



# **WASTE MANAGEMENT SYSTEM USING THE INTERNET OF THINGS**

Case study of Kathmandu Valley

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## **ABSTRACT**

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Waste management is one of the arising issues in the populated city area. In a city like Kathmandu Valley, there is confusion between the collection of garbage and waste management or disposal. Both the collection as well as the disposal is the part of the waste management. The waste management consists of different other activities in the business organization like separation of different forms of waste, recycling, reducing reusing along with the disposal of solid waste.

The internet of things is a system of interrelated computing devices which could be helpful for the management of waste. This paper is assessing the internet of things for the use of waste management in Kathmandu Valley. The Internet of things is offerings automation which could change the way of solid waste management in Kathmandu Valley. As the application of the Internet of Things involves constitutes of smart surveillance, smarter energy management, water distributions, urban security, and environmental monitoring. It possesses the best role in the waste management system of Nepal as IoT is known as the extensions of internet connectivity in relation to physical devices and everyday objects.

Internet of things in waste management helps to save time, money manpower and fuel. IoT also reduces unnecessary collection from unfilled bins and help to identify best and effective routes for collection of the waste. The results also show the need and challenges along with disadvantages affiliated with the waste management in Kathmandu Valley. A requirement of the high initial cost during installment, reduce the requirement of manpower due to smart technology and high operational cost for the training at the beginning can create difficulties and challenges.

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Key words: waste management, internet of things

## CONTENTS

1	INTRODUCTION .....	6
2	WASTE MANAGEMENT .....	8
3	WASTE MANAGEMENT IN NEPAL .....	10
4	INTERNET OF THINGS .....	13
5	INTERNET OF THINGS IN WASTE ADMINISTRATION.....	16
6	DIFFERENT COMPANIES USING IOT IN WASTE MANAGEMENT .	19
6.1	Sensoneo.....	19
6.2	Nordsense .....	20
6.3	FohorMalai .....	21
7	RESEARCH METHOD .....	23
8	SWOT ANALYSIS OF IOT IN WASTE MANAGEMENT IN KATHMANDU .....	24
8.1	Advantages and Disadvantages of IOT in Kathmandu Valley .....	25
9	NEEDS AND CHALLENGES OF IOT IN KATHMANDU VALLEY .....	27
10	DISCUSSION.....	29
11	CONCLUSION .....	31
	REFERENCES .....	33

**GLOSSARY or ABBREVIATIONS AND TERMS (choose one or other)**

TAMK	Tampere University of Applied Sciences
cr	credit
IoT	Internet of things
MSW	Municipal solid waste
MSWM	Municipal solid waste management
SBWMS	Sensor-based waste Management system.
GON	Government of Nepal
KMC	Kathmandu Municipality
ADB	Asian Development Bank
CBS	Central Bureau of Statistics
SWRMC	South West Regional Maintenance Center

## 1 INTRODUCTION

In this 21st Century, waste management is taken as core environmental issues in city areas of different developing nations, including Nepal (EC Manfredi - 2010). While urbanization and economic development had shown major contributions leading to a significant increase in municipal solid waste (MSW). The continuous products which create hazardous waste are also another major concern. Also, unmanaged disposal of medical waste material and harmful products from both hospitals and clinics develops higher contributions towards pollution and public health threats in various areas of Nepal. Waste management is growing and increasing concern for metropolises and cities of Nepal (N Ferronato 2019).

Kathmandu Valley, (capital of Nepal) is on the verge of rapid urbanization and modernization having an emerging population of 2.5 million people in the contexts of South Asia. Though, at 52,000 persons per square miles or 20,288 per square kilometer. There are different opportunities and challenges created by growth, and the foremost problem is solid waste disposal (S. Kumar - 2017). Kathmandu Valley is known as the biggest producer of unsorted waste material, and also Kathmandu Metropolitan (KMC) is highly responsible for gathering and transforming waste from the Valley towards landfill sites.

In the context of Kathmandu Valley basically, scarp wastes are considered as a major part of solid waste that could be segregated and develop waste management activities which could be used for both reusing and recycling purposes (liutel and Khanal, 2010). An effort to mitigate the gap and solve different problems of Kathmandu Valley's Government of Nepal (GON) is initiating the Integrated Solid Waste Management Project. Along with particular details on those activities the Clean Valley company will actively engage in preliminary contract negotiations as they seem to be more continuous and considerable. There are also occurrences of continuous disturbances at the time of collections of solid waste leading to a significant increase in organic residues and also creating city stinking (N Ferronato 2019).

The idea of a smart city will always aim to develop the standard life of the entire citizen (Visuizi. 2018). Waste management involves not only the collection of the waste in the

field but also the transport and disposal of the waste to the appropriate locations. Proper management of solid waste is placed at lower priorities as demand is more for other different public services, for example, health, transportation, food, security, energy and so on in numerous municipalities in Nepal. Even though approximately 90% of the waste of Kathmandu Valley can be effectively reused and recycled and in the present contexts, young entrepreneurs are taking initiative actions to generate useful resources from those recycling waste. Under-developed and developing nations are intending to plan and implement a zero-waste policy system, smart solutions through applications of innovative technologies and which will create maximum influential impacts (ADB 2013). Cities of Nepal (Including Kathmandu Valley) are covered with different piles of plastic and other organic wastes. There should be strict rules and Regulations with the motive of ensuring that compliance is also required in the waste management system with new and advanced technology.

The main goal of this research thesis is to identify the importance of the Internet of Things (IoT) with the smart waste management system, analyzing the feasibility and explaining the advantages and disadvantages of IoT in the present situation of solid waste management in Kathmandu Valley.

## 2 WASTE MANAGEMENT

Administration of solid waste is one of the major objections in urban areas throughout the world and especially in the urban areas of the developing world (S.M Alam - 2016). There is an increase in the growth rate and the quantity of waste generation. As the quantity of the wastes boosts and also performs the variety of waste increases (Vergara and Tchobanoglous, 2012). Unlike the pre-consequential era where waste was only the of a nuisance that needed to be disposed at any cost. Proper administration and treatment were not a major issue as the population was small and a vast amount of land was available to the population at that time, and also the amount of waste produced was hardly any as compared to the present scenario. In those days, without any form of degradation, the environment easily absorbed the volume of waste produced (Amasuomo, E., & Baird, J. 2016).

Waste management could be solid, liquid and gas where each individual had several techniques of both disposal and management. Similarly, waste management is also intending to actively participate in different activities such as waste disposal along with monitoring and active regulations of the overall waste management system. Waste disposal basically deals with each and every kind of waste management involving industrial, biological as well as household activities (N. Ferronato - 2019). While a greater portion of waste management practices dealing with municipal solid waste that is developed by household, industrial involving commercial activity.

Discussing waste hierarchy system, waste hierarchy system constitutes of reducing, reuse and recycle along with which categorizes waste management tactics and policies on the basis of desirability as per waste minimization system (S Van Ewijk - 2016).

The waste hierarchy is considered as a cornerstone of almost different waste minimization policies in Kathmandu Valley. The material which should be adopted and implemented for the purpose of recycling wastes differs as per cities and countries. Similarly, the waste hierarchy demonstrates the development and growth of any product that passes through several sequential phases along with a pyramid of waste management. This hierarchy demonstrates other essential parts of the life cycle of every individual product. Along with history, the proportion of the waste generated by humans which were essential



because of lower population density and lower societal level of exploitations of natural resources.

Management of solid waste is taken as a wider challenge of urbanization. Different urban sectors of Nepal are encountering major difficulties and complexities along with the provisions of other services like water supply, wastewater treatment including solid waste management (SWM; WASH 2019). Also, the Government and municipalities are basically not responsible for performing any of the activities like collection, transportation, treatment, and solid waste management. Others might have unrelated ideas and perceptions on given concepts such as waste generation and compositions. Past studies had been conducted so as to collect Solid Waste Management baseline information, but they might be confined only within the municipalities of Kathmandu Valley.

People are still facing serious problems regarding environmental hazards, and a health hazard because of unmanaged dumping of domestic waste on the street, riverbanks, and open areas (Zurbrugg, 2003). Nepal requires a sustainable solution for waste management with new technology with different collection and treatment options with involvement and participation of different local and governmental bodies (Joseph, 2006). Local government is now looking at waste as a business opportunity to extract valuable resources and to safely dispose of the waste with minimum impact on the environment (Chandak, 2014). Waste management in the valley has been challenging over a decade. The main concern of the waste management in the valley is the siting of landfills. There has been the enhancement of practice in the city on the river banks which is the illegal dumping of waste. This kind of practice has increased environmental and public health problems. Still, there are different types of waste certain materials as textile, plastic bags, shoes, plastic bottles, glass bottles, traces of medical waste (syringes and drug bottles), batteries, construction material, tires, packages, paint tubes, old pens, and aluminum cans and so on.

### 3 WASTE MANAGEMENT IN NEPAL

Population and Urbanization are expanding at an increased rate in Nepal, putting high pressure on municipal service for the management of the waste. Solid waste is one of the growing concerns in Nepal as urbanization increases and the density of population increases. The flat land is in short supply at the moment (WASH, Pokhrel D. et al 2005). Approximately, about \$200 billion every year is basically spent on solid waste management and lost the energy resources at the time of disposing of trash.

Solid waste itself is not waste if it properly used it can be valuable resources, if not, then it can result in a serious effect on the environment and public health. According to a survey, which was done by Nepal's Central Bureau of Statistics (CBS), most urban residents acknowledge solid waste management as the essential environmental obstacles in urban areas of Nepal (CBS 2013). On average, all the municipalities are spending more than 20% of their total budget (Approximately, about \$200 billion every year) on waste management activities. (SWMRMC, 2004). The Internet of things will surely help with the smart waste management system due to its real-time base cleaning which reduces road traffic, workers, transportation costs due to real-time and schedule.

All the municipalities and small village development committees are poorly suffering from lack of infrastructure, technology, and financial resources to cope with waste management. The essential guidelines that are actually involved in waste management comprise source reduction, concentration, segregation, recycling, reuse and recycling procedures. Based on the survey, it is identified that 1,435 tons/day and 524,000 tons/year of Municipal Solid Waste are generated in Nepalese Contexts and also management; updating and disseminations possess an imperative role in the process of improving planning and developmental activities established by local bodies imposing implementation activities (ADB 2013). Through data analysis and surveyor based on ADB 2013 report, the per capita municipal waste generation in Nepalese Contexts is termed to be 317 grams per day where total solid waste generation for the upcoming 217 Municipalities are referred to be 3445.41 tons per day (ADB 2013).

In the context of the regional waste management system, waste collection street sweeping involves larger scale composting & biogas plants, transferring and sorting of stations,

transporting the waste and landfilling. There is seen a huge gap in power distance and individualism, along with initiating controlling and decision-making activities from the senior authorities and political bodies (Irbid & Mafraq,2014). While discussing the developing nations, because of the lower budget and also non-availability of trained workforce, the open dumping system for MSW is taken as common practice as per Nepalese Contexts. The local institutional bodies must be able to take initiative policies and actions by taking necessary approvals which is helpful in the collection, transportations, action and final removal of overall solid waste (KMC).

In Kathmandu Valley, nearly 1300 staff are perceived daily as solid waste management which is considered as 60% of the entire municipal staff. Waste materials generated from different schools, offices, and colleges are categorized as institutional waste materials, and composition analysis disclosed 45% of paper products, 22% of organic wastes, 21% of plastics and also 8% are associated with other factors P.Luitel and N. Khanal, 2009). Other mechanical strategies will also be planned for minimizing several concerns like organic composting, resource recovery technologies along with landfill developmental operations.

Awareness Campaigns in relations to indigenous communities is taken as a highly important aspect of solid waste management in Kathmandu Valley (da Silva, Weins, & Potinkara, 2019) and several municipalities can be liable enough to create the message as per grass root levels in the process of attaining success at a faster and reliable rate. Nepal's MSW shows larger organic contents comprising of 66% of domestic wastages and 34% of overall waste materials. Similarly, larger proportions of both reusable and recyclable materials deliver favorable opportunities for a significant increase in both waste reuse and recycling (Sharma Anchal 2019).

In Nepal, 3R like Reduce, Reuse, and Recycling can ultimately help to decrease the rate of waste based on final disposal sites by effectively saving costs for proper management of waste as per source level (HI Abdel-Shafy - 2018). This 3R has not implemented as most of the Nepalese People are illiterate and unaware, there are also few people who are vigorously engaged in solid waste management activities. Holding the core objective of proper solid waste management, there could be a lack of skilled and well-qualified workforce or staff at Smart Waste Management System using new technology (David Robson, BBC 2017).

Management of solid waste had been placed in the lower priorities as compared to other public services like health, security, education, transportation in several municipalities of Nepal (Henry, Yongsheng, & Jun 2006). Also, the local institutional bodies are facing numerous difficulties in the context of developmental plans and policies, so it is not needed to manage every facility to install all individual activities. Other crucial challenges could be managing appropriate transportation mechanisms in the urban areas, and there is also a lack of an effective transportation system. Also, another reason could be poor road conditions which could be extremely difficult to reach towards suitable source generations because of geographical reasons properly. There are even not any systematic techniques of waste collections and disposals all wastes might end up along with landfills, riverbanks, water and road resulting in the unhealthier environment and causing more challenges for the people and the country's health (JN Edokpayi - 2017).

Similarly, short-term goals and objectives planned and developed by various municipalities of Nepal on solid waste management predict to be inadequate towards sustainable solid waste management (SWM, ADB 2019). Therefore, long-term missions, visions, and objectives possess an impactful role in the waste management system as people are not highly conscious about outcomes of throwing overall household waste materials and garbage's in the riverside. The outdated models of systematically monitoring the waste materials can be taken as one of the most important problems in the present context (Global waste management 2015). The ultimate solution could be developing a proper method where the waste management system is consistently developed.

## 4 INTERNET OF THINGS

Internet of Things (IoT) is one of the essential technologies which are expanding slowly and steadily in this era of Technology. IoT helps to automate processes and save time money and manpower. It also helps to reduce waste and improves service. IoT is a new emerging technology that has innumerable properties such as Wi-Fi, GSM, Bluetooth, Zigbee, and other components. IoT is used to connect wireless (Elkhodr and Shahrestani, 2016). The examples of internet of things consist of connected security systems, thermostats, cars, and electronic appliances, lights in the household along with the commercial environment, alarm clocks, speaker systems, vending machines and other aspects (KILIÇ and BAYIR, 2017). All the physical things which are connected to the internet are the internet of belongings. ( M Domb 2019). It is one of the new revolutions of the internet. IoT also needed to generate a real-time data system where we can clearly analyze and used them for the objective of developing desired business outcomes (Anon, 2018).

The main goal of the internet of things is to enable people to efficiently communicate along with each other and efficiently accessing the online data and process system. This is an internet of three different things connecting; thing connecting people to people, people to the machine and things to things with our without wireless and interacting through the internet. For example, smartphone users to connect two people in social media using the internet of things. This smart IoT technology helps people live and work smarter and spend quality of time. The general benefit of the Internet of things are:

- Defend time and Money:

With the help of the IoT based waste management, the waste management activity will be effectively enhanced from the smart dumpsters for their real-time fill level information to the waste collectors. The solution of IoT enhances the data selecting the optimum routes for the waste-collecting trucks. This leads to the collection procedure which does not consider the empty trash bins saving the fuel along with the human resources.

- Make a better decision:

IoT decision relies on artificial intelligence and machine learning. IoT for waste management will be programmed for the particular situation. There will be an enhancement in

the decision-making activities in real-time about the fill level of the bin and send a notification to the municipality from the sensor in it. Due to its forward-thinking capacity of the software and machine learning tools, it is highly emphasizing the Internet of Things (IoT) on establishing bold approaches for proper management of development of new business models in different parts of the world including Nepal, IoT will be helpful in establishing smart cities by managing waste in smarter way using IoT technology.

- Waste generation analysis:

The IoT based waste management not only consists of the route optimization, but it also consists of the analysis of the data. The IoT based system in the market consists of the data analytic feature which helps in the estimation of the waste generation coming near future.

- Increase the quality and quantity of work done:

As there is the enhancement of the activity's procedure with the help of the IoT in waste management, there is the enhancement of the support for the human resource assessed for the activities. This also helps in the enhancement of quality and quantity of work done for waste management.

- CO<sub>2</sub> emission reduction:

The recycling and management of the waste also consist of the carbon footprint. With the help of the optimized routes assessed with the IoT for waste management, there will be less fuel consumption that ultimately reduces the carbon footprint for the enhancement of making the waste management procedure eco-friendly.

The Internet of things assists in using affordable wireless technology to transmit data and information into the cloud at a certain component level. IoT also conveys a significant place to save data and other management or security (LM Dang, 2019). The growth of the internet of things will transfigure a number of subdivisions, from mechanization, transportation, energy, healthcare, financial services to nanotechnology (Narayan Sharma 2015). The Internet of things is one of the best technologies in smart waste management schemes. With the application of IoT and smart sensors, waste management organizations can be liable enough to raise operational efficiencies, reduce cost level and increase the level of people's satisfaction. The applications of IoT in waste management are persuading both citizens and cities in the process of creating waste practices highly advanced and

sustainable. Similarly, optimizations of garbage collection routes on the basis of actual disposal is the best applications that are deemed to be highly impactful and influential. Also, the transformations of waste management need impactful collaborations among the public as well as private shareholders.

## 5 INTERNET OF THINGS IN WASTE ADMINISTRATION

Internet of Things (IoT) had been able to efficiently penetrate various aspects of business activities along with its terraforming industry landscapes arising from education towards retail to health care and also from automotive towards the entertainment sector (Anzelmo, E., Bassi, A. and Caprio, D.2011). IoT impact in terms of waste management industry increases along with the upcoming recycling activities. The planning and implementation of IoT helped in significant deliberations and improvements of municipal operations which is intending to define routes and traditional techniques of waste collection measures. Likewise, IoT applications in waste management are persuading the citizens and cities in the process of making waste practices as far as sustainable. Also, transforming waste management might also need clear and comprehensive negotiations between the public as well as private stakeholders. Similarly, the deliberate impacts on the waste management industry increases as the future of the recycling process look more delightful and promising.

The implication of the IoT in the management of the waste helps in the enhancement of the efficiency in waste management. With the help of the proper implementation of the internet of things in the management of waste, there is an enhancement in the system for waste management. The new system might be fast as well as well organized. This smart technology helps in the proper organization of the waste. With the help of the IoT, the classification of waste into different types of waste could be done in a more efficient time.

IoT helps in preventing as well as the reducing of the waste generation. Waste will be segregated in such a way that; all the reusable and recyclable waste can be turned into some useful resources (K Pardini - 2019). It asses for the reusing as well as the preparation for the reuse of the generated waste is prioritized after it. With this, the internet of things also enhances the recycling of the waste with the proper identification as well as the classification of the waste. Along with this, the IoT also helps in the recovery of the incinerated wastage which is based on a political non-scientific formula upgrading the less inefficient formula. Finally, the proper amount of the waste is identified for the disposal procedure. With this, it helps in the promotion of the resource's efficiency cutting unwanted costs. It also helps in the contribution towards the sustainable consumption of the energy



with the recycling and reusing along with the prevention. It lowers the greenhouse emission gas as well as pollution.

The IoT had deliberate applications in Waste Management System. The applications of IoT in waste management are significantly increasing and are also inspiring all the citizens and cities. Sensor-enabled and internet associated garbage bins can accumulate adequate information in case of fill level, temperature, locations and any kinds of sensors gather (IoT for all 2019). Smart bins possess the convenience and potentiality of Waste Management. The Internet of Things is going to change the world dramatically, affecting all businesses and modes of life. An efficient waste collection can reduce operation costs (Fuel and manpower) to avoid unfavorable circumstances and situations; the Internet of Things (IoT) had been planned and implemented to plan smart cities (Min and Yoon, 2019). In case of a proposed system, multiple dustbin system from several areas through the entire cities is associated with applying IoT technology. The application of an ultrasonic sensor will raise the level of dust in dustbins indicating the active presence of any kind of toxic wastes by an alarm sound. This can be one of the sustainable methods to collect waste.

In the current working contexts, dustbins are placed on the roadside, and there might be an overflow of a dustbin with an unpleasant smell. In some cities, it seems like, the garbage collecting vehicle visit the area once, twice thrice or even more depending upon the population but this system will inform the status of every dustbin in real-time. Multiple dustbins from different areas/locations are interconnected using IoT technology. All the dustbins are interconnected to the central office or so-called municipal head office, once they are full then automatically, the office (Collecting point) will receive the notification, once they receive the notification, then the municipality sends a notification to the truck driver to collect the waste from overflowed dustbins. The application of an ultrasonic sensor will raise the level of dust in dustbins indicating the active presence of any kind of toxic wastes by an alarm sound. The waste collection then works perfectly according to the schedule; it helps to reduce a lot of things (Transportation cost, time, manpower fuel and so on) sensor-enabled and internet-connected dustbins can also inform on the fill level, the temperature of the waste and planned the route accordingly. All the hardware and software solution work perfectly which will also inspire the local people to invest in it and motivates them to use the dustbins.

Some of the flaws of IoT in waste management have been noticed which are listed below:

- Requires more attention:

All the IoT devices are made with sensor-based technology so they should be handled with care. They need extra attention and care. Once they are damaged then it's too costly to maintain those. So, more attention is always the best.

- The requirement of adequate treatment and disposal facilities

Proper treatment and disposal of waste are also one of the important factors. After the installation of the Internet of things in waste management adequate number of treatment and disposal places are required to run the system smoothly and efficiently.

- Effective horizontal co-operation between local authorities, municipalities and governmental bodies:

To run a system effectively and smoothly local people should be aware of proper waste management using advanced technology. Public awareness and general knowledge are also the most. People should be aware beforehand in handling, using and some basic knowledge is most. There should be mutual cooperation between the municipality, local people and governmental authorities. Political stability is also one of the key requirements for mutual understanding between local people and local authorities.

- Consists of data security threats:

During the process of managing waste using the Internet of things, all the systems run in an automation way. It means all the decisions are made by machine. In some cases, there might be data security threats due to the Lack of a secure update mechanism

Old and unpatched embedded operating systems and software and insecure data transfer and storage of the device. In some cases, some devices might have some problems while operating as well.

- The need for skilled manpower:

Skilled manpower is the person who is trained, well-educated, energetic, experienced, and devoted to their field and is capable of doing any specific work in a balanced way and efficiently. There might be a lack of skilled manpower who is responsible and capable to handle and work with those automatic machines and devices. All the internet-based machines and devices should be handled properly.

## 6 DIFFERENT COMPANIES USING IOT IN WASTE MANAGEMENT

This statement emphasizes that the most significant asset of case lessons is the aptitude to assume an investigation into a process in its context. Thus, case studies are an appreciable way of looking at the world around us. In some cases, a case study can be one of the great sources to understand the different Phenomenon. Case study inquiry can be centered on any mix of measurable and qualitative methods. (K. Poulis- 2012) Characteristically, it usages multiple databases including two or more direct detailed observations, interviews, and documents. This is one of the fruitful ways to explain the situation. Case studies are particularly well suitable for new investigation areas or investigation areas for which the prevailing theory seems insufficient. A case study of three different IOT based companies in waste management along with one in Nepal has been studied.

### 6.1 Sensoneo

Sensoneo is one of the smart waste management company located in Slovakia. Senseo enables cities and business areas to manage the waste cost-effectively (Way much cheaper), be more responsive to the sustainable Environment and properly improve the wellbeing of the people. The head office is located in Slovakia, but the solution now has been installed across Europe, North America, South America, Australia New Zealand, and the Middle East. They are also planning to expand in China and India as well.

The smart waste management include the unique ultrasonic smart sensor (Single, Double, and Quatro) responsible for monitoring real-time of the waste with advanced software which works accordingly (Smart analysis, smart way preparation, and smart waste management scheme) which provides the municipal and business with data-driven, decision creation and optimization of waste gathering Routes. (The route with highly dense population and more business area with priority and vehicle load. The sensors recognized and can notify the filled bins during the pick-up. If the bins have not been filled, then there is no point to go through the bins which help to save time and the planning of the Routes.

The collection routes, frequency, and vehicle load are better optimized Resulting in overall cost reduction by 30 % (Sensoneo 2019). The real-time monitoring, Smart Analytics, and Smart Route planning to ensure more efficient, Flexible, a smaller number of

employees which result in a smaller number of Vehicles and traffic in the street, less noise and less carbon production decrease up to 60% in the capitals and Rural Areas.

The smart sensors are of high technology which can monitor the bins of various types and sizes. They are protected in such a way that, they are robust, water and well shock resistant and can be connected to all the currently IoT networks. The hardware is of high quality, making use of top-quality electronic chips available. They are equipped with replicable batteries and made from recyclable polyamide optical fibers which are in a way eco-friendly and are recyclable.

Sensoneo also has a smartphone application for the entire citizen that helps to track their location and find the best and closest empty bins to dispose of their waste with the best possible short route. The individual doesn't have to worry about the empty bins and can dispose of the waste as near as possible which is more environmentally friendly. This will help and motivates the people to make their cities greener, cleaner and free from Litter.

## 6.2 Nordsense

Nordsense is located in Denmark. In the early beginning of 2016, the first idea has been established. Nordsense is redefining the waste organization commerce by providing smart sensors in waste boxes to enhance the method of waste gathering is achieved (Nordsense 2016). At the very beginning, the first 100 nor sense pods were connected in the street bins in dissimilar parts of the city. The sensor offers a simple and affordable solution to optimize the waste collection process. The installation has been done to figure a baseline of the waste facility optimization possible.

From this project, Nordsense found that 40 % of the deflated bins contain less than 25% of the waste and the remaining 60% of the bins are not full at all during the time of emptying. This clearly explains about the unreal pickup time. Nordsense is now aiming to decrease the cost and reduce the waste collection rate by 50% and comprehend big investments in the waste gathering by picking the waste exactly at the right time. (once the bin is fully overflowed) they also found that it helps to reduce the overall CO<sub>2</sub> emission by 50% lesser and decrease noise pollution, traffic congestion, and also prevents unsanitary bins overflows.

The key benefit of Nordsense smart waste management solution is cost saving through improved routes plans, resource handling and monitoring. Nordsense also helps to improve overall workflow as well as helps in Reducing Carbon footprint.

### 6.3 FohorMalai

FohorMalai is one of the start-up company Located in Kathmandu Valley (Nepal). It was established in 2016. It targets to generate the best Sensor-based waste Management system. (SBWMS) Chiefly including productions and national households in Kathmandu Valley. The formation of such a technology will allow the placement of a wide infrastructure that will deliver the essential motivation for proper waste administration in other cities of Nepal. (FohorMalai 2019)

FohorMalai is an operation for an alteration of the way people perceives waste by showing them that it is the extreme untapped resource accessible to manhood. FohorMalai will transform waste inputs into useful outputs or resources. They are planning to implement a monetary incentivizing mechanism where the citizens are rewarded for proper waste management. This will automatically help the people for proper waste management amongst all. FohorMalai is an exceptional sensor-based effort at interfering waste from homes and businesses and efficiently manage the waste into resources.

This new technology will be extremely Profitable for FohorMalai. Waste administration division, directly and indirectly, exploits the worker who works in the cruel circumstances (especially in South Asia) on merge or almost no payroll in the absence of any employment contracts and worker protection. FohorMalai has separately delivered labors with all of the basic facilities. FohorMalai will also grow a charitable infrastructure to serve the less privileged through its network-fee influence. The assets accrued through this will be honestly and clearly distributed separately, invest in some other big projects and also to uplift increase the existing morals of the last person in the civilization.



Figure 01: Workflow diagram of FohorMalai Smart technology (Published with kind permission of FohorMalai)

S Bag (Smart Bag) is the smart bin labeled with the sensor in it. Once the smart bin is filled, then the citizen or the user sends the notification using the Mobile app to Fohormlai or waste collecting point then the truck driver, drives through the best and short route to pick the waste. At the same time, the waste will also be measured using a measuring device to know the weight of the waste. The driver then drives to the waste plant. At the same time, the waste will be then checked. (If the waste is separated properly or not) After that, the point will be rewarded to the citizen. During the process, some of the recycled and reusable waste is then transferred to the Vendor, and mixed waste is then transferred to the incineration plant to produce Electricity and Gas.

FohorMalai is now encouraging local people to properly manage their wastes with incentivizing them financially for correct waste disposal and raising their mindfulness about the issue. This is central to the proposed resolution FohorMalai offers. FohorMalai will implement waste segregation at source in sensor bag to eliminate this problem.

## 7 RESEARCH METHOD

Different papers have been effectively studied about waste management in Nepal, recognizing the potentiality of IoT (Internet of Things). Different applications had been efficiently studied about waste management. The descriptive research method had been used by the researcher in the thesis topic entitled “Smart Waste Management System using the Internet of Things” (K Pardini - 2019). The application of the descriptive study was done with the help of the observation approach. The respondents are observed from distance.

In any kind of cross-sectional study, data and information as per the prevalence of exposures and health outcomes are attained for achieving the core goals of comparing health consequences differences among both exposed and unexposed (CJ Mann 2003). As the study is allied with the waste management system, it is assumed that smart waste management plays an important role in the given research thesis. Therefore, descriptive research is helpful as it is used in obtaining necessary information associating the recent status of phenomena to explain what factors exist in relation to several circumstances and situations.

Similarly, a descriptive method is basically done as a researcher is intending to obtain a clear and comprehensive understanding of each topic. A case study of different IoT used companies has been discussed which helps to describe the characteristics of the topic from different Scenarios by comparing their results. At the same time, the observation of the research area has been done by studying different scientific papers and journals.

## 8 SWOT ANALYSIS OF IOT IN WASTE MANAGEMENT IN KATHMANDU

Waste management is one of the key issues for the entire citizen in the Kathmandu Valley. The IoT based waste management can be one of the suitable technologies for proper and real-time waste management of Kathmandu Valley which is assessed by the metropolitan government of the city including some young entrepreneurs. This could be assessed by the metropolitan government because the metropolitan government has been doing all the waste management activities in the city. With the help of IoT based waste management, the government could enhance the activities for proper waste management.

Alongside the government, there could also be the establishment of the business organization assessing the waste management activities with the help of the IoT. This could make the business organization raise revenue in order to assess waste management. The raising of the money from the local citizens could be done on a monthly basis or on the basis of the weight of the waste from a particular house.

However, the initiation of the IoT based waste management by a business organization could help the organization earn revenue and enhance the waste management activities in the Valley. On the other hand, the assessment of this activity by the government could help in the enhancement and efficiency of waste management activity. This could be cost-effective from which the government could also generate revenue by increasing sustainability in the Valley.

Implementation of the Internet of things helps in the assessment of waste management at a different level but it also consists of weaknesses and threats alongside opportunities which helps in planning new ideas and techniques improving weaknesses and (H. Ding 2011).

Some of the opportunities of the Internet of things are as follows;

- Helps in increasing the quality of the waste management in Kathmandu Valley
- Helps in bringing waste management in an efficient way
- Reduction in the external cost for the management of the waste
- Gaining public interest as well as the hype and even motivation from the local people



- Easy for the execution

The weakness of the internet of things for the management of the waste consists of the following elements; -

- Challenges in the collecting data
- Security
- Challenges for the management of the data due to lack of infrastructure
- Requires huge investment which can be one of the big risks for developing country like Nepal.
- Lack of proper direction for the implementation of the technology

The internet of things affiliation for waste management also consists of different opportunities as well. Some of the opportunities are illustrated below

- Attracts more and young investors
- Helps in the proper analysis of activities for the enhancement of the waste management in Kathmandu Valley
- Better assessment of the services developed by the Internet of Things
- Enhancement of infrastructures/ infrastructural Development
- Helps in making a better system in the waste management

The threats for implementation of Internet of Things in Kathmandu Valley for the smart waste management consists of the following; -

- Lack of proper security to the management of data
- The threat of not meeting the expectation of people/
- Lack of proper understanding among citizen to co-op with the developed system
- Lack of public awareness among the people
- Illiterate citizen to get used to with new technology

### **8.1 Advantages and Disadvantages of IOT in Kathmandu Valley**

Implementation of the internet of things also consists of different types of advantages and disadvantages for waste management in Kathmandu Valley.

Some the advantage of the smart waste management using the internet of things are as follows; -

- Helps in the real-time pickup. it means there is no need to drive through the waste bin time to time, once it is fully filled then the smart technology informs.
- It helps to save time, fuel and money by using smart waste collection bins.
- It helps in reducing the required infrastructural, operational costs as well as maintenance costs by 30%.
- Reduction in collection cost
- No missed pick-ups
- Waste generation analysis
- Reduce Overflows of the bin
- Avoid unnecessary collection from unfilled bins.
- Identify the best and effective routes for collection of the waste.
- It helps in the enhancement of the transparency of waste management.
- It helps in the enhancement of the transparency of the waste management procedure.

The disadvantages affiliated with the waste management powered with the Internet of Things in Kathmandu valley are as follows; -

- Requires a number of waste bins for the separation of waste collection as compared to the population in the city which results in high initial cost as the separate dustbins are sensor-based which is way too expensive.
- Reduces the requirement of manpower from which the minimum skilled people have to be unemployed
- Training is very essential for the employee for the operators for this smart system which costs time as well as money.
- The bins are made with so sensitive materials which may result in expensive costs in maintenance.

## 9 NEEDS AND CHALLENGES OF IOT IN KATHMANDU VALLEY

Kathmandu valley has been listed as one of the most polluted cities in the entire world. Looking over the situation of the nation, Kathmandu must be able to utilize the needed strategy within the workplace so that they can carry out the work in an effective way (Turner Elen, 2018). The nation, especially in an urban area, has been affected by the pollution and the people living over there's health has been affected by environmental pollution. Due to the upsurge in the pollution within the valley, the nation has been facing different risks which might be life-threatening too. To bring a positive impact and work on the health of the people, the government should bring the needed policy and utilized the latest technology while carrying out the work so that they can carry out the tasks in an appropriate way.

The valley does need the latest technology utilization within the workplace so that they can carry out the work in a good way. At the same time elder people, children, and illiterate people should be aware of the technology. Public awareness and public participation are also the most essential things to carry out the development work in an efficient way, the government should bring changes in its policy and technology so that they can carry out their work in a good method. The valley does need IOT due to the immense negative impact of the pollution within the valley. The health of people residing over there has been deteriorating due to which they should bring positive changes within the valley so that the people residing here can have good health. Nepal is one of the developing nations which must focus on improving the environment quality so that they can attract a large number of investors within the nation. With the increasing number of investors within the nation, the nation can carry out the work in a good manner. To develop the standard of environment and control wastage of the nation, the nation should bring new strategies within the nation so that they can carry out the work. To improve the situation of the nation, Nepal can utilize the technology by a developed nation such as Australia, the USA, and Canada, and European countries too.

The interrelation between the waste management in Kathmandu Valley, before and after could be assessed with the help of the calculation of the total waste generated in the city in accordance with the population. With the help of the secondary sources like journal articles and different other resources, it is known that the Kathmandu valley produces

around 300 tons of waste each day (MB Dangi- 2011). The proper management of the produced waste each day in Kathmandu valley takes around a week. This is mainly because the time for the proper identification of the type of waste management activities according to its hierarchy is not done. This increases the waste which is disposed of without the identification of whether the waste needs to be recycled, reused, prevented, or disposed of. According to the research (MB Dangi- 2011) following are the waste and its types each day; -

Table 01: Types of waste produced in the Kathmandu valley on a daily basis (MB, Dangi 2011).

<b>Waste type</b>	<b>Percentage</b>
Organic waste	64.24%
Plastic	15.96%
Paper products	8.66%
Glass	3.75%
Metals	1.72%
Textiles	3.4%
Leather	1.12%
Others	1.15%

With the application of the Internet of things, organic waste could be assessed for the food waste recycling procedure which could be used as the element for increasing the fertility of the soil. With this, around 50% of organic waste could be reused. Further on, 50% of the plastic, paper products, Glass, metals as well as textiles waste could be reduced from which the disposable waste could be reduced with approximately 50%. This reduces pollution as well as the carbon emission in the air.

## 10 DISCUSSION

As the population is increasing at a higher range, waste is also generated daily as per the equations. Recently, some governmental institutions and organizations might not have the ability and proficiency to plan and create a day to day business operations as they are forced to live in such an unhealthier environment. The given analysis demonstrates that there are various solutions linked with waste management implementing with IoT technologies.

The result of improvement using the internet of things in waste management is the reduction in the unwanted disposal of the waste. This further helps in decreasing carbon emission helping to reduce the pollution in the Kathmandu Valley. It also helps in the reduction of the extra cost assessed for the management of the waste once initialized. The other result in the improvement of using the internet of things in waste management is the decrease in keeping surroundings clean as well as green free from the waste.

Along with this, it helps in the reduction of the manpower requirements for handling the collection procedure of waste. It also helps in the enhancement of the full transparency which happens in the management of the wastage which can be reused and recycled. The waste management could be known improved if the waste management with the IoT enhanced efficiency in the procedure mainly.

People usually focus on the disposal of waste and the major common way is landfill. This causes not only a decrease in median landfill life but also air degradation and global warming due to the production of CO<sub>2</sub> and CH<sub>4</sub> from the waste. This IoT technology can solve this issue by introducing the sensor-based smart system. Solid waste disposal and proper management of solid waste in Kathmandu Valley. Proper waste management is also due to is a lack of public awareness and the basic environmental ethics of the local people. They usually focus on the disposal of waste and the major common way is landfill. Public awareness about the proper management of waste is also one of the essential things. Child education, providing general knowledge for the local people can significantly help to reduce the waste which can increase landfill life and also provide clean and fresh air.

Similarly, short-term goals and objectives planned and developed by various municipalities of Nepal on solid waste management predict to be inadequate towards sustainable solid waste management (SWM, ADB 2019). Therefore, long-term missions, visions, and objectives possess an impactful role in the waste management system as people are not highly conscious about outcomes of throwing overall household waste materials and garbage's in the riverside. The outdated models of systematically monitoring the waste materials can be taken as one of the most important ultimate solution which could develop a proper method where the waste management system is consistently developed. There might be some Challenges in collecting data, security, challenges for the management of overall data due to insufficient infrastructure and so on. Tackling all the challenges and problems, the internet of things will positively benefit the people living in Kathmandu Valley.

## 11 CONCLUSION

The increase in the population of Kathmandu valley is directly proportional to an increase in waste. Waste is one of the biggest challenge's society is grappling with. Waste management is a necessity for humans being for the quality of life. Waste can be one of the precious wealth if managed properly. Smart waste management systems using the internet of things can be a very effective way of treating the waste of Kathmandu valley. The unmanaged waste cause health hazard to the inhabitants. About 90% of Municipal solid waste is disposed of in open landfills, lakes, and rivers and the street. This IoT technology will help to decrease landfill waste.

This smart technology will make the environment clean and ensure a healthy and hygienic atmosphere. False disposal and false maintenance of household garbage create issues in public health and environmental pollution. It is the most efficient and cost-effective system. Its branches can be merged into different smart systems. Technology demand "To be smart" only if we adopt intelligent systems for our problem-solving needs. The prospective mobilizations of local communities hold crucial objectives in Kathmandu valley, like increasing public awareness, persuading people, child education at school to segregate and recycle several sources, mobilizing local resources and aware people from different local Media.

To sum up, there is the potential of a smart waste management system using the internet of things in Kathmandu Valley. There are also a few challenges and drawbacks which were discussed above but struggling with those challenges there is a great need for advanced technology for the proper management of waste. This IoT technology helps to focus on improving the total efficiency of waste collection and recycling. The most common IoT use case in waste management is route optimization which helps to save fuel consumption, time, money manpower and also for the real-time pick up of the waste from the bin.

Internet of things will also encourage people to segregate the waste due to its technological advancement with this technology, around 50% of organic waste could be reused. Further on, 50% of the plastic, paper products, Glass, metals as well as textiles waste

could be reduced from which the disposable waste could be reduced with approximately 50% which helps for the betterment of Kathmandu valley.



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