Adaptive Reuse and the ARP Model: Background and Method Analysis

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Abstract

The continuous urbanization and modernization of cities spurred by population growth and economic development results in numerous challenges such as socio-economic inequalities, movement and space congestion, exhaustion of resources and energy among others. As a solution to these challenges, many turn to adaptive reuse as a more efficient form of redevelopment and progress. This study focused on the utilization of the ARP Model by Craig Langston as a tool for site selection in adaptive reuse and dissecting the efficiency of its criteria in decision-making. The two case studies analyzed are the Tate Modern in London and the High Line in New York City. The analysis of these two conversion projects uncovered the limitations of the ARP Model and its variables in determining the potential of a heritage structure to be reused. Results show that the ARP Percentage and Scoring do not directly relate to any critical success factors or outcomes and that the potential and reusability of a structure are uncorrelated due to physical obsolescence being solely based on maintenance and neglecting damages brought by the weather. Therefore, several recommendations were made to enhance the accuracy and efficiency of the ARP model. First, the year of assessment affects obsolescence rating factors thus, an averaging method is suggested to be used to compensate for discrepancies. Second, since the physical life of a structure is assigned arbitrary values, the determinant values may need to be enhanced for structures that have longer physical lifespans. Third, an assessment is recommended to account for other obsolescence factors that have affected the life of a structure. Lastly, environmental obsolescence should be fully implemented to account for sustainable development and other environmental factors.

Keywords: Heritage Preservation, Adaptive Reuse Potential Model, Obsolescence, Sustainable Development

I. Introduction

Adaptive reuse introduces the concept of recycling and reusing an existing structure for a different purpose than it was intended for, which breathes a 'new life' into these structures. Factors such as the economic, environmental, and social value of a structure must be considered before implementing an adaptive reuse approach to ensure that the history and significance of the structure are respected. With the growing number of structures entering a state of obsoletion, practitioners are challenged on where and how to begin the process of adaptive reuse. With this being said, the Adaptive Reuse Potential (ARP) model was developed by Craig Langston (2008) as a tool for site selection as it recognizes and categorizes the potential of an existing building for adaptive reuse with a criterion that requires the assessment of physical, economical, functional, technological, social, legal, and political obsolescence. Langston's ARP model is a potential tool for stakeholders and professionals in adaptive reuse decision-making. By using the concept of obsolescence as a criterion, it reduces the expected physical life of a building to its expected useful life. Each of the seven obsolescence factors is assessed on a scale of zero to 20, in increments of 5, where zero shows no negative influence and 20 indicates a significant negative influence. When calculated, ARP scores below 20% have low potential, scores between 20 to 50% have moderate potential, and scores above 50% showcase high adaptive reuse potential. With this assessment, the ARP model allows practitioners to prioritize the adaptive reuse of an existing structure based on the quantification of its useful life.

The research objective is to conduct a background study on adaptive reuse. It aims to explain the practice and the circumstances that influence its multiple stakeholders and professionals. By illustrating that adaptive reuse is a convergence of heritage preservation and sustainable development; the benefits, challenges, decision-making, and critical success factors are enumerated through a selective literature review. Lastly, the ARP Model of Craig Langston is analyzed for its robustness and limitations as a tool for site selection in adaptive reuse. This is applied to the case studies of the Tate Modern and the High Line. Recommendations are based on the evaluation of results vis-à-vis actual events.

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A. Background of the Study

In 2007, the global urban population surpassed the global rural population (see Figure 16) according to the United Nations World Urbanization Prospects Report (2014). By the year 2050, urban dwellers are estimated to account for 66% or two-thirds of the world's total population. In addition, there are 28 megacities or city agglomerations that have 10 million or more inhabitants accounting for almost half a billion people, from merely 10 megacities in 1990 (United Nations, 2014). To put this into perspective, the world's top-five megacities are Tokyo which has an estimated 38 million dwellers, followed by Delhi, Shanghai, Mexico City, Mumbai, and São Paulo each having between 21 and 25 million. The last few decades have indeed witnessed rapid urbanization, spurred by population growth and economic development. The world's societies are rapidly converting into an urban or built-up environment. In effect, these future trends reveal a rate of urban conversion particularly characterized by increasing urban footprint, with increasing though varying population densities and population dispersions (Wendell Cox Consultancy, 2016). Although urbanization can be associated with progress and development, it does not come without its challenges. The most common drawbacks are socio-economic inequalities, movement and space congestion, exhaustion of resources and energy, pollution, and massive expansion of built-up areas. Consequently, urbanization causes the depletion of greenfield sites or a city's surrounding unbuilt 'green' areas and conversely, the proliferation of brownfield sites such as abandoned or derelict areas (BBC, 2017).

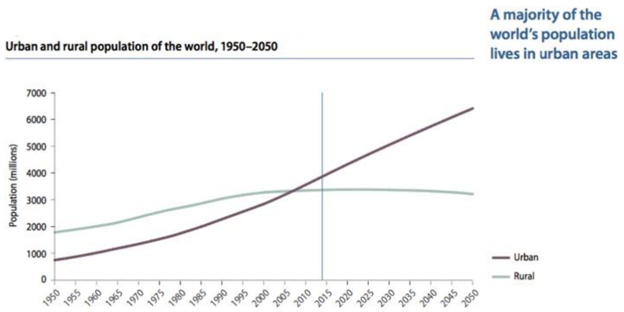

Figure 1. Urban versus Rural Population of the World, 1950-2050

Source: United Nations, 2014

As populations grow, cities expand. Therefore, urbanization is synonymous with building and construction. The Global Construction 2030 Report projects that the worldwide construction output will grow by approximately 85% by the year 2030, amounting to a USD 15.5 trillion industry (PwC, 2017). More than half of this growth is forecast to take place in China, the US, and India. On average, global construction is expected to grow by 3.9% per annum until the year 2030 (Global Construction Perspectives and Oxford Economics, 2015). By the same year, the UK is expected to be the world's sixth-largest construction market (PwC, 2017). In January of 2017, construction contracts in the UK rose to GBP 6 billion (Jolly, 2017) with housebuilding as a predominant factor for this growth (Kollewe, 2017). This coincides with the prediction that in the residential sector of the construction industry, the UK alone will be needing 3 million new homes by 2030 (BBC, 2017). As a result of these developments, the construction industry and the built environment are at the focal point of sustainable development challenges. With the world's finite resources such as space, time, and materials, successful and sustainable growth is emphasized to abate the issues of an expanding built environment.

Figure 2. Iconography of the UN's 17 Sustainable Development Goals

Source: Division of Sustainable Development UNHQ, 2017

According to Accenture (2012), the seven trends to transform the construction marketplace are (1) accelerated globalization, (2) urbanization and the emergence of megacities, (3) challenging access to capital, (4) 'war' or the competition for talent, (5) the upcoming crisis of energy, (6) new technologies driving innovation and (7) higher standards of sustainable living. These trends link with the overall question of equitability and sustainability. The United Nations has espoused a vision for the future guided by 17 Sustainable Development Goals (see Figure 17). Sustainable Development Goal 11 – Sustainable Cities and Communities, targets to "*make cities and human settlements inclusive, safe, resilient and sustainable*" (Division for Sustainable Development UNHQ, 2017). Consequently, the indicators published by the U.N. to reach this specific sustainable development goal are the reduction of inadequate or informal housing, equitable access to public services, green or open spaces, and transport, sustainable and planned land consumption proportionate to population growth, reduction in crime and harassment, reduction in pollution and waste, responsiveness and resilience to natural disasters and lastly, financial aid funneled to less developed areas that are in need of support. With the foregoing, the ultimate question of how heritage plays into achieving this goal comes to mind.

II. Review of Related Literature

A. Heritage and Sustainable Development

What is the role of heritage in sustainable development? And in turn, what is the role of sustainable development in heritage? These are two mutually reinforcing concepts. Sustainability relies on the concept of intergenerational equity (Cassar, 2016), wherein the present generation serves as a link between past and future generations as stewards of the earth's resources. Heritage is a resource that is finite and provides people and societies with a connection to the past. Heritage provides for cultural identity, social cohesion, and economic progress. These are the same shared values that underpin sustainable development. In addition, the sustainable development principles of social, cultural, economic, and environmental equity provide for the conservation of heritage (Fouseki, 2016).

The built environment presents the perfect opportunity for the merging of these two key issues, the preservation of tangible heritage and the challenge of sustainable development. One predominant feature of urbanization (see APPENDIX A) is the disuse of historic buildings mostly due to migration patterns. The movement of people can be attributed to economic, social, cultural, and political changes that naturally take place within urban settings. In recent decades, major cities such as London have been faced with derelict structures and blighted neighborhoods that have fallen into disrepair or abandonment. English Heritage reported in 2012 that there were almost 6000 historic buildings and sites around England that were in danger mainly from disuse, decay, and abandonment (Mail Online, 2012). Although there is a steady decline in the Register for Buildings and Structures at Risk, more than half of these sites are incapable of economic use (Historic England, 2017). For the current scenario, the proposition to reuse and adapt timeworn structures is meritorious. Indeed, the practice of 'adaptive reuse' is the confluence of heritage preservation and sustainable development.

B. Adaptive Reuse

Adaptive reuse involves rehabilitating buildings to enable the structure to host a new and different occupant. Once a structure has outlived its original purpose, it is no longer considered useful for its original users. Economic, social, cultural, and political drivers may result in the occupiers of these structures relinquishing usage and ownership and therefore deciding to abandon the structure. This results in the underutilization of the structure's embodied energy. Embodied energy—in the totality of a structure's life cycle, is defined as the accumulated energy used to construct, maintain, operate, and demolish the said structure (Designing Buildings Wiki, 2017). Hence, the adaptation of structures is a practice that promotes sustainability as it maximizes the embodied energy in historic buildings.

C. Benefits and Challenges

In this regard, repurposing historic buildings highlights improvements in building restoration technology, giving way to more creative and unexpected outcomes. Adaptive reuse nowadays can be considered almost a standard design practice in the modern real estate market (Nonko, 2016). From a theoretical point of view, the method of adaptive reuse lends to creativity and innovation that is in dialogue with built heritage. Repurposing creates a definitive link between the past, present, and future allowing for its contribution to sustainable development. The wider remunerations are illustrated in the form of social, cultural, environmental, and economic benefits.

According to Shipley, Utz, and Parsons (2006), an interview analysis conducted with a network of public-interest advocates and local professionals in the Canadian province of Ontario reveals a detailed outline of benefits (or advantages) and challenges (or constraints) associated with adaptive reuse. The statements of the respondents of the study were deduced and grouped into four categories for benefits or advantages. These were the (1) **special character** of historic buildings that give a unique quality and style to the project, (2) **building location and site advantages** that may allow for certain opportunities such as increasing occupancy capacity in prime locations, (3) **return on investment** owing to financial savings compared to cost implications of new builds and, (4) **government incentives** in the form of financial and political support for heritage development. Interestingly, these outcomes could be associated mostly with economic benefits, lending more room for socio-cultural (i.e., regeneration) and environmental benefits (i.e., waste reduction) to be realized by the different stakeholders.

From the same study, the four main categories deduced for the challenges in adaptive reuse practice are (1) the **uncertainty** and **risk in financing and profitability,** compounded by unexpected **site remediation** costs. This is mainly attributed to **latent conditions** such as site contamination (in the case of industrial sites) or structural damage. (2) An inflexible **building code** is a hindrance to the innovation and ingenuity necessitated in solving issues in adaptive reuse projects. (3) **Design requirements** may also pose challenges, especially in relation to adapting a structure's original **spatial layout and configuration** to accommodate modern standards, etc. In most cases, tensions run high due to antagonism between developers and heritage committees. Lastly, (4) there is difficulty in procuring **skilled and experienced professionals** (Shipley, Utz, & Parsons, 2006). Even though these deductions are based on a local scenario, they are the same sentiments found in heritage sectors of other countries, in varying degrees and complexities. Dyson, Matthews, and Love (2016) have expressed parallels to these findings of Shipley, Utz, and Parsons (2006), with the addition of (5) **energy efficiency** of the building fabric. Due to a structure's use over time, deterioration of the building envelope may cause insulation and weather-tightness issues that result in operational energy consumption inefficiency.

D. Decision-Making Process

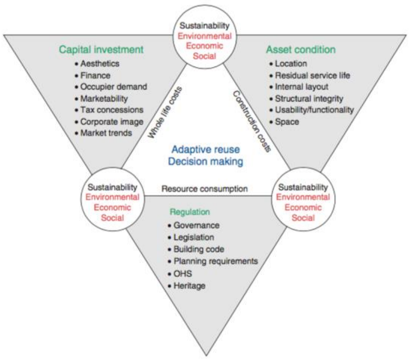

Figure 3. Adaptive Reuse Decision-Making Model

Source: Bullen and Love, 2011

There is great pressure on practitioners to weigh the unique circumstances that come with each adaptive reuse project (Misirlisoy & Günçe, 2016). The decision-making process varies between groups of stakeholders in finding a balance between pros and cons. Every decision in the process, from site selection (or reversely—new use selection) to construction, could prove to be challenging. Bullen and Love's (2011) study determined the most influencing factors that affect decision-making (see Figure 3) as (1) Capital Investment and other financing options hinge on a project's commercial viability. In the long run, this is defined by profit and return on investment (Bullen and Love, 2011). The feasibility of an adaptive reuse

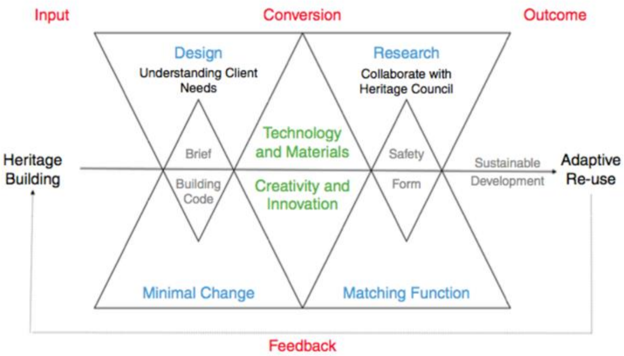

Figure 4. Critical Success Factors (CSF) Framework for Adaptive Reuse of Heritage Buildings. Main emergency CSF in BLUE, sub-themes in GREY, and "tools" in GREEN.

Source: Dyson, Matthews, and Love, 2016

project is governed by a balance of stakeholders' requirements, socio-economic trends, investors' motivation, and projections for capital and operational expenditure. (2) Asset condition, whether latent or evident, are the crucial physical factors that determine a structure's suitability for new use. Location versus target market, transport access, spatial configuration (or reconfiguration thereof), structural integrity, etc. determine a building's usefulness (Bullen & Love, 2011). (3) Regulation pertains mostly to legislation, building code compliance, and political support that enable efficient project implementation. As Bullen and Love (2011) reveal, stakeholders prefer policies to acquire a flexible and supportive stance for adaptive reuse, rather than as a regulatory mandate.

E. Critical Success Factors

A research study in Perth, Australia involving interviews with property owners and industry professionals enabled Dyson, Matthews, and Love (2016) to identify emergent themes for critical success factors for adaptive reuse of heritage buildings (see Figure 4). Clearly, these are a response to the previously mentioned challenges and constraints. The four main themes are (1) research as a form of due diligence (Dyson, Matthews, & Love, 2016), to investigate site history, socio-cultural significance, and the condition of the structure. Indeed, the investigation of these matters allows for informed and responsive decision-making by all stakeholders. (2) Compatibility or matching functions between the original versus the new use of the building (Dyson, Matthews, & Love, 2016) ensure that the design and implementation thereof, are less complicated, more cost-effective, and sensitive to the significance and history of the structure. When a "matching function" is not possible, (3) creative and innovative design (Dyson, Matthews, and Love, 2016) would bridge the gap between the new function and a structure's limitations. Any inadequacies with regard to modern standards and statutory constraints are also mitigated through design. More importantly, the design also allows the new intended function to be integrated into a structure's history and significance. Lastly, (4) minimal change reduces construction costs, and waste production and maintains the unique character of the structure (Dyson, Matthews, & Love, 2016). Professionals are advised to work with the structure and maintain a level of flexibility to ensure successful design and implementation for adaptive reuse projects (Hein and Houck, 2008).

F. Adaptive Reuse Potential (ARP) Model

Considering the different factors that affect the practice of adaptive reuse, practitioners and stakeholders are faced with the undertaking of where and how to begin. Shipley, Utz, and Parsons (2006, p. 508) state, "*While conventional real estate development usually involves a use in search of a site, heritage development almost always features a site in search of a use.*" Heritage professionals need to take a wider stance to be able to consider the multitude of heritage sites that would benefit from adaptive reuse. Considering finite resources versus the numerous heritage sites perhaps all of which present a potential for reuse, which site should professionals and stakeholders prioritize? Site selection is a critical step in real estate and heritage development. For this, Langston and Shen (2007) have developed a tool identified as the Adaptive Reuse Potential Model. It is used to rate heritage properties and existing buildings in terms of conversion potential and timeliness for reuse.

1. ARP Model: Analysis of Variables

The ARP Model (Langston & Shen, 2007) is an index method devised to quantify reuse potential for existing buildings and rank these scores against each other. In this methodology, four formulae are provided in order to ultimately calculate the following: (1) A building's useful life, is the best point in a building's lifetime for repurposing as it is at this point when a building possesses its maximum potential for reuse. The other calculated value is the structure's (2) adaptive reuse potential. Using the model to evaluate a given structure, the assessor first estimates the following variables in years:

L^p = Building's Physical Life (a hypothetical value assigned by the assessor)

L^b = Building's Age (from year built to year of assessment or current year)

Although determining a building's age (L^b) is straightforward, the building's physical life (L^p) is an estimated value. Physical life is the length of time that a building is meant to physically last. The methodology suggests that modern buildings are given a value of L^p = 100 years or less (Langston & Shen, 2007). Other values suggested for L^p were 150 years and 200 years. To illustrate everything (see Figure 5), L^u (useful life) is a point in a structure's timeline between the year it was built and the estimated physical life value. As the diagram suggests, the building is 14 years old and is estimated to last for 100 years. L^u is to be calculated. According to Langston and Shen (2007), a building's ARP increases to its maximum at L^u, and thereafter, the ARP decreases to zero when the building age reaches L^p.

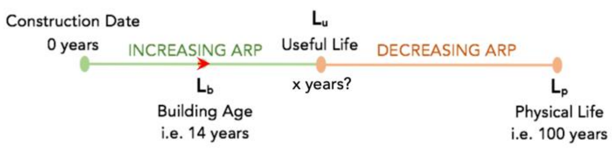

Figure 5. A building's timeline illustrating L^b (building age) moving along to the right as time progresses, eventually passing through L^u (useful life) and finally ending at L^p (physical life)

Prior to calculating for L^u, the methodology next requires the assessors to estimate six obsolescence variables as percentages (Langston & Shen, 2007). For these, values ranging from 0% to 20% were suggested. A seventh obsolescence variable (O^7) was added to the methodology later on (Wilkinson, Remøy, and Langston, 2014, p. 196). A building's obsolescence happens when it is out of use as an asset (Douglas, 2002, p. 29). Obsolescence has been expressed as a function of time (Iselin and Lemer, 1993, cited in Douglas, 2002, p. 29), being the fourth dimension in building, next to space (length, width, depth). It is important to note that all these obsolescence variables are not intended to equate to a combined total of 100% but rather, they are assessed independently and in equal weighting. The following are the suggested criteria:

O^1 = Physical Obsolescence (estimated by examining maintenance policy)
20% - low maintenance (budget) / 0% - high maintenance (budget)

O^2 = Economical Obsolescence (estimated by location of a building)
20% - low density location / 0% - high density location

O^3 = Functional Obsolescence (estimated by flexibility of building's spatial layout)
20% - high conversion cost / 0% - low conversion cost

O^4 = Technological Obsolescence (estimated by building's use of operational energy)
20% - high energy demand / 0% - low energy demand

O^5 = Social Obsolescence (estimated by relationship of building function and marketplace)
20% - fully rented spaces / 0% - fully owned spaces

O^6 = Legal Obsolescence (estimated by quality of building design / compliance to standards)
20% - low quality design / 0% - high quality design

O^7 = Political Obsolescence (estimated by community or public interest)
-20% - supportive environment / 0% - apathetic / +20% - inhibiting environment

2. ARP Model: Analysis of Formulae

Formula 1: L^u or Useful Life (see Figure 6) uses the method of discounting (Langston and Shen, 2007; Wilkinson, Remøy, and Langston, 2014), where the discount rate is the sum of all seven obsolescence variables in decimal form on a per annum basis. For example, if O^1 was scored by the assessor as 10% and L^p as 100 years, the value of O^1 in the summation is as follows: $O^1 = 0.10 / 100$, equating to 0.001. The same is done for all other obsolescence. Formula 1 results in $L^u = L^p$ if all obsolescence variables are scored at 0%, whereas a result of $L^u = 0$ value if all obsolescence variables are scored at 100%. From this formula, it can be deduced therefore that L^u and O^{1-7} are inversely proportional to each other.

$$\text{Useful life}(L_u) = \frac{L_p}{\left(1+\sum_{i=1}^{7} o_i\right)^{L_p}} \qquad (1)$$

Figure 6. Formula 1; Useful life

Source: Langston and Shen, 2007; Wilkinson, Remøy, and Langston, 2014

Next, the ARP model suggests that in order to compare buildings of different ages, useful life, and physical life, all L values (L^u / L^b / L^p) are to be scaled by 100 to produce the **Effective Life** (Langston and Shen, 2007; Wilkinson, Remøy, and Langston, 2014). For example, if L^b = 14 years and L^p = 100 years, the effective building age (EL^b) is 14 years. Whereas another building with Lb = 14 years but L^p = 200 years will have an effective building age (EL^b) of 7 years. In effect, the preceding examples express that these buildings have a current age of 14% and 7% of their physical life, respectively. The EL^u, EL^b, and EL^p are calculated by multiplying the individual values of L^u, L^b, and L^p by 100 and dividing each by L^p.

Formula 2: Decay Curve illustrates the graph where all ELu values for all buildings will evidently lie (see Figure 7). Although, this is not directly related to the calculation of useful life (L^u) and adaptive reuse potential (ARP). The shaded region in the graph illustrates where all possible ARP values are plotted. Dissecting the formula, the 100 in the first term gives the maximum limit for the vertical (y) axis, and the 100 as the denominator in the second term, gives the maximum limit for the horizontal (x) axis. The x^2 in the equation provides the curves' concavity. The graph of Langston gives the perception that buildings with a shorter useful life (L^u) have a higher (ARP) potential for reuse and buildings with a longer useful life (L^u) have a lower (ARP) potential for reuse.

(2)

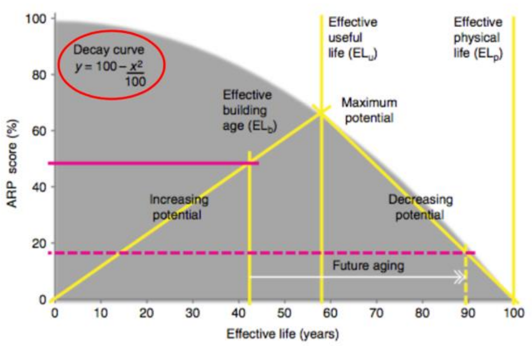

Figure 7. Formula 2 (see encircled), Decay Curve and Graph

Source: Langston and Shen, 2007; Wilkinson, Ramøy, and Langston, 2014

Formulae 3-4: ARP^INCREASING | ARP^DECREASING (see Figures 8-9) show a linear progression for increasing ARP towards the maximum point at ELu (refer again to Figure 7) and decreasing ARP from the maximum point at EL^u towards zero ARP value, where x = 100 (Langston and Shen, 2007; Wilkinson, Remøy, and Langston, 2014). Formula 3 is used when the effective building age is less than or equal to the effective useful life (EL^b £ EL^u). Formula 4 is used when the effective building age is more than or equal to the effective useful life (ELb 3 EL^u). As illustrated below, formula 2 is inserted as the first two terms in the numerators of both formulas 3 and 4. In doing so, the linear equations of Formula 3 and 4 are linked to Formula 2, ensuring that the peak (EL^u) always falls on the decay curve.

$$ARP_{(\text{increasing})} = \frac{100 - \frac{{EL_u}^2}{100} \cdot EL_b}{EL_u} \qquad (3)$$

Figure 8. Formula 3; ARP Increasing

Source: Langston and Shen, 2007; Wilkinson, Ramøy, and Langston, 2014

$$ARP_{(\text{decreasing})} = \frac{100 - \frac{{EL_u}^2}{100} . (100 - EL_b)}{100 - EL_u} \qquad (4)$$

Figure 9. Formula 4; ARP Decreasing (5)

Source: Langston and Shen, 2007; Wilkinson, Ramoy, and Langston, 2014

$$ARP_{(\text{increasing})} = \frac{y \cdot EL_b}{EL_u} \qquad ARP_{(\text{decreasing})} = \frac{y\,.(100 - EL_b)}{100 - EL_u}$$

Figure 10. Formula 5; ARP Formulae illustrating Formula 2 (Decay curve), multiplied to the ratios mentioned.

Since EL^u refers to a value along the x-axis, plugging this in the numerator of the equation enables the interpretation (see Figure 10) that ARP^INCREASING is derived from the ratio EL^b : EL^u applied to the y-value of EL^u. At the same time, ARP^DECREASING is derived from the ratio 100 - EL^b : 100 - EL^u, applied to the y-value of EL^u. Consequently, when EL^b = EL^u, the third terms in both formulae's numerators cancel out with their respective denominators, returning the equation back to Formula 2 (see Figure 11).

$$ARP_{(\text{increasing})} = \frac{100 - \frac{{EL_u}^2}{100} \cdot \cancel{EL_b}}{\cancel{EL_u}} \qquad ARP_{(\text{decreasing})} = \frac{100 - \frac{{EL_u}^2}{100} .\cancel{(100 - EL_b)}}{\cancel{100 - EL_u}} \qquad (6)$$

Figure 11. Formula 6; ARP Formulae illustrating the cancellation of terms when EL^b = El^u, returning to Formula 2

III. Analysis of Case Studies

A. Tate Modern in London

Figure 12-13. Tate Modern, exterior (left). Interior (right)
Source: Wikimedia Commons, 2013 and Godliman, 2013

The conversion of Bankside Power Station to what is now the Tate Modern (see Figures 12-13) has always been a primary example in various literature. The redundant power station designed by Giles Gilbert Scott in the 1940s was disused in 1981—a mere thirty years of use. In 1995, Swiss architects Jacques Herzog and Pierre de Meuron were awarded the re-design project and the structure finally opened to the public as the Tate Modern in 2000 (ArchDaily, 2013). The adaptation and retrofit design work of Herzog and de Meuron complement the original aesthetic of the power station's existing fabric. Today, the Tate Modern attracts millions of visitors each year, particularly appealing to younger audiences (Tate, 2015). The same iterations in the case studies for the Western Market Building (Langston et al., 2008) and Lui Seng Chun (Langston & Shen, 2007) in Hong Kong and the GPO Building in Melbourne (Wilkinson, Remøy and Langston, 2014) are applied to estimate the following variables for the Tate Modern. Results are illustrated (see Figure 14) to guide the assumptions.

Built: 1947
Year of Assessment: 1981 (shutdown)
L_P = 100 years (estimated)

O_1 = 15% due to the continual cycles of use and disuse prior to the shutdown.

O_2 = 0% due to the site's location within Central London (high-density area).

O_3 = 5% due to the predominantly open plan being an industrial space.

O_4 = 20% due to the high amount of operational energy to provide for user comfort, safety, etc.

O_5 = 0% due to full ownership as a government / private asset.

O_6 = 5% due to high-quality design, construction, and minimal standard compliance issues

O_7 = 5% due to slight political apathy and the lack of attention for reuse in 1981.

TATE MODERN - LONDON

Physical	O1	15 %	Physical Life	Lp	100.00	actual years
Economic	O2	0 %	Building Age (1981)	Lb	34.00	actual years
Functional	O3	5 %	Useful Life	Lu	60.73	actual years
Technological	O4	20 %	Lp scaled by 100	ELp	100.00	% of Lp
Social	O5	0 %	Lb scaled by 100	ELb	34.00	% of Lp
Legal	O6	5 %	Lu scaled by 100	ELu	60.73	% of Lp
Political	O7	5 %	Residual Physical Life	Lp-Lb	66.00	actual years
DISCOUNT RATE	ΣO	0.005	Residual Useful Life	Lu-Lb	26.73	actual years

GRAPHED POINTS	x	y	PATH POSITION	EVALUATION
ELb	34.00	35.34	INCREASING ARP (Elb<Elu)	MODERATE (20-49)
ELu	60.73	63.12	MAXIMUM ARP (ELb=ELu)	HIGH (50-100)
Year 1995	48	49.89	INCREASING ARP (Elb<Elu)	MODERATE (20-49)

TATE MODERN - LONDON

Physical	O1	20 %	Physical Life	Lp	100.00	actual years
Economic	O2	20 %	Building Age (1981)	Lb	34.00	actual years
Functional	O3	20 %	Useful Life	Lu	24.90	actual years
Technological	O4	20 %	Lp scaled by 100	ELp	100.00	% of Lp
Social	O5	20 %	Lb scaled by 100	ELb	34.00	% of Lp
Legal	O6	20 %	Lu scaled by 100	ELu	24.90	% of Lp
Political	O7	20 %	Residual Physical Life	Lp-Lb	66.00	actual years
DISCOUNT RATE	ΣO	0.014	Residual Useful Life	Lu-Lb	-9.10	actual years

GRAPHED POINTS	x	y	PATH POSITION	EVALUATION
ELb	34.00	82.43	DECREASING ARP (ELb>Elu)	HIGH (50-100)
ELu	24.90	93.80	MAXIMUM ARP (ELb=ELu)	HIGH (50-100)
Year 1995	48	64.95	DECREASING ARP (ELb>Elu)	HIGH (50-100)

1. Extrapolation and Assumptions

- High obsolescence gives a shorter useful life; inversely, low obsolescence, a longer useful life.
- When all obsolescence decreases to 0%; $L_u = L_P$, ARP decreases to 0% (see APPENDIX B)
- When all obsolescence reaches the suggested maximum of 20%, Lu is approximately 25% of L_P.
- When all obsolescence increases to 100%, L_u reaches 0 years and ARP increases to 100%.

a. YELLOW GRAPH

- 2007 was the optimal time (EL_u) for repurposing the structure, 60.73 years after it was built and 7.73 years after it was reopened as the Tate Modern in 2000.
- In 1981, the redundancy of Bankside Power Station was premature by 26.73 years (residual useful life) in relation to ELu. The structure had 66 years of residual physical life.
- In 1995, the year when Herzog & De Meuron were awarded the project, ARP was 48.49%.

b. BLUE GRAPH

- With 20% maximum obsolescence, redundancy in 1981 would have been 9.10 years overdue the optimal time (EL_u) for repurposing in 1971. It would have the same residual physical life.

- 1971 – the optimal time (EL_u) would have been 24.90 years after it was built and 28.10 years after.
- before it was reopened as the Tate Modern in 2000.
- In 1995, ARP would have been 64.95%.

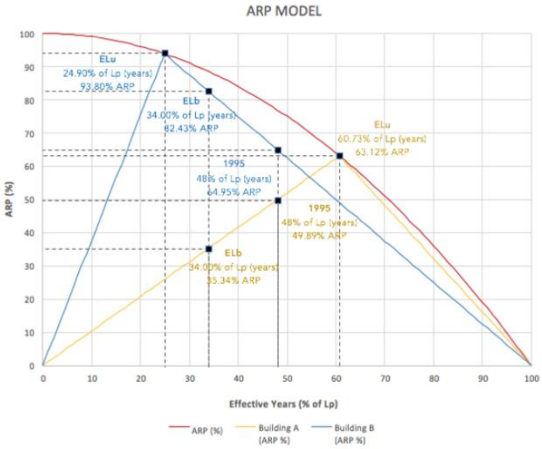

Figure 14. Tate Modern ARP Assessment based on evaluated obsolescence value (YELLOW) and maximum obsolescence value (BLUE). Values in GREEN evaluated by assessor.

B. High Line in New York City

Figure 15-16. (Left) Joel Sternfeld's photograph prior to the conversion project. (Right) The freight railway reopened as a public green space in Manhattan.
Source: Sternfeld, 2000 and The Highline, 2007

The practice of adaptive reuse provides a plethora of options for architects and developers though most importantly, it also allows opportunities for community involvement. Another prime example of adaptive reuse is the High Line in New York (see Figures 15-16). From 1934 to 1980, the High Line served as a train viaduct serving Manhattan's industrial district. Not long after its disuse, property owners in the surrounding neighborhood lobbied to demolish the defunct railway. This was opposed by Chelsea resident, Peter Obletz, and in 1999 the community group advocating to adapt it as a public space 'Friends of the High Line,' was founded by Joshua David and Robert Hammond. After five years, plans were in place to redevelop the train viaduct into a linear park. This community initiative was supported by the City of New York and the project was co-designed by James Corner Field Operations, landscape architects Diller Scofidio + Renfro, and planting designer Piet Oudolf. The High Line opened to the public in three phases in 2009, 2011, and 2014.

HIGH LINE - NEW YORK

Physical	O1	15 %	Physical Life	Lp	100.00	actual years
Economic	O2	0 %	Building Age (1999)	Lb	65.00	actual years
Functional	O3	5 %	Useful Life	Lu	86.08	actual years
Technological	O4	5 %	Lp scaled by 100	ELp	100.00	% of Lp
Social	O5	0 %	Lb scaled by 100	ELb	65.00	% of Lp
Legal	O6	10 %	Lu scaled by 100	ELu	86.08	% of Lp
Political	O7	-20 %	Residual Physical Life	Lp-Lb	35.00	actual years
DISCOUNT RATE	ΣO	0.0015	Residual Useful Life	Lu-Lb	21.08	actual years

GRAPHED POINTS	x	y	PATH POSITION	EVALUATION
ELb	65.00	19.56	INCREASING ARP (Elb<Elu)	LOW (1-19)
ELu	86.08	25.90	MAXIMUM ARP (ELb=ELu)	MODERATE (20-49)
Year 1980	46	13.84	INCREASING ARP (Elb<Elu)	LOW (1-19)

HIGH LINE - NEW YORK

Physical	O1	15 %	Physical Life	Lp	200.00	actual years
Economic	O2	0 %	Building Age (1999)	Lb	65.00	actual years
Functional	O3	5 %	Useful Life	Lu	172.15	actual years
Technological	O4	5 %	Lp scaled by 100	ELp	100.00	% of Lp
Social	O5	0 %	Lb scaled by 100	ELb	32.50	% of Lp
Legal	O6	10 %	Lu scaled by 100	ELu	86.08	% of Lp
Political	O7	-20 %	Residual Physical Life	Lp-Lb	135.00	actual years
DISCOUNT RATE	ΣO	0.00075	Residual Useful Life	Lu-Lb	107.15	actual years

GRAPHED POINTS	x	y	PATH POSITION	EVALUATION
ELb	32.50	9.78	INCREASING ARP (Elb<Elu)	LOW (1-19)
ELu	86.08	25.91	MAXIMUM ARP (ELb=ELu)	MODERATE (20-49)
Year 1980	23	6.92	INCREASING ARP (Elb<Elu)	LOW (1-19)

(The High Line, 2017). Today, local residents and tourists flock to the repurposed railway to enjoy not just a public open space, but a green space.

Next, in order to investigate the relationship of L_P in the equation, the model is applied to the High Line (see Figure 17) where two versions with different L_P are illustrated using the same O:

Built: 1934
Year of Assessment: 1999 (Friends of THL established)
L_P = 100 / 200 years

O^1 = 15% due to increasing disuse (due to trucking industry) leading to the shutdown.

O^2 = 0% due to the site's location in Manhattan's west side (high-density area).

O^3 = 5% retained, due to the railway open plan facilitating the conversion to a linear park.

O^4 = 5% due to minimal operational energy to provide for occupant comfort, safety, etc.

O^5 = 0% due to full ownership as a government / private asset.

O^6 = 10% due to reasonable quality of design/construction in relation to compliance issues.

O^7 = -20% due to the 'Friends of the High Line' community movement in 1999.

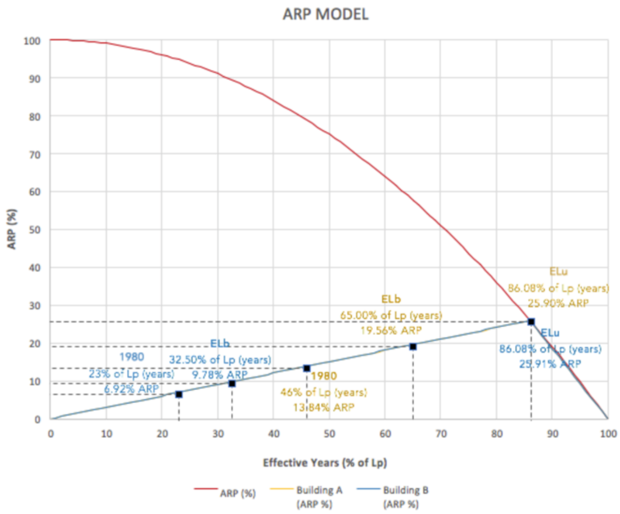

Figure 17. The Highline ARP Assessment based on evaluated obsolescence values versus L^p=100 years (yellow graph) and L=200 years (blue graph). Values in green determined by assessor.

1. Extrapolation and Assumptions

○ Knowing THL's new use (linear park) during assessment influenced the scoring for O^3, O^4, and O^6. Not knowing THL's new use would yield higher values for these obsolescence variables as for example, conversion to an enclosed space i.e., apartments, renders the criteria inflexible.

- Structures of the same age and obsolescence yield the same ARP% at the end of useful life.
- As L^P is increased, residual physical and residual useful life increases (ARP% at EL^b decreases).
- As L^P is decreased, residual physical and residual useful life decreases (ARP% at EL^b increases).

a. YELLOW GRAPH

- 2020 was the optimal time (EL^u) for repurposing the structure, 86.08 years after it was built and 11.08 years after its first phase reopened as a linear park in 2009.
- In 1980, the redundancy of the High Line was premature by 40.08 years in relation to ELu. o In 1999, the year (EL^b) when 'Friends of the High Line' was formed, ARP was 19.56% with a residual useful life of 21.08 years. The structure had 35.00 years of residual physical life.

b. BLUE GRAPH

- If L^P is doubled (200 years), 2106 would be the optimal time (EL^u) for repurposing. This is 172.16 years after it was built and 97.16 years after it was first reopened in 2009.
- In 1980, the redundancy would have been premature by 126.16 years in relation to ELu.
- In 1999, the ARP would have been 9.78%, with a residual useful life of 107.15 years and a residual physical life of 135 years.

IV. Discussion and Recommendations

In both cases, economic and political trends were the governing factors for the disuse of the structures. Bankside Power Station was shut down due to pollution issues, the redundancy by power stations outside London, and the Middle East oil crisis of the 1970s (Murray, 2010). Whereas the High Line was disused mainly due to the rise of the trucking industry (The High Line, 2017). Crucial factors such as these could not be properly quantified in the criteria for obsolescence, hence, yielding uncorrelated results to actual events. Based on the preceding, it is suggested that the ARP Model can be developed further. However, the complexity of heritage may ultimately prove difficult to quantify. Qualitative methods for multi-criteria decision-making for site and reuse selection such as the Analytic Hierarchy Process and Analytic Network Process (Saaty, 1980; 1996, cited in Wang and Zeng, 2010, p. 1424) can be explored to improve the model. The following are the ARP model limitations and recommendations:

- **ARP Percentages / Scoring** is a tool for guidance in site selection. Being an index method, it is meant to compare structures to each other using the ARP scoring. The ARP percentage does not directly relate to any critical success factors or outcomes.
- **AR Potential versus Reusability** are uncorrelated. A high ARP score does not necessarily connote high reusability. Consider a building that is highly rated for all seven obsolescence. High obsolescence being inversely proportional to Lu, will give a shorter useful life. The maximum ARP though at ELu would yield a high score. However, due to exceptional physical deterioration from weather damage, the reusability of this structure could be determinately low. This is due to physical obsolescence being solely based on maintenance and being equally weighted versus all other obsolescence variables. Therefore, further research is suggested to investigate the correlation between AR potential and the structure's reusability. (see Obsolescence Criteria for further recommendations)

- **Year (Timing) of the Assessment** can influence obsolescence rating as factors that contribute to obsolescence scoring can change over time. As illustrated in the High Line, the year of assessment was 1999 when the community movement was established to save the structure. The assessment warranted -20% for political obsolescence. If the year of assessment were 1980, political obsolescence would have warranted a theoretical score of +20% to reflect the immediate response of local residents to demolish the train viaduct (The High Line, 2017). It is suggested that an averaging method be used to account for obsolescence spanning a period of time to compensate for these discrepancies. Further testing on historic-use scenarios would also strengthen possible weaknesses in the model in being able to span intergenerational timelines.

- **Physical Life (L_P)** estimated with arbitrary values may lead to misconceptions about residual physical life and residual useful life, as these variables are directly proportional to each other. Therefore, a high value assigned to L_P stretches a structure's timeline. Langston (2011) developed a questionnaire based on environment, usage, and design to improve the precision of L_P. In this method, the result is calculated within a range of 50 to 300 years. Although this supplementary step enhances objectivity, there is a need to improve this to account for (heritage) structures that evidently have had much longer physical lifespans.

- **Obsolescence Criteria** is generalized and may lend to subjectivity. Obsolescence in the ARP model relies on singular criteria for each of the seven variables. This may not be applicable to a wide range of scenarios. Also, each variable is equally weighted, producing a maximum total of 140%, which can be misleading. It is therefore suggested that an assessment (yes or no) questionnaire similar to the physical life worksheet by Langston (2011) be developed in order to fully account for all factors that might affect the useful life of a structure.

- **Environmental Obsolescence** is not distinctly integrated. To fully implement a holistic approach to sustainable development, energy efficiency, and other pertinent environmental issues should be fully considered (Yung and Chan, 2012). Although it is implied that environmental obsolescence is accounted for in other variables such as social, technological, and legal obsolescence (Langston et al., 2008), this is not evident. It is therefore suggested that the assessment questionnaire should include queries that investigate the environmental issues relating to the structure and its use.

- The **Exponential Decay Curve (Formula 2)** suggests that a building with a shorter useful life has a higher potential for reuse versus a building that has a longer useful life. Further research is suggested to investigate this interrelationship of useful life versus ARP.

- **ARP Formula 3 and 4** suggest that buildings begin with 0% potential at the beginning of their life increasing to a maximum point at EL^u, then from this point decreasing back to 0%. Further research is suggested to investigate the ARP trend line vis-à-vis a structure's timeline. Qualitative information investigating the perception of industry professionals and stakeholders with regard to this model can also be explored.

V. Conclusion

Adaptive Reuse is repurposing an existing structure to accommodate a new use. It is when buildings such as the Bankside Power Station and the High Line train viaduct are rehabilitated to give new purpose to what otherwise would have been obsolete and disused structures. The adaptive reuse of these projects has directly benefitted the public. If not for these conversion projects, the public would not have gained access to such structures and benefited from them directly in such a context. As Bollack (2013, p. 9) has conveyed, "*An old building is not an obstacle but rather a foundation for continued action*." Hence, adaptive reuse ensures that historic buildings such as these would have a reason for continued existence (Kincaid, 2002), whilst taking full advantage of their embodied energy. This is vital for sustainable development and the preservation of built heritage. The advantages are established through social, cultural, economic, and environmental sustainability (Mohamed et al., 2017). However, the challenges lie in negotiating the shared value and significance for the multiple stakeholders and in bridging the past, present, and future. Adaptive reuse is a demonstration not only of intergenerational equity but of skill, innovation, and ingenuity. Langston's ARP model is a potential tool for stakeholders and professionals in adaptive reuse decision-making. The method enables the ranking of existing structures in terms of its reuse potential and the quantification of their useful life. However, the analysis suggests that further research on the key points of obsolescence and the interrelationship of variables in the ARP model in order to strengthen the method. It is without doubt that the practice of adaptive reuse would immensely benefit from such a model for site selection once these recommendations are fully explored.

References

Accenture. (2012). *Seven trends transforming the construction marketpl*ace. Retrieved April 3, 2017, from https://www.accenture.com/gb-en/~/media/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Industries_2/Accenture-Construction-Research-Infographic.pdf.

ArchDaily. (2013). *AD classics: The tate modern / herzog & de meuron*. Retrieved April 3, 2017, from http://www.archdaily.com/429700/ad-classics-the-tate-modern-herzog-and-de-meuron.

BBC. (2017). *BBC - GCSE Bitesize: Causes of urbanisation*. Retrieved April 4, 2017, from http://www.bbc.co.uk/schools/gcsebitesize/geography/urban_environments/urbanisation_medcs_rev1.shtml.

Bollack, F. (2013). *Old buildings, new forms* (1st ed.). Monacelli Press.

Bullen, P., & Love, P. (2011). A new future for the past: a model for adaptive reuse decision-making. *Built Environment Project and Asset Management*, *1*(1), 32-44.

Cassar, M. (2016). *Philosophical issues of value and sustainability - Technical Note* (2003).

Designing Buildings Wiki. (2017). *Embodied energy in construction - designing buildings wiki*. Retrieved April 3, 2017, from https://www.designingbuildings.co.uk/wiki/Embodied_energy_in_construction.

Division for sustainable development unhq. (2017). Sustainable Development Knowledge Platform. Retrieved April 3, 2017, from https://sustainabledevelopment.un.org.

Douglas, J. (2002). *Building adaptation* (1st ed.). Butterworth-Heinemann.

Dyson, K., Matthews, J., & Love, P. (2016). Critical success factors of adapting heritage buildings: an exploratory study. *Built Environment Project and Asset Management*, *6*(1), 44-57.

Fouseki, K. (2016). *Values, heritage and sustainability lecture* (UCL ISH BENVGSH01).

Global Construction Perspectives and Oxford Economics (2015). *Global Construction 2030, Global Construction Perspectives and Oxford Economics.* Retrieved April 3, 2017, from http://constructingexcellence.org.uk/wp-content/uploads/2015/09/GCP_Conference_ENR_2030_WEB.pdf.

Godliman, D. (2013). *AD Classics: The tate modern / herzog & de Meuron*. [image]. Retrieved April 3, 2017, from http://www.archdaily.com/429700/ad-classics-the-tate-modern-herzog-and-de-meuron/52291c42e8e44e1a330000cd-ad-classics-the-tate-modern-herzog-and-de-meuron-photo.

Hein, M., & Houck, K. (2008). Construction challenges of adaptive reuse of historical buildings in Europe. *International Journal of Construction Education and Research*, *4*(2), 115-131.

Historic England. (2017). *Historic England - buildings and structures at risk*. Retrieved April 3, 2017, from https://historicengland.org.uk/advice/heritage-at-risk/buildings/buildings-at-risk.

Jolly, J. (2017). *The UK's construction industry started 2017 on a high*. Cityam.com. Retrieved April 4, 2017, from http://www.cityam.com/259210/uks-construction-industry-started-2017-high.

Kincaid, D. (2002). *Adapting buildings for changing uses* (1st ed.). Taylor & Francis.

Kollewe, J. (2017). *UK construction industry enjoys fast growth in new orders*. The Guardian. Retrieved April 4, 2017, from https://www.theguardian.com/business/2017/jan/04/uk-construction-industry-growth-new-orders.

Langston, C. (2011). Estimating the useful life of buildings. *36th Australasian University Building Educators Association (AUBEA) Conference*. [online] Gold Coast, Queensland, Australia: Bond University, 418-32. Retrieved April 12, 2017, from http://epublications.bond.edu.au/cgi/viewcontent.cgi?article=1029&context=aubea_2011.

Langston, C., & Shen, L. (2007). Application of the adaptive reuse potential model in Hong Kong: A case study of Lui Seng Chun. *International Journal of Strategic Property Management*, *11*(4), 193-207.

Langston, C., Wong, F., Hui, E., & Shen, L. (2008). Strategic assessment of building adaptive reuse opportunities in Hong Kong. *Building and Environment*, *43*(10), 1709-1718.

Mail Online. (2012). *Almost 6,000 buildings and historic sites are at risk of being lost to neglect and decay, say English heritage*. Retrieved April 3, 2017, from http://www.dailymail.co.uk/news/article-2216540/Almost-6-000-buildings-historic-sites-risk-lost-neglect-decay-say-English-Heritage.html.

Mısırlısoy, D., & Günçe, K. (2016, October). Adaptive reuse strategies for heritage buildings: A holistic approach. *Sustainable Cities and Society*, *26*, 91-98.

Mohamed, R., Boyle, R., Yang, A., & Tangari, J. (2017). Adaptive reuse: a review and analysis of its relationship to the 3 Es of sustainability. *Facilites*, *35*(3/4), 138-154.

Murray, S. (2010). *The rise, fall and transformation of Bankside power station, 1890-2010*. Greater London Industrial Archaeology Society. Retrieved April 3, 2017, from http://www.glias.org.uk/gliasepapers/bankside.html.

Nonko, E. (2016). *'Adaptive reuse' gives new life to old buildings*. Observer. Retrieved April 3, 2017, from http://observer.com/2016/01/adaptive-reuse-gives-new-life-to-old-buildings/.

PwC. (2017). *Global construction 2030: a global forecast for the construction industry to 2030*. Retrieved April 3, 20017,

.
from http://www.pwc.com/gx/en/industries/engineering-construction/publications/pwc-global-construction-2030.html.

Shipley, R., Utz, S., & Parsons, M. (2006). Does adaptive reuse pay? A study of the business of building renovation in Ontario, Canada. *International Journal of Heritage Studies*, *12*(6), 505- 520.

Sternfeld, J. (2000). *About the high line, friends of the high line*. [image]. Retrieved April 3, 2017, from http://www.thehighline.org/about.

Tate. (2015). *Tate Annual Report 2014-15*. Retrieved April 3, 2017, from http://www.tate.org.uk/about/press-office/press-releases/tate-annual-report-2014-15.

United Nations (2014). *World urbanization prospects: The 2014 revision - highlights*. New York, United Nations.

Wang, H., & Zeng, Z. (2010). A multi-objective decision-making process for reuse selection of historic buildings. *Expert Systems with Applications*, *37*(2), 1241-1249.

Wendell Cox Consultancy (2016). *Demographia: World urban areas*. Retrieved April 3, 2017, from http://www.demographia.com/db-worldua.pdf.

Wikimedia Commons (2013). *AD classics: The tate modern / herzog & de meuron*. [image]. Retrieved April 3, 2017, from http://www.archdaily.com/429700/ad-classics-the-tate-modern-herzog-and-de-meuron/522800a9e8e44e5fdf000052-ad-classics-the-tate-modern-herzog-and-de-meuron-.

Wilkinson, S., Remøy, H., & Langston, C. (2014). *Identifying Adaptive Reuse Potential*. In S. Wilkinson, H. Remøy, & C. Langston (Eds.), *Sustainable building adaptation: Innovations in decision-making* (1st ed., pp. 187-2017). Wiley-Blackwell.

Yung, E., & Chan, E. (2012). Implementation challenges to the adaptive reuse of heritage buildings: Towards the goals of sustainable, low carbon cities. *Habitat International*, *36*(3), 352-361.

Bibliography

Cantell, S. (2005). *The adaptive reuse of historic industrial buildings: Regulation barriers, best practices and case studies*. [Master's thesis in Urban and Regional Planning, Virginia Polytechnic Institute and State University].

Cherchi, P. (2015). *Rehabilitation of abandoned monumental hospitals: Tools for urban liveability*. *Journal of Civil Engineering and Architecture*, *10*(6).

Department of Arts, Heritage and the Gaeltacht (2012). *Shaping the future: Case Studies in Adaptation and Reuse in Historic Urban Environments*. Dublin, Ireland, Department of Arts, Heritage and the Gaeltacht.

Ijla, A., & Broström, T. (2015). The sustainable viability of adaptive reuse of historic buildings: The experiences of two world heritage old cities; Bethlehem in Palestine and Visby in Sweden. *International Invention Journal of Arts and Social Sciences*, *2*(4), 52-66. Retrieved April 3, 2017, from http://internationalinventjournals.org/journals/IIJASS.

Jäger, F. (2010). *Old & new: design manual for revitalizing existing buildings* (1st ed.). Birkhäuser.

Latham, D. (2000). *Creative re-use of buildings*. (Vol.1-2, 1st ed.). Domhead.

Mirza-Avakyan, G. (2013). *Adaptive reuse of historic churches in New York City: The opportunities and challenges for community development*. [Master's thesis in Urban Planning, Department of Urban Planning (Graduate School of Architecture), Columbia University] .

Niesewand, N. (2002). *Converted spaces* (1st ed.). Conran Octopus.

Plevoets, B. (2014). *Retail-Reuse: an interior view on adaptive reuse of buildings*. [Doctoral dissertation, Universiteit Hasselt].

Powell, K. (1999). *Architecture reborn: The conversion and reconstruction of old buildings* (1st ed.). Calman & King Ltd.