STRIVING FOR ENVIRONMENTAL EXCELLENCE BY CONTROLLING FUTURE BROWNFIELDS IN AFRICA SPECIFICALLY FOR ETHIOPIA: A GREY INCIDENCE DECISION-MAKING APPROACH

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ABSTRACT

Purpose: The increasing African population, and economic growth leading to urbanisation, continues to increase the need to redevelop brownfields as a strategy of encouraging the sustainable development of cities, in particular in Ethiopia. In the 21st century, most African countries have adopted an industry-led economy to support an ever increasing population growth and urbanisation; this involves using large volumes and types of hazardous chemicals. Accidental spills and damping of these chemicals leads to environmental contamination and, subsequently, to brownfields. This research reviewed key dimensions of the definition of brownfields

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in developed countries, and recommends a consensus-based pioneer brownfield definition and proposals for brownfield redevelopment guidelines in Ethiopia. In addition, the research highlights the framework based on a grey incidence decision-making approach to manage brownfields in African countries by taking Ethiopia as case example. The grey incidence decision-making model integrates multiple factors such as economic, social, environmental, technical and associated risk, and provides an effective decision-making and management tool for environmental practitioners and government agencies.

Design/methodology/approach: Questionnaires were used to collect data on terms and definitions of brownfields. The questions were prepared on the basis of currently used definitions developed by a number of developed countries. Moreover, this study utilises a grey incidence decision-making approach to help in management and decision-making for the implementation of brownfield redevelopment projects in the remediated sites.

Findings: Standard definitions and essential guidelines for brownfield redevelopment are proposed for the Ethiopian context. The grey incidence decision-making approach is applied for the evaluation of brownfield redevelopment projects in the remediated sites. The research findings were tested and verified using literature data and surveys from major stakeholders. In addition, a framework is proposed to control future brownfields for African countries by taking Ethiopia as case example.

Originality/value: This research stresses the significance of urban structure to address sustainable development, and the need to consider redevelopment of brownfields and identify the potential for a specific government policy framework. In addition, the research recommends brownfield redevelopment support from international development programmes. The new research provides the best opportunity for Ethiopia and Africa at large:

- to devise an urban land policy and create a strategy to contribute social, economic, financial and environmental benefits;
- to provide a foundation to solve environmental issues by involving all major stakeholders, including community citizens, municipalities, environmentalists, government agencies and policy makers; and
- to serve as guidelines to transform brownfields into greenfields.

Focusing on the vision of striving for excellence and developing smart cities, the concrete application of a study framework to manage brownfield problems will help to remove hazardous substances and improve the quality of life. The fair participation of all stakeholders, learning from the lessons of developed countries, and improved urban infrastructure will help Ethiopia and Africa at large.

Keywords: brownfields; environment; contamination; research framework; guidelines; urbanisation; Sustainable Development; grey incidence decisions

INTRODUCTION

Albert Einstein said that "intellectuals solve problems; geniuses prevent them" (Ushakov, 2007). Unlike in the industrialised world, the concept of brownfield is not widely recognised on the African continent as a whole and particularly in Ethiopia. However, with the increasing population growth and economic development in Ethiopia, the significant role of brownfield redevelopment will be investigated as a strategy of encouraging sustainable development in Ethiopian cities. From the developing countries point of view, brownfield sites are the result of waste materials from air pollution control facilities, wastewater treatment plants, community activities, agricultural operations, mining, commercial, industrial and other interrelated problems, such as urban sprawl and residential segregation (Van Rooyen, 2001). These environmental issues are creating hurdles in achieving environmental excellence in Ethiopia. Brownfield redevelopment projects (BRPs) are the practical solution to achieving environmental excellence and sustainable cities in Ethiopia.

In the present circumstances, brownfield problems are capturing a deepening concentration of government policy makers, real estate developers, investors, and researchers. There are a suspected 500,000—600,000 contaminated brownfield sites in the United States (Simons, 1998), with around 362,000 in Germany (National Round Table on the Environment and the Economy, 2003). There is still an ambiguity about the common understanding of brownfields and their basic concept. However, an initial effort has been made by the United States Environmental Protection Agency (USEPA), who defined brownfields as underutilised land where redevelopment or expansion is not an easy task due to real or perceived environmental contamination (van Vliet, 2003). There is different perspective about the definition of brownfield in the UK planning context. In the UK, a brownfield site can be any kind of property that has been previously developed for non-rural purposes (Alker et al., 2000).

It is clear from the above definitions that brownfield land is that having real or perceived contamination problems, affected by previous use, ruined and underused properties in urban areas that require redevelopment for sustainable development. Worldwide, brownfield redevelopment land strategy is taken as sustainable land use strategy due to the focus on the environmental and health protection; they have a major role in the contribution towards economic development and community revitalisation (Brebbia, 2006; De Sousa, 2003, 2005; Dixon, 2007).

In order to achieve the sustainable development goal, the Ethiopian government is collaborating with different international private and governmental agencies in order to create a green economy and save the country from the negative effects of environment and conventional development. Considering all the points, such as greater growth in population, urban growth, and development through the green economy, the Ethiopian government is trying to encourage the city municipalities to adopt brownfield redevelopment as a strategy for sustainable development.

The countless benefits of brownfield redevelopment for sustainable development make brownfields significant in the eyes of developing countries. The major benefits of brownfield redevelopment have been described as including social, environmental, economics, improved quality life around the community, the minimisation of health threats by removing hazardous waste materials, the transformation of brownfields into greenfields in congested urban areas, housing facilities, employment opportunities in the surroundings and neighbourhood, payment of taxes and duties to government (De Sousa, 2006; Greenberg et al., 2001). Currently, BRPs are capturing more attention from policy makers due to the focus on environmental issues. They are also gaining deepening interest from different government agencies, financial institutions, environmental scientists, scientific research scholars, environment legal advisors and community citizens for the betterment of society (Eckerd and Heidelberg, 2015).

Different approaches from the social sciences and management fields have been used to deal with the environmental problems. An approach, named as a rough set approach, was employed by Chen et al. (2009) to solve problems related to brownfield redevelopment in urban areas. Another approach was used by Guo et al. (2010) to evaluate BRPs with multi-hierarchical grey evaluation modelling. For the evaluation of compound and financial benefits provided by BRPs, BenDor et al. (2011) utilised the system dynamic model. Chrysochoou et al. (2012) developed an index for evaluating different alternatives for brownfield sites, and focused on the strategic view of brownfield sites for the allocation of resources.

In a case study, the results of Schädler et al. (2013) show that a spatially explicit algorithm assessment of different indicators of sustainable development can successfully improve its application, comprehensiveness and reliability. Grey cluster methods can also be an effective way of dealing with the environmental issues related to renewable energy resources and climate change (Wang et al., 2014). Zhu et al. (2015) developed a framework for optimising and establishing an evaluation index for BRPs. Structural equation modelling was used in order to verify the effectiveness of the index with the help of a real world example. Furthermore, the further application of this index was recommended for the evaluation of brownfield projects, and the construction of guidelines for other researchers in the area of brownfield redevelopment. Although all these approaches were mainly utilised by developed countries, there is less attention in developing countries. Specifically, BRPs are at the development stage in Africa, and there is no focus by the Ethiopian Government specifically.

METHODOLOGY

A great deal of international literature was reviewed to create a foundation for defining brownfield in the Ethiopian context. However, there is no consensus-based universal definition of brownfield, and every country has its own definition and parameters of brownfield. For example, the US definition focuses on the presence of contaminants, while the UK definition focuses on previously developed sites in urban areas. Due to the unfamiliarity of the term brownfield in the Ethiopian context, this research is dependent on international literature to devise primary guidelines. Moreover, it was also difficult to take the appropriate population and sample due to lack of awareness about the brownfield problem. Therefore, multiple non-probability sampling techniques were used to solve the population and sampling issues.

Three sampling techniques including judgement, convenient and snowball, were utilised to simplify the data collection by following the guidelines of Nachmias and Nachmias (2008), as their research proves the significance of using multiple sampling techniques in research. The judgement sampling technique is useful to propose a sample based on researcher experience; the convenient sampling technique also increases the flexibility in data collection due to the involvement of multiple stakeholders. Data were collected from government employees working in environmental agencies and municipalities, private investors, community citizens, real estate agents, and academicians. A pilot test was conducted before the data collection by asking some basic questions related to brownfields and the transformation of brownfields into greenfields for environmental excellence. If the average score obtained by a respondent was up to mark, that respondent was considered an appropriate participant in the research.

A survey-based questionnaire consisting of two parts was developed to gather information. The first part was about different elements of brownfields that can be a part of the pioneer definition of brownfield in the Ethiopian context. Definitions developed by different countries were considered as a base, and different elements of brownfield (e.g. vacant, derelict, contaminated, underused, etc.) were included in the final questionnaire. A sample question related to the definition of brownfield redevelopment was, for example, is brownfield a location or land vacant for development. The second part includes questions related to the evaluation of brownfields. This study received support from the research of Hou et al. (2014), including social economic and ecological benefits of brownfield redevelopment, and Zhu et al. (2015), including health benefits, brownfield development policy, financial, public welfare policy. Although the reliability and validity of both questionnaires are appropriate, the analysis technique is different. As far as their studies are concerned, the Likert scale was utilised under the rigorous analysis technique of structural equation modelling. However, this study utilised the grey incidence approach to evaluate brownfield redevelopment projects.

Data were collected during the period July–December 2015. It took three months to collect data with 10 key members helping with the data collection. Masters' level students from three key Ehtiopian universities, Addis Ababa University, Mekelle University, and Awassa University, were hired for the collection of data. A nominal remuneration was given to them for keeping the ethical consideration of the research. Questionnaires were sent out to relevant stakeholders as mentioned above. From the 300 questionnaires that were sent out, only 221 completed questionnaires were returned; 79 respondents declined to complete the questionnaire as they were not aware of the term "brownfields" and were not in a position to complete the questionnaire.

This led to the conclusion that the above survey assisted us to extract the elements of brownfield definitions based on Potts and Cloete (2012), and on judgements of different stakeholders in Ethiopia as shown below in Figure 1:

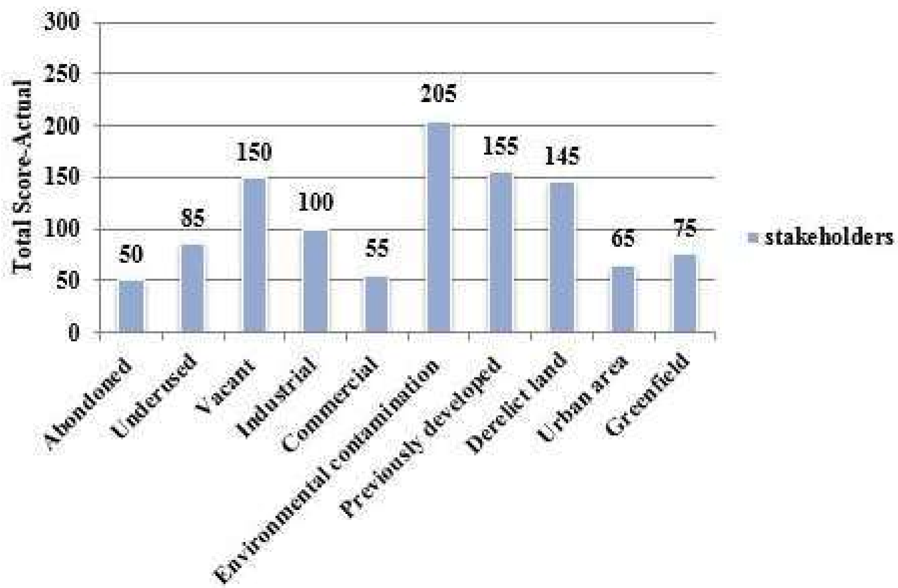

Figure 1 Elements of Brownfield Definitions

Source: Potts and Cloete, 2012

Brownfield Definition: an Overview

Generally, brownfield refers to underused, abandoned, derelict and often contaminated lands and premises, which can vary in terms of size and location. The first official definition of brownfields was proposed by the US Environmental Protection Agency (USEPA) as follows:

> *"Abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination"* (USEPA, 2002).

Similarly, in Europe, Ferber et al. (2006) defined brownfields as:

> *"Currently derelict or underused sites which have been affected by former uses of the site or surrounding land; they are mainly located in fully or*

partly developed urban areas and may have real or perceived contamination problems thus require intervention to bring them back to beneficial use" (Ferber et al., 2006).

However, this concept of brownfield does not work in the UK. According to the views of UK brownfield professionals, it is not necessary to have hazardous contaminants on the site. Michael Gwilliam, Director of the Civic Trust, stated that in the UK:

"Brownfield sites are buildings and land either now vacant or that could become vacant or suitable for development, during a relevant [development] plan period" (Gwilliam, 1997).

In France, it is taken as a different concept. Darmendrail (1999) reports that the French Ministry of Environment interprets brownfield as,

"A space that has been temporarily abandoned following the cessation of activity (agricultural, protoindustrial, service, processing, military defense, storage or transport) and that needs to be reclaimed for a future use." (Darmendrail, 1999)

Karin Freier of the German Environment Agency (Freier, 1998) has defined brownfield land as,

"Abandoned pieces of land, mainly in inner cities, which are often blocked for economic development due to their ecological and economic risks." (Freier, 1998)

An Australian expert web site (Plater-Zyberk, 1998) suggests that:

"A brownfield site is one which has been urbanised or used industrially, subsequently vacated and available for re-urbanisation." (Plater-Zyberk, 1998)

This definition implies that the site is urban and vacant, but it does not consider the condition of any buildings that might be on the site, nor does it incorporate any mention of land contamination.

Potts and Cloete (2012) devise a definition for South Africa described as;

"A brownfield site is infill land or premises where remedial action is required prior to redevelopment. It may also be vacant, derelict or contaminated. No specific land use is attributed." (Potts and Cloete, 2012)

Comprehensive literature reviews on the definitions of brownfields are used to propose a definition for the Ethiopian context, as well as draft the direction for preparation of the guidelines.

RESULTS

Proposed Definition of Brownfields for the Ethiopian Context

Potts and Cloete's (2012) definition in the South African context was the base to get a basic concept of brownfields in Africa. When considering the extensive international literature review and the research that was undertaken, one can conclude that it is essential to set out a common definition of the term brownfields. In proposing a definition, it is important that the Ethiopian context is taken into consideration in order to ensure that the proposed definition is broad enough to cover all relevant aspects. Special consideration has also been given to the questions that the respondents were asked in relation to the understanding and development of its definition in the Ethiopian context. It is obvious that there already exist various accepted categories of land use, for instance, vacant, derelict, and statutory contaminated land, which impinge on the definition of brownfield, and that this has the potential to cause confusion. Taking into account the factors related to brownfield in the Ethiopian context, and the internationally accepted definitions of brownfields, the following definition for Ethiopian usage is proposed:

> *"A brownfield site is land located in urban areas where remedial action is required for development or redevelopment. It could be vacant, derelict or contaminated; regardless of the quality of the land use."*

Proposed guidelines for brownfield redevelopment in Ethiopia

The following guidelines are merely based on the international literature, however, as previously mentioned, brownfield redevelopment is at the rising stage in Africa, particularly in the Ethiopian context. Indeed, it is important to only depend on the international literature. The following guidelines are proposed:

- In order to achieve environmental excellence by controlling future brownfields in Africa as a whole and particularly in Ethiopia, it is necessary to propose a common definition for the so called "brownfield". The proposed brownfield definition based on the Ethiopian context should be accepted and assimilated into Ethiopian National Environmental Policy for standard use.
- The Environmental Policy of Ethiopia should update its policy and legislation in order to assimilate a relevant policy on brownfield redevelopment, and the concerned bodies must set out brownfield redevelopment as a priority to achieve environmental excellence.
- The government of the Federal Democratic Republic of Ethiopia should place a high premium on the environmental excellence by controlling future brownfields.

To achieve this, risk assessments should be carried out for brownfield redevelopment; identifying the possible risks that might be associated with brownfield sites could assist in setting out a strategy about how to control future brownfield problems. Risks associated with brownfield sites could be:

- Environmental risks
- Public welfare risks
- Healthy risks, etc.

- Certainly, BRPs contribute a great deal to sustainable development goals. In order to set up excellent brownfield redevelopment planning, it is critical to include the following elements in the brownfield redevelopment planning database:
  - Identifying the site circumstances. For example, site size, location and boundaries.
  - Identifying the circumstance of land from different angles. For instance, previous land use, proposed future redevelopment planning options, and its ownership.
  - Identifying types of contamination. For example, groundwater contamination, soil contamination, air contamination.
  - Evaluating the potential cost of remediation and its geotechnical circumstances.
- In the present circumstances, governments are facing financial deficits; identifying potential stakeholders and supporting Public-Private Partnerships for brownfield restoration projects are the icing on the cake. Above and beyond that, allowing public participation and preparing conferences will add value in the achievement of environmental excellence by controlling brownfields in Ethiopia. Their advantages are infinitely greater than grateful. Such as:
  - satisfying community health concerns;
  - making sites with poor ground conditions economically viable;
  - minimise overall environmental damage;
  - restore the land as a contributing element of the local ecosystem;
  - prevent future contamination.

MANAGEMENT FRAMEWORK FOR BROWNFIELDS IN ETHIOPIA

Progress and Need to Control Brownfield Issues

Ethiopia is growing significantly in Africa; Africa's degree of urbanisation (the percentage of urban population in the total population) by continent in 2017 was 41%. Ethiopia's urban growth rate in 2017 was 20.2%. Although this is not the highest growth rate in the continent, it is greater than the least developed nations in the African continent. All these indicators can be seen in Worldometers (2017).

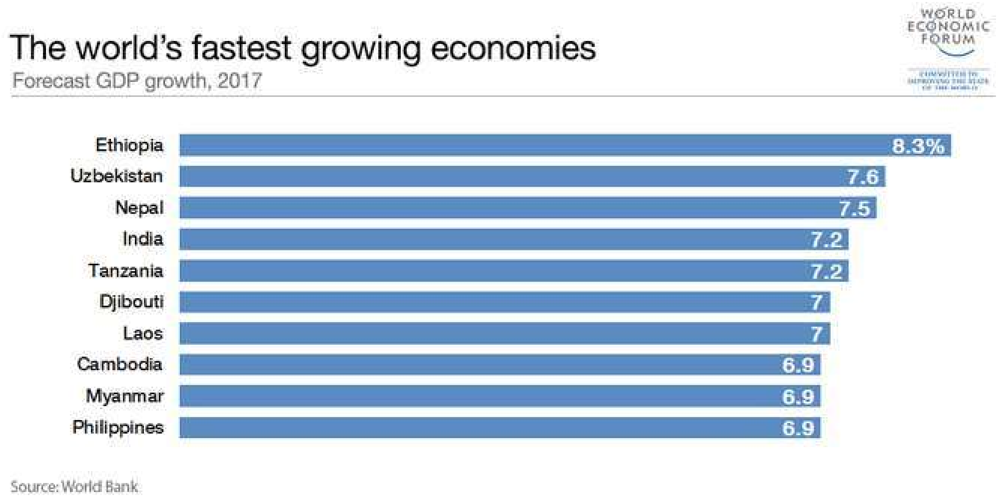

Figure 2 Ethiopian Progress and its Future Brownfield Challenges

The growth of Ethiopia is indicated by the report of the International Monetary Fund (IMF), as shown in Figure 2. The IMF ranked Ethiopia in the list of top five fastest growing economies in the world. The growth can be seen over the last decade, and it is continuously growing by 8.3% (Gray, 2017).

Every sector in the country is part of the country's growth. Ethiopia is also showing responsibility for the betterment of society and climate change. It has a very important role to play in the different environmental changes for a sustainable world. The major aim of Ethiopia at this moment is to gain the status of a middle-income country by adopting green economic strategies; this is also necessary for Ethiopia to progress. Following the conventional methods of development, this progress impacted adversely and caused a rise in GHG emissions (Federal Democratic Republic of Ethiopia, 2011). It also created a hazardous environment by utilising natural resources in an unsustainable way.

Therefore, as Ethiopia's economy and population growth continue to increase, the possible role of brownfield redevelopment will be investigated as a strategy for encouraging sustainable development in Ethiopia. Proposing a framework to control future brownfields could help to achieve the sustainable development goals in Ethiopia.

Proposed research framework to control future brownfields

The research framework has been prepared for African governments in a precise and simple way to understand the core source of brownfield sites and their health, environmental and public welfare risks. It also outlines an opportunity for African countries to encourage and facilitate the forming of legislation for brownfield redevelopment.

A project that is evaluated using a research framework, as shown below in Figure 3, illustrates the stages for controlling future brownfields in African countries by taking Ethiopia as an example. These stages are described below:

Stage 1 Summarises the core sources of brownfield sites. In this phase, it is mentioned that the possible source of brownfield sites is solid waste due to improper land administration. According to the international context, solid waste means any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility, and other discarded materials including solid, liquid, semi-solid, or contained gaseous material, resulting from industrial, commercial, mining and agricultural operations, and from community activities (Department of Environmental Conservation, 2017). From this work, African countries can learn and be aware of the possible sources of brownfields sites.

Stage 2 Establishes policy for brownfield redevelopment and includes a relevant policy of brownfield redevelopment on the Ethiopian National Environmental Policy. Ethi-

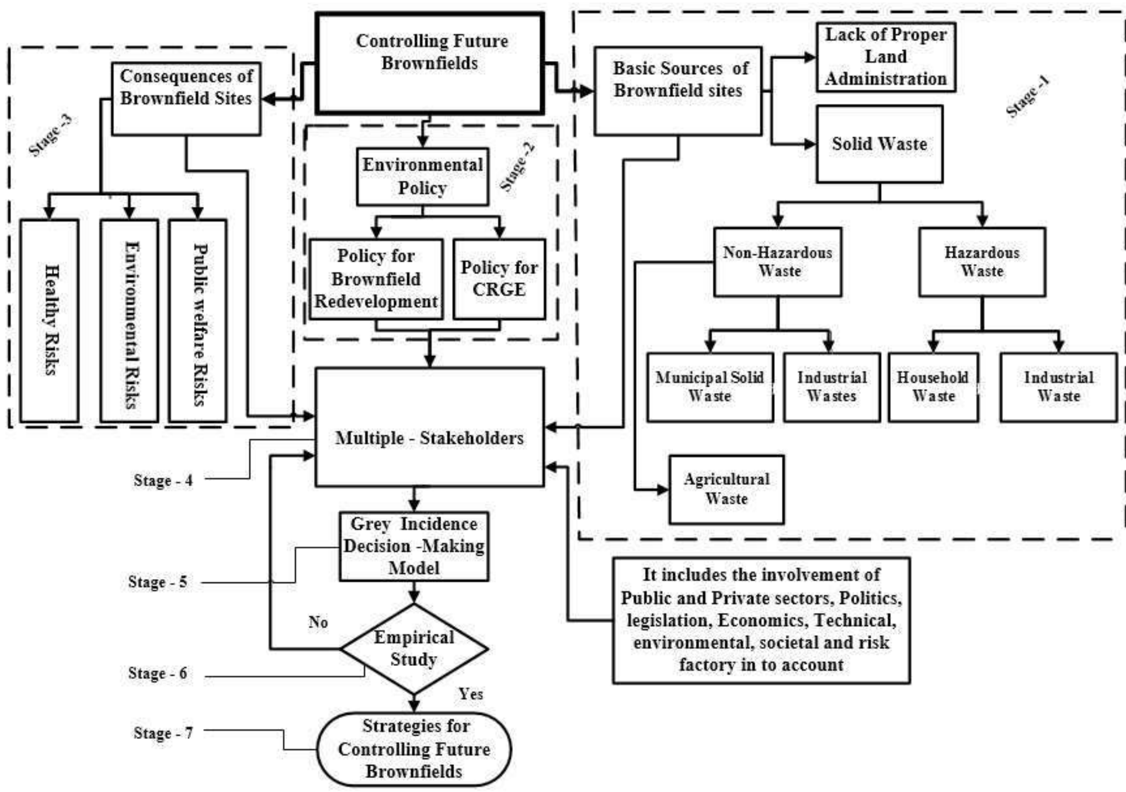

Figure 3 Evaluating Project-using a Research Framework for Controlling Future Brownfield

Source: Devised by authors

opia is experiencing the effects of climate change. In addition to the direct effects, such as an increase in average temperature or a change in rainfall patterns, climate change also presents the necessity and opportunity of switching to a new sustainable development model.

The Government of the Federal Democratic Republic of Ethiopia has therefore initiated the Climate-Resilient Green Economy (CRGE) initiative to protect the country from the adverse effects of climate change, and to build a green economy that will help realise the country's ambition of reaching middle-income status before 2025 (Federal Democratic Republic of Ethiopia, 2011). Therefore, establishing a policy for brownfield development will accelerate Ethiopia's vision of achieving middle-income status by 2025 in a climate-resilient green economy (CRGE).

Stage 3 Summarises and analyses the risks and consequences of brownfield sites. Through this work, African countries can learn and be aware of the risks and consequences of brownfield sites.

Stage 4 Indicates the multiple stakeholder's involvements in the evaluation system. The evaluation system will include criteria from the public and private sectors, political, legislative, economic, technical, environmental, and societal and risk factors, and take the different characteristics of stakeholders into consideration within the context of a project's full life span. While establishing an evaluation criteria system, one has to take every factor into consideration, and must be aware that the factors will change together with the different phases of the full life span of the projects (Zhu and Hipel, 2007).

Stage 5 Establishes a grey incidence decision-making model for brownfield redevelopment. An illustrative example is prepared in the next section to show how the proposed grey incidence decision-making model works. The decision-making process starts from an overview of the situation, from which three alternatives, A) industrial park planning, B) commercial centre planning, and C) real estate planning, are identified for further evaluation. Above and beyond that, the grey incidence decision-making approach is selected because it is a convenient approach to utilise, regardless of the sample size. In addition, the amount of computation assimilated is small and can be succeeded classically, without the difficulty between quantitative and qualitative conclusions (Gebreslase and Zhu, 2016). The process of a grey incidence decision-making model will be explained in detail below in the next section.

Stage 6 Verifies the established grey incident decision-making model through empirical studies.

Stage 7 Recommends strategic opinions for controlling future brownfields to African countries based on the obtained analytical results.

BASIC CONCEPTS OF THE GREY INCIDENCE DECISION-MAKING APPROACH

The grey system theory and application is well studied and applied around the globe in different disciplines. Over the past 30 years, it has been a well-known theory in the area of artificial intelligence; as a result it has attracted a wide range of researchers from the four corners of the world. The grey relation analysis approach is employed by Delcea et al. (2012), in shaping the relationship between a firm's situation, its symptoms, the bankruptcy syndrome and the causes that led to a certain situation. A new structure grey forecasting model, NSGM (1, 1), is proposed by Zeng et al. (2017) to forecast the trend of China's total energy consumption.

Grey incidence analysis was used by Zhan and Liu (2015) to optimise agricultural industrial structure and distribute the ratio of various inputs in agriculture, farming, forestry, animal husbandry and fishery, so as to improve the GPA of Huangshan City.

Above all, grey system theory mainly deals with uncertain systems, mini samples and poor information. Therefore, its application assimilates industry, environment, ecology, agriculture, economy, biological protection, medicine, and management. In addition, remarkable projects have been completed successfully with grey system theory, including; regional economic planning for several provinces in China, analysing the agricultural economy in China, forecasting yields of grain for some provinces in China, and building a diagnosis model available for medicine, to estimate economic effects (Liu et al., 2012). This led to the conclusion that the grey incidence decision-making approach is selected because it is a convenient approach to utilise, regardless of the sample size. In addition, the amount of computation assimilated is small and can be succeeded classically without the difficulty between quantitative and qualitative conclusions (Gebreslase and Zhu, 2016).

Let $X = \{X_{ij} = (a_i, b_j) \mid a_i \in A, b_j \in B\}$ be a set of circumstances, and $Z_{i_0j_0} = \left\{Z^{(1)}_{i_0j_0}, Z^{(2)}_{i_0j_0}, \ldots, Z^{(x)}_{i_0j_0}\right\}$ the optimum effect vector. If the circumstances corresponding to $Z_{i_0j_0}$, fulfils $Z_{i_0j_0} \notin x$, then $Z_{i_0j_0}$ is called the imagined optimum effect vector, and $x_{i_0j_0}$, is called the imagined optimum circumstance (Liu and Forrest, 2010).

Definition 1 Let M_i and M_j be two sequences having the same length (Zhang et al., 2012) represented as:

$$x_i = \int_1^n M_i^0 dt \qquad x_j = \int_1^n M_j^0 dt \qquad x_i - x_j = \int_1^n (M_i^0 - M_j^0) dt$$

Then: $\varepsilon_{ij} = \dfrac{1 + |x_i| + |x_j|}{1 + |x_i| + |x_j| + |x_i - x_j|}$ is known as an absolute degree of grey incidence between M_i^0 and M_j^0

Proposition 1 Let X be a set of circumstances and the effect vector of situation X_{ij} is $Z_{ij} = \{Z_{ij}^{(1)}, Z_{ij}^{(2)}, ..., Z_{ij}^{(k)}\}$ for i = 1, 2, ..., m.

1) When K is a purpose such that the larger its effect vector is the best, and it is defined as:

   $Z_{i_0 j_0}^{(k)} = \max_{1 \le i \le n,\, 1 \le j \le m} \{Z_{ij}^{(k)}\};$

2) When K is a purpose such that the closer to a fixed moderate value Z_0 its effect value is the best, and it is defined as: $Z = Z_0$; and

3) When K is a purpose such that the smaller its effect value is the best, and it is defined as:

   $Z_{i_0 j_0}^{(k)} = \min_{1 \le i \le n,\, 1 \le j \le m} \{Z_{ij}^{(k)}\},$

Then $Z_{i_0 j_0} = \{Z_{ij}^{(1)}, Z_{ij}^{(2)}, ..., Z_{ij}^{(k)}\}$ is the imagined optimum effect vector.

Proposition 2 Let $Z_{i_0 j_0} = \{Z_{i_0 j_0}^{(1)}, Z_{i_0 j_0}^{(2)}, ..., Z_{i_0 j_0}^{(k)}\}$ be the imagined optimum effect vector, ε_{ij} the absolute degree of grey incidence between Z_{ij} and $Z_{i_0 j_0}$, for i = 1, 2, …., n, j = 1, 2, ..., m. if for any $i \in \{1, 2, ..., m\}$ satisfying $i \neq j_1$, $\varepsilon_{i_1 j_1} \ge \varepsilon_{ij}$ always holds true, then $Z_{i_1 j_1}$ is a quasi-optimum effect vector and $X_{i_1 j_1}$ a quasi-optimum situation.

THE APPLICATION OF GREY INCIDENCE DECISION-MAKING TO CONTROL BROWNFIELDS IN ETHIOPIA

Numerical Example

A hypothetical scenario was developed in order to apply grey incidence decision-making approach to control the brownfield issue in Ethiopia. The scenario assumes that government intends to clean up a brownfield site, and after the remediation of the contaminated site the government has to select the best development proposal from three planning options. For example, A) Industrial park planning, B) Commercial centre planning, and C) Real estate planning.

The decision-making process starts from an overview of the situation, from which three alternatives, A, B, and C are identified for further evaluation. Next, the government employs the evaluation index system derived completely from a literature review as shown in Table 1 (Zhu et al., 2015). Relevant stakeholders evaluate each alternative based on their own skills by filling questionnaires. The values from the questionnaires are then used as the input to a grey incidence analysis, which computes the absolute degrees of grey incidence; this example is used to demonstrate the proposed approach.

Let us denote the event of evaluating the proposed option models by a_1.

Then the events set is A = {a_1}.

There are three plans of the development options under consideration:

Plan 1: building an industrial park which is considered as counter-measure A;

Plan 2: building a commercial centre, which is considered as counter-measure B;

Plan 3: building a real estate, which is counter-measure C.

So, the set of counter-measures is:

B = {b1, b2, b3}, and

The set of circumstances is:

$X = \{X_{ij} = (a_i, b_j)\ a_i \in A, b_j \in B\} = \{X_{11}, X_{12}, X_{13}\}$

$\mathcal{S}^{21}$: We used the software so called "*Grey System Theory Modeling Software 6.0 (GTMS6.0)*" to get the following results:

Table 1 Comprehensive Evaluation Index for Brownfield Redevelopment Project

Factor	*Purposes*	*Development planning options*		
		A	*B*	*C*
Environmental and Health Benefits	Improvement of the quality of groundwater	75	85	77
	Improvement of soil quality	70	82	60
	Improvement of air quality	78	84	65
	Lowering the health risk of local residents	80	89	68
	Increase of green cover percentage	77	87	85
	Improvement of remediation technologies	75	80	90
Financial	Payback period (PP)	5	7	4
	Return on investment (ROI)	21	30	17
	Total cost of brownfield remediation and construction	1500	2700	2100
	Ratio of brownfield remediation cost to total cost	15	27	18
	Net present value (NPV)	2580	3500	2600
Brownfield	Location of brownfield	75	85	80
	Status of infrastructure facilities of brownfield area	85	82	90
	Transportation convenience of brownfield area	80	88	90
	Size of brownfield	55	80	85
Societal Stability	Increase local employment rate	90	92	75
	Increase local tax base	85	90	72
	Improvement of local security status	80	75	88

Table 1 (*continued*)

Factor	*Purposes*	*Development planning options*		
		A	*B*	*C*
Policy and Technical	Protecting and recycling the land/soil resource	75	90	75
	Influence from other contamination hazards nearby	60	65	60
	Easing the pressure on green land development	60	90	85
Performance	Matchup with city planning	70	85	80
	Improvement of image of local community & government	70	80	85
	Increase land value of neighbourhood	75	70	85

Source: Devised by authors

Twenty-four (24) purposes were chosen. Following this, we compute situational effect sequences $Z^K(k = 1, 2 \ldots 24)$ with respect to the purposes.

For purpose 1, we have extracted $Z^1 = (Z_{11}^{(1)}, Z_{12}^{(1)}, Z_{13}^{(1)}) = (75, 85, 77)$

For purpose 2, we have extracted $Z^2 = (Z_{11}^{(2)}, Z_{12}^{(2)}, Z_{13}^{(2)}) = (70, 82, 60)$

For purpose 3, we have extracted $Z^3 = (Z_{11}^{(3)}, Z_{12}^{(3)}, Z_{13}^{(3)}) = (78, 84, 65)$

For purpose 4, we have extracted $Z^4 = (Z_{11}^{(4)}, Z_{12}^{(4)}, Z_{13}^{(4)}) = (80, 89, 68)$

For purpose 5, we have extracted $Z^5 = (Z_{11}^{(5)}, Z_{12}^{(5)}, Z_{13}^{(5)}) = (77, 87, 85)$

For purpose 6, we have extracted $Z^6 = (Z_{11}^{(6)}, Z_{12}^{(6)}, Z_{13}^{(6)}) = (75, 80, 90)$

For purpose 7, we have extracted $Z^7 = (Z_{11}^{(7)}, Z_{12}^{(7)}, Z_{13}^{(7)}) = (5, 7, 4)$

For purpose 8, we have extracted $Z^8 = (Z_{11}^{(8)}, Z_{12}^{(8)}, Z_{13}^{(8)}) = (21, 30, 17)$

For purpose 9, we have extracted $Z^9 = (Z_{11}^{(9)}, Z_{12}^{(9)}, Z_{13}^{(9)}) = (1500, 2700, 2100)$

For purpose 10, we have extracted $Z^{10} = (Z_{11}^{(10)}, Z_{12}^{(10)}, Z_{13}^{(10)}) = (15, 27, 18)$

For purpose 11, we have extracted $Z^{11} = (Z_{11}^{(11)}, Z_{12}^{(11)}, Z_{13}^{(11)}) = (2580, 3500, 2600)$

For purpose 12, we have extracted $Z^{12} = (Z_{11}^{(12)}, Z_{12}^{(12)}, Z_{13}^{(12)}) = (75, 85, 80)$

For purpose 13, we have extracted $Z^{13} = (Z_{11}^{(13)}, Z_{12}^{(13)}, Z_{13}^{(13)}) = (85, 82, 90)$

For purpose 14, we have extracted $Z^{14} = (Z_{11}^{(14)}, Z_{12}^{(14)}, Z_{13}^{(14)}) = (80, 85, 85)$

For purpose 15, we have extracted $Z^{15} = (Z_{11}^{(15)}, Z_{12}^{(15)}, Z_{13}^{(15)}) = (55, 80, 85)$

For purpose 16, we have extracted $Z^{16} = (Z_{11}^{(16)}, Z_{12}^{(16)}, Z_{13}^{(16)}) = (90, 92, 75)$

For purpose 17, we have extracted $Z^{17} = (Z_{11}^{(17)}, Z_{12}^{(17)}, Z_{13}^{(17)}) = (85, 90, 72)$

For purpose 18, we have extracted $Z^{18} = (Z_{11}^{(18)}, Z_{12}^{(18)}, Z_{13}^{(18)}) = (80, 90, 88)$

For purpose 19, we have extracted $Z^{19} = (Z_{11}^{(19)}, Z_{12}^{(19)}, Z_{13}^{(19)}) = (75, 90, 75)$

For purpose 20, we have extracted $Z^{20} = (Z_{11}^{(20)}, Z_{12}^{(20)}, Z_{13}^{(20)}) = (60, 65, 60)$

For purpose 21, we have extracted $Z^{21} = (Z_{11}^{(21)}, Z_{12}^{(21)}, Z_{13}^{(21)}) = (60, 90, 85)$

For purpose 22, we have extracted $Z^{22} = (Z_{11}^{(22)}, Z_{12}^{(22)}, Z_{13}^{(22)}) = (70, 85, 80)$

For purpose 23, we have extracted $Z^{23} = (Z_{11}^{(23)}, Z_{12}^{(23)}, Z_{13}^{(23)}) = (70, 80, 85)$

For purpose 24, we have extracted $Z^{24} = (Z_{11}^{(24)}, Z_{12}^{(24)}, Z_{13}^{(24)}) = (75, 70, 85)$

Hereafter we computed the average images of the situational effect sequences for each of the purposes:

$Z^1 = (1, 1.13, 1.03)$ $Z^4 = (1, 1.11, 0.85)$ $Z^7 = (1, 1.40, 0.80)$ $Z^{10} = (1, 1.80, 1.20)$

$Z^2 = (1, 1.17, 0.86)$ $Z^5 = (1, 1.13, 1.10)$ $Z^8 = (1, 1.43, 0.81)$ $Z^{11} = (1, 1.36, 1.01)$

$Z^3 = (1, 1.08, 0.83)$ $Z^6 = (1, 1.07, 1.20)$ $Z^9 = (1, 1.80, 1.40)$ $Z^{12} = (1, 1.13, 1.07)$

$Z^{13} = (1, 0.96, 1.06)$ $Z^{16} = (1, 1.02, 0.83)$ $Z^{19} = (1, 1.20, 1)$ $Z^{22} = (1, 1.21, 1.14)$

$Z^{14} = (1, 1.06, 1.06)$ $Z^{17} = (1, 1.06, 0.85)$ $Z^{20} = (1, 1.08, 1)$ $Z^{23} = (1, 1.14, 1.21)$

$Z^{15} = (1, 1.45, 1.55)$ $Z^{18} = (1, 1.13, 1.10)$ $Z^{21} = (1, 1.50, 1.42)$ $Z^{24} = (1, 0.93, 1.13)$

And then effect vectors Z_{ij} of the situations X_{ij}, $i = 1$, $j = 1, 2, 3$;

$Z_{11} = (Z_{11}^{(1)}, Z_{11}^{(2)}, \ldots, Z_{11}^{(24)}) = (1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1)$

$Z_{12} = (Z_{12}^{(1)}, Z_{12}^{(2)}, \ldots, Z_{12}^{(24)}) = (1.13, 1.17, 1.08, 1.11, 1.13, 1.07, 1.40, 1.43, 1.80, 1.80, 1.36, 1.13, 0.96, 1.06, 1.45, 1.02, 1.06, 1.13, 1.20, 1.08, 1.50, 1.21, 1.14, 0.93)$

$U_{13} = (Z_{13}^{(1)}, Z_{13}^{(2)}, \ldots, Z_{13}^{(24)}) = (1.03, 0.86, 0.83, 0.85, 1.10, 1.20, 0.80, 0.81, 1.40, 1.20, 1.01, 1.07, 1.06, 1.06, 1.55, 0.83, 0.85, 1.10, 1, 1, 1.42, 1.14, 1.21, 1.13)$

Finally, we calculated the optimum reference sequences, from the average images of the situational effect sequences of the purposes as follows:

For Purpose 1, the larger effect value is the best, so $Z_{i_0 j_0}^{(1)} = \max_{1 \le i \le n,\, 1 \le j \le m}\left\{Z_{ij}^{(1)}\right\} = \left\{Z_{12}^{(1)}\right\} = 1.13$

For Purpose 2, the larger effect value is the best, so $Z_{i_0 j_0}^{(2)} = \max_{1 \le i \le n,\, 1 \le j \le m}\left\{Z_{ij}^{(2)}\right\} = \left\{Z_{12}^{(2)}\right\} = 1.17$;

For Purpose 3, the larger effect value is the best, so $Z_{i_0 j_0}^{(3)} = \max_{1 \le i \le n,\, 1 \le j \le m}\left\{Z_{ij}^{(3)}\right\} = \left\{Z_{12}^{(3)}\right\} = 1.08$;

For Purpose 4, the larger effect value is the best, so $Z_{i_0 j_0}^{(4)} = \max_{1 \le i \le n,\, 1 \le j \le m}\left\{Z_{ij}^{(4)}\right\} = \left\{Z_{12}^{(4)}\right\} = 1.11$;

For Purpose 5, the larger effect value is the best, so $Z_{i_0 j_0}^{(5)} = \max_{1 \le i \le n,\, 1 \le j \le m}\left\{Z_{ij}^{(5)}\right\} = \left\{Z_{12}^{(5)}\right\} = 1.13$;

For Purpose 6, the larger effect value is the best, so $Z^{(6)}_{i_0j_0} = \max_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(6)}_{ij}\} = \{Z^{(6)}_{13}\} = 1.20$;

For Purpose 7, the mini effect value is the best, so $Z^{(7)}_{i_0j_0} = \min_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(7)}_{ij}\} = \{Z^{(7)}_{13}\} = 0.80$;

For Purpose 8, the mini effect value is the best, so $Z^{(8)}_{i_0j_0} = \min_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(8)}_{ij}\} = \{Z^{(8)}_{13}\} = 0.81$;

For Purpose 9, the mini effect value is the best, so $Z^{(9)}_{i_0j_0} = \min_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(9)}_{ij}\} = \{Z^{(9)}_{11}\} = 1$;

For Purpose 10, the mini effect value is the best, so $Z^{(10)}_{i_0j_0} = \min_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(10)}_{ij}\} = \{Z^{(10)}_{11}\} = 1$;

For Purpose 11, the mini effect value is the best, so $Z^{(11)}_{i_0j_0} = \min_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(11)}_{ij}\} = \{Z^{(11)}_{11}\} = 1$;

For Purpose 12, the mini effect value is the best, so $Z^{(12)}_{i_0j_0} = \min_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(12)}_{ij}\} = \{Z^{(12)}_{11}\} = 1$;

For Purpose 13, the mini effect value is the best, so $Z^{(13)}_{i_0j_0} = \min_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(13)}_{ij}\} = \{Z^{(13)}_{12}\} = 0.96$;

For Purpose 14, the mini effect value is the best, so $Z^{(14)}_{i_0j_0} = \min_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(14)}_{ij}\} = \{Z^{(14)}_{11}\} = 1$;

For Purpose 15, the mini effect value is the best, so $Z^{(15)}_{i_0j_0} = \min_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(15)}_{ij}\} = \{Z^{(15)}_{11}\} = 1$;

For Purpose 16, the larger effect value is the best, so $Z^{(16)}_{i_0j_0} = \max_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(16)}_{ij}\} = \{Z^{(16)}_{12}\} = 1.02$;

For Purpose 17, the larger effect value is the best, so $Z^{(17)}_{i_0j_0} = \max_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(17)}_{ij}\} = \{Z^{(17)}_{12}\} = 1.06$;

For Purpose 18, the larger effect value is the best, so $Z^{(18)}_{i_0j_0} = \max_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(18)}_{ij}\} = \{Z^{(18)}_{12}\} = 1.13$;

For Purpose 19, the larger effect value is the best, so $Z^{(19)}_{i_0j_0} = \max_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(19)}_{ij}\} = \{Z^{(19)}_{12}\} = 1.20$;

For Purpose 20, the mini effect value is the best, so $Z^{(20)}_{i_0j_0} = \min_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(20)}_{ij}\} = \{Z^{(20)}_{13}\} = 1$;

For Purpose 21, the larger effect value is the best, so $Z^{(21)}_{i_0j_0} = \max_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(21)}_{ij}\} = \{Z^{(21)}_{12}\} = 1.50$;

For Purpose 22, the larger effect value is the best, so $Z^{(22)}_{i_0j_0} = \max_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(22)}_{ij}\} = \{Z^{(22)}_{12}\} = 1.21$;

For Purpose 23, the larger effect value is the best, so $Z^{(23)}_{i_0j_0} = \max_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(23)}_{ij}\} = \{Z^{(23)}_{12}\} = 1.14$;

For Purpose 24, the larger effect value is the best, so $Z^{(24)}_{i_0j_0} = \max_{1 \le i \le n,\, 1 \le j \le m}\{Z^{(24)}_{ij}\} = \{Z^{(24)}_{13}\} = 1.13$;

We obtain the following optimum reference sequence:

$Z^{(11)}_{i_0j_0} = (Z^{(1)}_{i_0j_0}, Z^{(2)}_{i_0j_0}, \ldots, Z^{(24)}_{i_0j_0}) = (1.13, 1.17, 1.08, 1.11, 1.13, 1.20, 0.80, 0.81, 1, 1, 1, 1, 0.96, 1, 1, 1.02, 1.06, 1.13, 1.20, 1, 1.50, 1.21, 1.14, 1.13)$

From Z_{ij} and $Z_{i_0j_0}$, we computed the absolute degrees of grey incidence:

$\varepsilon_{11} = 0.6359$, $\varepsilon_{12} = 0.8251$, $\varepsilon_{13} = 0.8370$

This led to the conclusion that since Max $\{\varepsilon_{ij}\} = \varepsilon_{13} = 0.8370$, Z_{23} is the quasi-optimum vector and X_{13} the quasi-optimum situation. In terms of building the development planning, the commercial centre is most ideal choice among all the possible plans of the development planning.

CONCLUSIONS, PRACTICAL IMPLICATIONS AND FUTURE RESEARCH

The research indicates that very little understanding of brownfield redevelopment exists with the relevant stakeholders, and no common definitions exist for brownfield development in Ethiopia. The research did, however, propose a suitable definition of brownfield that can be used in the Ethiopian context. Due to health, environmental and public welfare risks associated with brownfield sites, it is convenient to design a framework to guide the theoretical and practical applications in brownfield redevelopment, which constitutes the main purpose of this study.

Under the umbrella of a grey incidence decision-making model, and with the consideration of multiple-stakeholders, tight environmental and economic constraints, the proposed research framework integrates different criteria from economic, social, environmental, technical and risk aspects into a grey incidence decision-making model, and gives useful guidance to control future brownfields on the African continent, particularly in Ethiopia.

Moreover, this research provides a significant opportunity for African governments in the following ways. First, this study will be helpful for African countries to utilise the urban land effectively, long term improvement in environmental quality, public and economic health. It will also be supportive in devising a strategy for employment, housing, taxation and environmental policy. Second, it identifies the potential for specific government policy frameworks for brownfield redevelopment to reduce city carbon emissions. Third, it recommends that government departments consider the coordinated facilitation of brownfield redevelopment. Lastly, it recommends brownfield redevelopment support from international development programmes.

Removing barriers to brownfield redevelopment, risk assessment using project life cycles, building up a comprehensive evaluation index for brownfield redevelopment projects according to Africa's situation, and evaluating brownfield redevelopment projects using grey incidence system theory can be potential work in the future.

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