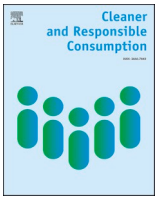
Cleaner and Responsible Consumption 7 (2022) 100084

Contents lists available at ScienceDirect

Cleaner and Responsible Consumption

journal homepage: www.journals.elsevier.com/cleaner-and-responsible-consumption



Moving towards a circular economy model through I4.0 to accomplish the SDGs

Raji Ajwani-Ramchandani [a], Sonali Bhattacharya [b,*]

[a] Ashank Desai Centre for Policy Studies, Indian Institute of Technology-Bombay, 400076, Powai, Mumbai, Maharashtra, India
[b] Symbiosis Centre for Management and Human Resource Development, Symbiosis International University, Pune, 411057, India

ARTICLE INFO

Keywords:
Blockchain technology
Municipal solid waste management
UN Sustainable development goals

ABSTRACT

In this study, we propose a Blockchain enabled Municipal Solid Waste Management Framework (SoGReIn Framework©) which will return benefits to the Consumers with corporate participation under Extended Producer's Responsibility Protocol. This inclusive approach will require integrated efforts from Corporates, citizens, Government, NGOs, technocrats, academicians and the waste pickers. The benefits of the model can also be shared by all the stakeholders.

The study is based on the insights received from exploring the experiences of some of the exemplar large residential housing communities located in the metropolitan cities in India who have undertaken voluntary efforts in segregating, recycling and reusing various types of wastes generated at the household level and converting them into resources. It further discusses how with the help of new age technology such efforts can help in negotiating corporate participation and help in the reduction of the consumption of plastic wastes.

The model, thus suggested can help in furthering the attainment of multiple UN Sustainable Development goals.

1. Introduction

The importance of converting waste into wealth has gained significance specially after the declaration of UN sustainable development goals in 2015. The wealth can be perceived as good health and well-being (SDG3) of the communities, sustainable consumption and production (SDG 13) of products, decent and sustainable livelihoodin terms of pollution free physical environment (SDG 7, 11, 13, 14 and 15), economic conditions (SDG 1, 2, 5 and 8)and social equity (4, 5, 10). The stakeholder theory calls for partnership between all stakeholders: the customers, suppliers, employees, and local communities, shareholders as the creators and consumers of the sustainable resources. Hence responsible behaviour is expected from each of these stakeholders (Heath & Norman, 2004).

Admittedly Multinational Enterprises(MNE)shave been contributing towards economic growth, technology transfers, enlarging the availability of choices available to developing economies (Kostova et al., 2016; Lowe & Kenny, 1999; Rugman, 2006). But they have also been held responsible for polluting the host country's environment, breaking the universal social and ethical norms by employing child labor, and creating unfavorable working conditions (Clapp & Dauvergne, 2005) through their entrepreneurial ventures. They often choose countries where the environment standards are lax (Blackman, 2008),for getting benefits ofreduced operating costs and increased profitability(Porter, 1999; Wheeler, 2001).

The existence of "institutional voids" in emerging economies (Khanna and Palepu, 2011) with respect to enforcement of laws and regulations and the absence of widespread international regulations pertaining to social and environmental issues allow MNEs to leverage the moral free space. Though there are legal frameworks on circular economy such as pay-as-you throw or responsible disposal of plastic package wastes by producers and consumers, but most of these laws are either non-mandatory in nature or there are lack of evidences of punitive actions against the violators. Taxes levied to individual consumers for use of plastic bags are limited to only some specific products (Nielsen et al., 2020). Non-mandatory nature of legal framework and lack of knowledge diffusion makesit difficult in implementation of circular economic framework in urban planning (Obersteg et al., 2019).

Another major stakeholder, whose role has not been discussed much in the literature is the community, who can both be influencers and drivers of sustainable development and circular economy. Communities can return the end of life cycle of products to the sellers for recycling and

* Corresponding author.
E-mail address: sonali_bhattacharya@scmhrd.edu (S. Bhattacharya).

https://doi.org/10.1016/j.clrc.2022.100084
Received 20 September 2022; Received in revised form 18 October 2022; Accepted 29 October 2022
Available online 12 November 2022

remanufacturing (Govindan et al., 2015), and can be the buyers of wealth created through disposable end-products. Though studies have highlighted roles of communities as collaborators to sustainable development, but we did not find much literature on perceiving communities as drivers of change. The exception is Nisbett et al. (2017) who through their case studies of three countries, have attributed the role of leaders and champions in driving forward policy formulation and enabling a positive ground level impact in reducing malnutrition. In another study Nisbett et al. (2015) highlighted the positive outcome of collaboration between communities and government in Maharashtra which resulted in a fast reduction of child stunting due to under nutrition.

Miles et al. (2021) for example found through their systematic literature review that community education, participation and legislative support are drivers of sustainable circular economy.An incentive mechanism that covers all the stakeholders involved in "production-consumption" value chain, combined with the use of technologies such as blockchain, artificial intelligence (AI), internet of things (IoT), big data analytics, and robotics can help to provide a solution to the current status. Aguiñaga et al. (2018) framed the Sustainable Wealth creation based on Innovation and enabling Technologies (SWIT) framework for returning socio-economic benefits to rural communities through a community driven bottom up approach. Diaz-Villavicencio et al. (2017) delved with Municipal led strategy that can be adopted for common good objective of the society, where social communities played participatory role only. Socio- Circular based model on the urban context driven by community initiatives have rarely been studied. Based on stakeholder theory this research paper attempts to explore following research questions in context of Indian municipal solid waste management:

1) How citizens or communities can enable the sustainable management of municipal solid waste?
2) How can emerging technologies like blockchain, AI, or robotics be leveraged for better municipal solid waste management?
3) How can such citizen or community initiated changes pave the way for the adoption of circular business practices by business corporations?

The rest of this research paper is structured as follows: Section 2 provides a review of literature on the theories and application of technology integrated sustainable development models, from the perspectives of circular economy. Section 3 summarizes the experiences of some of the large residential housing societies in India who have proactively participated in executing sustainable municipal waste management practices. The subsequent sections summarize the critical analysis of the observation, development of SogGReIn model framework and its implications from perspectives of various stakeholders.

Our exploratory study revealed that the proposed IoT-ICT integrated smart waste management system if adopted by the urban communities may help in conversion of wastes into wealth. This can be facilitated through behavioural intention and cognitive action from the members in segregation of bio-degradable, recyclable, toxic wastes (such as, sanitary wastes) at the point of waste generation itself (household level or residential community level), adoption of technology for the conversion of these complex wastes into resources and energy and the redistribution of benefits to various stakeholders such as policy makers, the technology partners, the industries, the waste pickers and the society at large (Adam et al., 2018; Anagnostopoulos et al., 2017; Gutierrez de Almeida et al., 2017). This involves appropriate treatment technologies of wastes categories, appropriate resource recovery methods, and mobilization of policy support to achieve sustainable development goals (SDG's).

2. Literature review

In this section we explored some of the existing theories which delved with the integration of technology with circular economy.

2.1. Stakeholder Theory and circular economy (CE)

The stakeholder theory conceptualized by Freeman (2015) argues that the traditional approach to focus on shareholder value is not enough to create firm value, but significant impetus should also be given to other stakeholders such as governmental bodies, political groups, trade associations, trade unions, communities, financiers, suppliers, employees, competitors, and customers. All these stakeholders have the capacity to affect the firm performance. Stakeholder Theory reinforces the need of Multi-national enterprises to legitimize CE practices in both home and host markets (DiMaggio & Powell, 1983; Hah & Freeman, 2014; Jamali, 2010; Tan & Wang, 2011). Subsidiaries of MNEs can anticipate legal threats as the host country may use preconceived notions, which negatively affect subsidiaries (Hansen et al., 2020; Campbell et al., 2012). Social regulations in most emerging economies are weaker than the western MNEs own country with inadequate enforcements (Christmann and Taylor, 2006; Sharfman et al., 2004). Differences between the MNEs and the government agencies in legislations can be resolved through cooperation than confrontation (Child and Tsai, 2005; Yang and Rivers, 2009). Further as per the stakeholder theory MNEs should take into account the legitimate rights of individuals who affect and are affected by their activities (Donaldson and Preston, 1995; Freeman, 1994). Focus of business strategies should be such that all stakeholders: the managers, the employees, the customers, communities, shareholders are in a win-win situation and they all travel in the same boat in a collectively identified mission. According to Harrison and Wicks (2019) stakeholder relationships are bounded by ethical values of integrity, respect, fairness, generosity and inclusiveness and any firm strategy perceived to be harmful by the stakeholders should be evaluated immediately based on remedial cost, revocable cost and stakeholder mobilization cost. Bondy and Charles (2020) point out that it is the marginalized or weaker stakeholders whose voice is often unheard. In this study we illustrate an approach through which the MNE can collaborate with primary and secondary stakeholders to develop a solution that can be scalable, replicable, and self-sustainable.

Theoretically, CE is positively viewed as a regenerative system where resources, inputs, waste emissions, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops (Geissdoerfer et al., 2017).CE is one of the most contemporary and prominent sustainable development approach (MacArthur, 2013), which encapsulates repair, reuse, recycle and upgrade of product leading to furthering of environmental, economic, and social goals(Geissdoerfer et al., 2017). The concept is drawing significant attention among practitioners, scholars, and policymakers(Geissdoerfer et al., 2017) in recent years. Recycling is considered important to reduce post-consumer and packaging waste. An exponential generation of plastic waste has led to calls for strict action from European Union and United Nations (Eygen et al., 2018). Circular economy considers products manufactured, not sold, not consumed and not at end of life cycle as potential waste (Gokarn and Kuthambalayan, 2017; Murray et al., 2017).

Jabbour et al. (2020) have found in the Brazilian context that both internal and external stakeholders can influence motivators of and challenges to circular economy, which on the other hand can lead to sustainable performance of firms. The research further elaborated that the internal stakeholders are stronger influencers than the external stakeholders. However, Govindan and Hasanagic (2018) found, through their systematic literature review, that government is most critical player in determining implementation of circular economy in the supply chain domain. Similarly some other studies have also hinted regarding the roles of citizens and communities in driving circular economy, for example, end of life cycle products can be returned by the buyers to the sellers for recycling and remanufacturing (Govindan et al., 2015), interlinkage between consumers to transfer or exchange surplus or used products (Kortmann and Piller, 2016), connecting of manufacturers to new consumers for whom disposable products can be of use or value. *Our proposed intended model intends to close the (resource→materials*

→post-consumer waste→ resource) recovery loop at the point of origin or the first mile level instead of the last mile where most traditional resource recovery takes place.

2.2. Circular Economy and smart enabled technology

Smart enabled technology can enable the adoption of circular economy. According to Stahel (2016) the usage of technologies such as the Internet of Things and Industry 4.0 can boost the shift from a linear approach to a circular approach. A comprehensive review of literature conducted by Pagoropoulos et al. (2017) concluded that the intersection of CE and digital technologies is at a pre-paradigmatic stage and needs further exploration. Zhang et al. (2019) found, in context of China, that the barriers to integration of Smart Enabling Technology for waste management are government regulations, lack of awareness of environmental concerns, non-conducive culture for environmental protection and the lack of market pressures and demands. We propose to use digital technology to provide a market intermediary platform through which suppliers (the end users) and buyers (MNES)of wastes can be connected (McIntyre and Srinivasan, 2017; Thompson, 2012). Use of industry 4.0, digitalization and IoT have made waste management more reliable, efficient and transparent (Abdullah et al., 2018). Jakhar et al. (2019) for example found exploratory innovation lead firms to adopt CE than exploitative innovation. We believe it can be effectively used for waste collection, segregation and treatment (Abdullah et al., 2019; Antikainen et al., 2018) with stakeholder participation.

3. Summary of some of the best practices adopted by exemplary big housing societies in India

By 2019, nearly 62 million tons of solid waste was generated in India (Ministry of Environment, 2016). This number is expected to increase to 165 million tons by 2030.Nearly 70–75 percent of this waste remains untreated (Sharholy et al., 2005). In our study we extensively gathered the experiences of stakeholders in the Pimpri Chinchwad Municipal Corporation (henceforth PCMC, one of the top performing municipalities in India. This area has witnessed a housing boom over the past decade due to the development of an information technology special economic zone (or ITSEZ) in the vicinity (Hinjawadi IT park area[1]). The PCMC had stopped picking up food waste (or organic component of the MSW) from large residential clusters, also known ase bulk waste generators effective[2]from 2017 and asked them to compost the food waste. Only dry waste (recyclables) and bio-hazardous waste (sanitary napkins and diapers) i is picked up by the civic authority. The PCMC also instituted a system of offering incentives such as subsidies on the property tax for large residential communities (also known as housing socities) undertaking eco-friendly initiative. Given this backdrop, the civic officials are seeking options that can help the PCMC manage its costs and generate alternate sources of funds. This municipal cluster also has a couple of exemplary residential housing societies have won many awards – such as the national award instituted by the Prime Minister of India—"Swachh Baharat" (Clean India) award in 2017 beside several other awards The rebate in property taxes couple with local and national recognition has helped to promote the practice of good sustainable waste management practices. Such exemplar societies are not only active practitioners of circular economy principles but also act as mentors to other residential complexes in adopting circular practices. They have used fly-ash for bricks for construction of the houses. Herbal liquids are distributed among residents for car washing. LED bulbs are used all over housing complexes. Solar energy is used to electrify common areas such as parking lots community gardens etc. Minimal use of refrigerators televisions is encouraged. Car-pooling is actively practiced. Wastes are segregated at source, separating out organic, plastic, and sanitary waste. The compost is used for in-house gardening and landscaping. Rain water harvesting, in-house sewage treatment and resuse for community gardens, are other sustainable practices adopted by these housing societies. Bird feeder's/water dispensers coupled with active tree plantation initiatives during festivals have transformed the place to green zones frequented by different bird species. They encourage householders to donate clothes in bulk in association with NGOs such as GOONJ.[3] Children's participation is encouraged and they form the ambassadors for driving home based sustainable practices.

However, despite such visionary efforts, there exists resistance and challenges in continuing with such measures. Many residents particularly the senior citizens believe that it is the responsibility of the civic authorities to collect, segregate and manage urban waste streams. They are also wary regarding the adoption of new technology for this purpose. Other deterrents are the fear of failure, public criticism, and the costs associated with experimentation. Property tax rebates are not guaranteed, and the process takes a long time to translate into real cash benefits. Such endeavors require upfront investment of resources (money and time). The evaluation of eco-friendly initiatives for the purpose of awarding property tax rebates is done manually and the final results are not available in the public domain for reference.

However there is a single waste segregation machine which is deployed by the civic authorities at the waste dump yard to take care of the waste being generated by 2.7 million.[4] residents !.

Nearly 1,500 tons of MSW is generated everyday in the PCMC area while the waste processing plant cum landfill located in Moshi has the capacity of handling only about 500 tons. The rest (mixed waste) is dumped into the nearby landfill. Organic waste is composted on-site. Everything else such as recyclables and sanitary waste[5] is processed in a semi-autonomous manner. If the recyclables are dry, then it is possible to segregate them in an automated manner. However, since only a two-way segregation is followed, the recyclables invariably come in contact with other kinds of wet waste such as discarded milk, oil packets, yoghurt packs, sanitary waste, and so on. The waste pickers (casual labor) manually separate the waste items and place them in discrete piles. They have to work in difficult conditions as the stench emanating from large piles of rotting waste is unbearable. They don't have any benefits such as paid medical leave or health insurance. Data pertaining to brand-wise waste is not maintained while some sort of records is maintained for the total waste that is dumped at the landfill every day. The last decade has seen a boom in real estate/construction industry due to the development of the Chakan SEZ area (Gadgil, 2013) and there have been protests by local residents who want the dump yard to be shut down. In February 2021, the PCMC approved a bio-mining project since the landfill has almost reached its full capacity (More, 2019)and plans to relocate the landfill to an alternate site were met with major protests

[1] https://en.wikipedia.org/wiki/Hinjawadi.

[2] https://punemirror.indiatimes.com/pune/civic/couple-destroys-kits-at-sample-collection-unit-for-delay-in-testing/articleshow/78134372.cms and https://www.hindustantimes.com/pune-news/no-more-says-pimpri-chinchwad-civic-body-as-it-stops-wet-garbage-collection-from-societies/story-zBmq4iHNoCTT389S3uktpK.html.

[3] GOONJ is an NGO that works with Indian rural and urban communities to address crucial gaps in rural infrastructure, water, environment, livelihood, education, health, disaster relief, and rehabilitation. See https://goonj.org/knowing-goonj/.

[4] https://indianexpress.com/article/cities/pune/pimpri-chinchwad-50-years-industrial-city-7214069/.

[5] The term semi-dry has been used because currently the civic waste collection trucks pick up waste from different locations across the municipal areas. All locations do not segregate waste properly hence the dry waste (recyclables) is usually not completely dry, which renders it useless. For example, if any food item or sanitary waste comes in contact with dry plastic bottles, then such "wet" bottles are dumped since there is no facility for washing and drying them. Moreover if used masks and gloves are discarded along with dry waste, then it is dumped in the landfill due to Covid-19 concerns.

from the residents of that area.

Knowledge of exemplar societies is localized and at present the only way that such initiatives are known is via word of mouth or through media news coverage.

Although the Indian SWM Rules, 2016, require brand owners to take back the post-consumer waste, this is not being implemented at the ground level. Waste pickers are adversely affected by items such as soiled sanitary napkins and diapers since they contain bio-hazardous contents such as human waste and fluids. Marketing linkages for enabling monetization of the organic fertilizer (compost) are required. Big Waste Generators are able to produce large quantities of high grade compost, but forward marketing linkages are missing, as a result of which they have to deal with a stockpile of the compost inventory, causing space problems.

"Marketing linkages are required. There are many uses for the compost such as usage for public gardens and parks and farming. However, transport costs can be a deterrent for farmers. Chemical fertilizer companies have a better distribution network plus those products give faster results compared to the organic fertilizers." —(A civic official)

There is a need for guidelines on re-packaging for e-commerce companies: E-commerce majors like Amazon repackage items prior to delivery. However currently there are no guidelines, which results in overuse of single use packaging materials. A resident from one of exemplary societies for example shared that.

"Something needs to be done urgently to tackle packaging waste. Even if I buy a lipstick online there is so much extra plastic that comes with it. There seem to be no guidelines for e-commerce companies. . . a small item comes in a big plastic cover. It is such a waste and is single use plastic. There is a major need to rethink this and reduce the packaging waste."

There is a need for all the concerned parties (citizens, brand owners, and civic authorities) to work together.

4. The proposed framework

4.1. Need of the model

It is evident that there is an urgent need to think of a solution for managing this issue by implementing the SWM Rules, 2016. From the civic authorities' perspective too, proper source level waste segregation practices can help in saving resources and reducing pollution. It is estimated that in India, urban local bodies spent between USD7 and USD14 per ton on solid waste management (Kumar and Samadder, 2017),whereas the collection and transportation of waste constitutes approximately 80–95 percent of the total budget allocated for municipal solid waste management(Sharholy et al., 2005). NGOs working with waste pickers perform the important task of facilitating recycling of waste. However they are severely strained for resources and have to depend upon donations and aid to manage their day to day operations. Corporations (brand owners) on the other hand spend millions of dollars for advertisements (Ajwani-Ramchandani et al., 2021). Weekly advertisement insertions in television range from INR 25 to 250 thousand,[6] with FMCG giants such as Hindustan Lever, Reckitt Benkiser, and Ponds, India being the leaders. However once the sale is completed they dissociate themselves from the packaging and leave the burden of the managing the post-consumer waste entirely upon the civic machinery.

4.2. Assumptions

A critical element for CE models to be effective at the ground level is an integrated approach involving participation from all the major stakeholders. Only then is it possible to move toward an economy that is restorative and regenerative by design(MacArthur, 2013). An important point that MNEs need to keep in mind is the fact that there is growing awareness in the host countries regarding the impact of large MNEs on the common pool resources (Purohit, 2009). The perception that consumers have of the firm's operations and ethical behavior is paramount (Moore and Manring, 2009) and a compelling enough reason for corporations to follow the correct path within the laid down policy framework. In order to disseminate the benefits of collective action and ensure transparency in sustainable waste management practices, it can be useful to use emerging technologies that are reliable and can be accessed by the concerned stakeholders to facilitate better governance. *The Social, Green initiatives, Resource use, and Innovation* (SoGReIn) framework has been conceptualized to fill some of the existing policy and implementation gaps.

4.3. A model to facilitate sustainable MSW[7] management: the SoGReIn (social, green initiatives, resource use, and innovation) Framework©[8]

This framework aims at combining the synergies of emerging technologies, community participation, and policy guidelines to create a reliable data-based approach that can: (a) propagate the benefits of adopting sustainable waste management practices,(b) highlight guidelines to help facilitate faster adoption of workable processes,(c) accelerate the adoption of UN SDGs through an inclusive approach,(d) generate reliable data,(e) facilitate the timely availability of data to facilitate governance and reduce the financial and infrastructure pressures on civic bodies through the implementation of Extended Producer Responsibility (EPR) (f) facilitate responsible BWGs[9] to monetize their efforts, and (g) accelerate the transition toward a CE approach. The details of the framework are illustrated below in Figs. 1 and 2.

Fig. 1 shows a model BWG's municipal solid waste segregation pattern.[10]On the left side of the figure are 5 waste fractions. They are food scraps, sewage water (toilet discharge), soiled sanitary napkins, soiled diapers, and packaging waste (can be sold to authorized waste dealers or given to waste pickers). Compostable food scraps and sewage water can be recycled on the premises of the BWG by installing a sewage treatment plant (STP) and compost bins.[11] However three items, namely, soiled sanitary napkins, diapers, and packaging waste have to be disposed outside the premises of the BWG. At present, packaging waste (dry waste) is segregated manually by the waste collectors once it is taken to the waste dealer's location. Sanitary waste is handed over to the civic authorities for disposal. These societies are undertaking recycling/reuse of sewage water for landscaping/gardening. Periodic waste management initiatives as well as socially relevant activities are also taken up by the model BWG—such as donation of clothes, used household items, and books to an NGO and handing over e-waste and batteries to authorized recyclers. Miscellaneous waste is sent to the landfills. Such socially relevant and eco-friendly initiatives are shown in the middle portion of the flowchart while sustainability initiatives are shown in its right section of Fig. 1.

[6] https://www.statista.com/statistics/1003821/india-top-television-advertisers-by-number-of-insertions/.

[7] MSW: Abbreviation for municipal solid waste.

[8] Copyright of this framework belongs to Dr Raji M Ajwani.

[9] BWGs: Bulk waste generators such as large housing communities also known as housing socities in India.

[10] The PCMC had stopped picking up food waste (or organic component of the MSW) from BWG effective2017 timeframe and asked them to compost the food waste. Only dry waste (recyclables) and bio-hazardous waste (sanitary napkins and diapers) would be picked up by the civic authority. They have also instituted a system of offering incentives such as subsidies on the property tax for BWG undertaking eco-friendly initiatives.

[11] Two of the BWGs had a surplus of the STP treated water available and were willing to offer it to the civic authorities for free for maintaining plants, traffic islands, and gardens in the vicinity. At present these are maintained by ferrying water tankers, which are expensive and cause pollution.

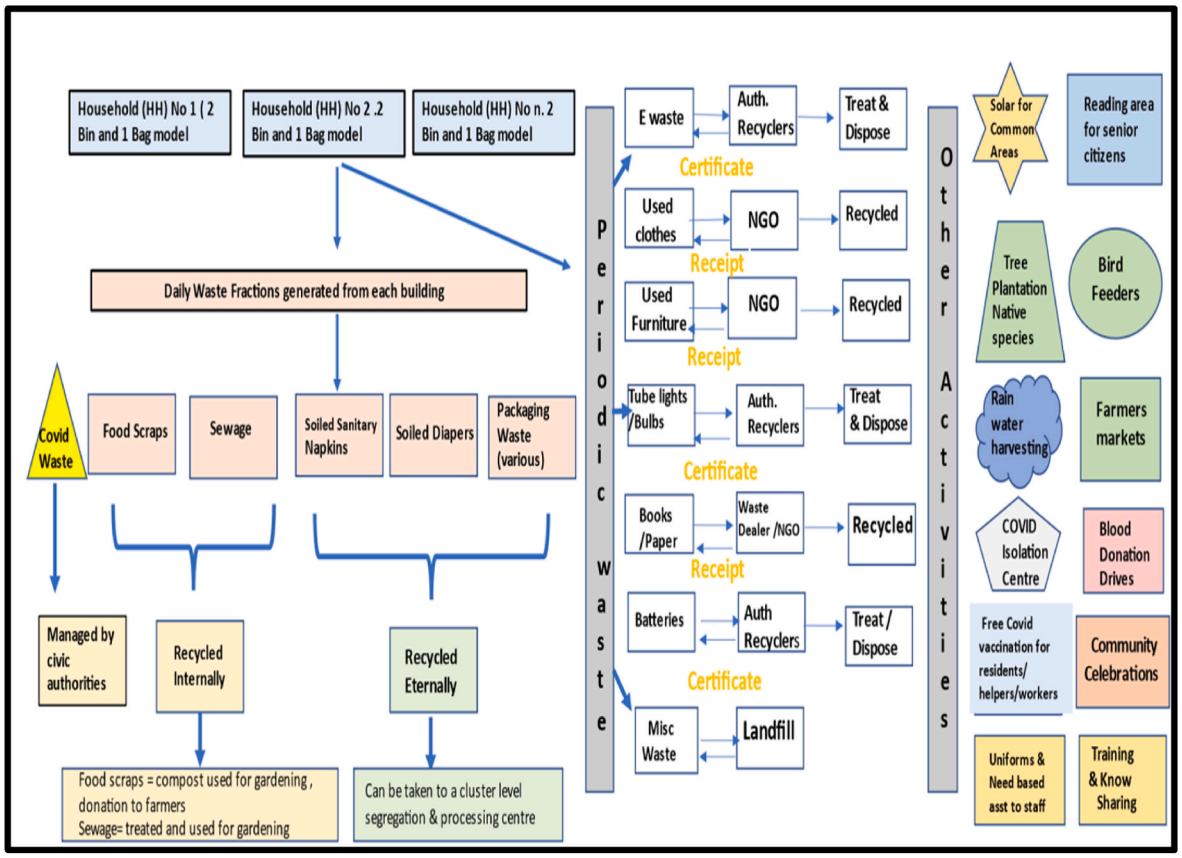


Fig. 1. Model for municipal solid waste (MSW) segregation.

4.4. Enabling the SoGReIn Framework through smart technology

As per the framework, the segregated waste generated by BWG will be transported to a resource recovery center (RRC). The waste will be digitally tagged to identify the originating entity. This data (total weight and type of waste) will be updated using a mobile application by the BWG. The trucks carrying the waste to the RRC will be tracked via GPS. The pickup routes will be designed based upon the location and quantum of waste so as to develop the most optimal pickup sequence. The BWGs will be able to track the arrival and departure of the pickup via the mobile app. The RRC will be a designated area that will be allotted by the civic authority such that MSW can be treated in a localized manner. Using robotic technology, the waste will be segregated at the RRC (see Fig. 1).

The SoGReIn framework (Fig. 2) will provide a data-based solution to the present scenario. Each BWG will be able to get a brand-wise report of the MSW segregated at the RRC at the end of each day. This data will also be available to other stakeholders such as the civic authority under whose jurisdiction the respective BWG is located as well as the entity managing the RRC. Brand owners can also be given access to data by the civic authorities. In compliance with the SWM Rules, 2016, a charge for each category of plastic waste and sanitary waste can be levied and this data can be updated in the database as shown in Figs. 1 and 2. The use of blockchain will ensure that the data is protected and smart contracts will be used to charge the brand owners a "waste disposal charge." An escrow account can be created, to be funded by the brand owners. For sanitary waste the charge will be levied on the basis of the weight and category (different charge for sanitary napkins and diapers). This will be charged to the Feminine and Infant Hygiene Association (FIHA), which is an Indian association comprising of the leading brand owners/manufacturers of feminine and infant hygiene products. The data generated can help large BWGs to earn revenues that can be used for funding their sustainability initiatives as well as cover their operational costs. It can also help the BWGs to get a comprehensive idea about the purchasing patterns of their residents. This data can then be used by the BWGs to strike bulk purchase deals that can cut down on unnecessary packaging waste and enable lower prices. BWGs can use their buying power to steer brand owners toward a more sustainable way of doing business. Civic authorities can deduct an administration fee for providing the space, pickup service for the garbage, as well as overheads required to run the RRC, such as electricity, water, and contractor charges, and then transfer the remaining amount to the BWGs. This approach will help the civic authorities comply with the SWM Rules, 2016, and utilize taxpayer collections for other development works/projects. The funds recovered as a part of the extended producer responsibility (EPR) can also help to provide waste pickers employed with the BWGs and at the RRC with better working conditions and basic amenities like medical and health insurance. Having several such decentralized RRC scan also help in reducing environmental pollution and traffic congestion by reducing the number of waste trucks plying on the road. The data generated can enable better governance and objective evaluation of the municipal wards as well as monitor the compliance of the brand owners with the laid down rules.

The dotted lines show data flows while the solid lines show the physical movement of the municipal solid waste(MSW). Livelihood generation and improvement opportunities are created at Point 1,2,3. In Point No 1 integration of waste pickers is possible to oversee that segregated MSW is digi tagged and reaches the RRC. The BWG (Housing society) can employ waste pickers for this task. Their salaries can be paid from the maintenance charges paid by the members (residents) of the co-operative housing society. Subsequently, property tax waivers offered by the civic authority for undertaking eco friendly/sustainable approach for managing MSW as well as socially inclusive approach-can offset some of those costs. At the RRC waste pickers along with other semi

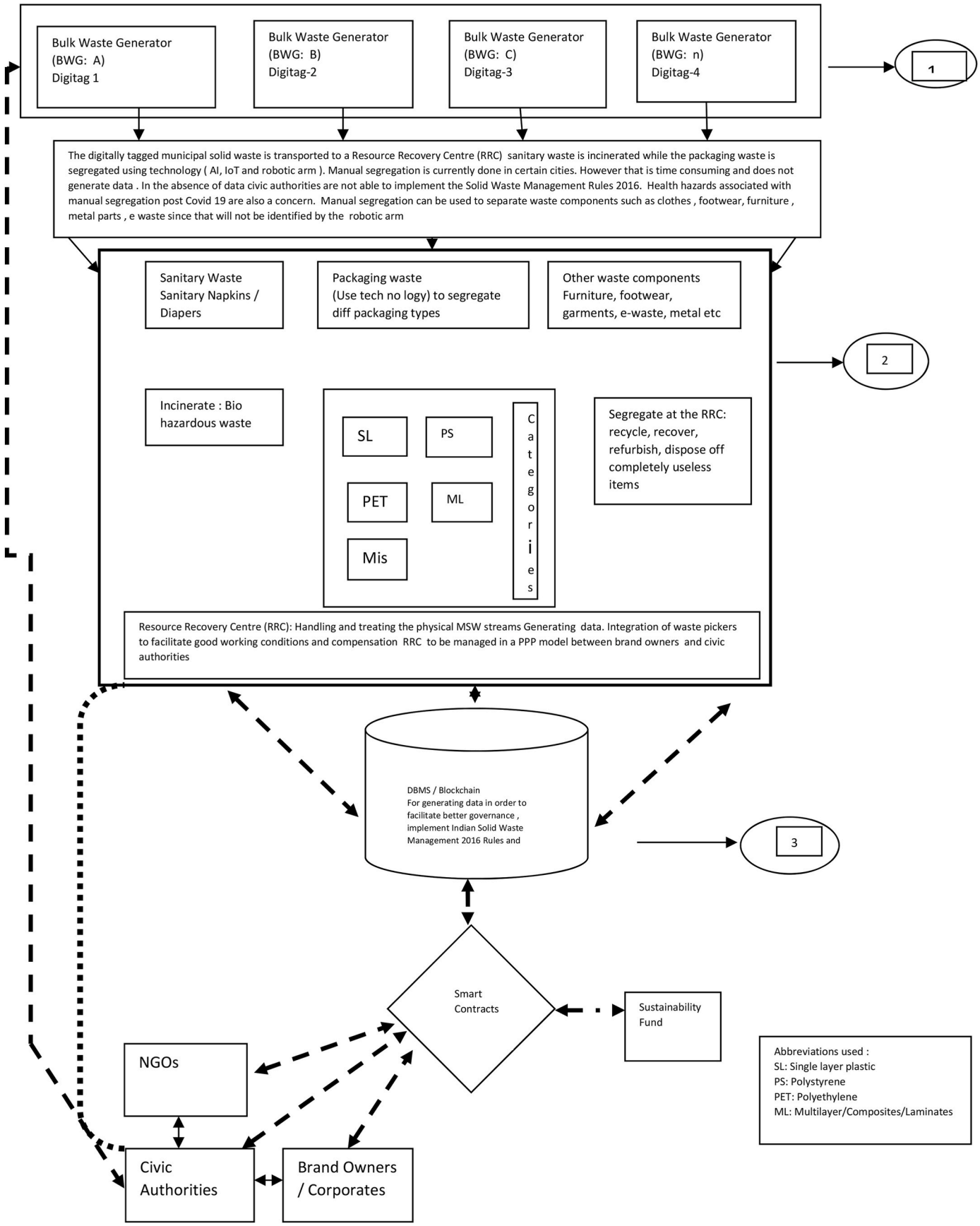


Fig. 2. Bulk waste generators- solid waste management model.

skilled staff (some training in IT) can be used for monitoring the waste segregation through technology as well as manual segregation of certain waste streams. Sanitary waste can be incinerated and charges recovered from FIHA (Feminine and Infant Hygiene Association of India) which is the apex body of manufacturers of such products. While the RRC will be managed by the civic authorities, implementation of the Solid Waste Management Rules 2016, and application of extended producer responsibility norms will enable civic authorities to recover costs from brand owners. These funds can be utilized for managing the RRC.This in turn will result in fewer tax payer funds being used for MSW management. Currently MSW activity is funded purely from tax payer funds. For waste pickers, this scenario presents an opportunity to earn fair wages and access good working conditions (as opposed to segregating waste on the roadside and not having access to proper drinking water, food, toilets. and often times becoming a target of verbal and physical abuse because of using open public spaces. At Point 3 employment opportunities for skilled personnel who can assist in the generation and interpretation of data that can facilitate better governance Using technologies like blockchain can help in overcoming trust issues. In the current scenario there is an absence of data due to which the implementation of the SWM 2016 is not taking place. This has resulted in a scenario where the entire cost of managing the MSW collection, transportation and disposal is being funded purely through taxpayer funds.

The dotted lines in Fig. 2 show data flows while the solid lines show the physical movement of the municipal solid waste(MSW). Livelihood generation and improvement opportunities are created at Point 1,2,3. In Point No 1 integration of waste pickers is possible to oversee that segregated MSW is digi tagged and reaches the RRC. The BWG (Housing society) can employ waste pickers for this task. Their salaries can be paid from the maintenance charges paid by the members (residents) of the co-operative housing society. Subsequently, property tax waivers offered by the civic authority for undertaking eco-friendly/sustainable approach for managing MSW as well as socially inclusive approach-can offset some of those costs. At the RRC waste pickers along with other semi-skilled staff (some training in IT) can be used for monitoring the waste segregation through technology as well as manual segregation of certain waste streams. Sanitary waste can be incinerated and charges recovered from FIHA (Feminine and Infant Hygiene Association of India) which is the apex body of manufacturers of such products. While the RRC will be managed by the civic authorities, implementation of the Solid Waste Management Rules 2016, and application of extended producer responsibility norms will enable civic authorities to recover costs from brand owners. These funds can be utilized for managing the RRC. This in turn will result in fewer tax payer funds being used for MSW management. Currently MSW activity is funded purely from tax payer funds. For waste pickers, this scenario presents an opportunity to earn fair wages and access good working conditions (as opposed to segregating waste on the roadside and not having access to proper drinking water, food, toilets. and often times becoming a target of verbal and physical abuse because of using open public spaces. At Point 3 employment opportunities for skilled personnel who can assist in the generation and interpretation of data that can facilitate better governance Using technologies like blockchain can help in overcoming mistrust that may exist between civic bodies and BWGs, as civic bodies have the authority to assess the performance of the BWGs and return benefits in terms tax waiver. Use of Blockchain will bring in more objectivity and transparency in the assessment. BWGs can segregate, weigh and digitally tag the wastes at the source with the help blockchain technology which will get recorded at the office of civic bodies. In the current scenario there is an absence of data due to which the implementation of the SWM 2016 is not taking place. This has resulted in a scenario where the entire cost of managing the MSW collection, transportation and disposal is being funded purely through taxpayer funds.

A deterrent in adopting this framework is the initial cost that is required to develop the technology solution and costs associated with setting up and the administration of the RRCs which can initially borne by the municipality (government) and the bulk waste manufacturers collectively. However, compared to the financial savings in terms of reduction of required man hours for waste disposal and transportation costs as well as benefits in form of tax waivers to citizens, better health conditions for waste pickers, new employment opportunities can be availed in the long run. Hence, this can be an option that is worth considering.

Another deterrent that can be anticipated is the concern from waste pickers regarding the perceived loss of income. However, using machine-based sorting avoids any direct contact with the waste. After the covid-19 crisis, a big concern of the waste pickers has been the possibility of coming in contact with MSW that contains discarded Covid prevention waste such as disposable masks, gloves, and tissues that are thrown on the roads and even discarded in residential dwellings and commercial locations. Machine-based sorting will not only handle more volume but also ensure that more waste makes its way into the recycling system so as to enable the creation of reusable products. This can result in greater employment opportunities at the RRC and the BWG locations for waste pickers. Proper sorting is important in order to recycle products effectively. Getting access to data can help BWGs to strategize their purchase patterns and negotiate bulk discounts and competitive pricing in lieu of packaging-free purchases. This will gradually help to reduce plastic waste and enable BWGs to monetize their power of making aggregate purchases, thereby enabling them to undertake development activities without depleting their funds. Having a reliable and transparent framework will also encourage more BWGs to learn by following the approach taken by exemplar BWGs.

5. Discussion

The proposed integrative model suggests a framework that calls for proactive participation of all the three major stakeholders the government, the corporates and the community to create a CE based urban society with the help of smart technology. Though literature has delved with the role that government has to play in developing and enforcing legislations and in spreading environmental consciousness and adopting sustainable practices, but pivotal role the urban communities can play by being the driver of change in the transition from linear to circular economy has largely been ignored. A smart technology enabled waste management model as suggested through our research will equip the citizens to create CE based model which will be beneficial to all stakeholders.

The first research question we attempted to answer was how citizens can contribute towards circular economy. Sustained campaign towards awareness, facilitation workshops, interaction with practitioners, can raise motivation and sustained action of community leaders. For example: the managers of large residential societies can motivate action towards circular economy, sustainable management of domestic wastes and adoption of other green practices. They can communicate the tangible and intangible benefits for adopting such practices among the residents. Engaging children in such campaigns has been proved to be successful. Exemplary housing societies not only segregate dry, wet and toxic wastes, but also contribute in converting bio-degradable wastes into composting, sustainable use of sewage water, rain water harvesting, e-waste management, recycling of solid waste, tree plantation, energy conservation, cloth donation, bird feeding providing services to needy like people suffering during pandemic. They are also willing to mentor other housing societies. Kala and Bolia (2020) pointed out there should be proper communication policy for waste management for different socio-economic strata of citizens to spread awareness and ensure their participation in the waste management activities. Civilians and communities can be the drivers of change towards circular economy.

The next research question we attempted to answer is how new age technology can be leveraged towards MSW management and attainment of UN sustainable development goals. Our suggested model, The SoG-ReIn (Social, Green initiatives, Resource use, & Innovation)

Framework© attempts to achieve this. The transport of wastes from households to resource recovery centers can be tracked by the stakeholders, the residents. The NGO authorities managing waste pickers and the civic governments by using mobile based technology. Brand-wise report of the MSW segregated at the RRC for the plastic wastes and the sanitary wastes can be generated at the end of each day for each housing society. Charges can be levied to brand owners using smart contract of blockchain based technology as part of Extended Producer Responsibility. Charges can be partially used by civic authorities for maintenance of the RRC, partly utilized for betterment of working conditions of waste pickers and providing insurance to them and rest will be returned to the BWG, the consumers for financing other sustainable practices. Hence these initiatives will contribute towards attainment of SDGs. It has also been found by Chin and Mees (2021) that local government's support in form of financial assistance, technical assistance, capacity building, networking can lead to success of citizen led initiatives in sustainability.

The third research question that has been attempted is if citizen or community initiated changes pave the way for adoption of circular business practices by corporations. BWGs by using blockchain based data can negotiate for bulk discounts and competitive pricing from brand owners in lieu of package free purchases This will gradually help to reduce plastic waste and enable BWGs monetize their power of making aggregate purchases, in form of negotiating bulk discounts, reduced cost of use and disposal of plastics, and negotiating tax benefits from civic bodies. Savings can be used by BWGs for developmental activities such as green harvesting, providing education, clothing, water & sanitation facilities to the marginalized sections in the neighborhoods. According to Freeman's (2015) theory the consumers-the citizens, academics, government, NGO and the waste pickers are all indirect social stakeholders who will be not only beneficiaries of the model but also active participants without whose integrated effort this technology enabled model will not be successful. The data collected can also be utilized by civic authorities to return proportionate property tax benefits to BWGs based on their sustainable development efforts. Industry 4.0 integrated smart solution for economic, social and environmental waste management have been found to be successful in bringing together all stakeholders for attainment of SDGs in Indonesia (Fatimah et al., 2020). It can thus be replicated in other emerging nations as well.

5.1. Implications for theory, practice and policy

Our work has a number of implications for theory. First, it contributes to the body of smart technology enabled urban waste management model, especially in emerging economic context. The research, further, contributes towards creating an integrated framework and is an original conceptualization of smart technology enabled CE model through stakeholder participation. As put forth by Govindan et al. (2015) this study reiterate that the loop of waste management can be closed at the origin by integrating the process with Industry 4.0 technology. This study contributes towards the theory of innovation diffusion by recognizing the potential of individual stakeholders to effect innovation diffusion using salience of industry 4.0 to effect contribution towards sustainable development goals. We also found that environmental managers, can be made to respond to both technical, social and institutional pressures. Citizens sometimes act as change agents, altering the framing of and discourse about environmental performance. Their strategies and ability depend, in part, on the relative institutional support they can garner through their proactive initiatives, the relationship between technical, social and institutional pressures, and the salience of these pressures.

We highlight that CE business models require clear support from Government officials, waste generating industries and technology enablers in order to contribute to sustainable municipal solid waste management practices. For managers and consultants dealing with CE policies and practices, this work generates provoking thoughts on how CE models can integrate social aspects, like concerns of waste pickers. For CE policy makers, industries, urban local bodies and technocrats the work highlights the motivators, deterrents and action plan from the perspectives of various stakeholders for creating a sustainable society and attainment of sustainable development goals.

6. Conclusion

Through our framework we demonstrate the application of CE concepts at a grassroots level through a participatory theoretical model based on an integrated approach involving the main stakeholders of the production-consumption value chain. We also help to shed light on the understudied social dimension that is often overlooked in the case of most literature surrounding CE. The importance of the real-world phenomenon is often overlooked in most research articles pertaining to MNEs, as they are more focused on analyzing parameters of performance such as the quantum of foreign direct investment, international trade, and firm's performance. Though there are limitations to our work since it is set in an emerging economy context that is unique to the subcontinent and involves bulk waste generators, this issue appears to be endemic to most emerging economies. The suggested framework can be replicated in the context of a developed economy as well, since it addresses a global issue (plastic waste) and provides a solution that can facilitate governance and enforce accountability in any setting. Using new technologies described in this article has become inevitable given the number of stakeholders, products, consumption patterns, modes of purchase involved, and the need for solutions that can provide measureable outcomes in a low trust environment.

Declaration

- The authors have no relevant financial or non-financial interests to disclose.
- The authors have no conflicts of interest to declare that are relevant to the content of this article.
- All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.
- The authors have no financial or proprietary interests in any material discussed in this article.
- Copyright of this framework belongs to Dr Raji M Ajwani.
- SoGReIn is the abbreviation for Social, Green initiatives, Resource use, & Innovation framework

Data availability

No data was used for the research described in the article.

References

Abdullah, N., Alwesabi, O.A., Abdullah, R., 2018 June. IoT-based smart waste management system in a smart city. In: *International conference of reliable information and communication technology*. Springer, Cham, pp. 364–371.

Abdullah, N., Yusof, N., Lau, W.J., Jaafar, J., Ismail, A.F., 2019. Recent trends of heavy metal removal from water/wastewater by membrane technologies. J. Ind. Eng. Chem. 76, 17–38.

Adam, M., Okasha, M.E., Tawfeeq, O.M., Margan, M.A., Nasreldeen, B., 2018. August). Waste management system using iot. In: *International conference on computer, control, electrical, and electronics engineering (ICCCEEE)*. IEEE, pp. 1–4.

Aguiñaga, E., Henriques, I., Scheel, C., Scheel, A., 2018. Building resilience: A self-sustainable community approach to the triple bottom line. J. Clean. Prod. 173, 186–196.

Ajwani-Ramchandani, R., Figueira, S., de Oliveira, R.T., Jha, S., Ramchandani, A., Schuricht, L., 2021. Towards a circular economy for packaging waste by using new technologies: the case of large multinationals in emerging economies. J. Clean. Prod. 281, 125139.

Anagnostopoulos, T., Zaslavsky, A., Kolomvatsos, K., Medvedev, A., Amirian, P., Morley, J., Hadjieftymiades, S., 2017. Challenges and opportunities of waste

management in IoT-enabled smart cities: a survey. IEEE Trans. Sustain. Comput. 2 (3), 275–289.
Antikainen, M., Uusitalo, T., Kivikytö-Reponen, P., 2018. Digitalisation as an enabler of circular economy. Procedia Cirp 73, 45–49.
Blackman, A., 2008. Can voluntary environmental regulation work in developing countries? Lessons from case studies. Pol. Stud. J. 36 (1), 119–141.
Bondy, K., Charles, A., 2020. Mitigating stakeholder marginalisation with the relational self. J. Bus. Ethics 165 (1), 67–82.
Campbell, J.T., Eden, L., Miller, S.R., 2012. Multinationals and corporate social responsibility in host countries: Does distance matter? J. Int. Bus. Stud. 43 (1), 84–106.
Child, J., Tsai, T., 2005. The dynamic between firms' environmental strategies and institutional constraints in emerging economies: evidence from China and Taiwan. J. Manag. Stud. 42 (1), 95–125.
Chin, W.Y., Mees, H.L., 2021. The rising stars of social innovations: how do local governments facilitate citizen initiatives to thrive? The case of waste management in Brussels and Hong Kong. Environ. Pol.Govern. 31 (5), 533–545.
Christmann, P., Taylor, G., 2006. Firm self-regulation through international certifiable standards: determinants of symbolic versus substantive implementation. J. Int. Bus. Stud. 37 (6), 863–878.
Clapp, J., Dauvergne, P., 2005. Paths to a green world: The political economy of the global environment. MIT Press, Cambridge, MA.
Díaz-Villavicencio, G., Didonet, S.R., Dodd, A., 2017. Influencing factors of eco-efficient urban waste management: Evidence from Spanish municipalities. J. Clean. Prod. 164, 1486–1496.
DiMaggio, P.J., Powell, W.W., 1983. The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. Environ. Soc. Manag. J. 147–160.
Donaldson, T., Preston, L.E., 1995. The stakeholder theory of the corporation: concepts, evidence, and implications. Acad. Manag. Rev. 20 (1), 65–91.
Eygen, V., Laner, D., Fellner, J., 2018. Circular economy of plastic packaging : current praactice and perspectives in Austria. Waste Manag. 72, 55–64.
Fatimah, Y.A., Govindan, K., Murniningsih, R., Setiawan, A., 2020. Industry 4.0 based sustainable circular economy approach for smart waste management system to achieve sustainable development goals: a case study of Indonesia. J. Clean. Prod. 269, 122263.
Freeman, R.E., 1994. The politics of stakeholder theory: some future directions. Bus. Ethics Q. 409–421.
Freeman, R.E., 2015. Stakeholder Theory. Wiley encyclopedia of management, pp. 1–6.
Gadgil, M., 2013. 2nd Mumbai, Pune airports in limbo, 2nd Mumbai, Pune airports in limbo. Business Standard News. business-standard.com. Acceseed on 11th November, 2022.
Geissdoerfer, M., Savaget, P., Bocken, N.M., Hultink, E.J., 2017. The Circular Economy–A new sustainability paradigm? J. Clean. Prod. 143, 757–768.
Gokarn, S., Kuthambalayan, T.S., 2017. Analysis of challenges inhibiting the reduction of waste in food supply chain. J. Clean. Prod. 168, 595–604.
Govindan, K., Hasanagic, M., 2018. A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective. Int. J. Prod. Res. 56 (1–2), 278–311.
Govindan, K., Soleimani, H., Kannan, D., 2015. Reverse logistics and closed-loop supply chain: a comprehensive review to explore the future. Eur. J. Oper. Res. 240 (3), 603–626.
Gutierrez de Almeida, M.D.F., Figueiredo, P.S., Dantas, J., 2017. The socioeconomic conditions of waste pickers in bahia, and an evaluation of a workforce restructuring: a multiple case study. Environ. Soc. Manag. J./Revista de Gestão Social e Ambiental 11 (1).
Hah, K., Freeman, S., 2014. Multinational enterprise subsidiaries and their CSR: A conceptual framework of the management of CSR in smaller emerging economies. J. Bus. Ethics 122 (1), 125–136.
Hansen, U.E., Larsen, T.H., Bhasin, S., Burgers, R., Larsen, H., 2020. Innovation capability building in subsidiaries of multinational companies in emerging economies: Insights from the wind turbine industry. J. Clean. Prod. 244, 118746.
Harrison, J.S., Wicks, A.C., 2019. Harmful stakeholder strategies. J. Bus. Ethics 1–15.
Heath, J., Norman, W., 2004. Stakeholder theory, corporate governance and public management: what can the history of state-run enterprises teach us in the post-Enron era? J. Bus. Ethics 53 (3), 247–265.
Jabbour, C.J.C., Seuring, S., de Sousa Jabbour, A.B.L., Jugend, D., Fiorini, P.D.C., Latan, H., Izeppi, W.C., 2020. Stakeholders, innovative business models for the circular economy and sustainable performance of firms in an emerging economy facing institutional voids. J. Environ. Manag. 264, 110416.
Jakhar, S.K., Mangla, S.K., Luthra, S., Kusi-Sarpong, S., 2019. When stakeholder pressure drives the circular economy: measuring the mediating role of innovation capabilities. Manag. Decis. 57 (4), 904–920.
Jamali, D., 2010. The CSR of MNC subsidiaries in developing countries: global, local, substantive or diluted? J. Bus. Ethics 93 (2), 181–200.
Kala, K., Bolia, N.B., 2020. Waste management communication policy for effective citizen awareness. J. Pol. Model. 42 (3), 661–678.
Khanna, T., Palepu, K.G., 2011. World Financial Review, pp. 18–20.
Kortmann, S., Piller, F., 2016. Open business models and closedloop value chains: redefining the firm-consumer relationship. Calif. Manag. Rev. 58 (3), 88–108.
Kostova, T., Marano, V., Tallman, S., 2016. Headquarters–subsidiary relationships in MNCs: fifty years of evolving research. J. World Bus. 51 (1), 176–184.
Kumar, A., Samadder, S.R., 2017. A review on technological options of waste to energy for effective management of municipal solid waste. Waste Manag. 69, 407–422.
Lowe, N., Kenney, M., 1999. Foreign investment and the global geography of production: why the Mexican consumer electronics industry failed. World Dev. 27 (8), 1427–1443.
MacArthur, E., 2013. Towards the circular economy. Journal of Industrial Ecology 2 (1), 23–44.
McIntyre, D.P., Srinivasan, A., 2017. Networks, platforms, and strategy: Emerging views and next steps. Strat. Manag. J. 38 (1), 141–160.
Miles, A., Reeve, M.J., Grills, N., 2020. Effectiveness of Community Health Worker Delivered Interventions on Non-communicable Disease Risk and Health Outcomes in India: A Systematic Review. *Christ.* J. Global Health 7 (5), 31–51.
Ministry of Environment, F. a, 2016. April 5). *Solid Waste Management Rules Revised after 16 Years; Rules Now Extend To Urban And Industrial Areas':*. Retrieved february 1, 2018, from Press Information Bureau: http://pib.nic.in/newsite/PrintRelease.aspx?relid=138591.
Moore, S.B., Manring, S.L., 2009. Strategy development in small and medium sized enterprises for sustainability and increased value creation. J. Clean. Prod. 17 (2), 276–282.
More, M., 2019. Pimpri-Chinchwad: over 6 Lakh Families to Get Two Garbage Bins; Rs 300 Fine for Not Segregating Waste. Retrieved from Indian Express. https://indianexpress.com/article/cities/pune/pimpri-chinchwad-over-6-lakh-families-to-get-two-garbage-bins-rs-300-fine-for-not-segregating-waste-5919143/.
Murray, A., Skene, K., Haynes, K., 2017. The circular economy: an interdisciplinary exploration of the concept and application in a global context. J. Bus. Ethics 140 (3), 369–380.
Nisbett, N., Wach, E., Haddad, L., El Arifeen, S., 2015. What drives and constrains effective leadership in tackling child undernutrition? Findings from Bangladesh, Ethiopia, India and Kenya. Food Pol. 53, 33–45.
Nielsen, T.D., Hasselbalch, J., Holmberg, K., Stripple, J., 2020. Politics and the plastic crisis: A review throughout the plastic life cycle. Wiley Interdiscip. Rev. Energy Environ. 9 (1), e360.
Nisbett, N., van den Bold, M., Gillespie, S., Menon, P., Davis, P., Roopnaraine, T., et al., 2017. Community-level perceptions of drivers of change in nutrition: evidence from South Asia and sub-Saharan Africa. Global Food Secur. 13, 74–82.
Obersteg, A., Arlati, A., Acke, A., Berruti, G., Czapiewski, K., Dąbrowski, M., ... & Knieling, J. (2019). Urban regions shifting to circular economy: Understanding challenges for new ways of governance. *Urban Plann.*, *4*(3), 19-31.
Pagoropoulos, A., Pigosso, D.C., McAloone, T.C., 2017. The emergent role of digital technologies in the Circular Economy: a review. Procedia CIRP 64, 19–24.
Porter, M.E., 1999. *Competição: estratégias competitivas essenciais*. Gulf Professional Publishing.
Purohit, P., 2009. Economic potential of biomass gasification projects under clean development mechanism in India. Journal of Cleaner Production 17 (2), 181–193.
Rugman, A., 2006. Inside the Multinationals 25th Anniversary Edition: the Economics of Internal Markets. Springer.
Sharfman, M.P., Shaft, T.M., Tihanyi, L., 2004. A model of the global and institutional antecedents of high-level corporate environmental performance. Bus. Soc. 43 (1), 6–36.
Sharholy, M., Ahmad, K., Mahmood, G., Trivedi, R.C., 2005, December. Analysis of municipal solid waste management systems in Delhi–a review. In: *Book of proceedings for the second International Congress of Chemistry and Environment, Indore, India*, pp. 773–777.
Stahel, W.R., 2016. The circular economy. Nature News 531 (7595), 435.
Tan, J., Wang, L., 2011. MNC strategic responses to ethical pressure: An institutional logic perspective. J. Bus. Ethics 98 (3), 373–390.
Thompson, D.N., 2012. 2UDFOHV﷿KRZSUHGLFWLRQPDUNHWVWXUQHPSOR\HHV into Visionaries. Harvard Business Review Press.
Wheeler, D., 2001. Racing to the bottom? Foreign investment and air pollution in developing countries. J. Environ. Dev. 10 (3), 225–245.
Yang, X., Rivers, C., 2009. Antecedents of CSR practices in MNCs' subsidiaries: a stakeholder and institutional perspective. J. Bus. Ethics 86 (2), 155–169.
Zhang, A., Venkatesh, V.G., Liu, Y., Wan, M., Qu, T., Huisingh, D., 2019. Barriers to smart waste management for a circular economy in China. J. Clean. Prod. 240, 118198.