Public Management And Operation Review (PMOR)

Volume 2 Issue 1, Spring 2026
Homepage: https://journal.vu.edu.pk/PMOR
ISSN: Online (3106-8057) – Print (3106-8057)

Title: **Brownfield redevelopment as a path towards urban sustainability: Uncovering driving forces for cleaning and greening brownfields in cities**

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A Publication Of
Department of Public Administration
Virtual University of Pakistan, Islamabad

Brownfield redevelopment as a path towards urban sustainability: Uncovering driving forces for cleaning and greening brownfields in cities

Abstract:
As a response to mitigate sustainability challenges in urban areas due to non-redevelopment of brownfields, recent years captured greater attention in brownfield redevelopment (BR). Brownfields are sleeping beauties in urban areas, and their redevelopment could promote urban sustainability. Consequently, studies on driving forces towards BR in developing economies are very few. Current study aims to identify main driving forces (DFs) to BR in the developing countries context especially in Pakistan. ISM-MICMAC approach was used to analyze 29-DFs extracted from literature review. Expert opinion indicated that 'landfill reduction', 'reduced contamination and hazardous substances', improvement in groundwater quality' are major DFs. Surprisingly, increased taxes from redevelopment' and 'employment opportunities' are the least important DFs which are the major drivers of economic development in developing countries. This study provides a sound understanding of DFs for BR in Pakistan and a roadmap for policy makers to facilitate wider application of BR. It would be interesting to evaluate the relationships between important DFs in future studies and further work is also needed to take a detailed view of different stakeholders regarding BR adoption**.**

Keywords: *Brownfield Redevelopment; Driving Forces; ISM-MICMAC; Pakistan; Developing Countries*

Brownfield redevelopment as a path towards urban sustainability: Uncovering driving forces for cleaning and greening brownfields in cities

1. Introduction

Brownfields as contaminated, hazardous, polluted or sites significantly influence the natural environment, and community as a whole. Globally, plenty of brownfields exist in different nations and damaging environmental beauty in urban areas. Brownfields are sleeping beauties in urban areas, and their redevelopment can be an effective solution to cope with the negative consequences of their existence (Gebremariam Mikiale, Zhu, Ahmad, & Bekele Dawit, 2019; Wei, Maruthaveeran, Shahidan, & Sha, 2025). Most of the developed nations have attempted to preserve the natural environment by redeveloping brownfields in a sustainable way. Sustainable redevelopment of brownfields is essential to "meet the needs of current generations without compromising the potential of meeting needs for future generations" (Hongli Lin, Zhu, Ahmad, & Han, 2019). Ahmad, Zhu, Ibrahim, Waqas, and Waheed (2018) defined brownfield redevelopment as "Restoring a polluted, hazardous, contaminated or vacant land to promote sustainability and to obtain hidden benefits of brownfields". BR is composed of different activities to clean-up the contaminated site (as shown in Figure 1) (Ameller, Rinaudo, & Merly, 2020)The objective of the BR is to enhance the environmental quality along with the plenty of economic and social benefits. Therefore, it is essential to address the need to promote sustainable remediation of brownfields (Y. Chen, Hipel, Kilgour, & Zhu, 2009; Ramezani, Fazia, Vicari Aversa, & Ilieș, 2026).

Despite the BR adoption is hampered by multiple barriers such as lack of capital, high cost, and lack of governmental regulations, there are many driving forces (DFs) that drive the adoption of BR in developing countries such as preservation of nature, environmental protection, and effective use of underused land (Ahmad et al., 2018; Ahmad, Zhu, Shafait, Sahibzada, & Waheed, 2019; Ahmad, Zhu, Shao, & Lin, 2020; Wan, Chen, Liu, & Jin, 2024). An improved and in-depth understanding of these DFs is significant to the wide adoption of BR, because it would support urban planners and potential adopters to reuse brownfields in a sustainable way. Further, stakeholders will exert more pressure to the relevant authorities for adopting BR because of a sound understanding of these DFs.

A very few studies explored drivers of BR in literature (Loures, 2015); however, these studies are not comprehensive in nature and do not provide sufficient knowledge about drivers of BR. Therefore, it is necessary to conduct a study by using expert mining to enrich the BR literature. As, BR has captured attention by environmental authorities and has become an international issue, a comprehensive analysis and development of a framework on BR driving forces is worthwhile.

BR, a common agenda of many countries as highlighted by different international forums such as United Nation Organization (UNO) – (17 sustainable development goals), it has become essential to explore the driving forces of BR in different regions. For the sustainable growth of developing countries, conducting a study using expert opinion is essential to enrich the BR knowledge. This study aims to provide a better understanding of BR drivers and an in-depth understanding of influencing forces which drives the major stakeholders to implement BR.

By concentrating heavenly on these factors, stakeholders can implement BR more effectively. Further, this study provides an opportunity to local investors, real estate developers, and citizens to learn lessons from the experts regarding BR driving forces, who have diversified experience regarding BR implementation.

The arrangement of the remaining paper is as follows: second section includes relevant literature on driving forces of BR; third section explains research methodology; fourth section discusses the obtained results, and fifth section describes concluding remarks.

2. Literature review

Drivers can be defined as motivational factors and the reasons why BR is useful to be implemented for urban sustainability. Various motivational factors have been highlighted in literature regarding BR implementation. For example, De Sousa, Wu, and Westphal (2009) indicated that increasing property values in the surroundings of the redeveloped site is the major driver towards BR implementation and citizens



Figure 1. Brownfield redevelopment process

encourage the policy of redeveloping brownfields in community areas. Wang, Fang, and Hipel (2011) found that reduction in cost is one of the main driving forces while redeveloping a brownfield; however, cooperation from the government and negotiation could bring more benefits in implementing BR. Eckerd and Keeler (2012) stated that remediating brownfields receives government funding and grants, and also obtains tax incentives after redevelopment, which is the major inclination towards BR. Glumac, Han, and Schaefer (2015) highlighted that despite the numerous drivers of BR such as physical improvement of site, better environment, lower contamination value and increased property values, it is necessary to take care of the stakeholders' preferences and market forces.

Environmental impact of the brownfields could be consequent in negative outcomes and have adverse effect on the natural environment. Therefore, sustainability is the major driver while deciding a site for redevelopment. I.-C. Chen, Tsai, and Ma (2016) developed a sustainability index to evaluate brownfields for redevelopment and indicated that different options (e.g., commercial, housing, recreational park etc.) could drive differently for the adoption of BR. Introducing public participation in BR decision making could drive more interest of stakeholders (Geng, Zhu, Lin, & Ahmad, 2017) and it could also resolve the issue of conflict complexity about different stake of different stakeholders (H. Lin, Zhu, Ahmad, & Han, 2017). Existence of standards brownfield definition, brownfield redevelopment index and appropriate guidelines by relevant authorities could be significant drivers of BR in developing countries (Ahmad et al., 2018). Loures and Vaz (2018) segregated driving forces of brownfield redevelopment in different categories including infrastructure, economics, recreational, communitarian, ecological and cultural forces which pushed different regions of the world to adopt BR. Tendero and Plottu (2019) explained that there should be a mechanism to drive participation of different stakeholders and he established a decision support system to boost BR implementation. Ameller et al. (2020) categorized main motivational drivers of BR into direct on-site BR benefits and in-direct of-site benefits. Hongli Lin et al. (2019) conducted a review of studies related to brownfield redevelopment and their study found that most of the previous studies of BR studied different factors such as barriers, strategies, predictors, and influencing factors but there is a scarcity of studies focusing on driving forces of BR, which is the major motivation of the current study. Based on these studies, a list of driving forces of BR was compiled as shown in Table 1.

Table 1. Driving forces of BR from literature review

Code	Driving forces
1	Reduce contaminations & hazardous substances
2	Improvement in environment quality
3	Reduce health risks
4	Improvement in ground water quality
5	Improve brownfield site image
6	Improve government & local community image
7	Improvement in air quality
8	Landfill reduction
9	Reduction in soil degradation
10	Increased taxes
11	Employment opportunities
12	High return on investment (ROI)
13	Increase brownfield site value
14	Increase property value of neighborhood
15	Reduce life-cycle cost
16	Development of green space
17	Conservation of renewable energy resources
18	Improve accessibility & transportation convenience
19	Improve local security status
20	Improvement in regeneration technologies
21	Support urban & city infrastructure planning
22	Environmental justice
23	Promote green economy
24	Reduce urban sprawl
25	Promote local culture & heritage
26	Encourage recreational activities
27	Encourage new economics & business activities
28	Increase human-environment affiliation
29	Promote educational activities

3. Research methodology

This study aims to identify major driving forces of BR by following two main stages. At the first stage, driving forces were explored from the literature databases. The second stage consists of ISM-MICMAC methodology. ISM-MICMAC methodology is widely used to prioritize major barriers, enablers, strategies and driving forces in different system (Ahmad, Zhu, Hongli, et al., 2020; Bux, Zhang, & Ahmad, 2020; Hussain, He, Ahmad, Iqbal, & Taskheer mumtaz, 2019; Iqbal, Ma, Ahmad, Hussain, & Usmani, 2021; Muzaffar Iqbal et al., 2021; Waqas, Qianli, Ahmad, Zhu, & Nadeem, 2020). ISM-MICMAC methodology is beneficial in comparison of other MCDM methodologies e.g., AHP, DEMATEL, TOPSIS, SEM or VIKOR as it provides a systematic way to visualize and prioritize important influencing factors in a system (Bux et al., 2020). Based on ISM-MICMAC methodology, this study adopted two-stage methodology and different steps involved in these two stages are shown in methodological framework (Figure 2).

For modeling and classifying driving forces, the list of collected driving forces from the literature was presented before the experts including urban planners, real estate investors, architects and academicians. All experts were equipped with necessary BR knowledge and benefits of BR, having plenty of experience in their fields as shown in Table 2.

Table 2. Details of experts

No.	Experts	Sector/area	Experience (years)
1	Urban Planner	Housing and town planning agency	6
2	Private investor	Construction industry	12
3	Professional	Chemical Industry	4
4	Contractor	Private Firm	10
5	Architect	Construction company	3
6	Academician 1	Industrial engineering	8
7	Academician 2	Civil engineering	5
8	Academician 3	Public administration	5

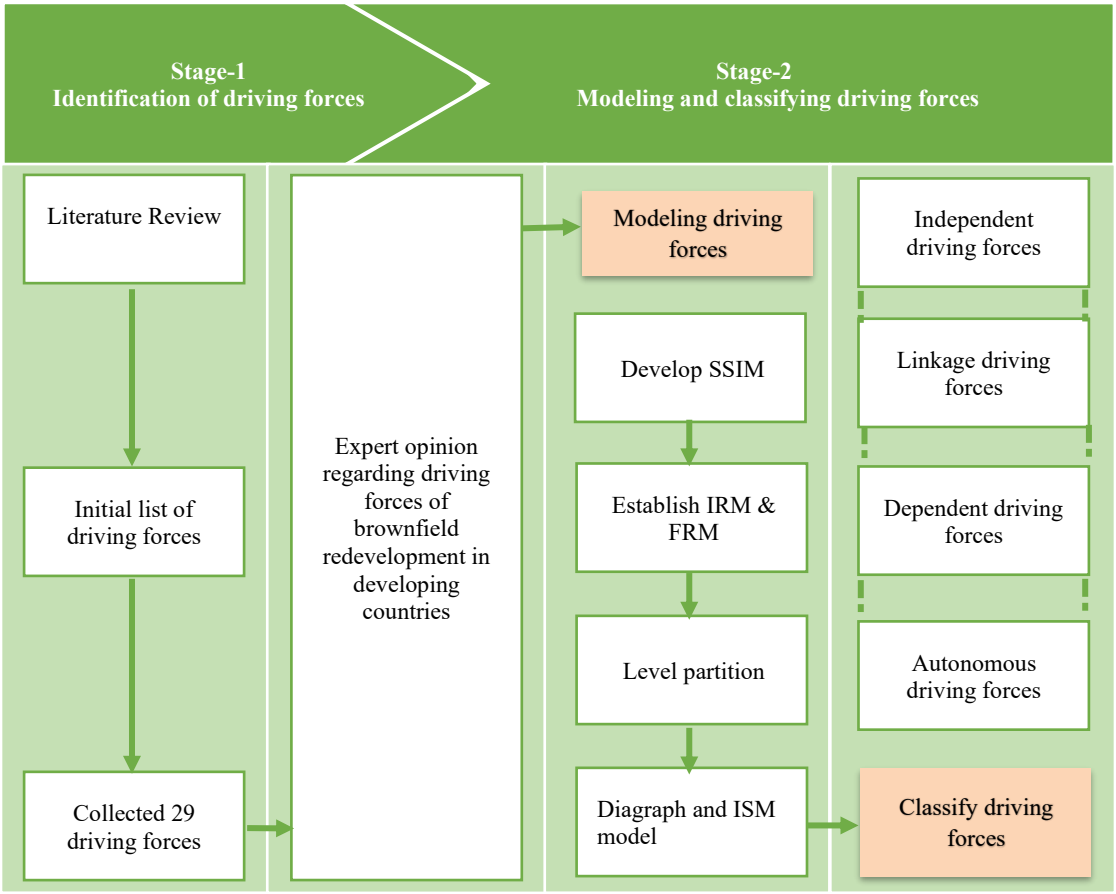


Figure 2. Methodological framework for identifying driving forces of brownfield redevelopment

By following the rules of ISM methodology, experts were invited to rate the importance of driving forces of

BR. By following the steps mentioned at stage 2 of step-by-step methodology, ISM-MICMAC methodology was applied in the following way:

a) At the first step of ISM methodology, SSIM was developed by using expert rating regarding driving forces. Four Alphabets were used to rate two specific driving forces (A, B) for their mutual interaction, where 'V' shows that a factor A affects factor B; 'A' represents that a factor B affect factor A; 'X' shows that both factors A and B affect each other; and 'O' represents that there is no relationship between two factors A and B. SSIM filled by the experts is shown in Table 3.

b) After developing SSIM, the second step in ISM methodology is to develop initial reachability matrix and final reachability matrix. In the initial reachability matrix (IRM), all the alphabetical values are replaced with the binary values (0,1) by following the guidelines of (Hussain et al., 2019). Detailed guidelines for converting SSIM in IRM are shown in Figure 3. Later, IRM is transferred into final reachability matrix (FRM) by following the recommendations of (M. Iqbal et al., 2021) in which transitivity is removed. The values for IRM and FRM are shown in Table 4 and Table 5 respectively.

Table 3. Structural self-interaction matrix (SSIM)

Driving Forces	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1		V	V	V	V	O	V	O	V	O	O	O	V	V	V	V	O	V	O	O	O	O	V	O	V	V	V	O
2			V	A	V	V	A	A	A	O	O	O	O	O	O	A	A	O	O	A	A	O	X	A	O	V	O	A	V
3				A	O	V	A	A	A	O	O	O	O	O	O	A	A	O	O	V	O	A	A	O	O	V	O	A	V
4					V	V	V	A	A	O	O	O	V	V	V	O	V	O	O	O	V	O	O	O	O	V	V	V	V
5						V	X	A	A	V	V	V	A	V	A	V	A	V	V	O	O	V	A	V	V	V	V	V	V
6							O	O	A	V	V	V	O	O	O	A	O	V	V	O	V	A	V	O	O	A	V	V	O
7								A	V	O	O	O	O	O	O	O	V	O	O	A	O	O	V	O	O	V	V	V	V
8									V	O	O	V	V	V	V	V	O	V	O	O	O	O	V	O	O	O	O	V	O
9										V	V	V	V	V	O	V	O	O	O	O	X	X	O	O	O	O	V	V	O
10											O	O	O	O	O	A	O	O	O	O	A	O	O	O	O	O	O	O	O
11												O	A	A	O	A	O	O	O	A	A	O	O	O	O	A	O	O	O
12													O	O	A	O	O	A	A	A	O	O	O	O	O	O	X	O	O
13														V	V	V	V	A	A	A	A	O	V	O	O	V	V	V	V
14															O	O	O	A	A	O	A	O	O	O	O	O	X	O	O
15																V	V	O	O	A	A	A	O	O	O	O	O	O	O
16																	V	V	O	A	V	V	V	V	V	V	V	V	V
17																		O	O	A	V	V	V	V	V	V	O	O	O
18																			O	O	V	O	O	O	O	V	V	V	V
19																				O	O	O	O	O	O	V	V	O	V
20																					V	O	X	O	V	O	O	O	O
21																						X	X	O	X	X	X	O	V
22																							V	V	V	V	V	O	O
23																								V	X	X	X	O	O
24																									O	V	O	V	O
25																										A	X	X	O
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29																													

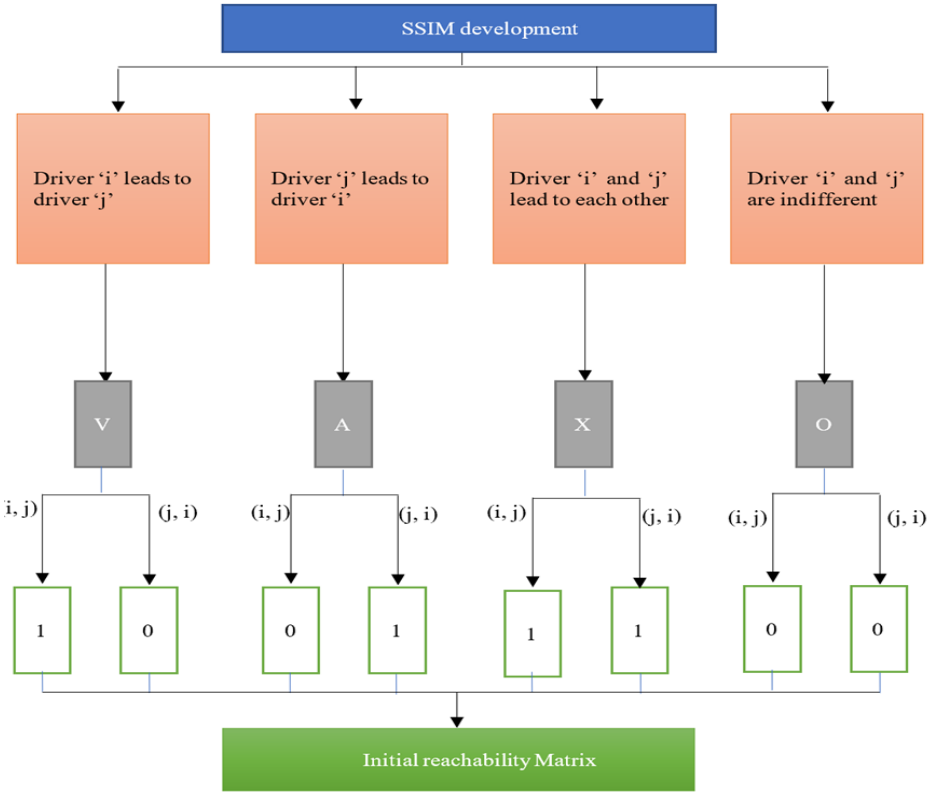


Figure 3 – Detailed guidelines for converting SSIM into IRM

c) After removing transitivity, different levels are extracted and DFs at each level are assigned to their relevant level. Results for level partitions are shown in Table 5.

d) Extracted levels help to develop a diagraph and final ISM model. The final diagraph is composed of eight levels as shown in Figure 4.

e) Based on the diagraph, the next step is to develop ISM model in which all nodes of diagraph are replaced with the DFs statements. Final ISM model is shown in Figure 5.

f) Lastly, MICMAC analysis was conducted by using the values of FRM, which classifies the driving forces into four main clusters (driving, dependent, autonomous and linkage factors).

4. Results and discussion

Adoption of brownfield redevelopment has gained the attention of scholars and stakeholders. Adoption of BR could drive to enhance sustainability, land utilization, reduce contamination and hazardous substances and eradicate environmental pollution also assists stakeholders to gain benefits in terms of profit. Developed nations such as the UK, New Zealand, Denmark and the United States of America got several benefits through the adoption of BR. Unluckily, developing economies such as Pakistan is far away from the adoption of BR. The government of Pakistan and other stakeholders could gain many benefits through the adoption of BR. Because

of reduction in natural resources, increase of carbon emission, shortage of useful land and scarcity of high-quality water, government of Pakistan is interested to design the policies for the proper adoption of BR. Different benefits including (landfill reduction, reduction in contamination of hazardous substances and improvement in groundwater quality) can be accomplished through the proper application of BR activities. The purpose of this study is to feat the significant drivers of BR activities in developing countries especially Pakistan. The MICMAC analysis and ISM approach is utilized to design the hierarchical structural framework of driving forces regarding the adoption of BR. A hierarchical framework of twenty-nine drivers is developed after a brainstorming session of experienced professionals. According to the rule of hierarchical structural ISM based framework, the driving factors that are enlisted on the bottom of framework are considered significant and the factors that are enlisted on the top of structural framework are given less importance.

According to the findings of present research (D8) landfill reduction is a significant driving factor that can assist government to utilize the land in an appropriate way such as replacing polluted and hazardous site into shopping malls, green belts and parks. By redeveloping brownfields for new uses such as housing, commercial development, or public spaces, land that would have otherwise been used for new development is preserved (Ahmad et al., 2018). This can help reduce the amount of new land needed for development, which in turn can help reduce the amount of waste generated from construction and demolition activities, as well as the need for new landfill space. This initiative can also be helpful to contribute in national economy (Glumac et al., 2015).

(D1) reduce contamination and hazardous substances is second most significant driving force which is placed on level seven. The core benefit to adopt the BR is conservation of environment and reduction in carbon emission because hazardous and contaminated lands cause to generate dust, diseases and environmental degradation (Loures & Vaz, 2018). Many brownfields are contaminated with hazardous substances or pollutants, often as a result of their previous use. These contaminants can pose significant health and environmental risks if they are not properly addressed. Through brownfield redevelopment, contaminated sites can be cleaned up and the contaminants can be safely removed or contained. This can help reduce the risk of exposure to hazardous substances, protect human health, and improve the quality of the environment. In addition, brownfield redevelopment can help prevent future contamination by promoting sustainable land use practices and encouraging the use of clean technologies (Thornton et al., 2008). For example, redeveloping brownfields for renewable energy projects or green infrastructure can help reduce greenhouse gas emissions and promote sustainable energy production. Brownfield redevelopment can also promote the use of eco-friendly building materials and practices, which can help reduce the use of hazardous substances in construction and minimize the potential for future contamination (Adelaja, Shaw, Beyea, & McKeown, 2010).

(D4) Improvement in ground water quality is enlisted in level six. The lands where there is a lot of garbage, hazardous substances and contaminated waste obviously affects the surrounding areas and also harm the soil inside too. Many brownfields are located in areas where groundwater has been contaminated due to historical activities, such as industrial operations or improper waste disposal. This contaminated groundwater can pose serious health risks to nearby communities, as well as impact local ecosystems and wildlife. Through brownfield redevelopment, contaminated groundwater can be addressed and remediated, with the goal of restoring it to a safe and usable state. This can be done through a variety of techniques, such as groundwater extraction and treatment, bioremediation, and natural attenuation (Li et al., 2017). Redeveloping brownfields for green infrastructure projects such as parks or wetlands can help improve the quality of groundwater by promoting infiltration and filtration of rainwater (Otsuka, Abe, Isehara, & Miyagawa, 2021).

According to the fruitful findings of this study level five is consist of four driving forces including (D9) reduction in soil degradation, (D15) reduce life cycle cost, (D17) conservation of renewable energy resources, (D20) improvement in regeneration technologies. These driving forces are significant to promote the BR but less important than those driving forces which are included in level six. (D9) reduction in soil degradation is an imperative factor regarding the adoption of BR practices because contribution of BR can help stakeholders to minimize the poison and other pollutant materials of soil. BR can lead to a reduction in soil degradation through various methods including: i) Soil remediation; ii) Soil conservation; iii) Green infrastructure; and iv) Land use planning (Anda, Velta, Maija, & Aina, 2019). (D15) reduce life cycle cost, this driver directly belongs to economic benefit because BR adoption helps to eliminate the life cycle cost of those structure that are

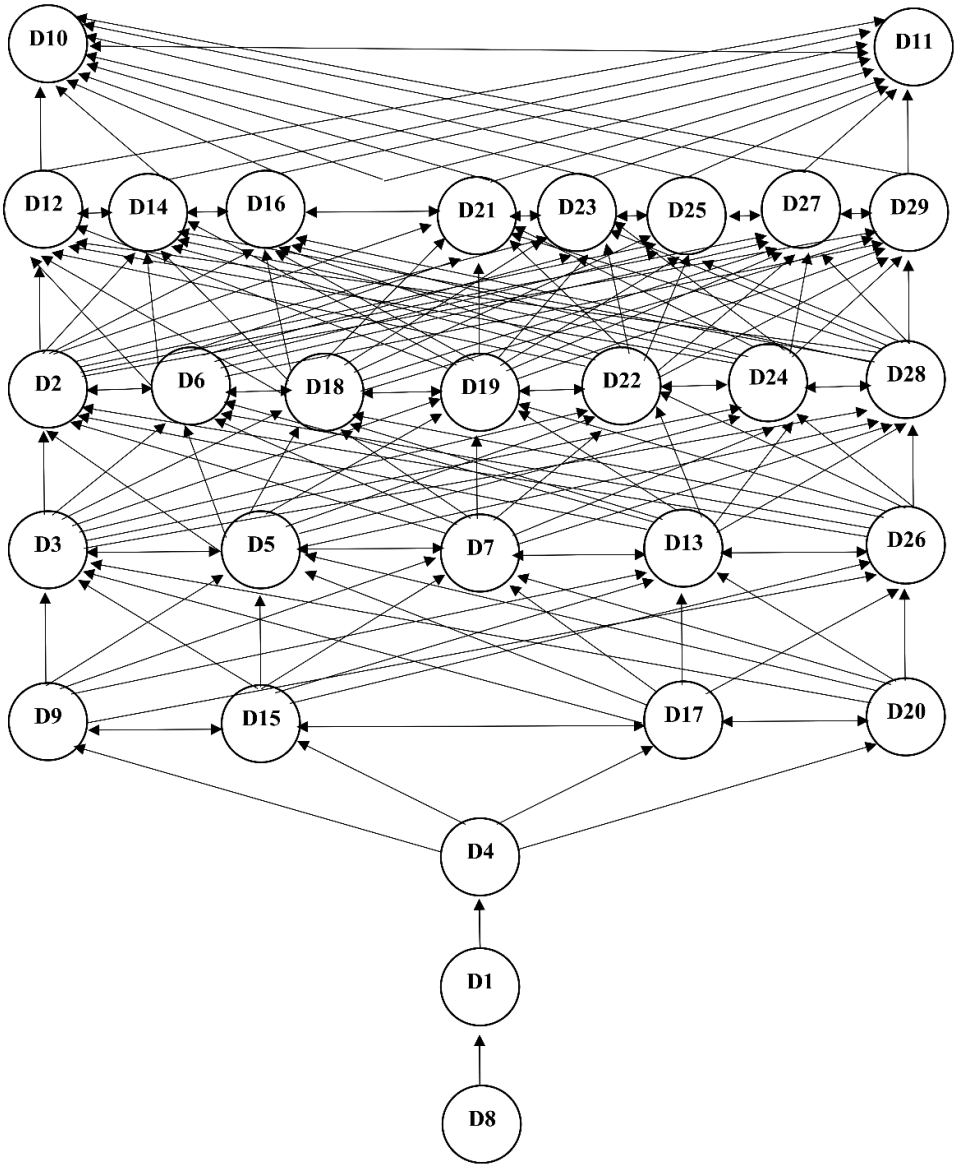


Figure 4 – Diagraph derived from FRM

developed to refill the land. BR can help to reduce the life cycle cost of a project by utilizing existing infrastructure, avoiding environmental liabilities, creating jobs and economic growth, and promoting sustainability (I.-C. Chen et al., 2016). (D17) conservation of renewable energy resources, this driver in level six is also a significant variable because sustainable BR practices lead to replace the conventional energy resources into sustainable and green energy resources. By utilizing solar and wind energy, incorporating

energy-efficient practices, reducing the need for new development, and promoting sustainable transportation, brownfield redevelopment can contribute to the conservation of renewable energy resources. This makes it an environmentally sustainable option for developers and investors, while also providing economic and social benefits to the surrounding community (Adelaja et al., 2010). The last and least important driver that exists in level five is (D20) improvement in regeneration technologies. Because in developing countries use of sustainable and advanced technologies regarding adoption of BR is rare. By providing opportunities for testing and refining new technologies, encouraging collaboration between stakeholders, promoting research and development, demonstrating the effectiveness of regeneration technologies, and stimulating market demand, brownfield redevelopment can contribute to the improvement of regeneration technologies (Reddy, Adams, & Richardson, 1999). This makes it a valuable tool for addressing environmental challenges and promoting sustainable development (Song et al., 2019).

If developing countries especially Pakistan use technology to utilize the contaminated and polluted lands into sustainable land, then a major benefit could be gain in terms of long-term profit. Meanwhile, local industry can attract investors to invest in the development of technology for adoption of BR. Furthermore, level four included five drivers, D5 (Improve brownfield site image), and D13 (Increase brownfield site value) are major drivers at this level. level three has seven drivers; level two consists of eight drivers and level one includes two drivers. These drivers are also important and can provide financial, economic and environmental benefits regarding the adoption of BR.

Along with ISM methodology, MICMAC analysis also has been performed to analyze the robust power of those driving forces. MICMAC analysis consists of four clusters including driving, autonomous, linkage and dependent drivers. However, autonomous factors are not important, as they have no influence from other factors in the system. Relationship direction of clusters and placement of different DFs in different clusters are shown in Figure 6 and Figure 7. Three DFs landfill reduction (D8), reduce contaminations & hazardous substances (D1), improvement in ground water quality (D4) had appeared in the independent drivers. These are independent drivers and drive linkage and dependence drivers. These three are most important DFs affecting the adoption of BRPs. Linkage cluster came up with twenty-two (22) DFs. However, these DFs link independent and dependent DFs. There were four (4) DFs in the dependent cluster. These are the least important DFs in promoting BRPs.

5. Conclusions

The objective of this study was to sort out the significant driving forces that support the adoption of BR practices in developing countries such as Pakistan. BR adoption is a major concern in Pakistan because of ineffective utilization of lands, improper policies of government and lack of professionals that have ability to perform their responsibilities towards the adoption of BR practices. Total twenty-nine significant drivers were identified through the investigation of extensive literature of previous studies. From the findings of the study these twenty-nine driving forces were enlisted into eight levels of BR adoption which delivers a fruitful roadmap to government, policy makers and other stakeholders regarding the benefits of BR adoption. In this research ISM approach was employed to explore the inter-relationship of driving forces further MICMAC analysis was performed to check the driving and dependence severity of driving forces.

This study presents that the driving forces that exist in level eight (D8) landfill reduction, level seven (D1) reduce contamination and hazardous substances and level five (D4) improvement in ground water quality are most important drivers that can be beneficial for the adoption of BR practices. If the government and other stakeholders willing to apply the BR practices they can achieve several benefits in the scenario of environmental protections, financial benefits, energy saving, water quality improvement, eradication of diseases, competitive advantage, technology advancement, fertile soil, utilization of land, carbon reduction and sustainability. Government policies to design rules and regulations can play an important role to regarding the reduction in landfills through the replacement of sustainable land instead of polluted, harmful and garbage sites. Reduction in contamination and hazardous substances are also considered a significant feature because through the adoption of BR practices this feature promotes sustainable land utilization. BR adoption enhances the water quality of that soil where sustainable practices are conducted.

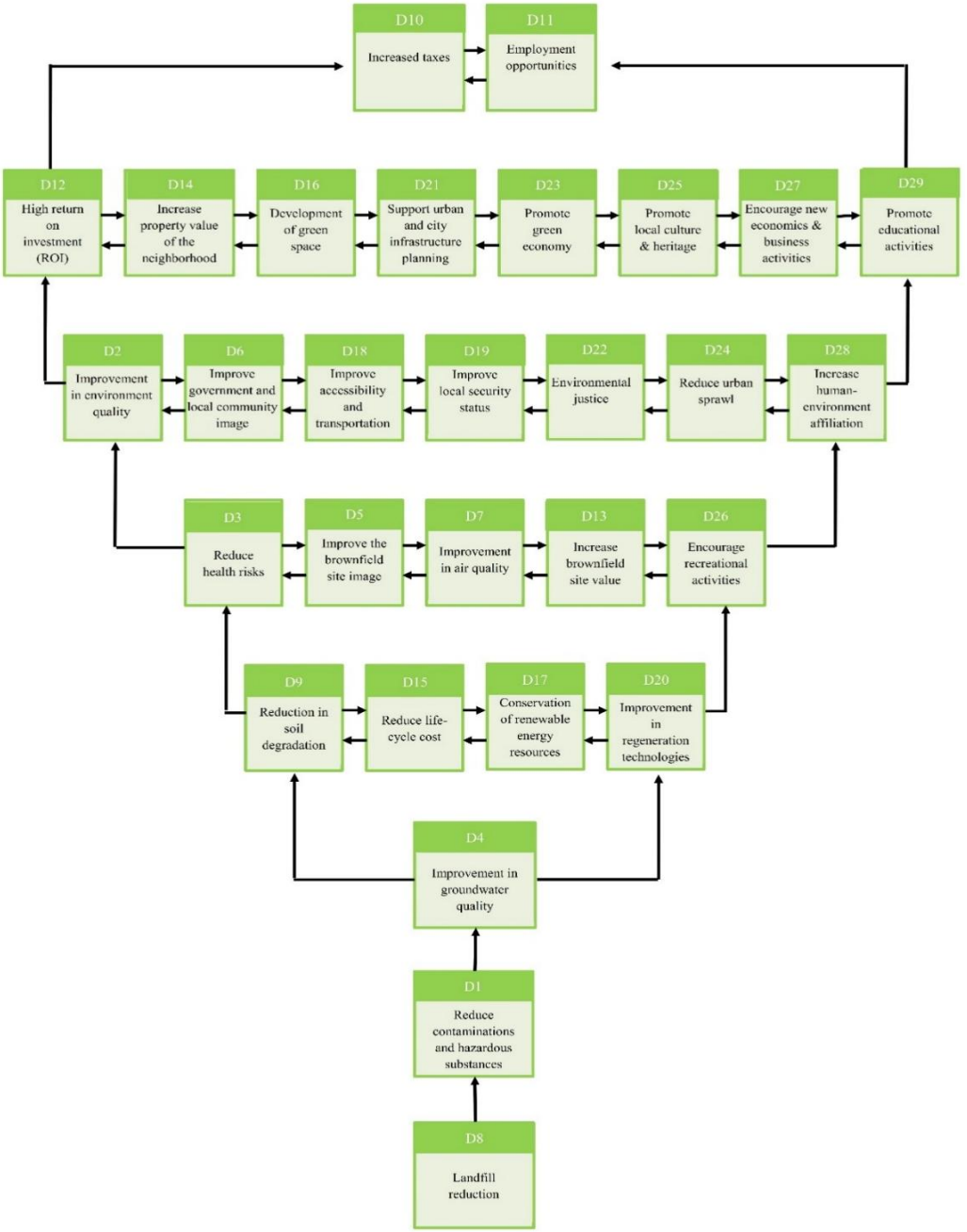


Figure 5 – ISM model for DFs of BRPs in Pakistan

There are some limitations that exist in this study. These limitations including, this study is piloted in the scenario of Pakistan which is according to the geographical location of Pakistan such type of study can be conducted in other developing economies. A multi criteria decision making approach ISM-MICMAC has been adopted in this study which is used to investigate the inter-relationship among variables this methodology is expert based in which there are chances of biasness. Further structural equation modeling can be used in this study to check the validity of results statistically.

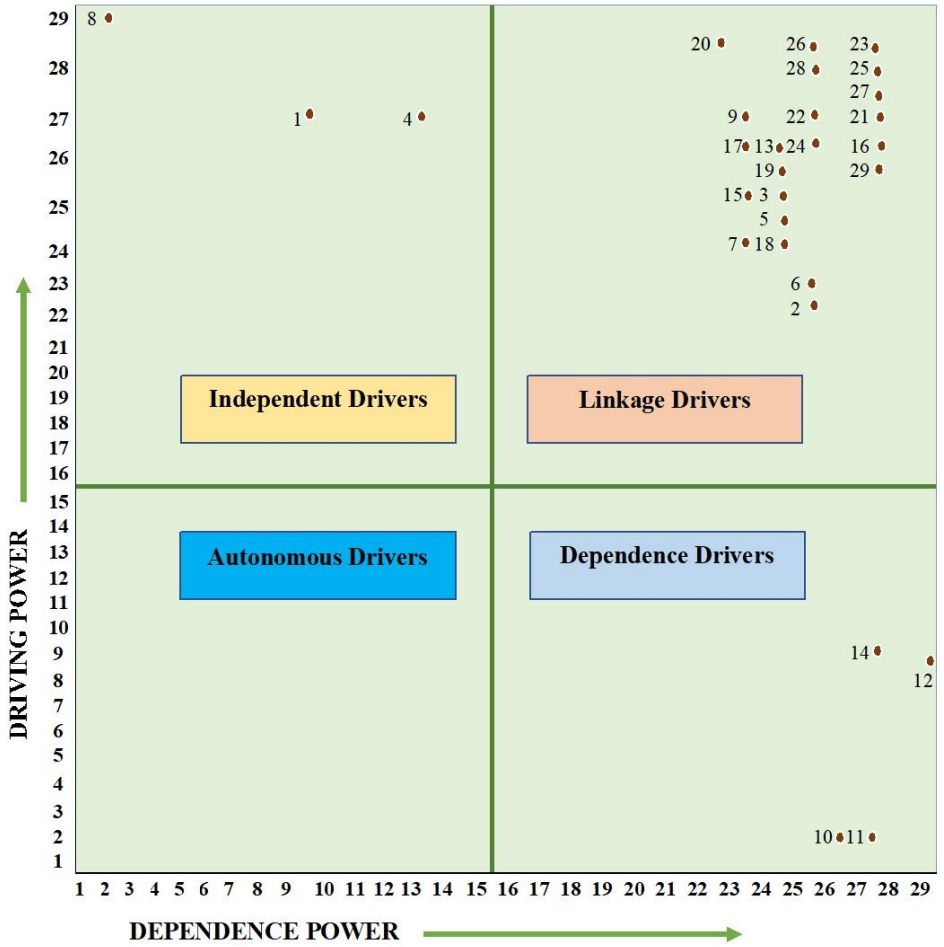


Figure 6 – MICMAC analysis for DFs of BRPs in Pakistan

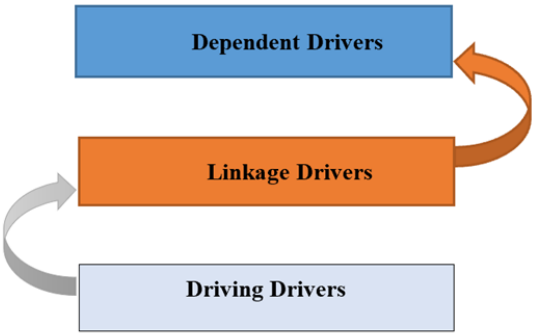


Figure 7 – Relationship direction in MICMAC analysis

6. Theoretical and managerial implications

The research study exploring the driving forces behind BRPs in Pakistan, with a focus on cleaning and greening cities, holds significant theoretical implications for the fields of urban planning and environmental sustainability. By analyzing the factors motivating BRPs within the Pakistani context, the research illuminates the complex interplay of economic, social, and environmental factors that underpin urban renewal initiatives. The study's findings provide valuable insights into the intricate mechanisms shaping decision-making processes at the crossroads of urban development and environmental conservation. This research not only enriches academic discussions by enhancing our comprehension of BR dynamics but also offers practical applications for policymakers, urban planners, and environmental advocates. Insight into these DFs can guide the creation of targeted policies and strategies aimed at fostering sustainable urban development, enhancing environmental well-being, and revitalizing urban areas. Additionally, the study's focus on Pakistan serves as a compelling case study that can be generalized to other developing countries facing similar adversities, amplifying its theoretical implications well beyond its immediate context.

This study holds significant practical and managerial implications for urban development stakeholders. Understanding the benefits and DFs of BRPs, such as redeveloping deteriorating urban areas, facilitating efficient land use, and mitigating environmental pollution, can guide the formulation of targeted policies. These policies can incentivize private sector investment in redevelopment projects, leading to more vibrant and eco-friendly urban sites. City planners, developers and implementation agencies can utilize this knowledge to make informed choices regarding site selection, resource allocation, and community engagement, confirming that BRPs are not only economically viable but also socially inclusive and environmentally responsible. By bridging the gap between theory and practical implications, this research equips stakeholders with the essential tools to effectively drive brownfield redevelopment efforts, ultimately contributing to cleaner, greener, and more sustainable cities in Pakistan.

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