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Drivers to Sustainable Plastic Solid Waste Recycling: A Review

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Abstract

Waste recycling is a livelihood for the marginalized society in the developing economies and it is not surprising to find recycling of municipal solid waste (MSW) been carried out. Plastic waste is a waste type in MSW yet a number of challenges still exist in managing this waste type. A literature review was conducted to identify the key drivers to sustainable development of post-consumer packaging plastic waste recycling systems in developed and developing economies. A number of articles focusing on drivers or factors influencing sustainable management and recycling of solid waste and municipal solid waste were reviewed. Further analysis of the results indicated a number of drivers from the economic, environmental and social aspect as drivers to sustainable development of recycling systems for post-consumer packaging plastic solid waste.

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1. Introduction

Rapid and unplanned urbanization leaves municipalities largely overwhelmed when it comes to the collection and disposal of increasing amounts of waste [1]. Municipal solid waste management continues to remain one of the most neglected areas of urban development and this has called for sustainable means of management. It is characterized by a number of waste types and of these are plastic solid wastes (PSW).

Plastics have become an integral part of our lives because of the many properties that they possess. The drivers to such growth is their low density, strength, robust, design and fabrication capabilities and low cost. As a result of such properties, plastics are not only used as packaging materials, they are also used in automotive and industrial

applications. Their usage in a number of applications including preservation and distribution of food, only makes it reasonable to find a considerable amount of PSW in the final stream of municipal solid waste (MSW). While plastics are found in almost all MSW categories, it is important to identify factors that influence the proper ways of managing such wastes. Despite having a number of positive properties, plastics contribute a variety of demerits from the waste management perspective.

Recycling is considered as one of the best options in the solid waste management hierarchy to reduce the impacts presented by end of life (EoL) and end of use (EoU) post-consumer packaging plastic wastes. Other than contributing to municipal solid waste management by diverting materials which have economic value from the main waste flow, thus reducing quantities of waste to be collected and disposed [2, 3], recycling provides the opportunity to use recovered plastics to manufacture a new product [4,5]. For these reasons, recycling provides opportunities for recovered polymers to cascade through multiple stages throughout their lives hence contributing to sustainable manufacturing. Recycling is recognized as the “most environmentally sound” strategy for dealing with MSW following only the preventive strategy of source reduction and reuse [6, 7]. [8] indicated that recycling could be categorized as the most positively received type of solid waste management practice and as an essential part of sound waste management. It is clearly a waste management strategy but can also be one current example of implementing the concept of industrial ecology whereas in a natural ecosystem there are no wastes but only products [9].

In developing economies, the issues of municipal solid waste management remain a challenge especially the recovery of end of life (EoU) post-consumer packaging PSW for recycling. Despite a number of studies having been conducted on recycling plastics, a majority of these have used the life cycle assessment (LCA) to evaluate the environmental, economic and social impacts of the processing and recycling chain [10, 11]. Other studies have either assessed solutions for reducing the damage coming from the most impacting phases during the production of recycled polyethylene terephthalate (RPET) fibre-based panel for building heat insulation [12]) while others have compared the environmental and economic impacts of different recycling technologies or have evaluated the different methods of reprocessing reclaimed PET resins (e.g. bottle to fiber) [13, 10]. These studies are useful in suggesting the sustainable technologies and higher –efficiency reprocessing of reclaimed resins.

In contrast, few studies have analyzed the drivers to sustainable post-consumer packaging PSW recycling. [14] conducted a review on plastics recycling: challenges and opportunities. The findings of the research indicated recycling as one of the strategy for end of life (EoL) waste management of plastic products. Further [15] conducted a literature review on recycling and recovery routes of plastic solid waste and the review indicated that, it is important to consider recycling and energy recovery methods in plastic manufacturing and converting facilities. Both [14] and [15] conducted a review on plastic recycling by describing the processes of plastic recycling and the challenges and opportunities of such processes. However [15] indicated that it is important to consider recycling methods in plastic manufacturing and converting facilities. In our research, plastic recycling is considered as an aspect of sustainable manufacturing as recovered plastic wastes are used to manufacture new products which would have otherwise been manufactured by using virgin material. As a result of recycling, sustainable management of material is implemented.

In our work, drivers are mechanisms that can significantly impact development in sustainable recycling (manufacturing) of plastic wastes. Therefore the literature review is basically aimed at identifying the drivers that can enhance the development of sustainable recycling systems for post-consumer packaging plastic wastes. The objectives of the research are; to identify the drivers influencing the development of sustainable systems for managing and recycling plastic solid waste or municipal solid waste (MSW). Second we analyze the drivers or factors influencing the development of sustainable systems for plastic solid waste management and recycling into economic, environmental and social aspects. In doing so, we will expand on the works that have looked at plastic solid waste management from the life cycle assessment since most life cycle assessment on plastics focus on the economic and environmental aspects, [16, 17, 18].

2. Literature Review

In developing countries, recent urbanization has increased the concentration of people resulting in accumulation of waste that needs to be properly managed and disposed [19]. With this in mind, it is necessary to determine the drivers that influence solid waste management specific to each country context [20]. Absence of the relevant drivers in solid

waste management, means problems in SWM will continue despite continued research and application of new technologies.

The need to identify the factors or drivers influencing sustainable development of waste recycling and solid waste management systems has been widely addressed using different research approaches: research focusing on analytical approaches and empirical approaches have been conducted. According to [21], most studies on waste recycling and waste management can be classified into two categories; studies based on households' data and those based on community data. This section discusses and identifies drivers or factors influencing solid waste management and recycling at community and household levels.

2.1 Drivers influencing solid waste management at community level

A number of studies have looked at drivers influencing solid waste management. [20] conducted a research on development drivers for waste management. He identified six broad group of drivers for development in waste management. Public health, environmental protection, resource value of waste, institutional and responsibility issues, closing the loop and public awareness. The study by [20] has been extended by [22] and [23]. [22] extended Wilson's work by reorganizing the six factors that influence sustainable waste management into four groups of drivers; human, institutional, economic and environmental drivers. [23], reviewed the drivers as part of the historical backdrop that frames current SWM practices in developing countries and explored the present day issues specific to SWM in developing nations.

[3] conducted a research on sustainable recycling of municipal solid waste in developing countries. The research identified twelve factors that influence sustainable recycling of MSW in developing countries; government policies, government finances, waste characterization, waste collection and segregation, household education, household economies, MSWM administration, MSWM personal education, MSWM plan, local recycled material, technological and human resources and land availability. [24] conducted an issue driven analytical framework to evaluate the past, present and future municipal solid waste management strategy for the cities of Yokohama and Boston considering four driver categories; legal drivers, technology development and institutional drivers, regional and international drivers and socio-economic drivers. [25] conducted a research on identification of waste management development drivers and potential emerging waste treatment technologies in the Swedish context. Social, economic and environmental drivers were considered.

Further research on the drivers or factors influencing solid waste management and recycling has continued. [26] aimed to contribute to the understanding of how recycling programmes affect the quantity of waste and sorting activities. [27] conceptually evaluated issues surrounding the sustainability of SWM. Despite all these researches, a number of developing countries are still facing recycling waste management related challenges.

A summary of the studies on drivers influencing solid waste management is presented in Table 1. The purpose of the summary is to find out the type of study previously carried out, the type of waste type considered, the drivers studied, methodology adapted and to identify the research gap.

Table 1: Summary of Studies on Drivers influencing SWM at Community Level

Source	Waste Type	Method Used	Broad Conclusion
[20]	SW	Historical and Comparative	There is no one single driver for development in waste management.
[24]	MSW	Analytical	The analysis identified changes in the role of some drivers influencing solid waste management.
[22]	SW	Review	Each driving group must be investigated in a local context and all information combined to devise sustainable waste management policies and strategies
[3]	MSW	Qualitative Analysis of Case Studies	Necessary and beneficial relationships drawn among 12 factors revealed the collaborative nature of sustainable MSWM

[21]	MSW	Case Study	Intensive source separation and other municipal recycling initiatives have a high potential for producing positive results.
[25]	MSW	Review, Case studies and Questionnaire	Waste management systems are involved with different multi-disciplinary factors.
[23]	SW	Review	Demonstrated the importance of founding new SWM approaches for developing country contexts in post-normal science and complex, adaptive systems thinking.
[27]	SW	Conceptual	Proposed a multi-pronged integrated approach for improvement that achieves sustainable SWM.
[28]	SW	Comparative Analysis	There is no 'one size fits all'; good, reliable data; and focusing on governance and technology.

Analysis of the literature at community level reviews that, none of the studies specially focused on post-consumer packaging plastic solid wastes. However, the steady increase in the use of plastic products has resulted in a proportionate rise in plastic waste in MSW streams in large cities [29]) and therefore the researchers identified a number of drivers (table 3) that can contribute to the development of sustainable recycling systems for post-consumer packaging plastic solid waste. Further the studies at community level have indicated that, interrelationships exist among the drivers and that no one driver should be considered in isolation of the other when developing SW or MSW management systems. Further, each driver should be investigated in the local context of each country as perspectives of local stakeholders vary. In the aspect of sustainable development of waste management systems, plastic solid waste recycling provides opportunities to reduce oil usage, carbon dioxide emissions and quantities of waste requiring disposal [14] hence in our research, it contributes to sustainable manufacturing.

2.2. Factors influencing SWM and recycling at household level

Other studies on determining the factors influencing solid waste recycling and management have either focused on the social, economic or environmental drivers separately. [30] conducted a study on the factors influencing the rate of recycling. [31] identified policy-relevant drivers for successful promotion of waste reduction and recycling. Their study indicated intensive source separation and other municipal recycling initiatives have a high potential for producing positive results. [32] highlighted the importance to waste policy-makers of understanding the relationships between recycling programme provision and the unit cost of residual waste collection and disposal.

Other studies at household level have revealed the role of incentives in inducing environmentally responsible behaviour [33, 34]. [35] conducted a study on domestic waste recycling, collective action and economic incentive: the case of Hong Kong. The study focused on the impact of reward schemes on waste recycling behaviour of residents in 122 private housing estates in Hong Kong. More recent studies on recycling behaviour indicate that economic incentives as well as education and communication play a very important role in initiating more sustainable behavioural patterns in the ICT sector [36]. They analysed the drivers and barriers to returning and recycling mobile phones and their consideration in existing communication and collection campaigns. A number of studies have revealed that incentives have a direct influence on waste recycling, [37].

Other studies such as [38] studied the profile of people who utilize drop-off recycling sites and analysed the factors influencing their usage. The findings of the study indicated that the usage of drop-off recycling sites is influenced by demographic factors such as age, education, income and household size. [39] found age to be a significant factor influencing recycling involvement. [40] found gender, age and household income as the three factors most influential to the activity of recycling. While other studies have focused attention on factors influencing recycling attitude. [41] investigated household attitudes towards recycling of solid waste in Malaysia. The findings indicated that participation in recycling of household waste relies on the level of awareness and understanding of recycling. [42] learned that residents of China possess greater knowledge of environmental issues and are more willing to participate in activities like recycling than US citizens. A summary of the studies on drivers influencing solid waste recycling and management at household level is presented in Table 2.

Table 2: Summary of Studies on Drivers influencing SWM at Household Level

Source	Driver Considered	Method Used	Broad Conclusion
[34]	Recycling Behaviour	Empirical	Economic incentives work in promoting recycling in Hong Kong.
[36]	Recycling Behaviour	Empirical	Participation in recycling of household waste relies on the level of awareness and understanding of recycling.
[40]	Recycling Attitudes	Survey	Participation in recycling of household waste relies on the level of awareness and understanding of recycling.
[35]	Recycling Behaviour	Case-study	economic incentives as well as education and communication play a very important role in initiating more sustainable behavioural patterns in the ICT sector
[37]	Recycling Behaviour		The usage of drop-off recycling sites is influenced by age, education, income and household size"
[42]	Recycling behaviour	Survey	Waste management attitudes, age, and income affected recycling and waste management significantly.
[43]	Recycling Behaviour	Questionnaire Survey	Collecting and processing secondary materials manufacturing recycled-content products, and then buying recycled products created a circle.

The studies reviewed at household level focused on drivers that influence households to participate in recycling programmes. None of the studies at household level conducted a comprehensive literature review on factors that influence households to recycle wastes. Each study was aligned on determining how an identified driver would influence recycling. Demographics, awareness and economic incentives were identified as some of the drivers that influence households to participate in recycling. However, the studies did not specifically focus on identifying the drivers or factors that would influence the development of recycling systems for post-consumer packaging plastic solid wastes. Nevertheless, MSW constitutes plastic wastes therefore the drivers identified can be considered in developing plastic waste recycling systems.

Behaviour and attitudes of individuals in recycling programmes has a significant influence in determining whether a recycling programme will be successful or not. As a result of this influence, it is necessary to understand and identify these drivers that influence the behaviour or attitude of individuals to participate in recycling SW or MSW. Education, awareness, economic incentives, age, income, communication are some of drivers or factors that influence individuals to participate in recycling. Understanding these drivers in the local context of each country can contribute to sustainable development and management of recycling systems.

3. Identified Economic, Environmental and Social Drivers

This section of the paper outlines the identified drivers or factors that influence the development of sustainable solid waste management and recycling systems. The reviewed work was analysed in order to classify the drivers influencing the development of sustainable solid waste management and recycling systems into three sustainability drivers. Under the economic aspect, the common drivers from all the reviewed work was identified. Also under the environmental aspect, the common drivers from all the reviewed work was identified and finally the same was done under the social aspect. Finally the intersecting drivers under the economic, environmental and social aspects were identified.

At community and household levels, sustainability has been considered as an aspect of development in solid waste management systems. Sustainability is concerned with resource utilization for future generations and therefore our

research focused on identifying the drivers that can be considered in developing sustainable systems for recycling post-consumer packaging plastic solid wastes. Analysis of the reviewed drivers from the sustainability aspect, the following was observed. From the economic aspect of sustainability, waste was considered as a valuable resource in all the studies reviewed. The fact that waste was considered as a valuable resource, it is important for municipalities and those charged with responsibilities to view waste (i.e. post-consumer plastic waste) as a value resource in recycling. At household level, individuals should be aware or educated on the value of plastic waste as a resource. When the community and the households' value waste as a resource, even the introduction and implementation of recycling programmes and systems for sustainable development can be progressive.

Environmental protection, climate change and global warming are drivers in SWM from the environmental aspect of sustainability and all the reviewed studies at community level highlighted this. Post-consumer wastes have a detrimental effect on the environment and educating the community and households on the effects of plastic wastes is a cardinal aspect in sustainable development of systems. In our research, environmental protection, climate change and global warming are drivers that can influence the community and households to participate and further develop sustainable recycling systems.

Social drivers have not be exempted, human population, public awareness and education are the drivers that have driven SW management from the social aspect identified at community level. Human population continues to grow and as a result of this growth, more resources are consumed and more waste is produced. Society should therefore be aware of the influence population can have on the resources. An increase in population means more resources are consumed. To sustainably manage our resources, human population should be used as a driver in developing recycling systems. Without education and awareness sustainable development of any system would not be possible. When communities and households are aware and educated about recycling systems, sustainable management would be possible.

Further analysis of the studies indicate that, producer responsibility, consumer responsibility and rules and regulations have been identified as drivers to sustainable development of SW management systems from the economic, environmental and social aspects. Producers and consumers of plastic wastes should be responsible for the management of these wastes. Even if systems for recycling are developed, without producer and consumers responsibilities as the drivers, it would be impossible to achieve sustainable recycling of these plastic wastes. Without rules and regulations especially in waste management, it becomes impossible to develop sustainable systems as usually most of the responsibilities will be left for the municipalities. If the community and households are binded by regulations and rules, sustainable development of recycling systems would be achievable from the economic, environmental and social aspects but not in isolation of other drivers.

4. Research Gap

The major observations of this review are as follows: from the studies conducted at community level, most of the research was focused towards SW and MSW. The intention of the studies were to identify the drivers that influence the development of sustainable systems for managing SW or MSWM sustainably. Further analysis of the studies at community level indicate none of the studies empirically analysed the identified drivers. The studies were either reviews, comparative studies or conceptual studies. The major conclusion on the reviewed studies at community level is that, there is no single balance between the drivers no matter where they are applied. There exists an interconnectivity among the drivers depending on the contest of application.

The researchers however, identified a research gap, in that, none of the studies focused on drivers influencing plastic solid waste recycling. All the studied have focused on SW or MSWM. Also since none of the studies empirically analysed the drivers influencing SW management, there is need to consider the same drivers influencing SW management and apply them on post-consumer packaging PSW recycling and analyse the drivers empirically. At household level, the researchers observed that most of the studied focused on factors influencing recycling behaviour and attitudes. Further analysis of the studies, indicate that most of the studied focused on the social aspect as a component of sustainability. The studies focused on factors such as policy drivers, impact of reward and effect of demographics on recycling behaviour and attitudes. None of the studies at household level focused on the factors influencing recycling of PSW. Based on our observations, the intention for future research should be to empirically analyse these identified drivers influencing SWM at community level and household level but specially applying them

to post-consumer packaging plastic solid wastes.

5. Conclusion

Sustainable recycling of post-consumer packaging plastic solid waste provides opportunities to reduce oil usage, carbon dioxide emissions and quantities of waste requiring disposal. As a result recycling of plastic waste is considered sustainable in manufacturing as new products are manufactured without utilizing new materials hence contributing to sustainable development. Economic, environmental and social drivers in development of SW or MSW systems were identified both at community and household levels. The drivers identified are applicable to the sustainable development of post-consumer packaging plastic waste recycling systems since plastics are a waste type in municipal solid waste. However, an empirical study should be conducted to statistically analyse the impact each driver has on sustainable development of recycling systems. Further the researchers identified that the major way forward is how to apply these drivers at different contexts both in developed and developing economies. The major way forward is how to close the loop using the identified factors in order to make post-consumer packaging PSW an economic material, environmentally acceptable material and a socially acceptable and profitable resource to the communities.

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