmental.

These six categories have further detailed factors that will influence the adaptation of a building it includes factors that are both quantitative and qualitative. In a broad way, the first 4 categories can be termed as a quantitative factor and the next 2 categories can be termed as qualitative categories [12].

In research, they also mentioned that the adaptation in a building can be classified into various types based on the quantity of work and effort that goes into the process of adaptation they mentioned this as the level of adaptation in a process of building adaptation. The studies categorized majorly into 5 levels of adaptation + plus 1 level (6th level) as demolition & and reconstruction, this reconstruction level states that none of the adaption techniques is possible or effective in terms of building adaptation of the building so demolition and reconstruction is the only way out, the first 4 includes the changes and modification to an existing building as per their level of work and effort are to be make the changes in the building, 5th level indicates the new construction in the site to cater for need [2].

The 5 levels of adaptation are:

Level 1: Minor Alterations

Level 2: Alterations

Level 3: Change of use adaptation

Level 4: Alterations and Extensions

Level 5: New Building

Level 6: Demolition and Reconstruction

The previous studies have also stated that the potentiality of the adaption can be both positive or negative since the people who are living in the comfortable environment have already stated that they are reluctant to change or modify even if they are getting some benefits after adaptation, the benefits which they are getting now is more satisfactory to the users, and also in some case the cost of adaptation is more than that of running the existing facility minor repairs or new construction these are some examples of negative potentiality where are reduction in power consumption, improved functionality, modernization, sustainability, etc., are some of the factors which are examples of positive adaptation potentiality [7].

3. Methodology

To assess the BAP of a building, since from the literature as we know that this potential could be positive or negative and the factors which are to be considered are both qualitative and quantitative the users’ interest is to be analyzed which will give us the actual potentiality towards the success of a building adaptation of the project. So, to do this the factors that are identified from various literature are collected and categorized as per the previous studies' categorization from the literature. This categorized factor is given to the users for their response on the building adaptation on a scale having both positive and negative indicators along with individual factors also, as a part of the study to know the importance of each category’s weightage relative to another category the users are asked to give a weightage in a scale of 1 to 5, this will give relative importance of each category. For the individual factors since they have both negative and positive impacts to give a score of individual factors a Likert Scale with 5 5-pointer is used.

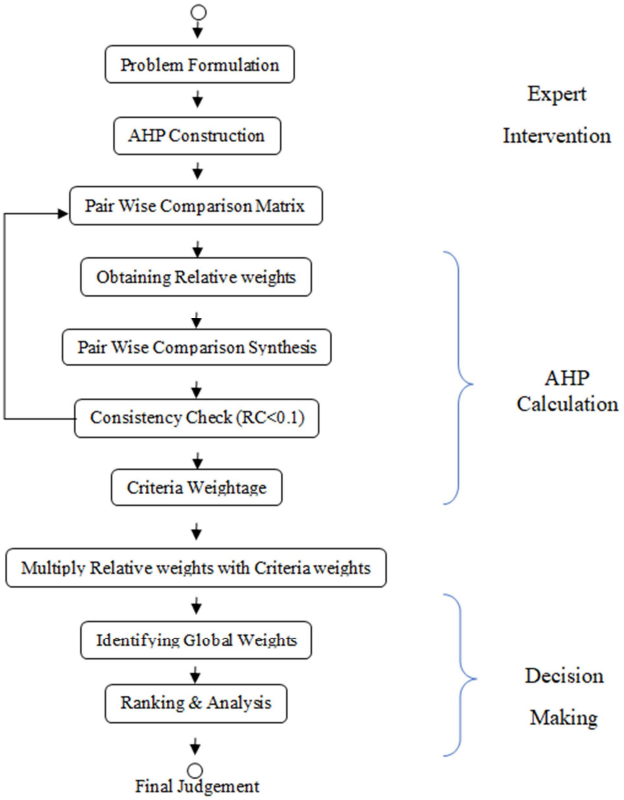

Figure 1. *Research Method (Author).*

In this -2 is the most negative influence factor on building adaptation, -1 is moderate negative impact, whereas 0 is a neutral impact and for the positive side +1 is a moderate positive impact and +2 is the highest positive impact on the building adaptation.

And the mean of the score is calculated as

$$\text{Mean 'm'} = \frac{(-2)(n_1) + (-1)(n_2) + (0)(n_3) + (+1)(n_4) + (+2)(n_5)}{n_1+n_2+n_3+n_4+n_5}$$

After getting the individual mean scores positive or negative the scores are multiplied with the relative weight of each category weightage to get the final weight of each score through the process of AHP, after checking the consistency factor in AHP for its validation of the scores obtained in the survey.

4. Case Studies

To know the actual impact of these influential factors on the success of the building adaptation of the project, the occupants of the building who are using the property after a successful implementation of the building adaptation are selected for this study. Two major projects are selected which were modified up to level 4 of the adaption level as indicated by [2]. and the adaptation is done across the type of usage.

Case 1: Hotel converted to 110 bedded Hospital with minimum intervention in Hyderabad.

Case 2: Storage warehouse converted in to a school with traditional envelope in Eluru, AP.

These two buildings are running successfully after the proper adaptation of building reuse with across the usage typology without having any major level 5 or 6 adaptation.

Details of Case study 1: Hospital at Hyderabad, Telangana state. -2019: In this case study of a 110 bedded Hospital (Figure 1) which earlier is a 3-star hotel near the kachiguda railway station (main railway station of old Hyderabad city) the Building adaptation was done in 2018 and hospital was set into working form 2019, the interior spaces were modified as:

1) Reception => Billing & Help desk; Restaurant area => Emergency care, other spaces are converted into waiting lounges & OPD cabins in Ground floor. In first floor earlier functional hall was converted into MICU, and some rooms are converted into dialysis.
2) In 2nd, 3rd and 4th floors the hotel rooms are converted into hospital rooms with either single sharing or twin sharing with a curtain partition in between, the tv sets, key card locking systems and the lighting at headboards near the bed are retained.
3) And in the 5th-floor Ball room was converted into an OT and SICU, with a major change in the HVAC system of these spaces. And some of the individual room along with the centralized AC, split ac is installed. And for the whole facility medical gas pipeline system and NCS are added in the existing ducting for HVAC and electrical conducting.

Details of Case study 2: School at Eluru, Andhra Pradesh -2010: In this case study of school form Nursery to 10th which is a branch of Siddhartha group of institutions was earlier a warehouse for jute and other food grain storage. The previous structural envelope is a load bearing brick structure with traditional burnt clay tile slope roofing in Eluru. During the process of building adaptation, the structural envelope is retained, and the classrooms are made by erecting brick wall partitions which were closed by a false ceiling at the top, this retaining of slope roof helped in reducing the cost of reconstruction of roof and decreased the energy consumption since the traditional burnt clay slope roof helps in trapping the air and through stack effect the overall build space remained cool. Even in a hot and humid climate region which is also vulnerable to heavy cyclones.

Bringing up a school of that scale with less rental and very few investments in the building adaptation process helped in the social benefits to the people in the area and connecting busses to nearby villages helped in spreading education to the remote villages of the West Godavari Dist. In Andhra Pradesh, this project is running well for 13 years after the building adaptation.

From these two case studies the stakeholders can be asked about their opinion on what factors may have influenced these projects to become successful in building adaptation. As stated in the methodology a survey is connected after giving a brief explanation of the BAP to the users they are asked to give 2 types of ratings one is for categories ranking with a range of 1 to 5 to know the interdependency and the other is the influence of individual factor on the building adaptation form a range of -2 to +2 in Likert Scale.

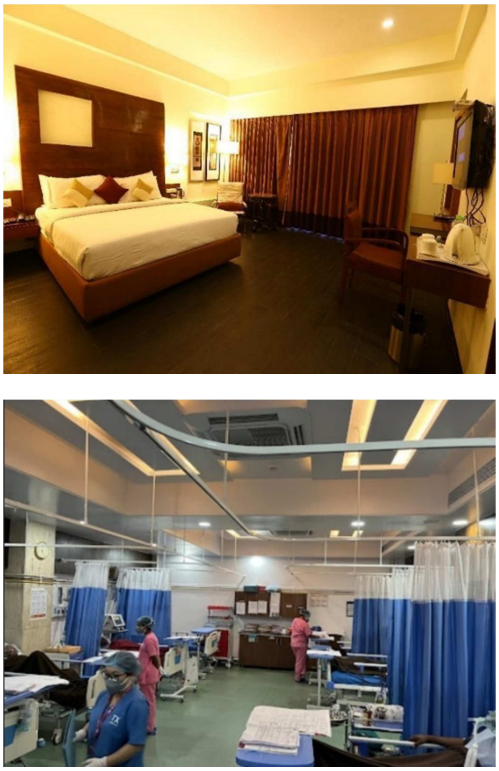

Figure 2. *Interiors of Hotel before and after converting into Hospital (Author).*

Application of methodology on case study:

From the literature study the factors that influence the building adaptation are categorized in to 6 types, these have been rated by the respondents to know the importance of factors which influence the most or the interdependency of the factors.

1) Identification of Influencing factors & Classification: From Various Literature studies the factors that influence the building adaptation are Identified are listed below some of the factors are repeated or may be similar all these are refined and sub categorized in to 6 major categories. [13].
2) Classification of Factors into Major Subheads. As Per the Literature Studies these Influencing factors can be Classified into 6 Major subheads
   a. Economic Factors
   b. Physical Factors
   c. Location & Land use Factors
   d. Legal Factors
   e. Social factors
   f. Environmental Factors

Pairwise comparison of main Categories:

Table 1. *Pair wise Comparison Matrix of Categories (Author).*

Pair wise Comparison Matrix						
Categories	**Economic**	**Physical**	**Location**	**Legal**	**Social**	**Environmental**
Economic	1	3	2	4	1/3	2
Physical	1/3	1	2	3	½	3
Location	1/2	½	1	4	2	1/2
Legal	1/4	1/3	1/4	1	1/3	4
Social	3	2	1/2	3	1	2
Enviro1nmental	1/2	1/3	2	¼	½	1
Cumulative	5.58	7.16	7.75	15	4.66	12.5

Pairwise Comparison matrix is prepared by comparing the weightage of each category with each other in the preference of their importance to adoption of Building Adaptation.

To get Category weightage after identifying the pairwise matrix, divide each cell with column sum to get Normalized Matrix. The sum Average of each row will give the Category Weightage.

Table 2. *Normalized Pair wise Comparison Matrix of Categories (Author).*

Normalised Pair wise Comparison Matrix								
Categories	**Economic**	**Physical**	**Location**	**Legal**	**Social**	**Envi.**	**weightage**	
Economic	0.179	0.419	0.258	0.266	0.070	0.160	0.225	23.7%
Physical	0.059	0.139	0.258	0.200	0.107	0.240	0.167	17.6%
Location	0.089	0.069	0.129	0.266	0.429	0.040	0.173	18.2%
Legal	0.043	0.046	0.032	0.066	0.070	0.320	0.096	10.1%
Social	0.537	0.027	0.064	0.200	0.214	0.160	0.203	21.3%
Enviro1nmental	0.089	0.046	0.025	0.016	0.107	0.080	0.085	8.9%

Source: Author

Check for the Consistency:

Multiply each Column with its category weight to get a matrix. Sum of each row gives the weighted sum of each category. λmax is obtained by Average of Weighted sub / Category weight. Consistency Index (CI) = λmax -n / n-1 (Where 'n' is No. Categories)= 6.43 – 6 / 6 -1 = 0.8 < 0.1.

Table 3. *Consistency Check Matrix (Author).*

Consistency Check Matrix – PM x CW									
Categories	**Economic**	**Physical**	**Location**	**Legal**	**Social**	**Envi.**	**WS**	**CW**	**WS/CW**
Economic	0.225	0.501	0.346	0.384	0.066	0.17	1.33	0.225	5.91
Physical	0.074	0.167	0.346	0.288	0.101	0.255	1.23	0.167	6.36
Location	0.112	0.083	0.173	0.384	0.406	0.042	1.19	0.173	6.93
Legal	0.056	0.055	0.043	0.096	0.066	0.340	0.655	0.096	6.83
Social	0.675	0.334	0.086	0.288	0.203	0.170	1.230	0.203	6.06
Enviro1nmental	0.112	0.055	0.346	0.024	0.101	0.085	0.552	0.085	6.50
CW	0.225	0.167	0.173	0.096	0.203	0.085		λ =	6.43

5. Survey

Individual mean of the scores of each factor:

Table 4. *Survey mean scores of Individual Factors (Author).*

S No.	**Categories**	**Factors**	**Mean value of survey 'm'**
1	Economical		
1.1		Cost of Building adaptation	-1.67
1.2		Savings in future energy consumption in long run	+ 1.62
1.3		Stakeholder's financial status	+ 0.07

S No.	Categories	Factors	Mean value of survey 'm'
1.4		Rental income level after the adaptation	+1.66
1.5		Maintenance cost saving in future long run	+1.19
1.6		Increase market value of the project	+1.45
1.7		Stakeholder's expectations of enhancing Value.	+1.08
2	Physical		
2.1		Height of the building	-0.04
2.2		Age of the existing building.	+1.83
2.3		Building services	-1.07
2.4		Floor plate area before and after adaptation	-1.55
2.5		Stakeholder's satisfaction with existing building condition & facilities	-1.82
2.6		Ease of Flexibility to change or modify design	+ 0.97
2.7		Noise control	-0.67
2.8		Building aesthetics and current appearance	-0.25
2.9		Existing structural technology and convertibility	-1.73
2.10		Time of inconvenience/ time of adaptation	-1.59
3	Location		
3.1		Ability to adapt multiple land uses	+0.96
3.2		Location proximity to public transport	+0.51
3.3		Existing Planning zones	-0.47
3.4		Potential of rezoning	+0.83
3.5		Occupation density	-0.38
4	Legal		
4.1		FSI & FAR	-0.49
4.2		Compatible to build codes of usage	-0.35
4.3		Life safety like fire and other safety compliance	-0.63
4.4		Control of height limit (for example aviation limit)	-0.31
4.5		Ownership period and Number of stakeholders	-0.11
5	Social		
5.1		Befitting the Local Community	+1.43
5.2		Cultural heritage retention	+1.30
5.3		Age and gender adaptability	-0.92
5.4		Urban design rejuvenation	+1.29
5.5		Facilities and amenities after development	+1.15
5.6		Negative impacts to surrounding neighbourhood	-1.40
6	Environmental		
6.1		Indoor Environmental & Air Quality	+1.38
6.2		Stakeholder satisfaction with surrounding environment	-0.87
6.3		Change in resource consumption	+0.37
6.4		Improvised waste management	+0.24
6.5		Hazardous materials in old structure	+1.84
6.6		Sustainable development	+1.35

Table 5. *Multiply Individual Score with category weightage to get global weightage (Author).*

S No.	Categories	Factors	Global Weight
1	Economical	23.7%	
1.1		Cost of Building adaptation	-0.396
1.2		Savings in future energy consumption in long run	+ 0.384
1.3		Stakeholder's financial status	+ 0.017
1.4		Rental income level after the adaptation	+0.393
1.5		Maintenance cost saving in future long run	+0.282
1.6		Increase market value of the project	+0.344
1.7		Stakeholder's expectations of enhancing Value.	+0.256
2	Physical	17.6%	
2.1		Height of the building	-0.007
2.2		Age of the existing building.	+0.322
2.3		Building services	-0.188
2.4		Floor plate area before and after adaptation	-0.272
2.5		Stakeholder's satisfaction with existing building condition & facilities	-0.320
2.6		Ease of Flexibility to change or modify design	+ 0.171
2.7		Noise control	-0.118
2.8		Building aesthetics and current appearance	-0.044
2.9		Existing structural technology and convertibility	-0.304
2.10		Time of inconvenience/ time of adaptation	-0.280
3	Location	18.2%	
3.1		Ability to adapt multiple land uses	+0.175
3.2		Location proximity to public transport	+0.093

S No.	Categories	Factors	Global Weight
3.3		Existing Planning zones	-0.086
3.4		Potential of rezoning	+0.151
3.5		Occupation density	-0.069
4	Legal	10.1%	
4.1		FSI & FAR	-0.040
4.2		Compatible to build codes of usage	-0.035
4.3		Life safety like fire and other safety compliance	-0.064
4.4		Control of height limit (for example aviation limit)	-0.031
4.5		Ownership period and Number of stakeholders	-0.011
5	Social	21.3%	
5.1		Benefiting the Local Community	+0.305
5.2		Cultural heritage retention	+0.277
5.3		Age and gender adaptability	-0.196
5.4		Urban design rejuvenation	+0.275
5.5		Facilities and amenities after development	+0.245
5.6		Negative impacts to surrounding neighborhood	-0.298
6	Environmental	8.9%	
6.1		Indoor Environmental & Air Quality	+0.123
6.2		Stakeholder satisfaction with surrounding environment	-0.077
6.3		Change in resource consumption	+0.033
6.4		Improvised waste management	+0.021
6.5		Hazardous materials in old structure	+0.147
6.6		Sustainable development	+0.120

6. Analysis of Results

The data collected was analyzed using the analytical hierarchy process AHP tool since the three are factors that are subdivided into categories and the interdependency of these categories will also affect the value of factors on decision-making for the building adaptation, the AHP which is a multi-disciplinary decision-making tool will help in knowing the relative influence of the identified factors.

From the survey results of the pair-wise comparison of subcategories, it is identified that the Economic factors are the major influencing category on the decision-making of building adaptation with a score of 23.7% followed by the social factors category with a score of 21.3% which is a qualitative measure category, so it shows that the qualitative factors are also almost as important as quantitative factors. Then stands Location- Land use, Physical, Legal, and Environmental categories with scores of 18.2%, 17.6%, 10.1%, and 8.9% respectively.

The individual factor results are obtained and then using AHP global score is calculated by multiplying it with category weightage. By analyzing the global score of individual categories, it is known that there are two types of factors one which are positive factors which will indicate that adaption is needed and will be successful whereas negative factors indicate that adaptation is not effective, from the results “Savings in future Energy Consumption” is highest positive factor with the score of +0.384 and the “Cost of building adaptation” is the highest negative factor with the score of -0.396. both come under the economic factors, followed by social factors where “benefiting the local community” is the highest positive social factor with a score of +0.304 and “negative impact on the surrounding neighborhood” is the highest negative social factor with a score of -0.298. Similarly, the other factors scores mentioned in the table of global scores can be studied in order to make a final decision on whether to go for building adaptation or not and the success of building adaptation.

7. Conclusion

Building adaptation is a major decision to be taken by the stakeholders keeping in consideration of all the factors. The previous studies majorly focused on the quantitative factors for the decision making but after analyzing the results its identified that along with the quantitative factors, qualitative factors will also have a major impact on the success of the building adaptation. And out of the quantitative factors, economic factors are the most crucial factors whereas among qualitative factors social factors are the major factors influencing the success of building adaptation.

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