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Exploring Applicability Of Lean Principles In SWM For Patna Municipal Corporation

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Abstract:

Rapid urbanization is driven by quality living aspirations, yet it has posed many challenges toward creating a sustainable built environment. One of the significant challenges is managing the enormous amount of waste created in the urban environment. The problem becomes more critical for cities like Patna (India), where infrastructure growth has not occurred concerning the growing population density. This paper is about exploring lean Thinking in Municipal Solid waste management to provide an efficient model that could manage the increasing quantity without scaling up the system. The study explores the applicability of Lean Principles in Municipal Solid Waste Management by identifying the Value Chain and creating flow within the system in Indian and Global contexts. Furthermore, it analyses the present condition of Municipal Solid Waste Management in the region of Patna Municipal Corporation, identifies its Value Stream and revenue generation potential. The study suggests suitable Lean suggestions for improving the present condition and revenue generation opportunities of Municipal Solid Waste Management in the area under the jurisdiction of Patna Municipal Corporation. This guides the path for introducing Lean management in the Municipal Solid Waste Management sector and improving the management capacity of ULBs with the optimum utilization of available resources.

Keywords: Solid Waste Management, Lean Management, Value, Value Stream, Flow, Sustainable Built Environment.

1. Introduction

The global population is increasing tremendously, with 2.5 billion people in the 1950s to 7.7 billion people in 2019, expected to increase to 9.3 billion by 2050 (UN, 2020). The level of urbanization is also growing tremendously; presently, 55% of the global population lives in cities, which is expected to increase to 68% by 2050. With the significant population increase occurring in cities, urban areas will be expected to accommodate an additional 2.5 billion people in the next 30 years, with close to 90% of the increase in Asian and African countries (DESA, 2018).The increasing urbanization has posed several management challenges to all the urban local bodies, and the developing countries are struggling to achieve the UN SDGs 2030 report (UNDP, The Sustainable Development Goals Report 2020, 2020). The management of municipal solid Waste is one of the major challenges for urban local bodies. Solid waste volumes are increasing daily with the growing urban population, and urban local bodies are constantly struggling to scale up with the increasing solid waste generation (NITI Aayog, 2021). There is a need to increase the efficiency of the current management system to manage the growing amount of generated Waste with the current management capacity.
The problem becomes more critical for cities like Patna (India), where infrastructure growth has not occurred concerning the growing population density (Kumar M. , 2016). The present study explores the opportunity of introducing Lean Thinking to manage Municipal Solid Waste for the city of Patna (India), which can help in capacity building by improving the efficiency of the current management system. Introducing lean Thinking in waste management can provide an efficient model of waste management services that could manage the increasing quantity of generated Waste without scaling up the system. A lean enterprise of waste management services can effectively manage Waste using the five principles of a lean enterprise. Furthermore, it can keep growing towards perfection to manage the predicted increase in waste generation. It will help to identify and eliminate the gaps in the current municipal solid waste management system. Lean Thinking can be a robust tool/technique to benefit the urban local body in managing municipal solid Waste.

2. Municipal Solid Waste

Asian countries have witnessed an era of development in the twenty-first century (the twenty-first century being recognized as the Asian century). However, this development has the other side of it, which is waste generation. Conventionally, Waste could be defined as unwanted material without immediate use at the point of generation (Das & Ramesha, 2012). In general terms, Waste is defined as any substance the user has discarded or intends to discard or is required to discard (Pharino, 2017). Problems due to Waste exist where there is a human inhabitant (UNEP, 2004). This clearly defines those human activities ought to generate Waste and its generation potential increases with enhancement in the living standard of people (World Bank Group, 2018).

After America (twentieth century), this development in the Asian region (twenty-first century) has put a tremendous burden on the environment, and waste generation is one such burden the world is struggling to manage now. A large portion of this generated Waste falls under the category of Municipal Solid waste, which is now managed mainly by the ULBs. According to World Bank Group Report (World Bank Group, 2018), Municipal Solid Waste (MSW) is one of the prominent reasons for environmental issues, including climate change. This scenario is a threat to a sustainable built environment, and it is crucial to handle the MSW in a manner that does not threaten the built environment's sustainability (Chadar & Keerti, 2017). The significance of Municipal Solid Waste Management (MSWM) in the current context is well understood by government bodies, academicians, and people, which is why it has become a topic of extensive attention in academic and popular literature (Tim, 2009).
The Municipal Solid Waste (Management and Handling) Rules, 2000 (revised in 2016), India, defines Municipal Solid Waste as: "*Commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated biomedical wastes*" (MoUD, 2000). The United States Environmental Protection Agency (US EPA) defines Municipal Solid Waste as: *"the materials traditionally managed by municipalities, whether by burning, burying, recycling, or composting*" (US EPA, 2008). Although different bodies define municipal solid Waste in their way, the basic idea of municipal solid waste remains similar. It predominantly includes domestic Waste (household waste) with commercial waste, construction and demolition waste, horticulture waste, and other wastes of similar nature collected by a municipality within the given area. However, from a scientific point of view, there are no wastes as such in the world. Almost all solid waste components have some potential when converted or treated scientifically. (Agarwal , Chaudhary, & singh, 2015). Hence, we can define solid Waste as "Organic or inorganic waste materials produced out of household or commercial activities that have lost their value in the eyes of the first owner, but which may be of great value to somebody else.".

3. Need for efficient MSWM system for Indian Cities.

In the Indian context, 31% of the Indian population resides in urban areas (Government of India, 2011). With the rate of 0.52 kg per person, as mentioned in Asia and the Pacific SDG Progress report (UN_ESCAP, 2021), the municipal waste generation is more than 2,20,263 metric tons per the country's population (Government of India, 2011). However, only 70% is collected from that generated Waste, while the remaining 30% mixes up and is lost in the urban environment (World Bank Group, 2018).
MSWM became the responsibility of urban local bodies under the municipal solid Waste (management and handling) rules, 2000 (MoUD, 2000). The urban local bodies are working towards properly managing the generated solid Waste and following the guidelines, yet most urban local bodies struggle to effectively manage the generated municipal solid waste. The reason could be increasing municipal solid waste generation, limited resources, lack of coordination among the management levels, and many others. The increasing urban population with the available services and resources sharply contrasts with the Indian municipal solid waste management system. India has an enormous gap in its solid waste management sector (Kumar & Kantoji, 2014). Although, as per the NITI Aayog report (NITI Aayog, 2021), Indian cities have significantly improved solid waste collection, the processing and disposal of the collected Waste are still far from achieving the necessary treatment. The reason is the inefficiency of current MSWM services with heavy expenses and low performance, which poses a potential threat to the public and environment (Biswas, et al., 2010).

4. Lean Thinking

A Lean set of actions created from a constructive mindset to achieve optimum efficiency and production is the idea behind Lean Thinking. Lean Thinking is a proven systematic technique used to improve the performance of an organization reliably. The analytical approach of Lean Thinking is primarily based on the actual Value of the output and steps comprising the stream that adds to the output's Value. The original ideas behind lean Thinking were primarily developed in Toyota's manufacturing operations (Toyota Production System) which is described in the book "The Machine That Changed the World" (Womack & Jones, 1996, 2003). It was later popularized in the seminal book "The Machine that Changes the world." Although the lean techniques were meant initially for production companies, their principles can now apply to any organization to form a lean set of actions to run the organization and achieve the desired goal with the given resources. A set of five Lean principles guides the approach to turn an organization into a Lean organization. They are: Value, Value Stream, Flow, Pull, Perfection.

4.1. Relevance of Lean MSWM system

The present solid waste management system addresses the lifecycle aspect, generation aspect, management aspect, cost-benefit analysis cantered around managing the Waste and developing methods for managing the Waste. However, the crisis is growing, and new concerns are emerging.

Although there are methodologies and systems present to manage the amount of generated Waste, the varying nature of generated Waste and location-specific issues are typically not addressed by the present methodologies. Kumar et el., in their review of Indian towns, have mentioned the location constraints in the implementation of SWM strategies (Kumar, et al., 2009) The discrepancy in available resources, knowledge, peoples' behaviour and various other factors which are specific to individual urban locations challenges the methodologies followed, which are focused on what should be done, instead of how should be done. Population growth, income, educational background, and local awareness directly impact the success of MSWM, which makes it challenging to plan and execute (Joseph, Rajendra, Senthilnathan, & Rakesh, 2012).

The waste generators play an important role in MSWM, and lack of source segregation is also identified as a major challenge in MSWM (Balasubramanian, 2018). The urban local body would not be able to provide better surroundings if residents do not stop throwing Waste onto roads and do not make efforts from their side to deposit Waste into the bins (Joseph K. , 2002).

One common aspect that can define how MSW should be managed is Value. All the urban local bodies or bodies involved in MSWM are creating or managing some value. The Value could be from the aspect of cleanliness, health, environment, aesthetics, etc. Understanding of actual Value generated by the MSWM will guide the MSWM bodies and give a different perspective to MSW generators to look at and understand the importance of a good MSWM system.
A Lean System of value based MSWM system will identify the actual Value generated by the management process. The value stream for specific Waste and respective techniques of managing that from current practices will reflect the amount of Muda. Identifying and eliminating Muda generated by improper practices will improve the stages of the SWM process by improving the initial stage to be helpful for the next stage. The concept of Lean Value would be an ideal way to move towards a sustainable SWM.

5. Data source and Methodology

The Database of PMC, interview by PMC officials and on-site visits are the primary data sources of the present study. To map value and value stream, and revenue generation potential, separate tables are created including parameters to provide weightage to specific MSWM stages identified as Nodes. Once the parameters are set, the next stage was to create a weightage system to provide weightage for each stage of value addition process. A scale of 0 to 5 is set to provide weightage to each of these stages (0 – least important, 5 – Most important). 11 members are selected from different background to assign weightage.

This weightage represents the Value added on that specific Node, which is tested further by their revenue generation potential through the MSWM practices. A comparison of resource expenditure and value addition is the carried out to identify the amount of Value addition and resource consumption at each Node. Figure 5.1.1 represents the detailed methodology used to guide the present study.

5.1. Value Chain Mapping

The value chain mapping process is carried out in view of identifying the relevant categories and associated values affected by way of managing the generated MSW. Handling and management of generated MSW is usually associated with huge monetary value consumption. But apart from that, the study identifies two other values that are significantly important and the way of managing generated MSW has huge impact on them. First, social values associated with people and second, environmental values that are important to sustain life. This value chain mapping exercise tries to explain the values associated with them and identify the corresponding stage in MSWM that is important from the aspect of maintaining or adding values to them.

The mapping process required all the aspects associated with the management of MSW. It was required to consider such factors that can include all the associated aspects. For this purpose, the triple bottom line of sustainability is considered as base elements for mapping the associated values as it includes moreover every aspect associated with MSWM mentioned below.

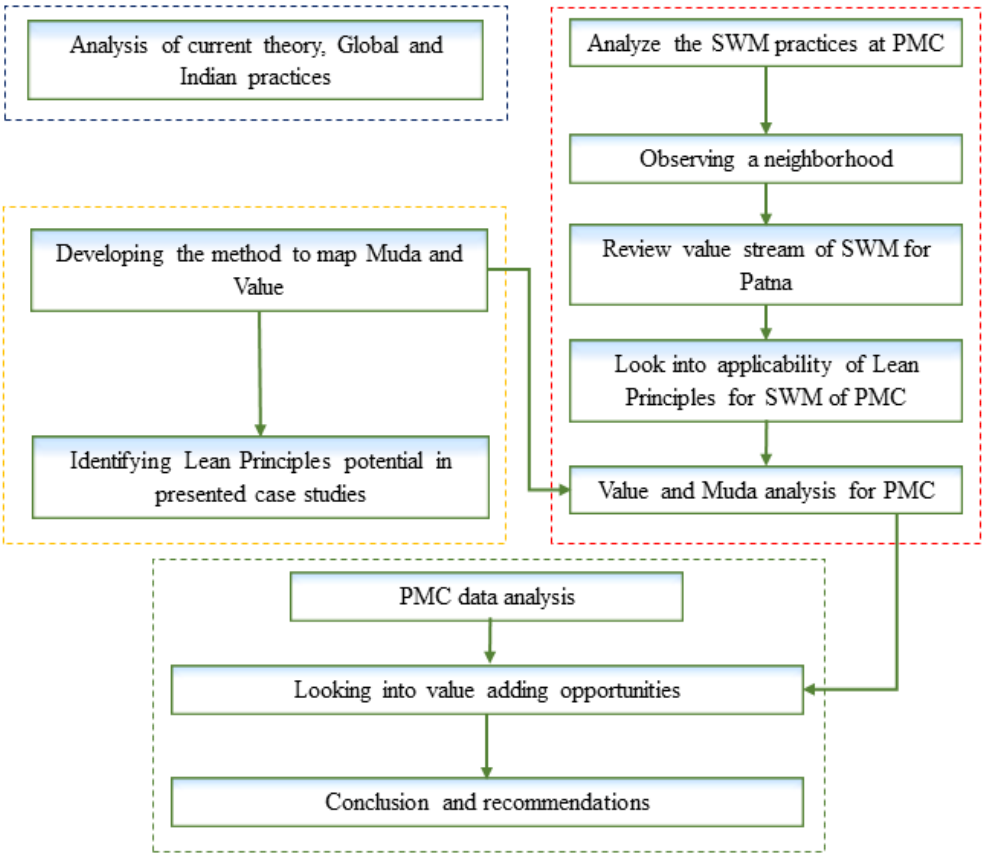

***Figure 5.1-1**: Methodology Table*

5.1.1. People

To provide Fair and beneficial social life for the people involved in the MSWM system,
Additionally, the impact of practices followed for MSWM on life of people in any form is to be accounted and eliminated to the best possible extent.

5.1.2. Profit

To go for an economically sustainable MSWM system where the burden of expenses of certain Waste will be recovered from generating revenue from other Waste, To go for a net zero approach and keep on reducing the expenses of the system until we reach to a net zero/positive system.

5.1.3. Planet

To go for a system having no/positive impact on surrounding environment. This can be achieved through a clear understanding of nature of waste and its possible uses in support of environmental benefit in the best possible way.
Table 5.1.1 contains the detailed description of considered factors for each chosen element. The criteria by which weightage is to be assigned at the particular stage for said category of MSW are listed in Tables 5.1.2, 5.1.3, and 5.1.4. The first row of each of the tables below categorizes MSW into four groups: biodegradable, recyclable, metal, and inert, and provides the pertinent information in the relevant table. The following rows offer parameters that need to be reviewed in order to provide weightage at six identified stages of the SWM process, starting with generation and ending with disposal. The provided tables can be used to review the actions taken at each stage and their effects on the mentioned criteria For example, the value loss of a product at the moment it is identified as Waste could be one of the parameters for estimating the impact of MSW generation on Profit.

Table 5.1-1: *Criteria for assigning weightage to the selected 3 categories*

Profit	***People***	***Planet***
Economically sustainable MSWM system. • *The overall economically sustainable system,* • *Reducing the cost (the net-zero approach)* • *Improving the circular economy*	*Analysing the role of M in economic and soci and health risks of (directly or ina involved), affected b decisions and practi MSWM system.* • *Financial stability* • *Growth opportunit*	*Analysing and reducing/eliminating negative impact(active/passive) of MSWM practices on natural elements (land, water, air)* *Active impact – by activities involved in the process of management.* *Passive impact – due to lack of proper management*
Considerate procedures/standards for capital building and to eli capital losses • *Land cost of areas surrounding the MSWM infrastructure* • *Efficient capital management*	*Economic benefits standards (salary and incentives)* *Nature of job oppo (job security, future gr*	*Look for the opportunities/potential to support in reducing the carbon footprint of possible products (recycling, upcycling, circular economy).* • *Minimizing/eliminating cradle to grave*
Potential for business (revenue generation) • *The revenue generation potential from the specified categ Waste (by any means – EPR, selling recycled/upcycled products profitable businesses)*	*Social equity* *Complete inclusion* • *every m (formal/informal) wori MSWM sector should*	*Opportunities to gain environmental benefits from the generated Waste (manures replacing fertilizers)*
Business interest • *The available business and recent business growth for the sp waste category*	*Impact on Life of (health hazards) in (short-term/long-term)* • *Involved risk (vuln population – slum/ living disposal/incineration site/informal waste pic*	*EIA of complete MSWM system to be evaluated at frequent intervals.* • *To understand the possible threat and improve the practice.*
Revenue/burden • *The gap between revenue and expenses for the specified categ Waste*	*The growth windows.* • *a person worked in management for 5-10 can now help in edu and research progra* • *use of his profes experience and ex for improving knowledge and pract*	*Align the other two bottom line (profit and people) in support of environmental benefits.* • *Circular economy* • *LCA* • *Education (ICT)*

Table5.1-2: Value Mapping table - People

VALUE MAPPING TABLE – PEOPLE

• ***stages)*** • ***in true value generation*** • ***consumed VS value added*** ***further contribution resource***	**CONSIDERED PARAMETERS (BASED ON THE ASSOCIATED ACTIVITIES AT THAT STAGE) FOR PROVIDING RELATIVE WEIGHTAGE**					
	Generation	*On-Site handling, storage, and processing*	*Collection*	*Transfer and Transport*	*Processing and Recovery*	*Disposal*
BIO-DEGRADABLE ***Probable ways of generating value for People from bio-degradable waste:*** *limiting the amount of food turning into waste, setting up units to get manure/gas.* ***Affected People values:*** *hunger caused by excess food waste, high impact on health and surrounding living environment, challenges of social equity.* **RECYCLABLES** ***Probable ways of generating value for People from recyclable waste:*** *multiple career opportunity, skill development, knowledge building.* ***Affected people values:*** *health risk and social challenge, poor management and decisions, lack of training (limited career growth).* **METAL** ***Probable ways of generating value for People from metallic waste:*** *multiple career opportunity, skill development, knowledge building.* **INERT** ***Probable ways of generating value for People from inert waste:*** *Career building (research and finding alternatives),* ***Affected people values:*** *impact on* ***People*** *affected by poor management and decisions.*	*Impact of generation (social)* *Potential livelihood opportunities* *address the work challenges* *probable engagement and impact on vulnerable population (human or animal)* *eliminate the associated health risk.* *eliminate the impact (short-term and long-term) on social life of associated personnel (maintaining social equity and eliminating associated risks)* *Potential to generate values for people*	*Required measures to eliminating the impact (short-term and long-term) on social life of associated personnel (considering the nature of work and associated challenges of social equity)* *Role in eliminate the probable engagement and impact on vulnerable population (human or animal)* *Role in reducing the non-preferred works.* *Impact of management in creating/maintaining degrading the prescribed living condition for inhabitants.* *Level of precaution and level of protection required for the job* *Potential to generate values for people*	*eliminating the impact (short-term and long-term) on social life of associated personnel (considering the nature of work and associated challenges of social equity)* *eliminate the probable engagement and impact on vulnerable population (human or animal)* *Impact (positive or negative) of this stage of management in creating/maintaining/degrading the prescribed living condition for inhabitants.* *Feasibility of machine used vs manpower.*	*Required measures to eliminating the impact (short-term and long-term) on social life of associated personnel (considering the nature of work and associated challenges of social equity)* *Role in eliminate the probable engagement and impact on vulnerable population (human or animal)* *Impact (positive or negative) of this stage of management in creating/maintaining/degrading the prescribed living condition for inhabitants.* *Level of precaution and level of protection required for the job*	*Required measures to eliminating the impact (short-term and long-term) on social life of associated personnel (considering the nature of work and associated challenges of social equity)* *Role in eliminate the probable engagement and impact on vulnerable population (human or animal)* *Impact (positive or negative) of this stage of management in creating/maintaining/degrading the prescribed living condition for inhabitants.* *Level of precaution and level of protection required for the job*	*Required measures to eliminating the impact (short-term and long-term) on social life of associated personnel (considering the nature of work and associated challenges of social equity)* *Role in eliminate the probable engagement and impact on vulnerable population (human or animal)* *Impact (positive or negative) of this stage of management in creating/maintaining/degrading the prescribed living condition for inhabitants.* *Level of precaution and level of protection required for the job*

Table 5.1-3: Value Mapping parameters – Profit

VALUE MAPPING TABLE - PROFIT

	CONSIDERED PARAMETERS (BASED ON THE ASSOCIATED ACTIVITIES AT THAT STAGE) FOR PROVIDING RELATIVE WEIGHTAGE					
• ***contribution towards zero waste production*** • ***contribution towards ease of management (for further stages)*** • ***contribution in some value generation*** • ***resource consumed VS value added***	*Generation*	*On-Site handling, storage, and processing*	*Collection*	*Transfer and Transport*	*Processing and Recovery*	*Disposal*
BIO-DEGRADABLE ***Probable ways of generating Profit from bio-degradable waste are:*** *biogas production, composting (locally or centralised plants), feeding animals, managing charges.* ***Capital requirement:*** *setting up composters, biogas production units, collection, and supply chain network.* *Present in majority (>50%) in low- and middle-income countries.*	*Impact of generation (economical)* *Value lost once the product/material is classified as waste* *Possibilities of alternate use of the discarded materials* *People involved – extent of required awareness among involved personnel (address relevant people in terms of number and role in MSWM with appropriate information)* *Amount of generation in the given scenario* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited)*	*Role of source segregation in easing out the further process and better processing efficiency* *On-site processing potential and benefits* *People involved – extent of required awareness among involved personnel (address relevant people in terms of number and role in MSWM with appropriate information)* *Amount of potential/total value added/retained/lost in this stage* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited)* *Role in creation of circular economy*	*required frequency of collection and type/number of vehicles used* *associated expenses and capital building for collection* *People involved – extent of required awareness among involved personnel (address relevant people in terms of number and role in MSWM with appropriate information)* *Amount of potential/total value added/retained/lost in this stage* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited)* *Role in creation of circular economy*	*required frequency and type/number of vehicles used* *People involved – extent of required awareness among involved personnel (address relevant people in terms of number and role in MSWM with appropriate information)* *Amount of potential/total value added/retained/lost in this stage* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited)* *Role in creation of circular economy*	*Infrastructure requirement* *revenue generation through recycling/recovery/ processing* *People involved – extent of required awareness among involved personnel (address relevant people in terms of number and role in MSWM with appropriate information)* *Amount of potential/total value added/retained/lost in this stage* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited)* *Role in creation of circular economy*	*Infrastructure requirement* *People involved – extent of required awareness among involved personnel (address relevant people in terms of number and role in MSWM with appropriate information)* *Amount of potential value added/retained/lost in this stage* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited)* *Role in creation of circular economy*
RECYCLABLES ***Probable ways of generating Profit from recyclable waste are:*** *EPR (extended producers' responsibility), recycled products, upcycled products, managing charges.* ***Capital requirement:*** *setting up collection and supply chain network, sorting stations, recycling, and production units.*						
METAL ***Probable ways of generating Profit from metallic waste are:*** *recovering metals,* ***Capital requirement****:* *setting up collection and supply chain network, recovery centres.* **contain some of the highest value scrap.**						
INERT ***Probable ways of generating Profit from inert waste are.*** *landfill in low laying areas* *Energy produced by* incineration. **Challenges:** Finding suitable ways to dispose inert waste.						

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Table 5.1-5.1-1: Value Mapping table - Planet

VALUE MAPPING TABLE - PLANET

- ***contribution towards zero waste production***
- ***contribution towards ease of management (for further stages)***
- ***contribution in true value generation***
- ***resource consumed VS value added***

CONSIDERED PARAMETERS (BASED ON THE ASSOCIATED ACTIVITIES AT THAT STAGE) FOR PROVIDING RELATIVE WEIGHTAGE

	Generation	*On-Site handling, storage, and processing*	*Collection*	*Transfer and Transport*	*Processing and Recovery*	*Disposal*
BIO-DEGRADABLE ***Probable ways of generating value for Planet from bio-degradable waste:*** *manufacturing manures, biogas, turning into sustainable useful products.* ***Affected Values for Planet:*** *degrading quality of surrounding environment, releasing gases, responsible for global warming.*	*Impact of generation (environmental)* *Relative importance of preventing it into entering the waste stream.* *Role in maintaining/degrading the quality of environment.* *Role in preventing/causing the potential impact on environment.* *Extent of considerable impact (land, air, water) (short-term/long-term)* *Contribution towards reducing carbon footprint of associated products.* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited)*	*Role in easing out the further process and better processing efficiency* *On-site processing potential and benefits* *extent of required awareness among involved personnel* *Role in preventing/causing the potential impact on environment.* *Negative impact caused by the associated activities of this stage.* *Contribution towards reducing carbon footprints of associated products.* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited).*	*Role in maintaining/degrading the quality of environment.* *Role in preventing/causing the potential impact on environment.* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited)* *Resources consumed VS value created* *Negative impact caused by the associated activities of this stage.* *extent of required awareness among involved personnel*	*Role in maintaining/degrading the quality of environment.* *Role in preventing/causing the potential impact on environment.* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited)* *Resources consumed VS value created* *Negative impact caused by the associated activities of this stage.* *extent of required awareness among involved personnel* *Resources consumed VS value created*	*Negative impact caused by the associated activities of this stage.* *extent of required awareness among involved personnel* *Role in maintaining/degrading the quality of environment.* *Role in preventing/causing the potential impact on environment.* *Preferred enhancement/reduction of the process (whether the process should be encouraged or limited)*
RECYCLABLES ***Probable ways of generating value for Planet from recyclable waste:*** *preventing further manufacturing of non-biodegradable materials, reducing product's carbon footprint, using it as alternative of non-renewable energy sources.* ***Affected Values for Planet: -*** *long-term impact on various elements of nature.*						
METAL ***Probable ways of generating value for Planet from metallic waste:*** *recovering metals to reduce further extraction, reducing carbon footprint.* ***Affected Values for Planet:*** *presence of potentially harmful/toxic metal, loss of valuable natural resource.*						
INERT ***Probable ways of generating value for planet from inert waste:*** *landfill in low laying areas prevents sand extraction from rivers.* ***Affected Values for Planet***: excess production results in higher landfilling rate, degrades air quality upon burning. .						

6. Overview of Study Area

6.1. Location and Regional Setting

The city of Patna is located on the southern bank of river ganga. The total area of Patna is 250 sq, km, 109.218 sq. km of which is under the jurisdiction of PMC, located between Latitude: 25°33'22"- 25°39'2" North and Longitude: 85°31'12"- 85°15'5" East. The region of PMC is 10.2 km wide (North-South) and 21.3 km long (East-West) approximately.

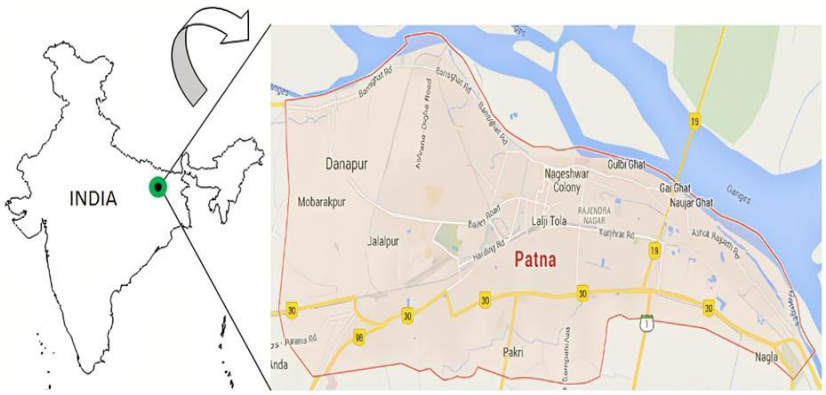


Figure 6.1-1: *Location of study area (Patna, india)*

6.2. Overview of MSWM in Patna Municipal Corporation

PMC is responsible for managing the MSW generated in the region under PMC. PMC was able to implement SWM in the PMC area limitedly. PMC decided to implement SWM – collection, transportation, and processing in all 75 wards of PMC as per MSW Rule 2016 and other guidelines issued under Swachh Bharat Mission by the Ministry of Housing and Urban Affairs (MoHUA) from time to time. To implement the SWM in the PMC area, a Detailed Project Report was prepared and was approved by MoHUA under Swachh Bharat Mission (urban).

6.3. The flow processes of MSWM at PMC

The flow of MSW in PMC can be classified by identifying four nodes at which the generated Waste is picked-up or transferred. These nodes are:

Node 1: - It is where the Waste gets generated, such as residences, commercial establishments, hospitals, and others.

Node 2: - The local dumping point where the surrounding household used to throw their generated Waste, which the PMC then picks up.

Node 3: - The secondary transfer locations where the collected Waste from node1 and 2 is transferred into larger transfer vehicles to be transported to the final dumpsite. Currently, PMC has no permanent secondary transfer station, although there are six designated locations (one in each circle) where this activity is taking place.

Node 4: - It is the final dumping point where all the collected Waste from the 75 wards of PMC is dumped. Currently, the final dumping is carried out in an 80-acre site at Ramchak, Bairia.

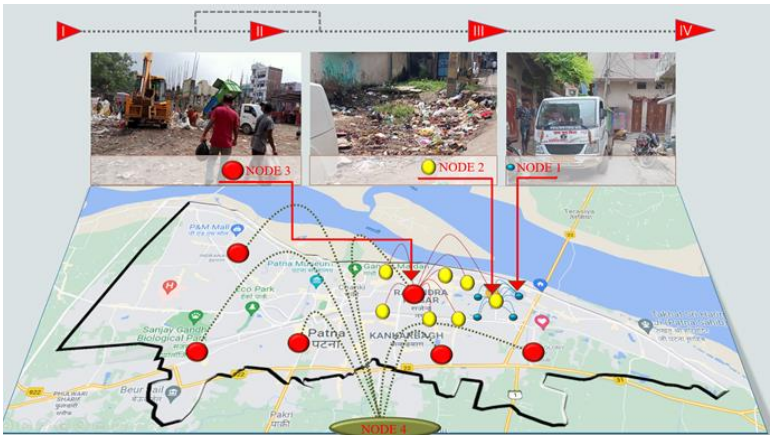


Figure 6.3-1: *Identified Nodes to represent the flow of MSWM system in Patna, India*

6.3. Generation

The Patna Municipal Corporation covers 109 square kilometers and will have 1798123 residents by 2021, according to PMC. According to a report in Telegraph India, since 2008, approximately 1200 TPD of solid Waste have been dumped in Ramchak Bairiya, leaving out the unaccounted Waste within the city. However, the amount of MSW generated in the given region is accounted to be 1000TPD. Figure 6.3.2 illustrates the physical makeup of municipal solid Waste generated.

6.3.1. On-Site handling

To date, PMC has not attempted to manage the Waste on-site. However, according to the officials, PMC intends to give each household two bins so they can separate their dry and wet Waste. Currently, each residence handles this in a unique manner. Others store it in polythene bags, cartons, or paper until the collection vehicle picks it up, while some keep it in trash cans. Some people choose not to store their trash at home and instead dispose of it at the closest GVP, which are later picked up by collection trucks. In addition to generating bulk Waste, bulk waste generators also deposit their Waste at GVPs for truck pickup, making it difficult to remove GVPs from the designated locations. It has a total of 8-10 GVP in each ward (PMC).

6.3.2. Collection

The collection of MSW from areas under the jurisdiction of PMC is carried out majorly through two streams. Initially, The waste generators used to throw off their Waste in open street dumping points, left unattended until the PMC collection vehicle collects the same as first stream.

On 2 October 2018, the PMC initiated a door-to-door segregated (organic and inorganic) waste collection facility under Swachh Bharat Mission (a centre-led clean India initiative). It became the second stream for the flow of MSW, where Waste generated from the source is collected door-to-door with the help of a door-to-door collection system.

6.3.3. Transfer and Transport

PMC does not have any permanent transfer station. Although, there are areas (1 for each circle) currently used for transferring all the collected MSW to bigger vehicles to be transported to the dumpsite.

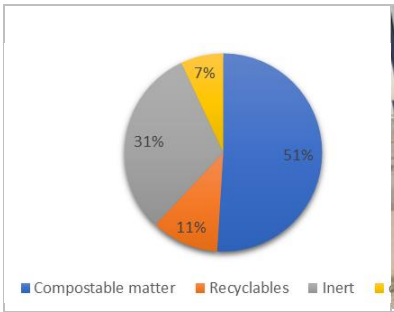
6.3.4. Disposal

PMC is primarily dumping off their collected MSW in the 80-acre landfill site at Ramchak, Bairiya. The lack of processing and recovery has overburdened the current landfill site of PMC. The current landfill site receives almost 1200TPD of MSW which is filling it at quite a faster rate. The increasing Waste in landfill site has posed several health and environmental threats to the habitants of surrounding area.

The PMC has started to remove the legacy waste and allotted this work on PPP model. The process of segregating the Waste is active and segregation process is carried out with the use of mechanical trommel machines. Trommel machine segregate the Waste of different sizes, the smallest ones are used as manure and bigger ones are mostly plastic which are collected and sent to the recyclers. Although, the process of removing the legacy waste is in progress, the addition of large amount of everyday fresh Waste is ultimately increasing the burden on landfill sites and increasing the size of landfill size which is a scenario of great concern.

The PMC, mostly like other ULBs is following the non-preferred method of MSWM, i.e., collecting the Waste from one place and throwing it on other (dumpsite). In today's scenario following the above process is not aligned with the SWM Rules, 2016. Although, the PMC has shown improvement in its MSWM process since last few years, it still must go a long way to meet the current goals of MSWM. Like every other ULB, the PMC has its own challenges and limitations on which it needs to work on, the next section of this report will try to identify the actual challenges, opportunities, and limitations of PMC by analysing the acquired data which will guide the way forward to draft Lean solutions in the available resources.

Table 6.3-1: *Images representing six stages of MSWM at PMC*

		
The physical composition of generated MSW in PMC region	*Dustbin placement by PMC*	*A GVP at PMC*


Collection by Close-Tipper at PMC


Open waste transfer station at PMC


Trommel Machine at Disposal site of PMC

7. Result and Discussion

7.1. Achieved Value and Resource consumption.

The estimated value through conducted surveys is represented in figure 7.1.1, it represents the value (on a scale of 0-5, 5 being maximum value) achieved at each stage of the SWM process. The values are estimated on three categories as mentioned in table 5.1.1, which is averaged to find out the average value achieving potential in three mentioned categories at each step of management process. Figure 7.1.2 represents the percent expenditure on each stage from total allocated budget for MSWM is calculated using the data received from PMC.

The value mapping process mentioned above reflects the importance of different stages of the MSWM process. This mapping process is significantly important, and it provides a different perspective towards the management of MSW. It helps create a clear distinction between 'what is happening' and 'what could be done' towards MSWM for respective ULBs.

The expenses of PMC when analysed with the value mapping exercise, its deviated enough from the relative weightage of the stages. This is the condition where most of the generated Waste is converted into Muda. Values from the generated Waste can be created by aligning the expenses with relative weightage to the best possible extent.

7.2. Value Mapping for efficient MSWM system.

Value Mapping could be a guiding way to manage the resource distribution at different stages of MSWM system. As in the case of PMC, a significant amount of the total budget is spent on collection followed by processing and transfer and transport (refer figure 7.2.1). However, value mapping reflects on-site handling and processing and recovery as major value adding stages followed by collection. This requires redistribution of resources to promote the value adding stages and limit the stages that are not adding value in comparison of their resource consumption.

Exploring the applicability of Lean methodology in MSWM has brought forward the potential of MSWM sector and opportunities that this sector offers for the future. The study presented the value stream in SWM process and accordingly suggestions are presented to optimize the flow process based on the outcome of value mapping.

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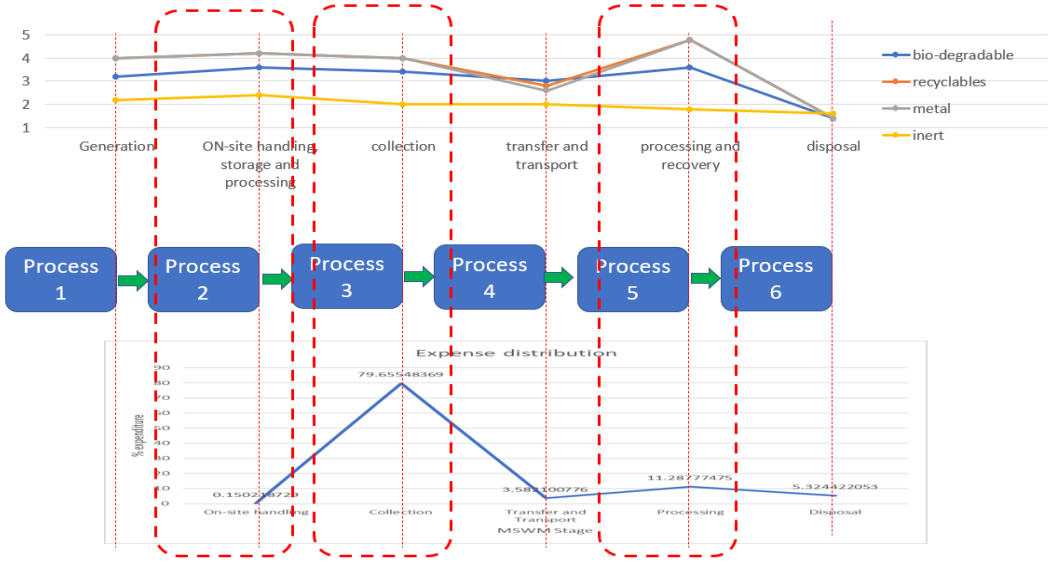

Figure 7.2-1: *Comparing value addition and resource consumption*

7.3. Current Process Expense Distribution

The current process of SWM of PMC is primarily focusing on collection and very less emphasis is given to processing. The complete collected waste is dumped in the PMC dumpsite at Bairiya. This is reflected clearly in the expenditure analysis for the year 2021-22 of PMC on SWM mentioned in figure 7.3.1.

The expenses of PMC when analysed with the value mapping exercise, its deviated enough from the relative weightage of the stages. This is the condition where most of the generated waste is converted into Muda. Values from the generated waste can be created by aligning the expenses with relative weightage to the best possible extent.

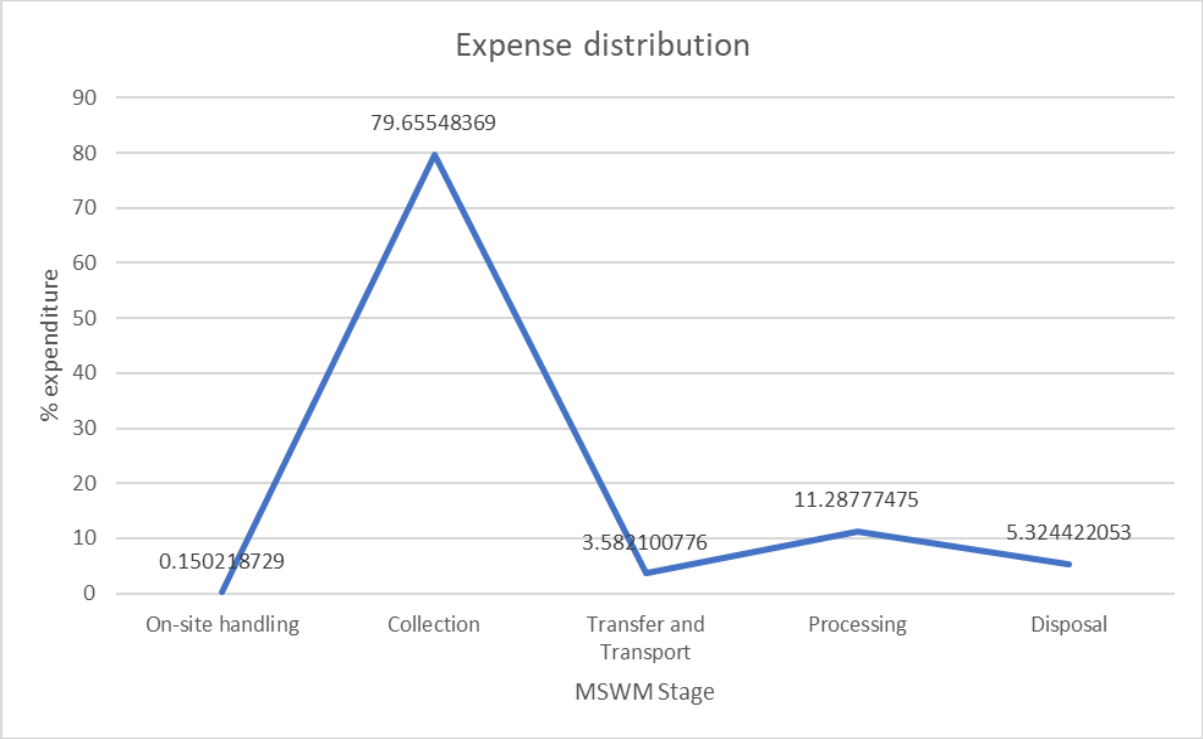

Figure 7.3-1: *Expense distribution on MSWM by PMC*

7.4. Proposed Scenario based on Value Stream Identification

As Quoted by SCG circular way (way, 2019) "Waste – isn't Waste until we waste it", reflects the fact that the generated waste can be treated in different ways. Either it could be utilised in the best possible way, or it could be wasted completely and converted into Muda.

There are values associated with the generated waste that could be utilised or enhanced by the process of value addition, otherwise the potential values of waste will be converted into complete Muda. This section discusses the value generation potential from the generated MSW of PMC region. For the value estimation process, biodegradable waste is considered as it comprises the larger portion of generated MSW. The comparative study of current process and possible lean alternatives will present a clear picture of values associated with waste and how it can be achieved.

i. Tipping and dumping expenses

For calculating the possible savings of resources spent on management of biodegradable waste in business-as-usual scenario, only the transfer and transportation stage is considered. Since the processing might be centralised or decentralised which will involve the collection expenses hence it is not considered for the expenses savings, although it can be further included, and savings could be made in further studies.

Since biodegradable waste comprise 51% of the total waste, 51% of the total expenses are considered as expenses as tipping fee on biodegradable waste mentioned in table 6.4.8.

Table 7.3-1: *Business as usual expenses*

Process	Total expense	Expense on biodegradable waste (51% of total expenses)
Transfer and Transport (heired vehicles)	84096000	42888960
Disposal	125000000	63750000
Total	209096000	106638960

This much amount of expenses can be saved only if the generated biodegradable waste is not sent to landfills after being collected.

ii. Carbon crediting

The decomposition of solid waste under aerobic condition, especially in sanitary landfills releases CH4 which accounts to 40-60% of the total waste (Alzaydi, Alsolaimani, & Ramadan, 2013). CH4 is a strong greenhouse gas and its GWP is 25 CO2 eq. for a 100-year scale (IPCC, 2007). With the amount of 500 TPD of biodegradable waste, assuming the conversion rate to 40%, the amount of CH4 emission goes to 200TPD. Since it is 25 times stronger than CO2, its effective carbon credit value can reach up to 5000TPD.

The Indian rupees equivalent for carbon credit goes around 12 rupees per TPD. With this rate the total carbon credit value potential becomes 60000 per day and 2,19,00,000 annually.

iii.Compost manufacturing

The organic fertilizer (compost) production potential with current composting technology calculates 25% production yield with 40% moisture content (Shah, et al., 2017).

With the current biodegradable waste generation (500TPD), the amount of manures that could be manufactured accounts to 125 TPD. The annual generation is 45,625 T. average cost of organic manure in Patna is Rs. 5/Kg that account to a total revenue generation of Rs. 228,125,000 annually.

By reviewing the cities that are performing best in production of manure, the usual collection, operation, and maintenance expense are taken care of by selling manures (Biswas, et al., 2021). Building on similar experience, considering the revenue gained by selling manures gets consumed in collection, operation, and maintenance of the facility, the net revenue would remain positive with carbon crediting and savings from tipping fees. Figure represents the process of value addition comparing from the business-as-usual model.

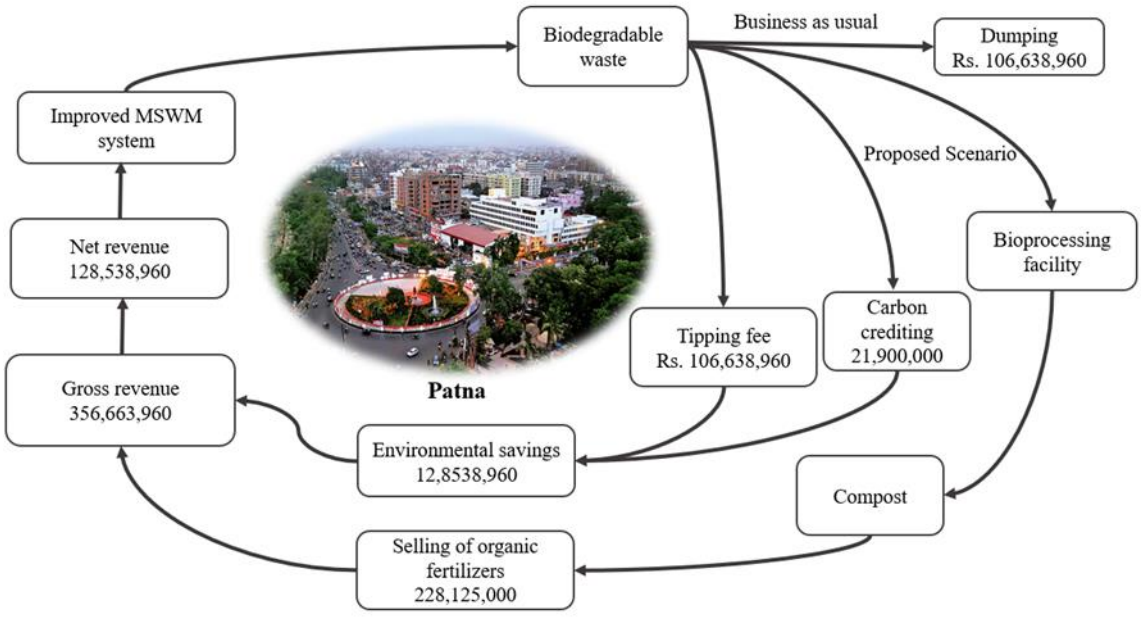

Figure 7.3-2: *value addition process*

Apart from revenue generation, the additional benefits would be:

- C enrichment of soil.
- Livelihood opportunities for workers of the facility.
- Prevention of soil exploitation from chemical fertilizers
- Environmental benefits and alignment towards SDGs.

8. Conclusion

This study evaluates the current solid waste management system in the Patna Municipal region and explores the applicability of Lean Practices and their potential benefits for the system. Once the Waste is generated it enters the MSWM system. In the management system, the MSW travels through the six management stages of MSW and each of these stages contributes to the values associated with the specific Waste, regardless of its category. The flow of MSW in this stream and effect of the mentioned stages on the values associated with it is the major aspect of this analysis.
Present way of looking at MSWM is requirement of a huge number of resources and infrastructure. The Lean Management will change this perspective and provide possible better management strategies with revenue generation within the available resources. The progress could be made in steps which will make it possible for ULBs to implement and generate revenue and use that for further improvement. This will create a self-sustaining process that not only sustain but improve itself with time.

The Key inferences from the study and analysis of PMC is as follows:

- Looking at the resource consumption and Waste generation of Patna, it can be said that Patna needs a lot of improvement towards its MSWM.
- Analysis of Value and Muda has cleared that the current MSWM system are converting most of the generated MSW into Muda which contains the value generation potential.
- The associated challenges of Patna are behavioural and managerial that needs significant improvement. The other challenge of technology will improve itself once the management improves its performance.
- Communication among the key players is important are it needs to be improved in case of Patna. The players present on ground needs to participate in the discussions of policy making and action plan.
- The exercise of value chain mapping has identified the deviation of resource distribution from the weighted values of the associated stages.
- The actual value generation potential from the MSW generated under PMC has made it clear that the current burden of PMC has the potential to convert itself into a revenue business with the required measures.

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Conflict of Interests Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

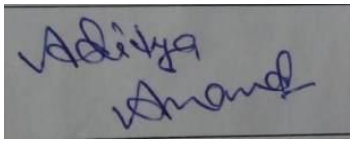
Declaration Letter

I confirm that the manuscript **"Exploring applicability of Lean Principles in SWM for Patna Municipal Corporation"** has been read and approved by all the named authors, and they have contributed significantly to the paper. This is also to declare that the paper has not been published earlier in full or as part, or been sent to some other journal for consideration for publication. The paper is also free from any plagiarism/self-plagiarism. There is no conflicts of interest associated with this paper. The authors would be fully responsible if the paper is found to violate any copyright law in future.

Ethical Statement

We affirm that the research presented in this paper has been conducted with utmost integrity and adherence to ethical principles. All data and results reported are accurate and authentic, and any intellectual contributions from others have been appropriately acknowledged.

Signature of Author



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