Conceptual frameworks for the drivers and barriers of integrated sustainable solid waste management

A TISM approach

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Abstract

Purpose – The purpose of this paper is to formulate frameworks for the drivers and barriers of integrated sustainable solid waste management (ISSWM) with reference to conditions prevailing in India.

Design/methodology/approach – A multi-phased approach was adopted in this paper to come up with the conceptual framework of the drivers and barriers of ISSWM. In the first phase, drivers and barriers of ISSWM were identified based on a systematic literature review process. In the second phase, 25 experts having 15 plus years of experience in the field of sustainable development and environmental management were consulted to get their opinion. Validation and understanding of the interrelationship among the selected drivers and barriers were done based on the insights from expert interviews. And in the final phase, structural self-interaction matrix and transitive links are defined based on the expert opinion to come up with the theoretical frameworks of drivers and barriers of ISSWM.

Findings – Findings reveal the importance to have a system view point approach by giving equal importance to social, environmental and economic pillars of sustainability along with the technology component to effectively and sustainably manage the solid waste disposal. Institutional effectiveness and the robust policy and frameworks are the two variables found to have the highest driving power. Poor social values and ethics, huge population and illiteracy are the three most critical barriers faced by developing nations in achieving the sustainability practices in the solid waste management. The proposed frameworks of drivers and barriers of ISSWM will definitely help policy makers to effectively manage the sustainable waste management practices for developing economies by focusing on the key variables listed out.

Research limitations/implications – One of the limitations is in the use of very limited sample size in the study. Another limitation is that total interpretive structural modeling fails to come up with the relative weightings of drivers and barriers used in the study. These limitations can be overcome by extending the research by using a semi-structured questionnaire survey with higher sample size for the empirical validation of the model.

Practical implications – This research will help to clearly understand the framework of drivers and barriers of variables and their hierarchical level based on the driving power and dependence. Since such articles focusing on the conceptual frameworks of drivers and barriers of ISSWM are found to be very scant, this paper will equally help academicians and waste management professionals to understand the concepts deeply, by getting answers to the fundamental questions of "what," "why" and "how." Developed framework of drivers explicitly shows the need to attain financial stability through the commercialization of the waste

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management initiatives, which will help to reduce burden on various governmental institutions. Commercialization opportunities will also help to have more successful start-up ventures in solid waste management domain that can provide improved employment opportunities and hygiene environment in the developing nations like India.

Originality/value – Based on the authors' best knowledge, there is hardly any article that explicitly explains the conceptual frameworks of the drivers and barriers of ISSWM by considering the conditions prevailing in developing countries like India. And thus, this can be considered as one of the unique research attempts to build a clear conceptual framework of ISSWM. The study contributes significantly to the existing literature body by clearly interpreting the interrelationships and the driving power and dependence of variables of ISSWM.

Keywords Barriers, Drivers, MICMAC analysis, Integrated sustainable solid waste management, Total interpretive structural modelling

Paper type Research paper

1. Introduction

Transforming the world through sustainable development is the agenda of all policy-building and research organizations like United Nations (United Nations Statistical Division, 2015). However, potential drawbacks of ever increasing economic growth and environmental impacts need more emphasis in this development agenda (Holden *et al.*, 2017). Challenges and influential factors affecting the solid waste management in cities are one of the major potential drawbacks of rapid economic growth and urbanization (Guerrero *et al.*, 2013; Agamuthu, 2003; Zia and Devadas, 2000; Ghose *et al.*, 2006). According to Yang *et al.* (2015), carbon emissions from solid waste management account for around 3-5 percent of the total greenhouse gas emissions and are still a major reason for global warming. Exponentially increasing solid waste generation exerts major pressure over natural resources and is becoming a major challenge to various authorities including government, municipalities, private sectors, national organizations and public (Sujauddin *et al.*, 2008; Burntley, 2007). Hence, to retain safe and secure livelihood, food and atmosphere, it is essential to follow appropriate waste management system and policies (Rao, 1999; Chalmin and Gaillochet, 2009; Dos Muchangos *et al.*, 2015; Rong *et al.*, 2017).

There is a rich literature content analyzing various aspects of sustainable solid waste management (see Guerrero *et al.*, 2013; Agamuthu, 2003; Zia and Devadas, 2000; Ghose *et al.*, 2006; Kum *et al.*, 2005; Wilson, 1985; Ak and Braida, 2015). Despite these research contributions, waste management in cities of developing nations is still a big challenge and needs further rigors research (Ezeah *et al.*, 2013; Lohri *et al.*, 2014; Permana *et al.*, 2015; Zapata and Zapata, 2013). Increasing population, urbanization and rise in living standards of inhabitants lead to the widespread increase of waste in developing countries (Minghua *et al.*, 2009; Sushil, 1990). Solid waste management systems in developed countries are far ahead in terms of methods and processes deployed, in comparison with prevailing conditions in developing nations (Dos Muchangos *et al.*, 2015; Chalmin and Gaillochet, 2009). In this context, our research can be considered as a response to this call as we attempt to come up with a conceptual framework of integrated sustainable solid waste management (ISSWM) with reference to the conditions prevailing in India. Most of the studies in solid waste management are ignoring the social aspects and the major focus is on environmental impacts (Allesch and Brunner, 2014; Vinyes *et al.*, 2013). This research is overcoming this limitation as well by considering economic, environmental and social dimensions with equal priority. Majority of the research outcomes on ISSWM are mainly with a focus on operational and tactical issues and these models are insufficient for long-term planning of waste management (Sudhir *et al.*, 1996). Based on a thorough literature review, Mwanza and Mbohwa (2017) state that studies that analyze the drivers of solid waste management empirically are very scant. According to Eltayeb *et al.* (2011), Jharkharia and Shankar (2005) and Jha and Devaya (2008), the view toward the system can be strengthened by identifying and interpreting the drivers and barriers of them. By considering all these literature evidence and arguments, we have carefully formulated our research questions which are elucidated below:

RQ1. What are the most important drivers and barriers of ISSWM?

RQ2. How they are interlinked with each other based on their driving and dependence power?

RQ3. What are the levels of these drivers and barriers in the conceptual framework of ISSWM?

A wide variety of research methodologies were adopted by researchers in ISSWM. Case study is one of the popular methodologies in ISSWM (Qian *et al.*, 2011). But it is a widely accepted fact that case study could not generalize the finding with limited sample size (Boyer and Swink, 2008) and it is expensive and time-consuming process (Luo *et al.*, 2017). Another drawback of case study research is in the rationale behind the selection of cases (Seuring and Muller, 2008). To overcome these critical drawbacks, many researchers strongly endorse the use of total interpretive structural modeling (TISM) by following the contributions of Sushil (2012), as an effective alternate methodology for theoretical framework development (Mangla *et al.*, 2014; Jayalakshmi and Pramod, 2015; Dubey *et al.*, 2015; Singh *et al.*, 2015; Shibin *et al.*, 2016; Yadav and Barve, 2016; Bag *et al.*, 2015; Dubey *et al.*, 2017). Lack of "systems thinking" in policy making is one of the reasons of gaps that are still existing in the solid waste management in developing nations (Seadon, 2010; Marshall and Farahbakhsh, 2013). Sushil (2012) argues that the TISM methodology is based on systems theory and the development of framework using TISM will provide great value in dealing effectively and efficiently with the system. There is a pressing need to have a holistic systems approach to deal with all existing issues in ISSWM (United Nations Environment Program, 2010; Boyer and Swink, 2008) and to come up with a comprehensive and integrated framework of sustainable solid waste management (Thyberg and Tonjes, 2015). Hence, rather than concentrating merely on technical issues, the challenging factors and policies have to be taken into serious consideration and to be put in place. This could be achieved by using TISM as an effective methodology to develop the theoretical framework of ISSWM. Despite the increasing popularity of TISM as a framework development tool, researchers very rarely attempted to use this methodology on solid waste management policy formulation. (Goyal and Grover, 2012; Mangla *et al.*, 2014; Prasad and Suri, 2011. The use of TISM as an alternative research method offers flexibility to interpret the link of complex conceptual model (Dubey *et al.*, 2017). The TISM methodology is one of the best ways to go for general frameworks which will help to answer "what," "why" and "how" questions (Singh and Sushil, 2016). Thus, the objective of this study is to come up with conceptual frameworks of barriers and drivers of ISSWM with the help of a multi-phased approach of literature review, expert opinion and TISM. The cross-impact matrix-multiplication applied to classification (MICMAC) analysis was also applied in the study to identify the driving and dependence power of the variables.

We have arranged the remaining section of this paper as follows. In the next immediate section, literature review is narrated with focus on understanding the concepts of ISSWM. Identification of drivers and barriers is also performed as a part of literature review process and the reasons behind the selection of each variable are also explained with literature evidences. In the third section, focus is on explaining research methodology in which TISM model building procedures are listed out. The fourth section is dedicated for discussion in which the theoretical and managerial contributions of the research are explained in detail. And finally, the concluding section is accommodated to give a short summary of the research. Limitations and further research directions are also included in the last section of this paper.

2. Literature review

An extensive literature review has been conducted to start with the research process with a clear objective to analyze the barriers and drivers affecting the ISSWM. Various databases referred for the study include SCOPUS, EBSCO, Springer, Elsevier and Emerald. A keyword search methodology was adopted in the literature collection process. Important articles appearing in the search with keywords such as "solid waste management," "sustainable waste management," "integrated sustainable solid waste management" and "integrated sustainable solid waste management + developing nations" were used in the study. Definitions and concepts of terms used in the study are described in the upcoming section.

2.1 Solid waste management

Researchers define solid waste as any kind of unwanted substances carried from all the areas like houses, industries, institutions and other public places (Bailie *et al.*, 1996). According to Shankar (2017), solid wastes are considered as unwanted or refuge substances mainly in the form of solid produced by anthropogenic activities. Solid waste can include all types of materials such as bottles, packages, leftovers, newspapers, food wastes, electronic items, batteries, dyes, chemicals, devices and equipment which are produced by the daily activities of human (Ekmekcioglu *et al.*, 2010; Ayotamuno and Gobo, 2004; Hao *et al.*, 2007; Karunasena and Amaratunga, 2015). Differences in living standard, income level, product consumption, rules and regulations and economy are some of the major reasons of increasing waste production and that makes the management of solid waste very difficult (Khan *et al.*, 2016; Zia and Devadas, 2007).

2.2 Sustainable solid waste management

Sustainable solid waste management refers to the management of the system without compromising the need of future generations. The term sustainability was first introduced by Brundland (1987). Sustainability has three widely accepted dimensions such as social, environmental and economic (Garbie, 2014; Carter and Easton, 2011). While considering the term sustainable development, it covers all the environmental, social and economic aspects of solid waste management (Kralj, 2011). For integrating sustainability concepts with solid waste management, it is necessary to firmly adhere to the environmental, economic and social performance and compliances for all the processes it adopts (Nilsson-Djerf, 2000; Petts, 2000). In developed countries, sustainable solid waste management is almost in a maturity stage whereas developing countries are at premature stage trying to focus on the environmental, economic and social aspects with equal priority.

2.3 ISSWM

"Integrated" is a term which was introduced in 1970s by Murray *et al.* (1971) and Tobin and Myers (1974). Post-1990s period, the term "integrated sustainable solid waste management" came into existence that covers all the levels in solid waste management. The term "integrated" also ensures the focus on various emerging technologies and management approaches to resolve complex issues existing in solid waste management (Crocker, 1985; Diaz and Golueke, 1989; Smith 1990; Karagiannidis and Moussiopoulos, 1970; Daskalopoulos *et al.*, 1998; Thorpe, 2001; Kerry Turner and Powell, 1991; Saxena *et al.*, 2010). Together the two terms "integrated" and "sustainability" provided an all-inclusive novel approach toward solid waste management and it got established by around the year of 2000. ISSWM also covers well-defined waste management hierarchy proposed by researchers like Ramachandra and Bachamanda (2007) and Perket (2010) such as prevention, reduction, recycling, recover and disposal. Challenges in solid waste management can only be handled by practicing an integrated and sustainable solid waste management guarantying prolonged safety for the living atmosphere (Batool and Chaudhry, 2009; Zhen-shan *et al.*, 2009). ISSWM is considered as a tool or lens that examines environmental, social, physical, political and economic aspects related to the solid waste management in developing cities (Diaz *et al.*, 1996).

Research rigor and focus on ISSWM have varied drastically over the time period. Environmental impact of solid waste management is one of the major concerns that many of the researchers attempted to address (see Phillis *et al.*, 2011; Gray *et al.*, 1998; Parker, 1999; Schaltegger and Burritt, 2000; Qian *et al.*, 2011). Solid waste management planning is one of the other areas that got much attention from researchers (see Faccio *et al.*, 2011; Kanchanabhan *et al.*, 2011; Revetria *et al.*, 2011; Nielsen *et al.*, 2010). According to Morrisseyand Browne (2004), research outcomes in solid waste management can be categorized into three sections that include: those based on cost benefit analysis, those based on life cycle assessment and those based on multi-criteria decision making.

Many researchers have successfully attempted to use scientific operations research techniques such as multi-criteria decision analysis (Pradhan *et al.*, 2017; Chatzouridis and Komilis, 2012; Islam and Rahman, 2012; Liu and He, 2012) and qualitative empirical research (Meadows, 2008) to address the planning issues in solid waste management. Economic optimization (Anderson, 1968), dynamic mixed integer programming model (Baetz and Neebe, 1994; Chi and Huang, 1998), fuzzy mathematical program (Chang *et al.*, 1997; Huang *et al.*, 1994), static non-linear programming model (Sundberg *et al.*, 1994), multi-period and multi-regional model (Everett and Modak, 1996), optimization model (Berger and Savard *et al.*, 1999; Tanskanen, 2000), etc., are also to be mentioned among the other few. However, it can be understood that research works identifying the critical drivers of ISSWM are still scant and the development of conceptual frameworks by using alternative robust methodologies in operations management is still critical. It is also equally essential in the present scenario to identify the major barriers that resist the smooth implementation of ISSWM systems. These factors are discussed in the following sections.

2.4 Drivers of integrated solid waste management system (ISSWM)

Several past researchers have attempted to analyze the solid waste management in developing countries by identifying and defining the influencing factors of solid waste management (see Hukari *et al.*, 2016; Zabaleta and Rodic-Wiersma, 2015; Aubain *et al.*, 2002). It is strongly influenced by several interlinked factors such as technical, political, legal, socio-cultural, recourses, environmental and economic factors (Sharholy *et al.*, 2007; Kum *et al.*, 2005). Thorough understanding of the barriers and drivers is very acute in ensuring the efficient and effective implementation of solid waste management system (Satapathy, 2017). Hence, this section tries to figure out all the critical drivers that could enhance the performance of solid waste management system within the Indian context.

2.4.1 Institutional effectiveness. Institutional effectiveness is getting influenced by many factors like institutional structure, culture, etc. According to DFID (1998), institutional structure is the whole structure of institutional arrangements which are responsible for undertaking all activities in the policy making. Other factors having impact on institutional effectiveness include level of decentralization of authorities, institutional capacity, cooperation, structure of organization and the level of collaboration (Schubeler *et al.*, 1996; Mohamad *et al.*, 2012; Shekdar, 2009; Sujauddin *et al.*, 2008; Geng *et al.*, 2009; Tai *et al.*, 2011; Guerrero *et al.*, 2013; Antipolis, 2000). According to World Bank (2000), a well-planned institutional framework with planned management is essential for running waste management in an acceptable level and to reduce the risk. Ineffective administration is the major cause that ends in declining effective performance of system (Ogawa, 2008). And thus institutional effectiveness must be considered as an important driver of ISSWM.

2.4.2 Robust policy and legal framework. It is critical to have a proper policy and legal framework to maintain an effective ISSWM system (Appiah Obeng *et al.*, 2009). The policy should cover various aspects such as maintaining environmental quality, public health, cleanliness and provision for financing. The legal frameworks should be developed in line with the national policy, law for effective function of rules and it should check the completion of the target within the given time frame (Shekdar, 2009). Proper strategic planning of the system is necessary to manage different stakeholders from all sectors (Sharholy *et al.*, 2007). Proper development of legal framework, satisfactory policies (Mrayyan and Hamdi, 2006) and proper regulation can contribute positive developments in the integrated waste management system (Asase *et al.*, 2009; Damghani *et al.*, 2008; Joseph, 2006). Hence, we strongly argue that robust policy and legal framework should be considered as an important driver.

2.4.3 Public participation. Several studies have revealed the wide and sustained participation of public in the source separation programs conducted in their countries which are stated as the success of a solid waste collection program (Chung and Poon, 2001; Folz, 1999; Lober, 1996; Tchobanoglus *et al.*, 1993). Cleanliness, energy recovery and system efficiency are directly associated with the public involvement (Chung and Lo, 2008). The perception of public about waste management has to be changed and only their involvement can bring success to the process (Chung and Poon, 2001). Public participation helps to improve public health and in reducing the financial investment of institutions in solid waste management programs (Wiedemann and Femers, 1993; Vidanaarachchi *et al.*, 2006; Sujauddin *et al.*, 2008; Henry *et al.*, 2006; Khalil and Khan, 2009; Sandhu, 2014; Voronova *et al.*, 2013; Yeboah-Assiamah *et al.*, 2017). Lack of workers in the ISSWM is the aftereffect of poor job respect and dignity being given by the society to the people involved in the solid waste disposal process (Vidanaarachchi *et al.*, 2006). Hence, we have considered public participation as one of the important drivers.

2.4.4 Innovative and cost-effective technology. Exploring and selecting appropriate technologies will enhance the development of sustainable waste management. Importance of conserving resources and energy has become a global concern which can be solved by the application of innovative technologies (Pappu *et al.*, 2007; Shimura *et al.*, 2001; Hazra and Goel, 2009; Moghadam *et al.*, 2009; Henry *et al.*, 2006). Efficient selection of cost-effective and innovative technologies should be made in such a way that it is apt to deal with the prevailing conditions and waste characteristics (Shekdar, 2009). Hence, this will promote minimal open dumping and maximum reuse and recycling of waste materials (Pappu *et al.*, 2007). Cost-effective technologies with progressive upgrading of system will provide long-term economic efficiency. Hence, the innovative and cost-effective technology is taken as a driver.

2.4.5 Financial stability. A need to have continuous financial support for institutions dealing with solid waste management process is a big hindrance and a reason for the failure of most of the waste management initiatives in developing countries (Ferreira *et al.*, 2017). This can be avoided by developing a new approach by restructuring waste management in a profitable way (Suocheng *et al.*, 2001). Effective utilization of solid waste as raw materials will show good market potential and develop a new scope for this innovative process. It could be obtained by proper implementation of segregation, recycling and technical efficiency aiming at introducing new system of financial structure that will balance the cost required for the solid waste disposal processes (Kinnaman *et al.*, 2014; Chung and Lo, 2008; Appiah Obeng *et al.*, 2009; Qian *et al.*, 2011; Sharholy *et al.* 2007; Agamuthu and Fauziah, 2011). Hence, we argue that financial stability must be considered as an important driver of waste management.

2.4.6 Improved resource availability. Marshall and Farahbakhsh (2013) stated the importance of resource availability in solid waste management and defined it as a major driver of the system. According to Shimura *et al.* (2001), proper installation of facilities and machinery is relevant for proper waste management practices. While considering the household waste, Tadesse *et al.* (2008) in their study analyzed the importance of sufficient containers, bins, infrastructure, transportation and vehicles and developed road ways, as these technical factors significantly affect the sustainable waste management systems. Guerrero *et al.* (2013) further highlighted the importance of disposal areas in shorter distances, as its reverse case causes the irregularity in collection which leads to the dumping of waste in public open areas (Pokhrel and Viraraghavan, 2005; Choe and Fraser, 1999; Tesfay, 2004; Worrell and Vesilind, 2012; Henry *et al.*, 2006). Hence, improved resource availability is also considered as a driver of ISSWM.

2.4.7 Effective waste segregation and collection. According to Ekere *et al.* (2009), segregation of waste at the household level can decrease the level of contamination of waste which can improve the quality of recycling and reuse either as feed or supporters. Hazra and Goel (2009) argue the importance of source separation which has to be promoted by campaigns and other methods among all the categories of people as public support is mandatory. Segregation promotes the reduction in quantity of landfill and increases the raw materials for manufacturers (Sharholy *et al.*, 2007). Hence, waste separation at source has to be included as a part of solid waste management policies and it has to be considered as mandatory aspect in all countries. While focusing on the recycling rate, it was observed that the presence of disposal bins in shorter distance improves the segregated collection of waste and it will at least increase the fractions that are separated (Guerrero *et al.*, 2013). Ease access of recycle bins near home or door-to-door collection of segregated waste is an incentive to recycling (Speirs and Tucker, 2001; Domina and Koch, 2002). Thus, effective waste segregation and collection is taken as a mandatory driver of the system.

2.4.8 Recycling and reproduction. Recycling is one of the major operations that have a major role in waste minimization (Hopper and Yaws, 1994). Source reduction and recycling itself could minimize the total waste produced. Institutions must proactively come forward to give preference to recycled and reproduced materials, which in turn will ensure the success of recycling industry. The support includes encouraging the utilization of recycled products and financial support for recycling projects and infrastructures (Nissim *et al.*, 2005). Other factors that will affect the system according to other scholars are recycling companies in the country, drop-off and buyback centers, public support and informal organization sectors (Sharholy *et al.*, 2008). These all facts highlight the importance to consider recycling and reproduction of solid waste as a driver of the sustainable waste management.

2.4.9 Commercial and profitable ISSWM ventures. Commercialization of waste management is the most desirable method for ensuring an integrated and sustainable waste management system (Suocheng *et al.*, 2001; Qotole *et al.*, 2001). This could increase the involvement of government, public and private organizations in solving the problem (Wang and Nie, 2001b). This practice will strategically cut down the economic investment to be provided on this system by the government and will increase the chance of development of more commercial models. Instead of considering the investment as a crucial barrier in waste management, it can be transferred into a profitable venture by the primary investment on equipment (Yuan *et al.*, 2006; Ogu., 2000). This will enhance the motivation for private organizations to come up with several startups in waste management especially in developing nations like India (Table I).

2.5 Barriers of ISSWM

ISSWM not only represents the implementation and functioning of a proper system but it also includes various factors that can be integrated to govern and streamline the functionality of the system (Asase *et al.*, 2009). So it is important to clearly identify and

S. No.	Drivers	References
D1	Institutional effectiveness	DFID (1998), Schubeler *et al.* (1996), Mohamad *et al.* (2012), Shekdar (2009), Sujauddin *et al.* (2008), Geng *et al.* (2009), Tai *et al.* (2011), Guerrero *et al.* (2013), Antipolis (2000), World Bank (2000), Ogawa (2008)
D2	Robust policy and legal framework	Appiah Obeng *et al.* (2009), Shekdar (2009), Sharholy *et al.* (2007), Mrayyan and Hamdi (2006), Asase *et al.* (2009), Damghani *et al.* (2008), Joseph (2006)
D3	Public Participation	Chung and Poon (2001), Folz (1999), Lober (1996), Tchobanoglus *et al.* (1993), Chung and Lo (2008), Wiedemann and Femers (1993), Vidanaarachchi *et al.* (2006), Sujauddin *et al.* (2008), Henry *et al.* (2006), Khalil and Khan (2009), Sandhu (2014), Voronova *et al.* (2013), Yeboah-Assiamah *et al.* (2017), Vidanaarachchi *et al.* (2006)
D4	Innovative and cost-effective technology	Pappu *et al.* (2007), Shimura *et al.* (2001), Hazra and Goel (2009), Moghadam *et al.* (2009), Henry *et al.* (2006), Shekdar (2009)
D5	Financial stability	Suocheng *et al.* (2001), Kinnaman *et al.* (2014), Chung and Lo (2008), Appiah Obeng *et al.* (2009), Qian *et al.* (2011), Sharholy *et al.* (2007), Agamuthu and Fauziah (2011), Ferreira *et al.* (2017)
D6	Improved resource availability	Marshall and Farahbakhsh (2013), Shimura *et al.* (2001), Tadesse *et al.* (2008), Guerrero *et al.* (2013), Pokhrel and Viraraghavan (2005), Choe and Fraser (1999), Tesfay (2004), Worrell and Vesilind (2012), Henry *et al.* (2006)
D7	Effective waste segregation and collection	Ekere *et al.* (2009), Hazra and Goel (2009), Sharholy *et al.* (2007), Guerrero *et al.* (2013), Speirs and Tucker (2001), Domina and Koch (2002)
D8	Recycling and reproduction	Hopper and Yaws (1994), Nissim *et al.* (2005), Sharholy *et al.* (2008)
D9	Commercial and profitable ISSWM ventures	Suocheng *et al.* (2001), Qotole *et al.* (2001), Wang and Nie (2001b), Yuan *et al.* (2006), Ogu (2000)

Table I. Drivers of ISSWM

target those factors to effectively streamline the functionality of the system. Moreover, links between the identified barriers are very complex and have to be addressed separately to overcome them in the most effective way (Qdais, 2007). Hence, in this section we identify and define the most influential barriers that exist as a hindrance in the effective management of solid waste disposal systems in the cities of developing nations. Common barriers affecting the ISSWM system are explained below.

2.5.1 Poor environmental commitment. Qian *et al.* (2011) analyzed that lack of environmental commitment is the major barrier that prevents the development of sustainable solid waste management. Lack of proper assessment of working waste management systems can predict the reduced influence of environmental commitment in developing countries (Agunwamba, 1998). The progressive development in waste management lacks commitment toward environment to fulfill the environmental objectives (Qian *et al.*, 2011). Lack of public knowledge on environment through training reduces their competency and commitment toward environmental and sustainable management (Liu and He, 2012). Indian cities have started facing ecological imbalances on air, land and soil (Kansal *et al.*, 1998; Askarian *et al.*, 2004) due to the negligence toward environment. Hence, poor environmental commitment is considered as a barrier.

2.5.2 Lack of technical expertise. Lack of technical expertise reduces the support toward building an environmentally sound waste management system (Ayotamuno and Gobo, 2004). Findings revealed that experts lack opportunities to transfer and share technical knowledge on developing waste management systems (Karunasena and Amaratunga, 2015). Lack of proper leadership and guidance reduces the commitment toward undertaking various training courses for raising adequate staffs. This acts as an obstacle in ensuring the availability of trained and skilled personals in waste management sectors (Mrayyan and Hamdi, 2006). These limit the spreading of information about the system among various agencies which create difficulty in obtaining insight and solving complex situations (Seng *et al.*, 2011). On job training is considered to be essential for providing professionalism (Chung and Lo, 2008). Providing training to personals and local waste administrators will provide confidence for implementing the equipment. Experienced staffs with proper professional background are mandatory in metropolitan areas (Appiah Obeng *et al.*, 2009). And thus lack of technical expert is to be considered as a barrier to the system.

2.5.3 Poor social values and ethics. Burritt (2004) and Parker (2005) emphasize that social ethics and values have important role in sustainable solid waste management. Schubeler *et al.* (1996) argues that ethics is essential factor in maintaining cooperation between community and municipal system that will ensure the success of a sustainable solid waste management system. Respecting and following ethical practices will help to ensure public cooperation in waste segregation, adoption of new technologies and responding to labors requirements (Dijkema *et al.*, 2000). This implicates the action of ethics and values in sustainable waste management and it became a topic for discussion among researchers and organizations. ISSWM cannot be a success without ensuring ethical practices and social values and thus it must be considered in the study.

2.5.4 Huge population. According to the World Urbanization Report, the population in cities is expected to increase from 50 to 63 percent by 2050 (UN, 2014). This growth rise will cause various extraordinary challenges including resource shortages as well as waste accumulation. Population explosion in rural and urban areas of developing countries is creating a huge challenge (Shekdar, 2009; Vesilind *et al.*, 2002; Aung and Arias, 2006; Ayotamuno and Gobo, 2004). Rapid increase in population makes current limited resources insufficient in fulfilling their requirements (Khalil and Khan, 2009). Large population is also a reason for lack of government control over their education systems. These factors impact the huge generation and open dumping of waste in the open areas. Hence, it is necessary to take concrete steps in taking initiatives toward improved waste management. As huge population results in high waste generation that is difficult to manage, it is considered as an important barrier.

2.5.5 Unscientific waste disposal. Open dumping and unscientific mechanical processes always remain as a barrier to the sustainable waste management. Indiscriminate dumping causes reverse impacts on environment such as pollution and insects leading to health effects (Tadesse *et al.*, 2008; Ayotamuno and Gobo, 2004). As authorities lack information and knowledge on the scientific methods to be followed while treating the waste, tendency of public to go for open dumping increases (Agamuthu, 2003; Chung and Lo, 2008; Pokhrel and Viraraghavan, 2005; Choe and Fraser, 1999; Tesfay, 2004). Unawareness of public on the utilization of litterbins and waste containers creates unhygienic environment (Rai Sharma *et al.*, 2013). The situation gets uncontrolled during monsoon which creates hauling and spread of leaches into the underground water resource (Hazra and Goel, 2009). Hence, unscientific waste disposal is a critical barrier in solid waste management.

2.5.6 Unscientific planning. Planning for an efficient waste management system is essential to develop clean environment in the country. Regular planning develops the potential for systematic administration of waste management (Schubeler *et al.*, 1996; Pradhan *et al.*, 2017). Lack of readily available quantitative and qualitative data regarding solid waste management parameters is a challenge toward ensuring effective planning. Hence, unscientific planning is taken as a barrier in the process.

2.5.7 Illiteracy. Lack of literacy is identified as the obstacle that reduces the cooperation of people with authorities. This will also lead to the unavailability of skilled and trained personals in solid waste management which always becomes a barrier in ensuring an efficient waste management system (Mrayyan and Hamdi, 2006). This can be considered as another reason for the failure in ensuring right incentives in environmental hygiene services and collection. Education and raising the living standards of individuals will improve the behavior and approach of society toward waste management (Rowe, 2007; Frisk and Larson, 2011; Goldman *et al.*, 2006; Owusu *et al.*, 2017). And thus illiteracy is considered as another barrier.

2.5.8 Ineffective processes and administration. Effective solid waste management can be achieved by the support and involvement of organizations and private organizations or NGOs which will motivate the residential community's involvement and other public participation (Zhuang *et al.*, 2008). Local authorities are the foot soldiers in practicing the daily waste management as a representative of the higher level governments (Chung and Lo, 2008). Lack of administrative capacity of the authorities leads to the lack of maintaining a trust from communities, along with the shortage of financial resources that hampers the development of waste infrastructure (Choe and Fraser, 1999; Diaz *et al.*, 1996). The lack of guidance from authorities due to their constraints in information will affect all other developments (Hazra and Goel, 2009). Hence, ineffective processes and administration is considered as a barrier (Table II).

3. Research methodology

As mentioned earlier, we have followed a multi-phased approach in this study (Sushil, 2016; Shibin *et al.*, 2017). We have started with literature review in the first phase to identify the critical drivers and barriers of ISSWM. The next was the data collection phase. In this phase, we have approached experts to get their opinion on the drivers and barriers identified. Experts were also requested to express their opinion on all possible interrelations among the selected drivers and barriers of ISSWM. The targeted experts where having more than 15 years of experience and were from public governing bodies and academics. In our study, 20 experts from public governing bodies and 10 academicians were approached for getting their opinion. Pune Municipal Corporation and Pimpiri-Chinchwad Municipal Corporation were the two local public governing bodies that we have targeted. Indian academicians working on sustainable development, environmental management and solid waste recycling and management having credible publication records and teaching experience were also approached to get their opinion. The context of the study and the expected outcome of the study in the Indian context were explained to the experts on phone before e-mailing the interaction data matrix form to them. The questionnaire was mailed to all 30 experts and few of them were directly met for understanding their response in a detailed way. Hence, out

S. No.	Barriers	References
B1	Poor environmental commitment	Qian *et al.* (2011), Agunwamba (1998), Liu and He (2012), Kansal *et al.* (1998), Askarian *et al.* (2004)
B2	Lack of technical expertise	Ayotamuno and Gobo (2004), Karunasena and Amaratunga (2015), Mrayyan and Hamdi (2006), Seng *et al.* (2011), Chung and Lo (2008), Appiah Obeng *et al.* (2009)
B3	Poor social values and ethics	Burritt (2004), Parker (2005), Schubeler *et al.* (1996), Dijkema *et al.* (2000)
B4	Huge population	UN (2014), Shekdar (2009), Vesilind *et al.* (2002), Aung and Arias (2006), Ayotamuno and Gobo (2004), Khalil and Khan (2009)
B5	Unscientific waste disposal	Tadesse *et al.* (2008), Ayotamuno and Gobo (2004), Agamuthu (2003), Chung and Lo (2008), Pokhrel and Viraraghavan (2005), Choe and Fraser (1999), Tesfay (2004), Rai Sharma *et al.* (2013), Hazra and Goel (2009)
B6	Unscientific planning	Schubeler *et al.* (1996), Pradhan *et al.* (2017)
B7	Illiteracy	Mrayyan and Hamdi (2006), Rowe (2007), Frisk and Larson (2011), Goldman *et al.* (2006), Owusu *et al.* (2017)
B8	Ineffective processes and administration	Zhuang *et al.* (2008), Chung and Lo (2008), Choe and Fraser (1999), Diaz *et al.* (1996), Hazra and Goel (2009)

Table II.
Barriers of ISSWM

of them, 25 responded and we achieved 83 percent response rate. These feedbacks included a critic review but no variables were dropped down. They included suggestions for modification of wordings and languages which will improve the clarity of the work. And in the third phase, the focus was on model building by using the data collected. We have used a TISM-based approach for model building, which is widely accepted as an effective alternative methodology for theoretical framework development (Dubey *et al.*, 2015; Shibin *et al.*, 2016). TISM is a modified extended version of interpretive structural modeling with the inclusion of transitive links in the model. TISM has been used successfully by various researchers in several areas such as total quality management, telecom sector, cloud computing, pharmaceutical, education sector and strategic management (Jain and Raj, 2015; Dubey and Ali, 2014; Goyal and Grover, 2012; Mangla *et al.*, 2014; Prasad and Suri, 2011; Singh and Sushil, 2013; Srivastava and Sushil, 2014; Yadav, 2014). The TISM approach is based on systems theory and graph theory, which help to solve complex problems and interactions of large set of variables with a holistic view (Rajagopalan and Batra, 1975; Tichy *et al.*, 1979; Eisenack and Petschel-Held, 2002). Even though several techniques are based on graph theory and systems theory, the current research with the use of TISM can be considered as a unique approach that can structure sets of dissimilar factors and directly relate them to comprehensive systematic models (Rajesh, 2017; Saxena *et al.*, 1990; Mandal and Deshmukh, 1994; Singh *et al.*, 2003; Sharma and Gupta, 1995; Ravi and Shankar, 2005; Hsu *et al.*, 2015; Kumar *et al.*, 2013; Venkatesh *et al.*, 2015). And thus, this approach is providing a clear direction toward solving a complex conceptual framework development problem on ISSWM with the two structural models (Sindhwani and Malhotra, 2017; Nasim, 2011; Sushil, 2012).

A total of eight barriers and nine drivers were identified from the literature analysis. The self-interaction levels of these variables based on expert opinion is presented in Tables III and IV.

3.1 Define and interpret contextual relationships among elements

We have followed the steps elaborated by Sushil (2012) and Jain and Raj (2015) on the TISM methodology. The first step in TISM is the creation of self-interaction matrix of variables under consideration based on expert opinion. Relationships among the variables are denoted using the letters V, A, X, O and the columns and nodes were represented by *i* and *j*. The symbols were representing by the variables as follows: V: if *i* leads to *j* and *j* does not lead to *i*; A: if *i* does not lead to *j* and *j* leads to *i*; X: if *i* leads to *j* and *j* leads to *i*; and O: if *i* and *j* are not in relation with each other. We have formulated two separate self-interaction

	D9	D8	D7	D6	D5	D4	D3	D2	D1
D1	O	V	V	O	O	V	O	X	X
D2	O	V	V	O	O	V	O	X	
D3	V	A	A	X	X	A	X		
D4	O	X	X	V	V	X			
D5	V	A	A	X	X				
D6	V	A	A	X					
D7	O	X	X						
D8	O	X							
D9	X								

Notes: D1, institutional effectiveness; D2, robust policy and legal framework; D3, public participation; D4, innovative and cost-effective technology; D5, financial stability; D6, improved resource availability; D7, effective waste segregation and collection; D8, recycling and reproduction; D9, commercial and profitable ISSWM ventures

Table III. Structural self-interaction matrix of drivers (SSIM)

	B8	B7	B6	B5	B4	B3	B2	B1
B1	X	A	V	V	A	A	X	X
B2	X	A	V	V	A	A	X	
B3	V	X	O	O	X	X		
B4	V	X	O	O	X			
B5	A	O	X	X				
B6	A	O	X					
B7	V	X						
B8	X							

Notes: B1, poor environmental commitment; B2, lack of technical expertise; B3, poor social values and ethics; B4, huge population; B5, unscientific waste disposal; B6, unscientific planning; B7, illiteracy; B8, inefficient process and administration

Table IV. Structural self-interaction matrix of barriers (SSIM)

matrices for drivers and barriers as shown above. In the next step, we have used transitivity property for converting structural self-interaction matrix to final reachability matrix and then to binary matrix. Final reachability matrix is prepared by using the transitivity principle (Sushil, 2005; Dubey and Ali, 2014) and it maintains the consistency of the model. It is illustrated as example: if a leads to b and b leads to c, then transitivity property implies that a leads to c. This property helps to remove any possible interactions considered among variables. The final reachability matrix prepared by following the transitivity criteria is given as in Tables V and VI.

Identification of the level of variables from reachability matrix depending on the dependence and driving power of variables was performed in the third step. Based on the level of variables identified from reachability matrix, a directed graph (DIGRAPH) was prepared. The next step followed is the conversion of DIGRAPH to structural model, which

	D1	D2	D3	D4	D5	D6	D7	D8	D9
D1	1	1	1*	1	1*	1*	1	1	0
D2	1	1	1*	1	1*	1*	1	1	0
D3	0	0	1	0	1	1	0	0	1
D4	0	0	1	1	1	1	1	1	1*
D5	0	0	1	0	1	1	0	0	1
D6	0	0	1	0	1	1	0	0	1
D7	0	0	1	1	1	1	1	1	1*
D8	0	0	1	1	1	1	1	1	1*
D9	0	0	0	0	0	0	0	0	1

Table V. Final reachability matrix – drivers

	B1	B2	B3	B4	B5	B6	B7	B8
B1	1	1	0	0	1	1	0	1
B2	1	1	0	0	1	1	0	1
B3	1	1	1	1	1*	1*	1	1
B4	1	1	1	1	1*	1*	1	1
B5	0	0	0	0	1	1	0	0
B6	0	0	0	0	1	1	0	0
B7	1	1	1	1	1*	1*	1	1
B8	1	1	0	0	1	1	0	1

Table VI. Final reachability matrix – barriers is self-explanatory about relation amongst the variables. Conceptual stability of the structural model is validated by reviewing and makes necessary correction. This is established through brainstorming. The association between the two variables is checked using "yes" or "no" questions. Hence, the total number of paired comparisons required is nC_2, i.e. total of 136 comparisons for all drivers and barriers.

3.2 Data analysis and results

Level partitioning is the process of ranking different variables into hierarchical levels. The reachability and antecedents are calculated to obtain the level of drivers from Tables V and VI (Warfield, 1974; Sushil, 2012). While conducting the iteration, if the reachability set intersection with the antecedent set is reachability set itself then that variable is kept in the top level of hierarchy. The final output of level partitioning is obtained as shown in Tables VII and VIII along with MICMAC analysis in Figures 1 and 2. Diagraph and binary matrix (Tables IX and X) derived is together utilised for the development of TISM model. Tables XI and XII are the transitive links between variables considered in the model, based on the expert opinion. These links will be helpful to understand interlinks of variables at intermitted levels. The conceptual frameworks for drivers and barriers are shown in Figures 3 and 4.

MICMAC is applied as a tool to analyze their hierarchical relationship based on their driving power and dependence (Warfield, 1974). During the analysis, the variables will be divided into four categories. The first category is dependent category which has variables

Table VII. Level matrix of drivers

Variables	Level
D9	Level 1
D3, D5, D6	Level 2
D7, D4, D8	Level 3
D1, D2	Level 4

Table VIII. Level matrix of barriers

Variables	Level
B6, B5	Level 1
B1, B8, B2	Level 2
B3, B4, B7	Level 3

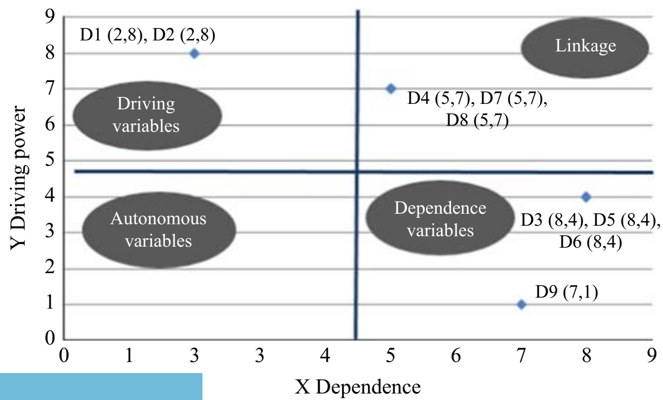

Figure 1. MICMAC analysis of drivers

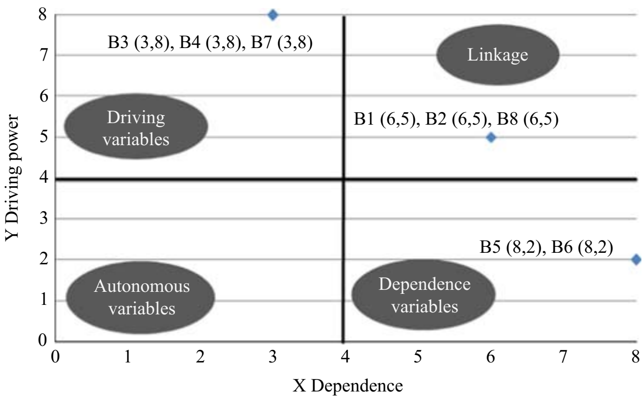

Figure 2.
MICMAC analysis of barriers

	D1	D2	D3	D4	D5	D6	D7	D8	D9	Driving power
D1	1	1	1	1	1	1	1	1	0	8
D2	1	1	1	1	1	1	1	1	0	8
D3	0	0	1	0	1	1	0	0	1	4
D4	0	0	1	1	1	1	1	1	1	7
D5	0	0	1	0	1	1	0	0	1	4
D6	0	0	1	0	1	1	0	0	1	4
D7	0	0	1	1	1	1	1	1	1	7
D8	0	0	1	1	1	1	1	1	1	7
D9	0	0	0	0	0	0	0	0	1	1
Dependence	2	2	8	5	8	8	5	5	7	

Table IX.
Binary interaction matrix of drivers

	B1	B2	B3	B4	B5	B6	B7	B8	Driving power
B1	1	1	0	0	1	1	0	1	5
B2	1	1	0	0	1	1	0	1	5
B3	1	1	1	1	1	1	1	1	8
B4	1	1	1	1	1	1	1	1	8
B5	0	0	0	0	1	1	0	0	2
B6	0	0	0	0	1	1	0	0	2
B7	1	1	1	1	1	1	1	1	8
B8	1	1	0	0	1	1	0	1	5
Dependence	6	6	3	3	8	8	3	6	

Table X.
Binary interaction matrix of barriers

with weak driving power and higher dependence. This is followed by linkage and independent category. The final category is "autonomous" section which includes the variables with least driving and dependency.

4. Discussions

The current study contributes significantly by helping to develop two distinctive and comprehensive frameworks for the drivers and barriers of ISSWM by using TISM with reference to Indian conditions. We followed the TISM approach which is based on a combination of graph theory and systems theory to generate the frameworks (Sushil, 2012; Matthews *et al.*, 2016; Alvesson and Sandberg, 2011). This conclusive model has been derived

Table XI.
Transitive links from experts for drivers

	D1	D2	D3	D4	D5	D6	D7	D8	D9
D1		Effective execution of the policies in all firms	Improved acceptance level	Better investment in innovative technologies	Minimum investment with maximum	Better distribution of resources	Better performance and commitment		
D2	Effective and planned management		Enhanced transparency	Green and energy-efficient technology	Better opportunities	Better coordination and response		Maximize demand for recycled products	
D3					Better coordination				Better commitment
D4					Improved quality of production	Better knowledge and planning	Achievement of better quality	Reduced risk	Robust process with minimum cost
D5			Better health care and support			Better investment			Minimum investment
D6					Effective management				Maximum coverage
D7			Develop the culture of waste elimination	Safe working condition	Better facility adoption				Reduces pollution and creates safe environment
D8				Reuses and saves the cost	Savings in process	Better resource utilization			Reduction in production of further raw material waste
D9									

	B1	B2	B3	B4	B5	B6	B7	B8
B1						Lack of technological awareness		Lack of responsible people
B2					Lack of professional knowledge			Poor commitment
B3	Lack of environmental awareness			Lack of investment in education	Lack of leadership	Poor knowledge		Lack of organizational policy
B4			Poor support of management		Lack of coordination	Poor knowledge of public needs	Unawareness about public	
B5						Lack of investment		
B6					Lack of efficient technology			
B7		Lack of organizational support		Poor service to public	Lack of awareness program	Lack of commitment		Poor public support
B8	Lack of quality education	Lack of proper guidance			Lack of safety	Lack of law enforcement		

Table XII. Transitive links from experts for barriers

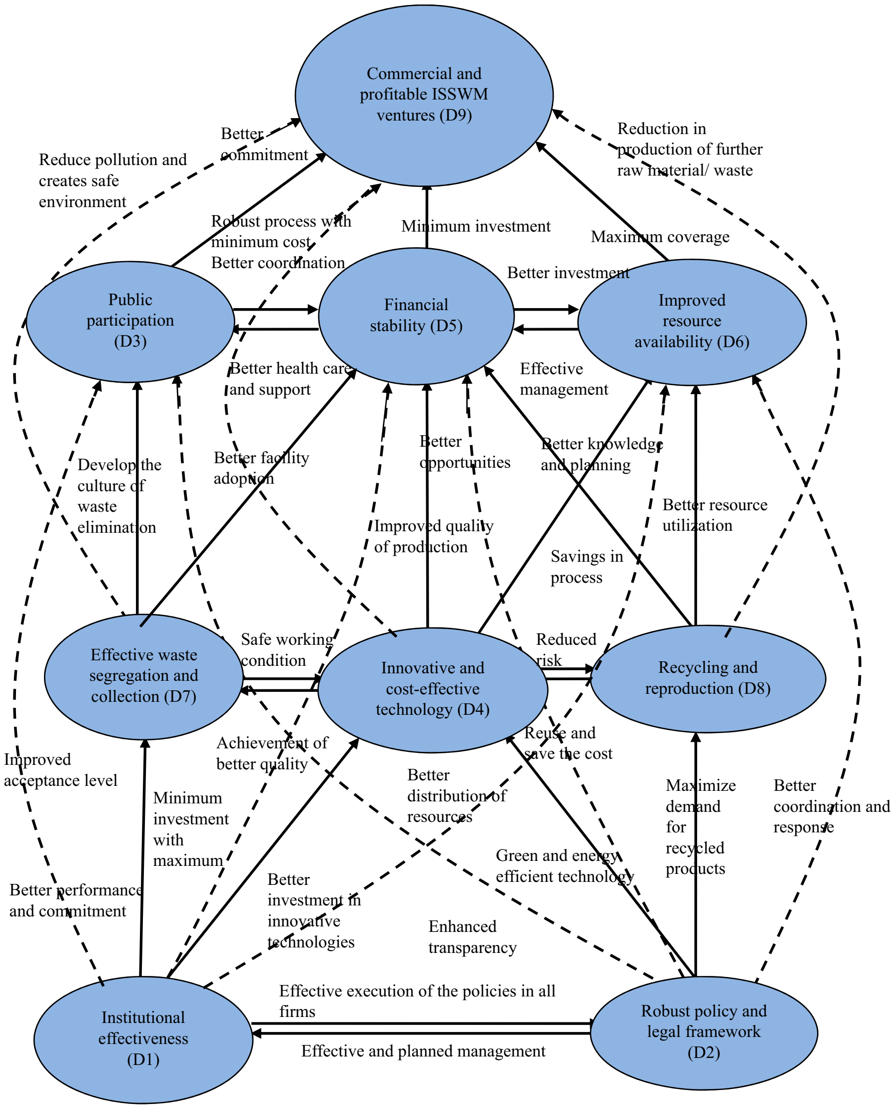

Figure 3.
TISM model of drivers of ISSWM

and tested from the survey conducted by following the guidelines of Guide and Ketokivi (2015). Based on the literature review, nine critical drivers of ISSWM were identified which include: institutional effectiveness (D1), robust policy and legal framework (D2), public participation (D3), innovative and cost-effective technology (D4), financial stability (D5), improved resource availability (D6), effective waste segregation and collection (D7), recycling and reproduction (D8) and commercial and profitable ISSWM ventures (D9). Important barriers identified from the literature include: poor environmental commitment (B1), lack of technical expertise (B2), poor social values and ethics (B3), huge population (B4), unscientific waste disposal (B5), unscientific planning (B6), illiteracy (B7) and inefficient process and administration (B8). TISM was used to generate the interactive and transitive links between these identified factors.

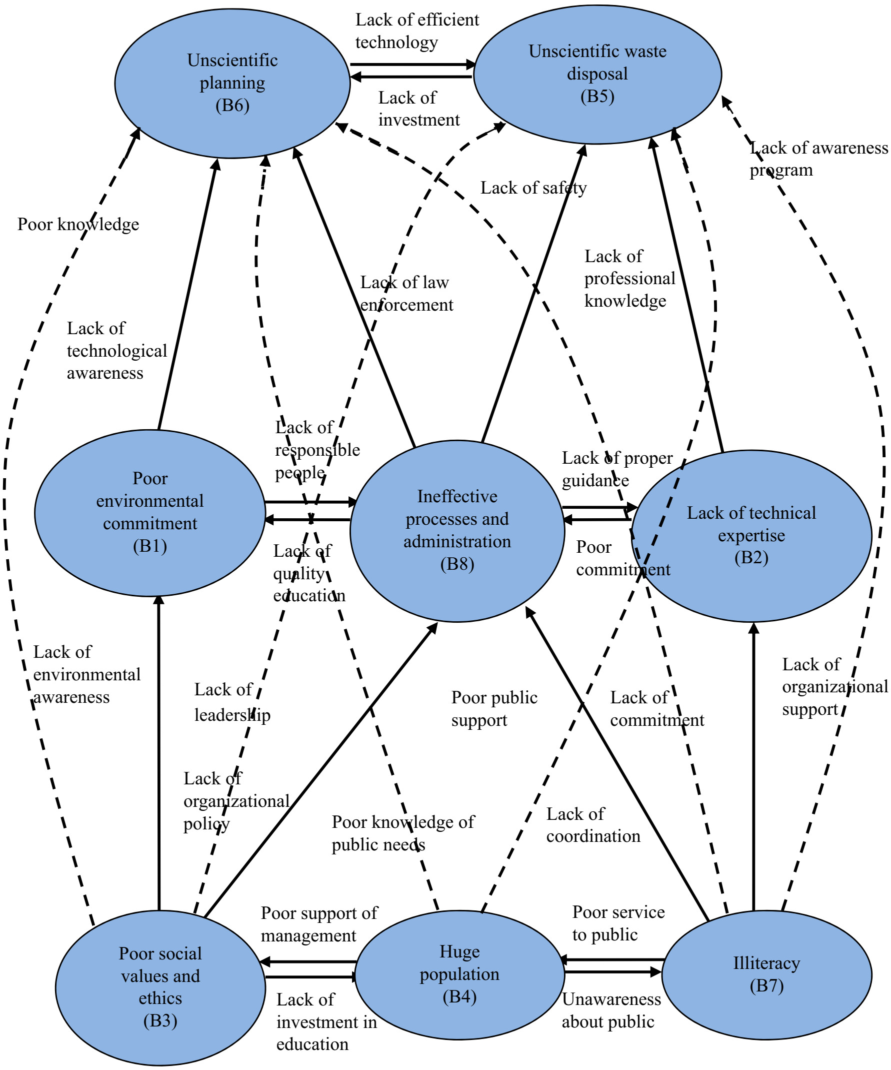

Figure 4.
TISM model of barriers

Clear understanding of the linkages between drivers and barriers will support the decision makers to tackle the problems and take right actions in attaining the ISSWM. Identification of drivers enables the policy makers to identify the appraising area which is to be focused and managed with more care. Barriers are the areas in the system which stand as a challenge in proper implementation of the ISSWM in countries. Relative importance and interdependence among these drivers and barriers are presented by the MICMAC analysis.

The current research framework highlights the role of institutional effectiveness (D1) and robust policy and legal framework (D2) in attaining ISSWM in the country. They are the two most critical variables having the highest driving power and lower dependence. So these two variables drive the effective operations in ISSWM by ensuring effective waste collection and segregation (D7), availability of innovative and cost-effective technology (D4) and the recycling and reproduction (D8) of solid wastes which are the linkage variable of the system.

These two key drivers fall in Level 4 in the TISM hierarchy and they have the strong driving power to affect the other drivers. Linkage variables have strong driving and dependence power and any uncertainty in these variables will affect each other and also other variables. The control of driving variable and linkage variable enhances the effective involvement of public participation (D3), financial stability (D5), improved resource availability (D6) and commercial and profitable ISSWM ventures (D9). Commercial and profitable ISSWM ventures (D9) occupying Level 1 of the TISM hierarchy is having the highest dependence power. Consequently, any action performed on other drivers will have the highest impact on the ISSWM. The top management should focus more on these factors in priority basis for the development of an existing solid waste management system.

This step was followed by the identification of barriers, identifying their interrelationships and outlining their influence levels. Unscientific planning (B6) and unscientific waste disposal (B5) are identified as the most influencing barriers which fall in Level 1 of the TISM hierarchy. This was followed by poor environmental commitment (B1), lack of technical expertise (B2) and inefficient process and administration (B8) in Level 2 and poor social values and ethics (B3), huge population (B4) and illiteracy (B7) in Level 3 having correlation with each other. The MICMAC analysis of the barriers identifies the interdependence among the barriers and shows that there are no autonomous barriers. The framework identifies poor social values and ethics (B3), huge population (B4) and illiteracy (B7) as the dependence power which also form the base of the TISM model and have to be strategically handled. The model depicts poor environmental commitment (B1), lack of technical expertise (B2) and inefficient process and administration (B8) as linkage variables of the system. These variables are highly sensitive and occupy the middle of the TISM model. Hence, the study reveals that strategic and effective management of the driving and linkage variable will control the dependence variable such as unscientific planning (B6) and unscientific waste disposal (B5) of the system.

4.1 Theoretical contributions

This research work attempted to provide significant and unique theoretical contributions to the existing literature body on ISSWM by designing and executing the research process to respond to several existing research gaps in ISSWM, which include:

(1) response to the call for more research on ISSWM with reference to the solid waste management issues in the cities of emerging nations (Ezeah *et al.*, 2013; Lohri *et al.*, 2014; Permana *et al.*, 2015; Zapata and Zapata, 2013);

(2) response to the call for more research attempts by using approaches having holistic view on ISSWM with a combination of systems theory and graph theory (Sushil, 2012; Rajesh, 2017; Eisenack and Petschel-Held, 2002);

(3) to address the call for more empirical research works on analyzing the critical variables of ISSWM (Mwanza and Mbohwa, 2017);

(4) to have a well-defined framework by identifying the drivers and barriers that will help to understand the system and to have a clear idea on the long-term strategy of ISSWM (Eltayeb *et al.*, 2011; Jharkharia and Shankar, 2005; Sudhir *et al.*, 1996);

(5) to address the existing research gaps of not addressing the conceptual framework of ISSWM through holistic system point of view (Seadon, 2010; Marshall and Farahbakhsh, 2013; Sushil, 2012); and

(6) another theoretical contribution of this paper is the clear classification of the drivers and barriers of ISSWM by considering the driving power and dependence through MICMAC analysis.

We have also ensured utmost care for giving equal importance to social dimension along with environmental and economic dimension, which is found as an existing research gap in the ISSWM research (Allesch and Brunner, 2014; Vinyes *et al.*, 2013). Thus, it can be seen that this paper has attempted to effectively address many existing valid research gaps in the ISSWM domain.

4.2 Managerial contributions

Identification of critical drivers and barriers will help decision makers to analyze the area to be focused more based on their importance and hierarchical level in the theoretical framework. This will help policy makers and administrators to focus their energy on boosting the drivers and overcoming the barriers for the effective and quick implementation of ISSWM policies to achieve tangible results. The study also figures out the driving power and dependence of all the selected 17 variables based on their interconnections. This will definitely help managers to prioritize their efforts on these variables on an ongoing basis for achieving the desired target. Identified key variables can be prioritized for assisting in formulating sustainable solid waste management policies efficiently and effectively. Moreover, the framework of drivers is explicitly showing the need to have economical self-reliability of the waste management system, which in turn will help to minimize the financial burden of various governmental bodies to support the initiatives. This will also help to create new start-up ventures in solid waste management domain to reduce burden on governments and to reduce unemployment in developing nations. And thus we can see that the authorities in the cities of developing nations can consider this study as a base for improving the sustainability performance of integrated solid management systems.

5. Conclusions

To conclude with, this study can be considered as an attempt to extend the existing literature content on sustainability (Brundland, 1987; Garbie, 2014; Carter and Easton, 2011), solid waste management (Hao *et al.*, 2007; Karunasena and Amaratunga, 2015) and sustainable development issues by considering the issues in developing nations like India (Ezeah *et al.*, 2013; Lohri *et al.*, 2014; Permana *et al.*, 2015). This study is also contributing toward the existing literature content with the TISM methodology (Sushil, 2012; Dubey *et al.*, 2017). The novelty of the research is in identifying the drivers and barriers associated with the ISSWM which has to be highlighted for better implementation of the system. Contributions of this paper can be considered as many fold:

(1) This paper helps to answer "what" by considering the question "What are the enablers and barriers of ISSWM?"

(2) It also helps to answer "why" by giving answer to the question "Why these elements are linked in that manner?"

(3) The third question "how" is also getting answered through the response to the question "How these variables are interlinked together?"

(4) Two separate frameworks of drivers and barriers were developed, which is very rarely found in the existing literature body.

(5) The framework of drivers shows the need to commercialize the ventures in solid waste management in a profitable way to make it sustainable by minimizing the burden on various governmental bodies in developing nations like India.

And thus, the study clearly depicts the interrelationships and hierarchy of drivers and barriers of ISSWM in a systematic way by using a multi-phased approach of literature review, expert opinion and TISM. From the MICMAC analysis, it is observed that drivers such as public participation, commercialization and financial stability, improved resource availability, ISSWM having high dependence are mainly driven by institutional effectiveness and robust policy and legal framework. The analysis also reveals that unscientific waste disposal and unscientific planning are the two major hindrances with high dependence driven by poor social values and ethics, huge population and illiteracy. Moreover, innovative and cost-effective technology, effective waste segregation and collection and recycling and reproduction are unstable variables and any changes will cause impacts on the effectiveness of all the variables. We can understand that poor environmental commitment, lack of technical expertise and inefficient process and administration are the highly sensitive barriers to the effective implementation of ISSWM.

6. Limitations and future research directions

Even though the work offers important aspects related to ISSWM, the current research also has its own limitations. Replacing MICMAC with fuzzy MICMAC methodology can also be considered as an extension of the work to improve the sensitivity. This study lacks the requirement of systematic questionnaire survey which could further test the framework and provide relative weighting to the variables. And thus future studies can consider including more sample size and validating the model using advanced structural equation modeling and confirmatory analysis.

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