Land Use Policy 77 (2018) 220–230

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

An ordinal classification of brownfield remediation projects in China for the allocation of government funding

Qingye Han[a], Yuming Zhu[b], Ginger Y. Ke[c,*], Keith W. Hipel[d]

[a] School of Management, Northwestern Polytechnical University, Xi'an, Shannxi, 710100, China
[b] School of Management, Northwestern Polytechnical University, Xi'an, Shannxi, 710100, China
[c] Faculty of Business Administration, Memorial University of Newfoundland, St. John's, NL, A1B 3X5, Canada
[d] Department of Systems Design Engineering, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada

ARTICLE INFO

Keywords:
Brownfield remediation project
Prioritization
Ordinal classification
Financing
Rough set theory
Multiple criteria decision analysis

ABSTRACT

Given the increasing number of brownfields in China, the Chinese government is now facing a huge financing gap in brownfield remediation projects. Accordingly, the authors present a framework that can assist a provincial government in classifying its brownfields so that the funding can be appropriately allocated. More specifically, the framework starts from constructing a criteria system based on the existing literature and expert opinions. Then, in consonance with the criteria system, a sample set of brownfields is measured by experts and then trained using a Dominance-Based Rough Set Approach to derive judging rules. After the validation, those rules are employed to generate an ordinal classification of the complete set of brownfields. The resulting ordinal classification provides the government with a sequence of brownfields from the highest priority to the lowest, which can support the government in budgeting and planning. Furthermore, as the number and conditions of the brownfields change over time, the criteria system and corresponding categories can be updated and reapplied at the beginning of each fiscal year (or each planning horizon) to facilitate the government's decision making. The proposed decision process can also be applied to assist the investment decisions of any brownfield stakeholders in other counties with limited funding based on their specific preference.

1. Introduction

Land is always a limited and valuable resource for human beings, especially for countries having huge populations. As the urban and rural transformation proceeds, a series of land-use issues, such as the contamination caused by industrializations, the degradation resulted from improper uses, and the food insecurity induced by farmland losses, have become an obstacle for sustainable developments (Long, 2014). Among all these issues, global industrialization led to a large number of brownfields, which have been exposing serious risk to the environment and human health. It is estimated that the number of brownfields in the US is between 500,000 and 1,000,000 (Hipel et al., 2010), while the number in Germany is approximately 120,000 (Limasset et al., 2017). To facilitate the remediation and redevelopment of these brownfields, a wide range of measures, such as economic incentives, relevant legal systems, and remediation standards, have been taken in different countries. Despite the efforts, the reuse progress of brownfields is extremely slow because of the significant remediation cost, diversified and complicated conditions, and high technical requirements.

Particularly in China, along with the adjustment of industrial structures, brownfields are produced in the process of the relocation of polluting and energy-intensive industries from urban area to the rural (Li et al., 2017). Although the redevelopment of brownfields is considered to be a sustainable land use strategy (Rall and Haase, 2011), brownfields have been overlooked in China until recently due to lack of knowledge and awareness. More particularly in 2015, approximately 500 students from Changzhou Foreign Language School, a local high school situated in the city of Changzhou, developed acute toxic reactions to the secondary pollution from the neighboring brownfield remediation process. A report about this event by the China Central Television, an official channel having a high reputation in China, led the entire country to realize the severity of brownfield problems (Liu et al., 2017). Several months following this toxic incident, the first state-level operable plan for soil management in China, the Action Plan for Prevention and Control of Soil Pollution (Ministry of Environmental Protection of the People's Republic of China, 2016), was released.

It is estimated that over 100,000 factories having polluted properties were closed from 2001 to 2015, and over 2 million hectares of land having serious contamination were left untreated in the major cities of China (Liu et al., 2017). Furthermore, along with the process of

* Corresponding author.
E-mail addresses: hanqy11@mail.nwpu.edu.cn (Q. Han), zym1886@nwpu.edu.cn (Y. Zhu), gke@mun.ca (G.Y. Ke), kwhipel@uwaterloo.ca (K.W. Hipel).

https://doi.org/10.1016/j.landusepol.2018.05.046
Received 2 February 2018; Received in revised form 23 May 2018; Accepted 23 May 2018

industrial upgrading, there are more brownfields being created each year. On the other hand, China is in great need of land for commerce, housing, and recreation as the population is increasing. These conditions necessitate the remediation and reuse of brownfields, especially in the urban areas. However, China's brownfield industry is still in its infant stage. Therefore, more studies are urgently required to overcome the challenges in relevant areas, such as administration, legislation, technologies, and finance. According to the international experiences, the cost of a brownfield remediation project is quite high in general (Spiess and De Sousa, 2016), and hence the shortage of funding plays a critical role in the slow progress of brownfield remediation. Furthermore, all of the lands and the majority of the initial polluting enterprises are state owned (Tian, 2015; Zhang et al., 2016). As a result of this unique situation, the government is responsible for most of the brownfield remediation projects (Ren et al., 2015). To be specific, although the central government can release certain leading policies, the provincial governments, including 4 municipalities, 5 autonomous regions and 22 provinces in China, are the main responders to brownfields (Li et al., 2017). Note that Hong Kong, Macau and Taiwan are not included here due to their special status.

Fig. 1 depicts the available financing channels for brownfield remediation in China. The four main financing sources are comprised of the central government funding managed by the provincial government, bank loans, sub-provincial government budgets, and funding from the collaboration between the sub-provincial governments and private consortiums in what is called a Public Private Partnership. It should be noted that the amount of funding contained in the latter three resources was relatively small until recently, and thus, they were usually utilized to directly fund specific projects. Exclusively focusing on the funds provided by the central government, this study aims to assist provincial governments in arranging and allocating the funds to address the most critical and important brownfield remediation projects.

More particularly, the central government offers provincial governments funding from "Special Funds for Prevention and Control of Soil Pollution", which is a special funding coming from the central fiscal budget. A certain portion of these funds are used to finance brownfield remediation projects. Although one can foresee that more central funding will be provided in the future for brownfield remediation as the awareness of brownfields increases, the available funding is still very limited compared to the number of brownfields that requires remediation. Therefore, it is critical for a provincial government to manage the limited funding wisely. Herein, an ordinal classification approach based on Rough Set Theory (RST) (Pawlak, 1982) is designed to categorize the brownfield remediation projects, so that the provincial government can identify the ones that need the most attention. To the best of our knowledge, this is the first time that a framework has been developed to classify the brownfield remediation projects, and thus to support the funding allocation for these projects from the perspective of the provincial government in China.

The contributions of this research are threefold. Firstly, based on the existing literature and expert opinions, the very first criterion system is developed to judge the importance of brownfield remediation projects. Secondly, given the expert evaluations of sample brownfields, a Dominance-based Rough Set Approach (DRSA) (Greco et al., 2002) is proposed to derive judging rules, which are employed to generate the ordinal classification of brownfields. The feature of RST allows for inconsistency in the decision making process or/and the missing of data to be taken into account. Finally, a numerical case study is employed to demonstrate the effectiveness and efficiency of the proposed framework.

The rest of this paper is organized as follows. Section 2 reviews relevant references in brownfields studies. Section 3 presents an overview of the various methodologies that are utilized while Section 4 introduces the new framework in detail, with explanations for the main associated procedures. A sample case is studied in Section 5 to illustrate the practicality and provide further insights. Section 6 compares the present approach with several existing methods used in various countries, followed by a conclusion of the paper and a discussion of future research directions in Section 7.

2. Previous studies

Financing problems have always been a huge challenge in many countries when dealing with brownfield redevelopments. Bartsch and Wells (2005) introduced several existing financial tools and strategies for brownfield cleanup and redevelopment in unique states, such as "Loan Guarantees" in Florida and "Cleanup Tax Credit" in Colorado. Kurdila and Rindfleisch (2007) explored three financial mechanisms for brownfield redevelopment: funding sources from government, insurance claims and cost recovery from initial polluters. Cobârzan (2008) tried to introduce financial and non-financial incentives for brownfield redevelopment to identify the ones that are most effective in attracting private investors. Sroka (2016) examined the effectiveness of "Tax Increment Financing" as an instrument to facilitate brownfield remediation and redevelopment from lessons learned in other jurisdictions. The aforementioned papers reviewed the financing channels and financing incentives in brownfield redevelopment, but they are not applicable for the unique situations in China. Han et al. (2016) built an Inverse Graph Model of Conflict Resolution for tackling the financing dilemma to remediate brownfields in China. Results showed that funding from the government is still the main channel for remediating most brownfields in China, yet the Public Private Partnership (PPP) may prove to be an important and effective way to finance brownfield remediation projects in the future.

Focusing on the government financing, the limited funding that is available necessitates the prioritization of brownfield projects. In America, Environmental Protection Agency (EPA) regulations provide the National Priority List (NPL) as a ranking list of brownfields being financed by the Superfund from the US federal government (USEPA, 1986). In this ranking list, three parts are required when judging the prioritization level of a specific site: exposure assessment, toxicity

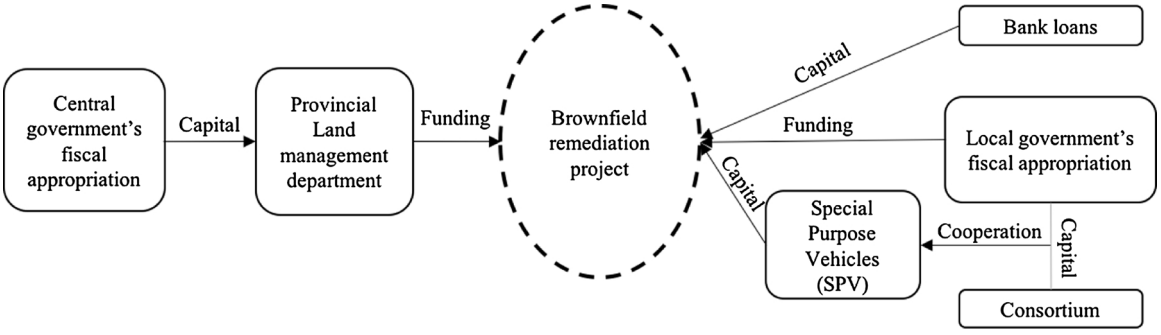

Fig. 1. The Available Financing Channel.