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Customization of Adaptive Reuse Potential (ARP) Model for Fossil Fuel Power Plants; Case Study: Besat Thermal Power Plant, Tehran*

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ABSTRACT

Adaptive reuse of existing buildings, by maximum use of buildings structural, physical and material potentials, is regarded as an approach meeting sustainable development goals. The Adaptive Reuse Potential (ARP) model is seen as a very effective tool to measure the re-usability potentials of existing buildings. This model can serve as an appropriate tool in architecture and urban planning in dealing with existing buildings and structures before becoming obsolete. The Adaptive Reuse Potential model evaluates buildings reuse potential by calculating the useful life of the building through measuring different building obsolescence types, the current age of the building, and itspredicted physical life. The Adaptive Reuse Potential model is a general model uniformly applied in all building types and can be used in all countries. This paper aimed to customize this model to fossil fuel power plants, which may yield highly accurate results. The research methods as consistent with different stages were as follows: documentary and library studies were used to study and analyze the Adaptive Reuse Potential model and determine all building obsolescence types; field surveys to investigate the case study; interviewing experts; using a pairwise comparison questionnaire and the Analytic Hierarchy Process (AHP) method to weight and prioritize the types of obsolescence in fossil fuel power plants. To validate the results, the customized Adaptive Reuse Potential model was deployed to a case study and the outputs are compared with those outputs obtained from applying the original model in the same case study. According to performed analyzes and based on the experts views, it is affirmed that the results obtained from the customized Adaptive Reuse Potential model for fossil fuel power plants were more accurate than those of the primary model.

Keywords: Adaptive Reuse Potential Model, Reuse, Building Useful Life, Building Obsolescence.

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1. INTRODUCTION

Reusing buildings is a kind of sustainable urban revitalization, as it lengthens the life of buildings and prevents the production of waste from destruction, generating substantial economic and social benefits for the society (Tam & Hao, 2018, p. 1). Reusing the existing buildings rather than demolishing them helps preserve the materials and embodied energy, prevents the unnecessary use of the resources, avoids the uncontrolled expansion of constructions, and preserves lands and resources for future generations. Therefore, from a sustainability perspective, this approach can serve as an attractive alternative to new constructions (Sanchez & Haas, 2018, p. 998). However, not all buildings have the needed potential to be reused, and implementing such an approach requires a thorough investigation. Various criteria and methods have been proposed by researchers to investigate the building potential to be reused and re-adapted (Geraedts & Voordt, 2004; Tan, Shen, & Langston, 2014; Wang & Zeng, 2010; Bullen, 2007). The problem with the criteria is that most of them are qualitative, thus making them difficult to study while yielding inaccurate results. The Adaptive Reuse Potential (ARP) model, developed by Craig Langston (2007), serves as a tool to measure the reusability potential of the building; this model quantifies the qualitative concepts to make indicators much more effective in this regard. ARP indicators above 50% suggest higher building reuse potential, indicators between 20% and 50% suggest moderate, and indicators below 20% suggest low building reuse potentials (Langston, 2012, p. 107). The Adaptive Reuse Potentialmodel estimates the useful life of the building, its expected physical life, and current age (Langston, Wong, Hui, & Shen, 2008). The useful life of a building is calculated using the following Equation:

Equation 1: Calculation of Useful Life: Useful Life (by Years) (Lu); Physical Life (by Years) (Lp); Obsolescence (Oi)

$$Useful\ Life(Lu) = \frac{Lp}{\left(1+\sum_{i=1}^{7} Oi\right)^{Lp}}$$

An investigation of the physical life of a building refers to its structural safety which helps reduce building obsolescence, leading to a useful life that is shorter than the expected physical life. As Langston (2007, 2008) suggested, types of obsolescence estimated by the model include physical obsolescence, economic obsolescence, functional obsolescence, technical obsolescence, social obsolescence, regulatory obsolescence, and political obsolescence. In the Adaptive Reuse Potentialmodel, a scale of 0 to 20% is used to assess the vulnerability from the obsolescence, with 0% meaning full safety and 20% severe vulnerability. As regards political obsolescence, this scale varies from -20% to +20%, with -20% considered as a supportive space and +20% a barrier (Wilkinson, Remøy, & Langston, 2014, p. 189). However, it should be stated that for all obsolescence, values between 0 to 20 include 5, 10 and 15, also. Langston (2008) also proposes a computational model using a 3-criteria questionnaire, including environmental context, job particulars, and structural strength, to calculate the physical life. He suggested that at the same time, the physical life of the building could be projected via consultation with experts.

By calculating the useful life and predicted physical life as well as the current age of the building, the values of effective useful life (ELu) (Equation 2), the effective building life (ELb), and the effective physical life (ELp) are estimated (all indicated by a percentage of the predicted physical life).

Equation 2: Calculation of Effective Useful Life (ELu); Useful Life (Lu) and Physical Life (Lp)

$$ELu = \frac{Lu \times 100}{Lp}$$

If the effective life of a building is found to be less than the effective useful life, the reuse potential is increasing with the ARP indicator calculated using Equation 3.

Equation 3: Calculation of the ARP Indicator in an Increasing State

$$ARP_{(increasing)} = \frac{[100-(EL_u^2/100].EL_b}{EL_u}$$

If the effective life of a building is greater than the useful life, the reuse potential is decreasing, and the ARP index is calculated using Equation 4.

Equation 4: Calculation of ARP Indicator in a Decreasing State

$$ARP_{(decreasing)} = \frac{[100-(EL_u^2/100].(100-EL_b)}{100-EL_u}$$

The area under the curve is a possible area for the model, defined by the equation Y = 100-X ^2/100. The maximum X-axis is 100, demonstrating 100% of the living space of a building (Wilkinson, Remøy, & Langston, 2014, p. 190) (Fig. 1).

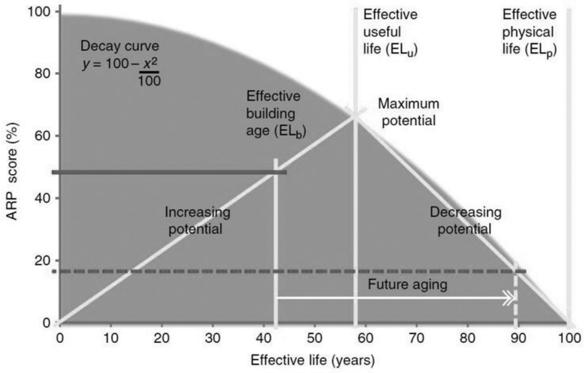

Fig. 1. Adaptive Reuse Potential (ARP) Model

(Langston & Shen, 2007)

The Adaptive Reuse Potentialmodel has been investigated and used in various studies (Langston, 2011, 2012; Conejos, 2013; Conejos, Langston, & Smith, 2015, 2014, 2012; Wilkinson, Remøy, & Langston, 2014; Yung, Langston, & Chan, 2014). One study has examined the deployment of the model in two concomitant research projects; one pertaining to the Hong Kong Polytechnic University and the other a partnership project between the Bond University, Williams Boag Architects, Deakin University, and the Church Union in Australia. The study, published in an article in 2010 (Shen & Langston, 2010), investigated the ARP model in urban and non-urban buildings in different areas in Hong Kong and Australia, respectively.

As demonstrated by the ARP model, the useful life and obsolescence have pivotal roles in calculating the useful life in the model. Although Langston (2007) first proposed six types of obsolescence for the computations, then adding political obsolescence as a type to the model, the question is: Are these the only and most important types of building obsolescence? On the other hand, this model provides the same weight and effect (from 0 to 20%) for each type of obsolescence, while each of these factors seems to have a different weight with the reduction of the useful life. For example, in office buildings, location obsolescence, and commercial buildings, economic obsolescence may have the highest impact on reducing useful life. Thus, a thorough examination of building obsolescence and also the determination of their significance and weight with the reduction of their useful life, consistent with different types of construction would yield highly accurate results and a specific model for each type of obsolescence. According to this hypothesis, the present article concerned the utilization of an Adaptive Reuse Potential model at fossil fuel power plants. Looking at the existing infrastructure, and considering the structural strength and presence of the open and flexible spaces of fossil fuel power plants, and the fact that these power plants are aging, it is important to study this issue in such plants.

The research first identifies the types of building obsolescence through documentary and library studies and by reviewing the literature on the subject. In the next stage, to weigh the obsolescence, a pairwise comparison questionnaire was developed using a Likert scale and then provided to experts via interviews. The results from the questionnaires were weighted using the Hierarchical Analysis Process (AHP) method and using Expert Choice software. To employ the model in the sample under study, the necessary data was collected by field visits and documentary studies.

2. EMPLOYING THE ADAPTIVE REUSE POTENTIAL MODEL IN BESAT THERMAL POWER PLANT IN TEHRAN

With the rapid development of cities, many power plants, once laid on the outskirts of cities, are now finding their way into the urban texture. In this way, they may not only produce contaminated and toxic waste but also create environmental and noise pollution. On the other hand, such industrial and large-scale buildings are seen to have integrated with the urban texture via heterogeneous elements. However, it should be pointed out that it is no longer appropriate to demolish such buildings under the existing conditions. Many of these buildings have high potentialities to merge with the urban texture, thus providing the required uses through adaptation and reuse. Besat thermal power plant is one of these structures. This plant was built in 1964 on a 20-hectare plot in the Kahazaneh-Bukhara area situated southeast of Tehran (Fig. 2).

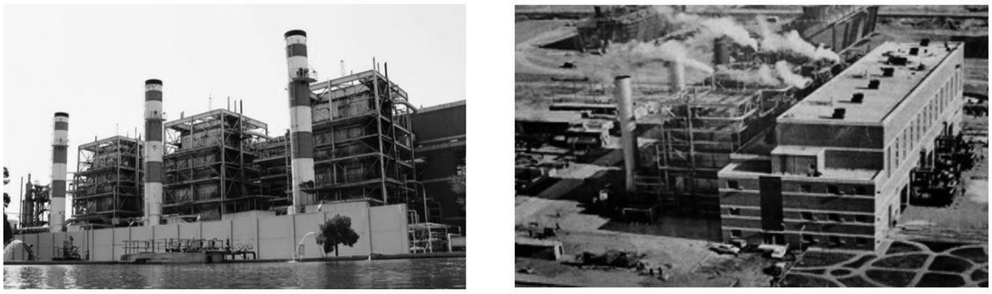

Fig. 2. Besat Thermal Power Plant in Tehran (Left: Image of Power Plant Units (2017), Right: Aerial View of the Power Plant (1970s))
(http://www.besatpower.ir/)

Because the power plant was built in 1964, its current age is now 52 years (as of 2016) and its predicted physical life is 50 years, as suggested by experts. Types of obsolescence for the building using the Adaptive Reuse Potentialmodel are as follows: physical obsolescence (10%), economic obsolescence (10%), functional obsolescence (20%), technical obsolescence (15%), social obsolescence (0%), regulatory obsolescence (5%) and political obsolescence (15%) (Pourebrahimi, Eghbali, & Ghafori Fard, 2018, p. 35). The extent to which each of the obsolescence affects the reduction of power plant life is as follows: Physical obsolescence occurs due to poor maintenance, economic obsolescence due to rising costs exceeding revenues, functional obsolescence as a result of inflexibility for catching up to modern technology, technical obsolescence as a result of consuming too much energy than existing standards, social obsolescence as a result of the society's reduced need for services provided by the building, regulatory obsolescence due to the introduction of new building codes and regulations, while political obsolescence from national and local interests over a project. Considering the types of obsolescence at the Besat power plant, the total number of obsolescence amounted to 75% (0.005 on a year-on-year basis). As the data and Equation 1 suggested, the useful life was 71 years. Also, considering Equation 2, the effective useful life of the power plant was 47 years, and its effective age 35 years. Thus, because the effective life of the building was less than the effective useful life (ELu> ELb), the ARP indicator was estimated by equation 3, to be at 58%.

Because the ARP indicator of the Besat thermal power plant in Tehran was greater than 50%, therefore, it is highly capable of being reused. The maximum reuse capacity of a building, represented in its useful life, is also calculated by the equation Y = 100-X ^2/100 (where x is equal to ELu). Thus, the maximum ARP indicator of the Besat power plant in Tehran is 78% (Fig. 3) (Pourebrahimi, Eghbali, & Ghafori Fard, 2018, p. 35).

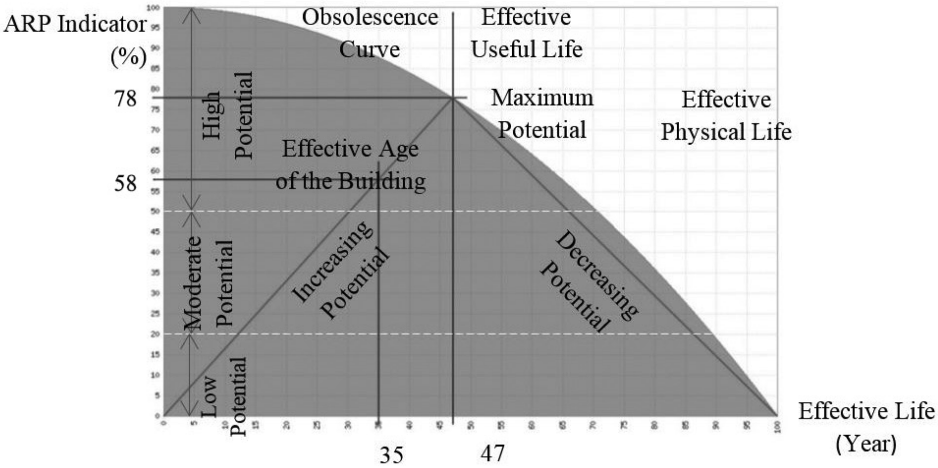

Fig. 3. Adaptive reuse potential model in Besat thermal power plant in Tehran
(Pourebrahimi, Eghbali, & Ghafori Fard, 2018)

3. CUSTOMIZATION OF ADAPTIVE REUSE POTENTIAL MODEL IN FOSSIL FUEL POWER PLANTS

To utilize the Adaptive Reuse Potential model, it is required to first identify the types of building obsolescence and then weight and rank them based on their significance and impact with the reduction of the life of the building.

3.1. Identifying Types of Building Obsolescence

Obsolescence is defined as the process of devaluation, and lost utility and inefficiency of a building that is caused by factors such as physical decay, technological advancement, changing demands, or environmental changes (Burton, 1933, p. 19; Flanagan, Norman; Meadows, & Robinson, 1989; Mansfield & Pinder, 2008; Khalid, 1994; Ashworth, 2004; Thomsen & Flier, 2011; Baum, 1991; Kintrea, 2007; Ahmad, Aspden, & Schreyer, 2005; Grover & Grover., 2015). The term obsolescence, once used in the mid-sixteenth century (Ashworth, 2004), was first introduced to English for a constructed environment around 1910 (Abramson, 2012). According to Note et al. (1976), the term "obsolete" describes the final state and "obsolescence" the transition to this state. Thus, obsolescence is a transition to becoming obsolete.

A review of the literature shows that there is no full consensus nor an inclusive classification of types of construction obsolescence, and researchers have proposed different types of it. A systematic examination of the literature on the subject yielded 33 different types of construction obsolescence (Table 1).

Table 1: Types of Building Obsolescence

Types of Obsolescence	Sources	Types of Obsolescence	Sources
Site	(Evelyn & Guangming, 2010)	Economic	(Aksözen, Hassler, Rivallain, & Kohler, 2016)
Physical	(Thomsen, Flier, & Nieboer, 2015)	Use	(Johnston, 2016)
Control	(Raftery, 1991)	Locational	(Sarja, 2006)
Visual	(Dunse & Jones 2005)	Legal	(Dunse & Jones, 2005)

Types of Obsolescence	Sources	Types of Obsolescence	Sources
Ecological	(Sarja, 2006)	Functional	(Rodi, Hwa, Said, Mahamood, Abdullah, & Abd Rasam, 2015)
Statutory	(Williams, 1986)	Structural	(Blakstad, 2001)
Style	(Evelyn & Guangming, 2010)	Technological	(Mora, Bitsuamlak, & Horvat, 2011)
Community	(Williams, 1986)	Regulatory	(Kalligeros, 2003)
Environmental	(Blakstad, 2001)	Financial	(Butt, Heywood, Paul, & Jones, 2014)
Political	(Goetz, 2012)	Aesthetic	(Mora, Bitsuamlak, & Horvat, 2011)
Equipment	(Grigsby, Baratz, & Maclennan, 1983)	Architectural	(Douglas, 2006)
Fashion	(Grover & Grover, 2015)	Cultural	(Iselin & Lemer, 1993)
Tenure	(Wilkinson, Remøy, & Langston, 2014)	Image	(Chaplin, 2003)
Market	(Thomsen & Flier, 2011)	Design	(Johnston, 2016)
Social	(Rodi et al., 2015)	Utility	(Thomsen & Flier, 2011)
Tenant	(Raftery, 1991)	Technical	(Caccavelli & Gugerli, 2002)
		Rental	(Nutt & Sears, 1972)

These 33 types of structural obsolescence have been similarly defined, confusing the subject. Using an analytical approach and considering their definitions, causes, and overlaps, the 33 types of structural obsolescence were classified under 10 comprehensive categories:

1. Economic obsolescence (e.g., financial obsolescence, market obsolescence)
2. Functional obsolescence (e.g., use obsolescence and performance obsolescence)
3. Physical obsolescence (e.g., structural obsolescence)
4. Location obsolescence (e.g., environmental obsolescence and site obsolescence)
5. Regulatory obsolescence (e.g., control obsolescence, regulatory obsolescence, legal obsolescence, and political obsolescence)
6. Social obsolescence (e.g., cultural obsolescence and general obsolescence)
7. Technology obsolescence (e.g., technical obsolescence and equipment obsolescence)
8. Aesthetic obsolescence (e.g., style-based obsolescence, design obsolescence, visual obsolescence, fashion obsolescence, form obsolescence, and architectural obsolescence)
9. Environmental obsolescence (e.g., ecological obsolescence)
10. Proprietary obsolescence (e.g., leasing obsolescence and rental obsolescence).

3.1.1. Weighting Types of Building Obsolescence

To weigh the types of construction obsolescence, the hierarchical analysis process was used and calculations were carried out on the Expert Choice software. Due to the limitations of the hierarchical analysis process method, 8 out of 10 inclusive categories of obsolescence were selected. Accordingly, the eight categories included economic obsolescence, functional obsolescence, physical obsolescence, location obsolescence, regulatory obsolescence, social obsolescence, and social obsolescence, technical obsolescence, and environmental obsolescence. In the meantime, environmental obsolescence replaced aesthetic obsolescence. Aesthetic obsolescence occurred due to fashion change or social demands, mainly compensated for in social and functional obsolescence. In the meantime, the findings suggested that environmental obsolescence was the third most important category to affect the fossil fuel power plants, as this issue can support the decision to replace aesthetic obsolescence with environmental aesthetics.

In the next stage, the pairwise comparison questionnaire was developed using the research criteria (eight types of obsolescence). Because the hierarchical analysis method does not necessarily need a high statistical population, and the proficiency and skills of experts are required, six highly proficient and skilled experts of fossil fuel power plants were chosen to distribute the questionnaire. Experts here are people with high experience and knowledge at fossil fuel power plants who may refer to maintenance technicians, engineers, designers, managers and researchers, and developers. To yield more accurate results, each of the experts was separately interviewed before the questionnaires were given out. Thus, before the distribution, the concepts and objectives were described.

After the questionnaires were collected, the results were analyzed on Expert Choice software by weighting by hierarchical analysis process. At this stage, the data were entered into the Expert Choice software; meantime, the inconsistency rate of the matrix pairwise comparison of the main criteria should be at an acceptable level of less than 0.1), otherwise the results could not be accepted and the questionnaires should be revised by experts. The mean pairwise comparison matrix of expert opinions is provided in Table 2.

Table 2: Mean Pairwise Comparison Matrix of Expert Views (Output of Expert Choice Software)

Relative Comparison of Obsolescence								
	Economic obsolescence	**Functional obsolescence**	**Physical obsolescence**	**Location obsolescence**	**Regulatory obsolescence**	**Social obsolescence**	**Technical obsolescence**	**Environmental obsolescence**
Economic Obsolescence		1	1.91293	1.3254	0.50778	4.5825	1.70764	0.66492
Functional Obsolescence			2.49805	4.8568	0.76472	4.6512	1.73205	0.90668
Physical Obsolescence				1.506	0.49324	2.6853	0.86830	0.83268
Location Obsolescence					0.52275	2.1411	0.57656	0.57735
Regulatory Obsolescence						2.2360	0.79743	1.15167
Social Obsolescence							0.20040	0.41743
Technical Obsolescence								0.66492
Environmental Obsolescence								
Inconsistency Rate	0.04							

As shown in Table 1, the inconsistency rate was 0.04 within the acceptable range. Thus, using the hierarchical analysis process method, the weight of each type of obsolescence at fossil fuel power plants was estimated using outputs provided by the experts (Table 3).

Table 3: Final Weight of Each Indicator of Obsolescence (Expert Choice Software Output)

Criterion (Obsolescence)	Weight
Economic Obsolescence	0.145
Functional Obsolescence	0.194
Physical Obsolescence	0.095
Location Obsolescence	0.075
Regulatory Obsolescence	0.169
Social Obsolescence	0.042
Technical Obsolescence	0.130
Environmental Obsolescence	0.151
Inconsistency Rate: 0.04	

Table 3 demonstrates that functional obsolescence with a weight of 0.194 is the most important as regards the fossil fuel power plants. Following functional obsolescence, regulatory and environmental obsolescence ranked second and third with weights of 0.169 and 0.151, respectively. Social obsolescence and location obsolescence were found to have less importance than other types of obsolescence. Therefore, ranking building obsolescence at fossil fuel power plants, as according to experts' opinion and hierarchical analysis process, was as follows: a) Functional obsolescence, b) Regulatory obsolescence, c) Environmental obsolescence, d) Environmental obsolescence, e) Technical obsolescence, f) Physical obsolescence, G) location obsolescence and h) Social obsolescence.

3.2. Running the Customized Adaptive Reuse Potential Model at Besat Power Plant in Tehran

To compare the results from implementing the customized Adaptive Reuse Potentialmodel and the original model in the case study, building age was considered to be 52 years as of 2016. Earlier, each of the obsolescence at the Besat thermal power plant was mentioned using the primary model. After literature review, 11 inclusive categories of building obsolescence were identified. Eight important types of obsolescence were identified and weighted using the views of the experts. Thus, environmental and location obsolescence were included in the Adaptive Reuse Potentialmodel computations and political obsolescence removed as a separate type. As regards the environmental obsolescence, it should be noted that the Besat power plant produces relatively high environmental pollution, but because that there are no serious prohibiting laws in this field in the country, the environmental obsolescence was considered to be moderate at 10%. Because the urban expansion has merged the Besat power plant within the urban context, this could lead to the obsolescence of the power plant location. However, because there are relatively many industrial sites close to the power plant, the location obsolescence of the power plant was also considered to be moderate of 10%. Table 4 illustrates the weight of each type of construction obsolescence and the level of each with and without considering their weight at the Besat power plant. Here, to use the indicators of different types of obsolescence at Besat power plant in the computations of the Adaptive Reuse Potentialmodel, the weight coefficient of all obsolescence was calculated 10.

Table 4: Final Weight of Each Indicator (Obsolescence)

Indicators (Indicators)	Weight-based Obsolescence	Level of Obsolescence	Weight Coefficient of 10
Economic Obsolescence	14.50	10	1.45
Functional Obsolescence	~39	20	1.94
Physical Obsolescence	9.50	10	0.95
Location Obsolescence	7.50	10	0.75
Regulatory Obsolescence	~8.50	5	1.69
Social Obsolescence	0	0	0.42
Technical Obsolescence	~19.50	15	1.30
Environmental Obsolescence	~15	10	1.51

As shown in Table 3, the weight of different types of obsolescence increases the impact of economic obsolescence from 10% to 14.5%, functional obsolescence from 20% to 39%, regulatory obsolescence from 5% to 8.5%, and technical obsolescence from 15% to 19.5% and environmental obsolescence from 10% to 15%, while decreases the impacts of physical obsolescence from 10% to 9.5% and location obsolescence from 10% to 7.5%. The rate of obsolescence and the total annual rate of obsolescence at the Besat thermal power plant in Tehran after being weighted are summarized in Table 5.

Table 5: Final Weight of Each Indicator (Obsolescence)

Types of Obsolescence	Physical	Economic	Functional	Environmental	Technical	Regulatory	Location	Social Obsolescence
Leve of Obsolescence	9.5	14.5	39	15	19.5	8.5	7.5	0
				113				
Total Obsolescence Rate			(1.13/150)	0.007				
Total Annual Obsolescence Rate								

According to Table 5 and the equation for the calculation of the useful life, the useful life of the Besat thermal power plant in Tehran was estimated to be 53 years.

$$Useful\ Life(Lu) = \frac{Lp}{(1+\sum_{i=1}^{7} Oi)^{Lp}} = \frac{150}{(1+0.007)^{150}} = 53$$

As explained earlier, the useful life, current building age, and predicted physical life should be estimated as a percentage of predicted physical life, known as effective useful life (ELu), effective building age (ELb), and effective physical life (ELp), respectively.

$$\mathrm{ELb} = \frac{\mathrm{Lb} \times 100}{\mathrm{Lp}} = \frac{52 \times 100}{150} = 35$$

$$\mathrm{ELu} = \frac{\mathrm{Lu} \times 100}{\mathrm{Lp}} = \frac{53 \times 100}{150} = 35$$

Thus, the effective useful life was 35 years and the effective age of the building 35 years. Because that the effective useful life and the effective age of the building were equal, the ARP indicator (maximum reusability also occurs at the same age) is calculated from the equation Y = 100-X ^2/100 which is 87%. (Fig. 4).

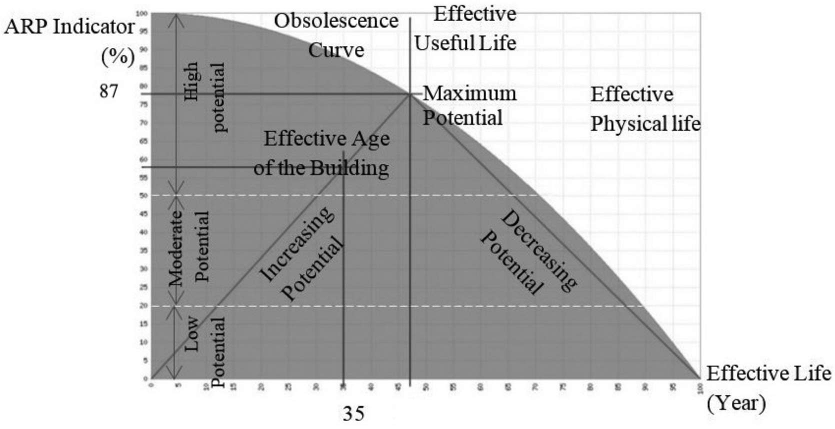

Fig. 4. Adaptive Reuse Potential Model at the Besat Thermal Power Plant in Tehran

Therefore, the Adaptive Reuse Potentialmodel at the Besat power plant also indicated the high capacity of the power plant to be reused. However, considering that the data, including the age of the building, were regarded using the initial model (2016), therefore, the building potential for reuse was indicating a decreasing trend.

4. COMPARISON AND ANALYSIS OF RESULTS

To investigate the results from customizing the Adaptive Reuse Potential model at fossil fuel power plants, the studied model was run as primary and customized forms on a case study (Besat power plant in Tehran). The results from the primary model (using data from 2016) are as follows: The total annual obsolescence rate was 0.005 and accordingly, the useful life of the power plant was estimated to be 71 years. Estimating the effective useful life and effective age of the building, the ARP score was 58% and experienced an increasing trend. In the meantime, the maximum ARP index was 78%, demonstrating an effective age of 71. The results from running the customized model for the Besat thermal power plant in Tehran using constant data as compared to the previous stage are as follows: The total annual obsolescence rate was calculated to be 0.007. As the rate of obsolescence went higher, the useful life shortened. Accordingly, the useful life of the power plant was estimated to be 53 years (up to 2017). Thus, the Adaptive Reuse Potentialmodel of the power plant showed a decreasing trend. Because the effective useful life and the effective age of the power plant were equal, the ARP index was at a maximum rate of 87%, indicating the very high reusable potential of the power plant (Table 6).

Table 6: Final Weight of Each Indicator (Obsolescence)

ARP Model	Predicted Physical Life	Annual Obsolescence	Predicted Physical Life	Effective Useful Life	ARP Indicator	ARP Maximum Indicator	Reuse Potential
Primary Model	150 Years	0.005	71 Years	47 Years	58%	78%	Higher Reuse Potential
Specific (Customized) Model	150 Years	0.007	53 Years	35 Years	87%	87%	Maximum Reuse Potential

A comparison of the results from running the model in the two forms suggested that the Besat thermal power plant in Tehran was generally experiencing a higher reuse potential rate. Also, as the data from the specific model showed, the annual obsolescence rate was higher and thus, the useful life was calculated to be shorter. As the types of obsolescence were weighted, the useful life was calculated to be about 18 years shorter. Rationally speaking, considering the weight and the impacts of different types of obsolescence on the reduction of the building useful life according to the building type, can yield highly accurate results. In the meantime, the views of experts could validate the research results. Thus, interviews with experts of fossil fuel power plants on weighting the types of obsolescence demonstrated that the useful life of the Besat power plant was already exhausted (at the time of interview in 2018) according to standards and from an economic point of view; however, due to some conditions in the country and the way the government handles the affairs, this plant is still that operating. Therefore, experts also reaffirmed the main hypothesis stating that determining the importance of types of obsolescence could yield more accurate results via the ARP model. Thus, by determining the obsolescence types and weighting them the customized ARP model for fossil fuel power plants is obtained.

5. CONCLUSION

This paper aimed to optimize and customize the Adaptive Reuse Potentialmodels at fossil fuel power plants. Examining the model, it was made clear that a specific model could be achieved by identifying the types of building obsolescence and weighting them based on their impact on fossil fuel power plants. In this regard, types of obsolescence were systematically reviewed and 11 types were classified. After this stage, the types of obsolescence at fossil fuel power plants were weighted. This step was performed using the Hierarchical Analysis Process method on Expert Choice software. Meanwhile, because of the limitations of the hierarchical analysis process method in terms of weighting criteria, the first eight types of mostly mentioned obsolescence were identified for weighting. In the next step, a pairwise comparison questionnaire was developed using the types of obsolescence. To yield more accurate results, before the questionnaires were provided to the experts, they were interviewed about the concepts and objectives. Finally, the results were analyzed using Expert Choice software and the types of obsolescence were weighted based on importance in fossil fuel power plants. In sum, the types of obsolescence were run in the general Adaptive Reuse Potentialmodel based on their weight and importance at fossil fuel plants. Thus, an optimal and specific model for fossil fuel power plants was developed. Comparison of the results from the specific and general model at Besat thermal power plant in Tehran, as a case study, suggested that the outputs of the specific model were more accurate.

The present research process can serve to customize the Adaptive Reuse Potentialmodel in different types of buildings. Thus, instead of a general model, a specific model can be used using the type of building with more accurate results. As regards the importance of reusing existing buildings to achieve sustainability in a constructed environment, the results of this paper can be applied practically and the process of the specific model be studied for future research.

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