# Rethinking Brownfield redevelopment features: applying Fuzzy Delphi

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**Abstract**
A Brownfield is well described in various definitions and supported the idea to redevelop while indentifying numerous benefits for the society. Further on, the existing literature covers a broad range of different aspects of the Brownfield redevelopment thus elaborating different features. Still at present, there is no overview of the Brownfield features from the perspective of the real estate that focuses on the physical characteristics of the place and legal - financial part of the property, two fundamental elements of the development. At first this paper contributes with the literature survey that was deployed based on this perspective. Additionally, it focuses on the features relevant for the Brownfield Redevelopment that served as an input for the Fuzzy Delphi technique that derived from the traditional Delphi method and Fuzzy Set Theory. The survey was deployed among the experts that are grouped by specific goals and tasks. This paper aims to give an answer to the question if the different groups value the relevance of the Brownfield Redevelopment features same or not and what are they? Fuzzy Delphi technique is considered as an excellent tool to gather and abbreviate information for realizing the key features of the Brownfield redevelopment. This technique benefits on the operational dimension as well since accessing the relevant information through the huge database is often not accessible due to the different reasons.

**Key words:** Brownfield Redevelopment Features, Fuzzy Delphi

## 1. Introduction

"A Brownfield site is any land or premises which has previously been used or developed and is not currently fully in use, although it may be partially occupied or utilized. It may also be vacant, derelict or contaminated. Therefore a Brownfield site is not available for immediate use without intervention" (Alker et al. 2000). This definition is used in this paper because it summarizes previous existing definition in Europe (CABERNET 2002; POST 1998) and also address US examples (USEPA 1996; Yount 2003). As a special case by this definition this paper will focus on the Brownfields that are located only in the urban area regarding both the urban land and the buildings.

One of the biggest challenges in European urbanization is the redevelopment of the Brownfields. For instance, in the Netherlands, approximately 27,500 hectares out of the total gross stock of industrial areas (79,800 hectares), most spread type of the Brownfield, was obsolete in 2007 in the Netherlands (Schuddeboom et al. 2007). In Germany there are 128,000 indentified hectares, going up to the figures of 800,000 and 900,000 hectares within Poland and Romania (Oliver et al. 2005). Numerous authors (Chen et al. 2009; NRTEE 2003) argue that the restoration and redevelopment of Brownfield can provide a range of economic, social, and environmental benefits. Leaving them unmanaged brings the losses of the economic opportunity to the community in which they are present. Some of the benefits are: better environment quality, provision of land for housing or commercial purposes, creation of employment opportunities, and especially a reduction in the pressure on urban centers to expand into Greenfields. The necessity to deal with these often complex environmental, economic, legal, social, and land use issues for a given property may explain why Brownfield problems are not easily resolved.

As the first step to resolving stated issue, this research paper structures and identifies the most significant features. Firmly, existing literature misses the place and property perspective on this task.

Additionally, the literature lacks the attention on the diverse expert's group that indicates the importance of certain features. That directly influences the derived list of the most important features.

Depending on a developer type the assessment of the key Brownfield site features for the promising development could vary. Similarly, the land use patterns would differ depending on the party(ies) that initiated development. Additionally, the indication of the most important features severely depends on the background of the decision problem or the given situation in specific time.

Due to the human factor in evaluation, specifically the importance of the set of features, a type of the uncertainty is present. There are three basic types of information uncertainty, namely ambiguity, discord and fuzziness (Klir and Yuan 1995) that are covered by numerous uncertainty theories. In regard to stated problem, we specified the fuzziness or vagueness as crucial to get a clear overview of the real estate features. This uncertainty results from the lack of definite or sharp distinctions. For this problem situation we employed the Fuzzy Set Theory implementation on the classical Delphi method (Murray et al. 1985).

In this paper, chapters follow this order. Chapter 2 elaborates existing literature addressing relevant features for the urban development. Chapter 3 describes theoretical background, benefits, and practical computations of Fuzzy Delphi Method. Chapter 4 documents the findings from the survey amongst urban development experts. Chapter 5 concludes previous results and elaborates the importance of having such a rigorous procedure that not requires a huge database.

## 2. Features - Literature highlights

A literature review provided numerous factors influencing urban development and it was a starting point for the survey. Since, the existing literature is relatively extensive it enable us to shorten the brainstorming phase in suggested method.

We want to highlight the most important articles out of many describing in detail the Brownfield features. These are: (Alberini et al. 2005; Nijkamp et al. 2002; Syms 1999; Thomas 2002). Lists with descriptions of the features are provided in Appendix.

The named features elaborated in Brownfield literature evidently miss the real estate perspective. Therefore, the important features are cut down and the proper hierarchy structure is lacking because it does not support place and property distinction that finally leads to difficulties when weighting the features. Additionally, we contributed to identify the most important features by incorporating experts' diversity.

## 3. Methodology - Fuzzy Delphi Method

Fuzzy Delphi derived from the traditional Delphi method and fuzzy set theory. Various researchers contribute to the origin of this approach (Hsu and Chen 1996; Ishikawa et al. 1993; Murray et al. 1985; Noorderhaven 1995). The traditional Delphi method questionnaires have tendency that both the questions and the answers are indistinct. Additionally, there is a notable problem to solve the fuzziness in expert consensus in group decision making. Murray, Pipino & Gigch (1985) first proposed the application of Fuzzy theory to the Delphi method. Further on elaborated by (Ishikawa et al., 1993) that used the Maximum-Minimum Method together with cumulative frequency distribution and fuzzy scoring to compile the expert opinions into fuzzy numbers. The expert prediction interval value was then used to derive the fuzzy numbers, resulting in the Fuzzy Delphi Method. Noorderhaven (Noorderhaven 1995) indicated that applying the Fuzzy Delphi Method to group decision can solve the fuzziness of common understanding of expert opinions.

This method is based upon group thinking of the qualified experts that assures the validity of the collected information. The benefits of using Fuzzy Delphi Method (FDM) underline practical matter such as saving the survey time and reduce the number of questionnaires. More important is that it takes into account the fuzziness that confronts every survey process assuring that there is no misinterpretation of an expert's prime opinion thus genuinely reports their responses. In this way the efficiency and quality of questionnaires are improved.

The triangular membership function is the most frequently used function. Although other functions like trapezoid, quadratic, Gaussian may contain more information. We decide upon trapezoidal fuzzy number. This study use FDM with geometric mean model (Klir and Yuan 1995) to find a common group understanding of the importance of identified attributes. The steps follow:

1. *Validate predefined list of the features* - In the first questionnaire the participants were ask to approve and add missing features from the initial list derived from literature survey. This step refers to brainstorming phase in classical Delphi method (Delbecq et al. 1975; R. Schmidt et al. 2001).

2. *Collect opinions of expert groups* - Find the evaluation score of every attribute given by each expert by using four points in a row from 1 to 10 associated with linguistic description in the second questionnaires. For example instead of giving an attribute 'proximity' only one weight (8 for example) participants will give four different weights instead within two ranges, maximal and optimal. At first, for the maximal range, they could say that its weight is from 6 to 10. Depending on case and different market condition a same feature has different importance. Sometimes the importance vary in its extreme (the range between two weights is very big) and sometimes vary slightly (the range between two weights is small). Secondly, for the optimal range, we could say that its importance vary from 8 to 9. And this range weight is based upon all experts' experience during different cases, market conditions, etc. To recapitulate, instead of giving just weight (8) experts will provide us with a four weights in range (6,8,9,10). In this way we have much more information from our respondent and making our data analysis more reliable.

3. *Set up overall trapezoidal fuzzy number* - Calculate separately the evaluation of each feature given by experts and derive the overall trapezoidal fuzzy number of the specific feature. At first, the evaluation value of a single feature by a single expert is expressed as trapezoidal fuzzy number $\widetilde{w_{ij}} = (a_{ij} + b_{ij} + c_{ij} + d_{ij})$ for the evaluation value of feature *j* of *m* feature by expert *i* of *n* experts where *i=1,2,…,n* and *j=1,2,…,m*. By using a general mean model (Klir and Yuan 1995) we estimated overall value of a feature that is $\widetilde{w_j} = (a_j + b_j + c_j + d_j)$ where:

$$a_{j=\min_j\{a_{ij}\}}, \qquad b_{j=\frac{1}{n}\sum_{i=1}^{n} b_{ij}}, \qquad c_{j=\frac{1}{n}\sum_{i=1}^{n} c_{ij}}, \qquad d_{j=\min_j\{d_{ij}\}}$$

4. *Defuzzification* - The purpose is to turn overall trapezoidal numbers into a single real number. We use simple center of gravity method (Klir and Yuan 1995) for fuzzy weight $\widetilde{w_j}$ of each attribute to derive a definite value $S_j$ where *j=1,2,…,m*.

$$S_{j=\frac{a_j + b_j + c_j + d_j}{4}}$$

5. *Screen evaluation indexes* – At the end a delineation of numerous features can be achieved by setting the threshold $\alpha = 7{,}00$. The principle follows:

If $S_j \geq \alpha$, then No. *j* feature is very important
If $S_j < \alpha$, then No. *j* feature is less important

The reasoning for setting this threshold value is drawn from experts' weighting results represented in Figures 1-4. At Figure 1, overall ratings, you can notice that just two features pass over this threshold-line and they are significantly weighted higher than the other features. Relatively same number of features can derive by setting this same threshold value among different expert groups that is necessary for their comparison. And finally, the derived number of very important features is manageable for

many modeling techniques (ex. Conjoint Analysis) that can give more insight on various experts' group preferences.

**4. Survey design and results**

As described in methodology steps this survey consist of two questionnaires. Developers with different background were asked to participate. The variety of the relevant experts in the brainstorming phase assures that all relevant features are collected. That is a suggestion by numerous authors exploring and using the Delphi method (Delbecq et al. 1975; R. Schmidt et al. 2001).

The total number of contacted experts in the first step is 95 amongst them 45 experts replied thus making the 47.37% response rate. This feedback is regarded as sufficient and genuinely reports the conditions in urban development practice. Experts were contacted personally by phone and asked to participate in two follow-up on-line questionnaires. The experts choose their discipline from well described options regarding distinct goals and objectives. Therefore there were developers with two different disciplines thus resulting in 52 distinct expert opinions. The distribution is as follows: independent developer 23.08%; contractor 19.23%; investor 7.69%; housing association 9.62%; financial institution 5.77%; architect 0.00%; government agencies 23.08%; academia 11.64%.

The finial outcome of the first questionnaire is a validated list of features divided in three aspects: Place, Legal and Finance. The features derived from literature were judged by the experts. Some of them were slightly modified and new ones were added based on the answers from the first questionnaire. For example, features accessibility initially was split in two features: one for the car and the other for public transport. Since same respondents included both feature and some added accessibility by "slow" traffic, we decided to merge them in one feature. An example for newly added feature is "embedded into the urban fabric" that came up latter as one of the most important features. We can conclude that this step was very important. The brought –up features and their descriptions follow in Table 1.

| Aspect | Code - Feature | Description |
|---|---|---|
| Place | A1 - Proximity | Site proximity to the key city locations, measured in range (km). |
| | A2 - Accessibility | How good is the access to the site by *car* (measured by the range (km) from high-way and traffic flow), by *public transport* (measured by walking distance (minutes) from the stop and their number), and by *slow traffic* (existence of walking and biking path). |
| | A3 - Usage | Usage of the Brownfield site can be described within three levels. Partially used (not used part regarded as Brownfield); Vacant (land on which some previous productive use has ceased for a significant period of time); Derelict (land so damaged by industrial or other development that it is incapable of beneficial use without treatment). |
| | A4 - Embedded into the urban fabric | Extent to which the development area can be integrated into the urban fabric. |
| | A5 - Contamination level | It constitutes of two elements. At first, it is the uncertainty level of the site contamination. Secondly, it regards the land contamination level by approved institutions and the types of buildings that are automatically regarded as Brownfield when not in use. |

| | | |
|---|---|---|
| | A6 - Skyline | How do surroundings (buildings, greenery) look like (ex. poor, fine, extraordinary) at present time. |
| | A7 - Land Relief | Third or vertical dimension of land surface (flat , slopes, hills) |
| | A8 - Soil properties | Relate to sand, hydrology and drainage patterns, grading or fill required to build, piles needed. |
| | A9 - Flora & Fauna | Presence of vegetation and endangered species. |
| | A10 - Heritage | Existing structures that are not allowed to be demolished as a cultural monument. |
| | A11 - Archeological site | The extent to which archeological excavations are necessary or they are already identified on the site. |
| | A12 - Current neighborhood image | The sum of beliefs, ideas and impressions that people have of that neighborhood at present. |
| Legal | A13 - Ownership | Describe the fragmentation level of the ownership of the land/buildings. |
| | A14 - Administrative support | Transparency and perceptions of continuity in governance, politics and the bureaucracy. Making potential to make various PPP. |
| | A15 - Approval process | Time and number of the documents needed to start up construction phase of development. |
| | A16 - Support of local residents/users | The extent to which the present inhabitants and / or users of the area support the redevelopment. |
| | A17 - Support of surrounding residents/users | The extent to which the surrounding area inhabitants and / or users support the redevelopment. |
| Finance | A18 - Governmental incentives | Various government incentives for development (tax shelter, subsidies) expressed as the percentage (%) of total investment. |
| | A19 - Potential for different land-use | The potential amount of $m^2$ that each land-use may be realized (manipulate land-use ratio, density, height) |
| | A20 - Value capturing | Various forms of taxes after the development. |
| | A21 - Liquidation option | The extent to which cost previous owners and / or users can be recovered. Who has the Legal obligation to clean or mange land or property. |
| | A22 - Current Real Estate Value | Present value of the land and property (appraisal). |

Table 1. List of the Brownfield features derived after brainstorming phase.

This list is used as an input for the second questionnaire in which experts rated the features within three panels. In the second questionnaire we used lower number of respondents, exactly 35 experts with the overlapping discipline attended. Structure of the participants is as follows: 11 independent developers (26.19%); 12 contractors (28.57%); 4 investors (9.52%); 2 housing association (4.76%); 1 financial institution (2.38%); 0 architect (0.00%); 6 government agencies (14.29%); 6 academia (14.29%). State of the art literature (Delbecq et al. 1975; R. C. Schmidt 1997; R. Schmidt et al. 2001)suggests the number of 10-15 participants from a homogeneous group could give more reliable results. Therefore, we have sufficient participants for two expert groups, independent developers and contractors. We regarded experts in these groups as homogeneous since the companies that were involved are the biggest developer companies in the Netherlands (NEPROM 1974). Additionally, the

experts asked to participate were drawn just from the project development departments of the company. All governmental agencies have the same task and position in urban development in general therefore they were regarded as homogeneous as well. Table 2 represents the fuzzy numbers (W), ratings - defuzzified number (S) and rank for every feature including the opinions of all 35 experts.

| **Aspect** | **Code - Feature** | W = (a,b,c,d) | | | | S | Rank |
|---|---|---|---|---|---|---|---|
| | | a | b | c | d | | |
| Place | A1 - Proximity | 1,00 | 6,94 | 8,09 | 10,0 | **6,51** | 6 |
| | A2 - Accessibility | 1,00 | 6,97 | 8,00 | 10,0 | **6,49** | 7 |
| | A3 - Usage | 1,00 | 6,12 | 7,29 | 10,0 | **6,10** | 13 |
| | A4 - Embedded into the urban fabric | 2,00 | 6,89 | 7,89 | 10,0 | **6,69** | 3 |
| | A5 - Contamination level | 1,00 | 6,55 | 7,52 | 10,0 | **6,27** | 11 |
| | A6 - Skyline | 1,00 | 4,03 | 5,53 | 10,0 | **5,14** | 21 |
| | A7 - Land Relief | 1,00 | 3,34 | 4,46 | 10,0 | **4,70** | 22 |
| | A8 - Soil properties | 1,00 | 4,89 | 5,97 | 10,0 | **5,46** | 20 |
| | A9 - Flora & Fauna | 1,00 | 5,51 | 6,51 | 10,0 | **5,76** | 19 |
| | A10 - Heritage | 1,00 | 6,50 | 7,50 | 10,0 | **6,25** | 12 |
| | A11 - Archeological site | 1,00 | 5,83 | 7,00 | 10,0 | **5,96** | 18 |
| | A12 - Existing neighborhood image | 1,00 | 5,91 | 7,03 | 10,0 | **5,99** | 17 |
| Legal | A13 - Ownership | 1,00 | 6,73 | 7,85 | 10,0 | **6,39** | 9 |
| | A14 - Administrative support | 4,00 | 7,54 | 8,63 | 10,0 | **7,54** | 2 |
| | A15 - Approval process | 1,00 | 6,82 | 7,97 | 10,0 | **6,45** | 8 |
| | A16 - Support of local residents/users | 1,00 | 6,69 | 7,80 | 10,0 | **6,37** | 10 |
| | A17 - Support of surrounding residents/users | 2,00 | 6,77 | 7,74 | 10,0 | **6,63** | 4 |
| Finance | A18 - Governmental incentives | 1,00 | 6,03 | 7,29 | 10,0 | **6,08** | 14 |
| | A19 - Potential for different land-use | 3,00 | 8,29 | 9,17 | 10,0 | **7,61** | 1 |
| | A20 - Value capturing | 1,00 | 6,03 | 7,17 | 10,0 | **6,05** | 15 |
| | A21 - Liquidation option | 1,00 | 6,11 | 7,00 | 10,0 | **6,03** | 16 |
| | A22 - Current Real Estate Value | 2,00 | 6,57 | 7,60 | 10,0 | **6,54** | 5 |

Table 2. Overall Rating of the Brownfield Redevelopment features.

In overall ratings, two features are significantly more important than the others: potential for different land-use and administrative support. Surprisingly, the contamination level, characteristic for many Brownfields, is not ranked in the first ten features as well as the liquidation option a financial instrument connected to the land contamination.

It is interesting to compare how different groups rated the features (Figures 1-4). Evidently, they have different priorities represented in their ratings thus we can regard them as truly independent groups. Only two features, potential for different land-use and administrative support, has been evidenced as the most important for all three groups (Figure 2-4). This fact is also represented in overall ratings (Figure 1).

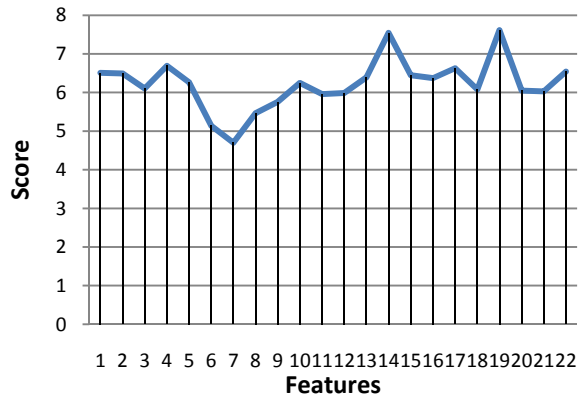


Figure 1. Overall Rating

Threshold value - 7,00:
1 - A19 - Potential for different land-use - 7,61
2 - A14 - Administrative support - 7,54

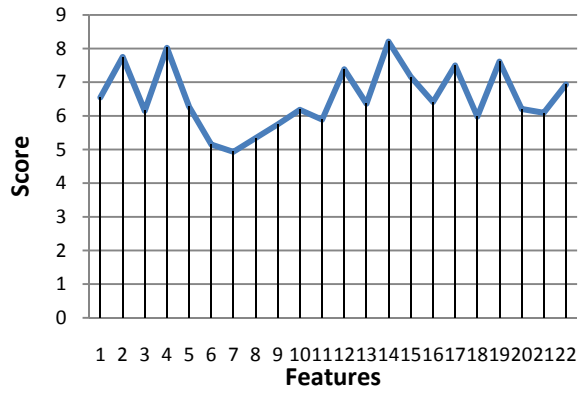


Figure 2. Rating of Independent developers

Threshold value - 7,00:
1 - A14 - Administrative support - 8,20
2 - A4 - Embedded into the urban fabric - 8,02
3 - A2 - Accessibility - 7,75
4 - A19 - Potential for different land-use - 7,61
5 - A17 - Support of surrounding users - 7,50
6 - A12 - Existing neighborhood image - 7,39
7 - A15 - Approval process - 7,16

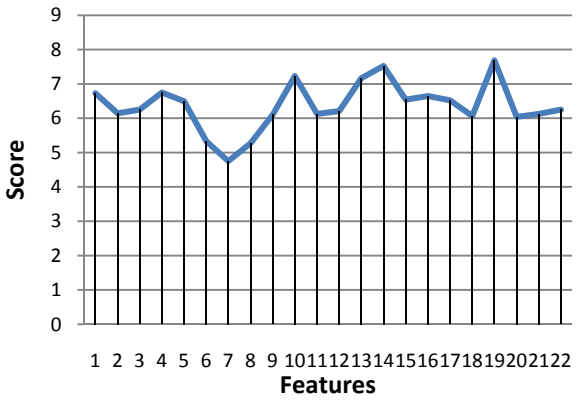


Figure 3. Rating Of Contractors

Threshold value - 7,00:
1 - A19 - Potential for different land-use - 7,69
2 - A14 - Administrative support - 7,52
3 - A10 - Heritage - 7,23
4 - A13 - Ownership - 7,17

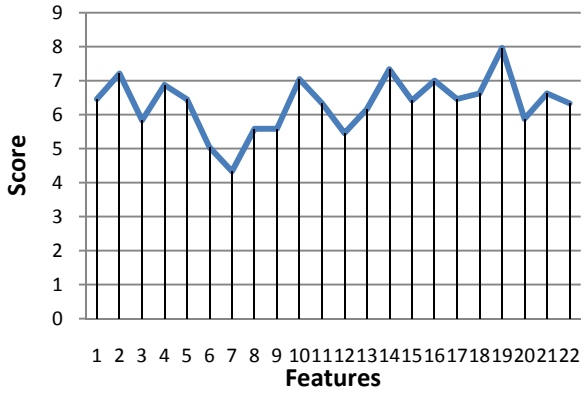


Figure 4. Rating of Governmental Agencies

Threshold value - 7,00:
1 - A19 - Potential for different land-use - 7,96
2 - A14 - Administrative support - 7,33
3 - A2 - Accessibility - 7,21
4 - A10 - Heritage - 7,04
5 - A16 - Support of local users - 7,00

## 5. Conclusions

This paper provides a new insight in the selection procedure and importance of the Brownfield redevelopment features. It brings a new insight in the importance and existence of the features relevant for the real estate practice especially. That was accomplished by systematically introducing appropriate hierarchical structure and including experts from the practice to validate it. Therefore features such as Embedded in the urban fabric and administrative support that are represent in every panel are in some cases completely missed or regarded as not that important (see appendix).

Additionally, this paper shows that diversification of the expert groups is necessary in order to incorporate all features for the Brownfield redevelopment. Also, it gives the quantitative proof (by comparing their ratings) of existing diversities among experts groups and their priorities. One of the things mostly surprising, the feature "embedded in to urban fabric" is regarded as very important by independent developers and not by governmental agencies and some could assume.

Using Fuzzy Delphi helps resolving uncertainty about expert sharp distinction in their weighting on the features. With this method we are sure of getting better quality results from the survey. Operationally, this method dramatically shortens the time needed for the final results compared to classical Delphi. Still there are place for the progress of this method. Research perspective would be more sophisticated aggregation method that is less sensitive on single response. Also, enlarging the number of governmental agencies' representatives will give more reliability of concluding on this group priority of the Brownfield redevelopment features.


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## Appendix - Literature highlights

| Alberini et al., 2005 - attributes for the site choice |
|---|
| • Site contamination<br>• Transportation network present in 20 km<br>• Certificate of no further action<br>• Oversight by governement agency<br>• Clean up standards<br>• City within 20 km<br>• Governemnt finacial insentives as % of total value |
| Nijkamp et al., 2002 - 18 cases with their stagnation causes in the Netherlands |
| • Procedures<br>• Co-ordination problems<br>• Complexity and juridical responsibility<br>• Delay of sanitation without statement of reason<br>• Co-ordination problems, procedures and unforeseen work<br>• Co-ordination problems, communication<br>• Procedures, indeterminacy about future use of location<br>• Waiting on the final date of a new regulation |

- Long lasting negotiation process
- Problems with finances, use of national legal procedure
- Unexpected sources of pollution, change in destination of location, co-ordination problems
- Problems with noise annoyance contours
- Waiting on permission for pulling down old buildings
- Procedures
- Problems with finances, co-ordination problems
- Co-ordination problems, petitions

Syms, 1999 - Most important factors, priority list, UK

Top 10 factors

- Migration of contaminants
- Investigate the quality of the soil
- Human health risks
- Tax incentives for remediation of'brownfields
- Investigate quality of subsoil
- Tax ownership of 'brownfields'
- Attractiveness and image of the site
- Tax development of 'greenfields'
- Insurance cover
- Financial standing of organisation

Bottom 10 factors

- Air quality
- View from adjoining land
- Redevelop 'brownfields' in areas of ample land supply
- A large development site
- Availability of compulsory purchase powers
- Other social issues
- Environmental risk of transporting waste
- An efficient railway network
- Fuel consumption in remediation treatment process
- Political composition of the local authority

Thomas, 2002 - Brownfield site selection, weighting and ranking criteria (from more to less important)

Local government ranking criteria

- Site conditions
- Compatibility with local land use controls
- Current use compatibility with local land use plans
- Utility infrastructure capacity
- Telecommunications infrastructure
- Transportation infrastructure
- Comaptibility with surrounding land uses

County BRA ranking criteria

- Financial incetives
- Labor resources
- Environement risk compliance
- Market conditions

- Land re-use preferences
- Proposed uses - ranges of acceptability

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