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Quantitative Support for a Qualitative Foundation Reuse Assessment Tool

ABSTRACT

This paper provides a quantification of the inputs for an existing qualitative foundation project planning model, namely ARUP's Sustainable Project Appraisal Routine (SPeAR®) diagram. The goal is to provide an improved mechanism for designers to communicate with clients about the potential benefits of foundation reuse from a planning and environmental perspective for an individual project or group of projects based on the relative value of eight factors: (1) Site Location on Previously Developed Land; (2) Archeology and Historical Constraints; (3) Geological Conditions and Constraints; (4) Sustainability and Materials Reuse; (5) Land Value and Cash Flow Projections; (6) Construction Costs; (7) Consistency in Building Location; and (8) Approvals and Development Risk. For each category a six-point scale is provided that can be fully adopted in any community worldwide to evaluate the absolute and relative benefits between sites, even between disparate cities or countries. An example of the implementation of this modified SPeAR model is provided for a city-center location in Dublin, Ireland.

INTRODUCTION

Increasingly foundation reuse is being considered as an option by designers and owners, yet the value of such an approach is frequently difficult to articulate. The tools presently available for objective assessment are currently qualitative in both input and output or only quantify direct costs (e.g. Laefer and Manke, 2008). The goal of this paper is to provide a more quantitative approach to the input factors for an existing qualitative model, namely ARUP's Sustainable Project Appraisal Routine (SPeAR®) diagram as will be described below.

BACKGROUND

As part of the European Union's funding of the project RUFUS: Reuse of Foundations for Urban Sites, significant efforts were brought to bear on the collating of foundation reuse efforts throughout Europe and beyond. This resulted in the RUFUS conference in 2006 where more than 30 related papers were presented (Butcher et al. 2006a) and an affiliated Foundation Reuse Handbook (Butcher et al. 2006b) was produced. Another major output was the 2007 CIRIA report on foundation reuse (Chapman et al. 2007). In parallel to these activities, the design firm ARUP developed the SPeAR® diagram (Figure 1). To date, this tool has largely been used for general comparisons on the viability of foundation reuse for various communities. As an example, in Strauss et al. (2007) published a comparison of foundation reuse drivers in London versus those in four American cities (New York, Houston, Chicago, and San Francisco). The drivers and subsequent results for London are shown in Table 1 and Figure 2, respectively.

Figure 1. SPeAR diagram (adapted from Strauss et al. 2007).

Table 1. Input Driver Descriptions for London (Strauss et al. 2007)

Sector	Driver	Rating for the City of London
Environment	Site Location on Previously Developed Land	In most cities greenfield sites are protected by planning constraints necessitating reuse of previously developed land: Medium rating
	Archaeology & Historical Constraints	Significant archaeological interest and materials congestion of soils: High rating
Natural Resources	Geological Conditions & Constraints	Geological conditions require substantial piled foundations for typical urban development, providing driver to reuse these expensive foundation elements: High rating
	Sustainability & Materials Reuse	Material savings in concrete and steel with subsequent reduction in transport requirements through compensated city streets: Medium-High rating.
Economic	Land Value & Cash Flow Projections	High cost of land provides driver to construct quickly to minimized lost revenue: High rating
	Construction Costs	Capital cost savings from reduced new-build requirements and faster construction schedule minimizes period of lost rental income: High rating
Societal	Consistency in Building Location	Community interaction is maintained when buildings remain and the site does not become vacant: Medium-Low rating
	Approvals & Development Risk	London building codes are favourable toward foundation reuse if engineers can demonstrate structural adequacy of the foundation and therefore development risk is reduced: Medium-High rating

Figure 2. SPeAR diagram for London (Strauss et al. 2007).

One challenge in using such a model is the lack of certainty in defining the inputs. To overcome this, the following section offers a potential quantifiable basis for each of the eight drivers. In each case, the driver is divided into six levels of designation, as described below.

MODEL

This section describes the proposed six-point quantification for each of the eight drivers. This reduces the SPeAR diagram from its initial eight-ring division to a six-ring one. In the proposed system, the bull's eye section is level 1 moving outwards to level 6 on the outer periphery. The result is still a qualitative model, but one in which the inputs can be better calibrated for individual projects and in the context of a historical record.

Site Location on Previously Developed Land

The drivers in this section relate to the potential of developing greenfield sites within a community. The rating is determined by the quantity of greenfield meterage that is not protected (e.g. not parks, not waterways, etc.) divided by the total square meterage of the community (Table 2). Those communities with little available land that is free from previous development will score close to the center (Level 1), while those with significant levels of available land will be closer to Level 6.

Table 2. Driver designations for previously developed land

Level	Greenfield land unprotected in the community as a percentage of the total meterage of that community (%)
1	$< .1$
2	$.1 < x < 1$
3	$1 < x < 2$
4	$2 < x < 5$
5	$5 < x < 10$
6	$10 <$

Archeology and Historical Constraints

The drivers here are based largely on external recognition of historical importance (Table 3). The top driver is for a property with an individual property architectural designation. The next level is for a property that is not individually recognized but a part of a designated neighborhood or district. The final four designations are for buildings without any specific architectural recognition and are based simply upon the building's respective age as a likely indication of potential archaeological remains, as well as future recognition of architectural merit.

Table 3. Driver designations for archeology and historical constraints

Level	Level of historic importance
1	Property-based architectural designation
2	Neighborhood/district-based architectural designation
3	100 years old $< x$
4	50 years old $< x < 100$ years old
5	25 years old $< x < 50$ years old
6	$x < 25$ years old

Geological Conditions and Constraints

The drivers for geological conditions and constraints are highly simplified and based only upon a crude division of problem geological materials found at the site (Table 4). Less desirable soils are ranked closer to the center of the bull's eye.

Table 4. Driver designations for geological conditions and constraints

Level	Soil type
1	Karst
2	High shrink-swell clay
3	Mixed
4	Low shrink-swell clay
5	Sand
6	Rock

Sustainability and Materials Reuse

The rationale for this section is based upon the quantity of constructed materials that are estimated to be in the ground as an indicator of the quantity of embodied energy. These will be considered the absolute minimum amount of materials that

would have to be replaced during new construction. The greater the quantity of the materials the higher the driver is (Table 5). There is an inherent assumption that the embodied energy per cubic meter of the replacement material will be equal to or greater than that currently installed.

Table 5. Driver designations for the quantity of embodied energy

Level	Quantity of Material (m ³)
1	250 <
2	200 < x < 250
3	150 < x < 200
4	100 < x < 150
5	50 < x < 100
6	< 50

Land Value and Cash Flow Projections

The land value has been represented as the monthly rental cost for a ground floor, retail location, as a multiplier of the median monthly household income for the community (as reported by the local taxation or central statistics' office) [Table 6]. Higher costs are represented closer to the bull's eye's center.

Table 6. Driver designations for the land's value

Level	Site monthly, ground floor rental cost as a multiplier of monthly median community household income
1	25 <
2	20 < x < .25
3	15 < x < .20
4	10 < x < .15
5	05 < x < .10
6	< .05

Construction Costs

This section applies a commonly used method for establishing economic equivalencies between communities. It is called the Big Mac Index and has been used and verified against a wide range of products and services (e.g. cigarettes) as explained by Ong (1997). In the case of the following comparison, the Big Mac is defined by the cost of one Big Mac from the MacDonald's on the most expensive shopping street in the community. As consumer prices and the prices for construction materials are not fully aligned, the cost is then used as a factor to describe the relative cost of a cubic meter of ready-mix concrete delivered to the site in question (Table 7). Higher costs are represented closer to the bull's eye's center.

Table 7. Driver designations for the construction costs

Level	Number of Big Macs whose cost is equivalent to a cubic meter of ready-mix concrete delivered to the proposed project site (m ³)
1	75 <
2	60 < x < 75
3	45 < x < 60
4	30 < x < 45
5	15 < x < 30
6	< 15

Consistency in Building Location

Companies must often decide whether to rebuild, renovate, or expand on an existing site or relocate. The upside to staying at the same location is customer familiarity. The downside is that facility closure, at least for some time (if not an extended time) is usually unavoidable. The affiliated scale relates to how long a company has been at that location in terms of years (Table 8). The level is closer to the bull's eye for periods of greater duration.

Table 8. Driver designations for consistency in building location

Level	Length of time in business at that location (years)
1	50 <
2	25 < x < 50
3	10 < x < 25
4	5 < x < 10
5	2 < x < 5
6	< 2

Approvals and Development Risk

The drivers in this section have been linked directly to the average planning approval period (Table 9). As this can change significantly depending upon the boom/bust cycle of the local community, this should be evaluated in the previous 12 months. Longer durations are represented closer to the bull's eye's center.

Table 9. Driver designations for approvals and development risk

Level	Length of time for planning approval permission (months)
1	12 <
2	10-12
3	7-9
4	5-6
5	3-4
6	< 2

SAMPLE CASE

To illustrate the use of these quantified drivers, the case of a property in Dublin's city center is offered. The proposed property is located on Grafton Street, which is Dublin's main shopping thoroughfare and a protected historic district, although few buildings within the area have further designation despite many dating back to the 18th century (Casey, 2005). The street is at heart of the walking sector of the city and represents one of the most expensive retail shopping areas in Europe (fig. 3). A 2007 retail survey found that the average price of rental space per square meter there was the fifth highest in Europe, at €8000/m² (McGabhann, 2007). Now two years after the height of the Celtic Tiger days a typical cost is only €2,888/m². The median monthly household income for Dublin is €5,612. The Grafton Street buildings are 2-4 stories with shallow foundations. The proposed property is 6m wide and 30m long, while the walls are typically 3 brick wythes thick (approximately 0.33m) with the foundations 3 times that width and 0.1m deep). This would result in the amount of foundation material 7.2m³. The subsurface conditions are predominantly boulder clay (DCENR, 2010). The average cost of a Big Mac on Grafton Street is €3.90. The cost of a cubic meter of ready-mix concrete is €170. Planning permission is generally taking 6 months, and because of the low-rise, nearly suburban nature of the city, the percentage of unrestricted, undeveloped land in the city exceeds 10% (although most of this consists of individual gardens, church properties, and old farmland. The assumption in this case is that the business is a brand new company without a market presence in Dublin. Based on these input factors, driver levels were determined from Tables 2-9. The results are summarized in Table 10 and graphically depicted in figure 4.

Figure 3. Image of the south, city-center of Dublin (Grafton Street circled).

Table 10. Input Driver Descriptions for Dublin

Sector	Driver	Rating for the City of London
Environment	Site Location on Previously Developed Land	Unprotected greenfield as % of total community meterage 10% < = level 6
	Archaeology & Historical Constraints	Neighborhood based architectural protection = level 2
Natural Resources	Geological Conditions & Constraints	Clay = level 4
	Sustainability & Materials Reuse	7.2m ³ = level 5
Economic	Land Value & Cash Flow Projections	The ratio of monthly rental over monthly median household income was 0.52 = level 1
	Construction Costs	43.59 Big Macs per cubic meter of concrete = level 4
Societal	Consistency in Building Location	0 time at that location = level 6
	Approvals & Development Risk	6 months = level 4

Figure 4. SPeAR diagram for Dublin 2010.

What Figure 4 shows is a relatively low level of drivers for even the most urbanized, central street in Dublin. When this is compared to that shown for London in Figure 2, the relatively low level of foundation reuse occurring in Dublin is easy to understand. In the Dublin case, only land values and historical constraints are proving major drivers.

SUMMARY AND CONCLUSIONS

This paper proposes a six-point set of quantitative inputs to better enable a use of a qualitative model for evaluation of foundation reuse considerations. A case his-

tory of a property in Dublin, Ireland's city center is used to illustrate the proposed system. Correlations to a previously published evaluation of London would seem to justify its further consideration as a formal system. While the model addresses planning and environmental concerns, it does not include other fundamental requirements such as the condition of the foundations. Furthermore, in no case can a final decision be made without a proper and rigorous engineering inspection of the site and any existing structures and their foundations.

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