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Overview of an Integrated Framework for Waste Chain Management

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The global economy is required to manage a massive amount of waste while the world moves toward a circular economy. Waste is a byproduct that should be managed in a chain system where an integrated framework would be required in designing a system. This paper provides an overview of the framework for waste chain management by discussing the activities, sectors, and considerations in the system. A case study in Australia is also discussed.

Key Words: Waste Chain Management, Reverse Logistics, Energy from Waste, Parkes Australia

I. Introduction

The industrial revolution in the 18th Century encouraged a mass production system that has given us various goods at affordable prices for a better lifestyle. The mass production system, however, has resulted in several problems with the environment: increasing air pollution, decreasing natural resources, and a growing volume of waste.

Rapid climate change has called for collective efforts primarily from developed countries since the 1990s and now most countries are also required to achieve “Carbon Neutrality” within 30 years. In this stream, the Japanese government declared “Carbon Neutrality by 2050” in October 2020 and set an ambitious reduction target of 46 percent from its 2013 volume by the year 2030 [1)].

Prior to the declaration of Carbon Neutrality, Japan introduced another target of a circular economy in 2000 with the *Basic Act on Establishing a Sound Material-Cycle Society*. A sound material-cycle society in this act (Article 2) is defined as below[2)]:

> “a society in which products, etc., are prevented or reduced from becoming wastes, etc., and when these products, etc., have become circulative resources their proper cyclical use is promoted, and proper disposal of circulative resources not put into cyclical use are ensured, thereby the consumption of natural resources are conserved and the environmental load is reduced to the greatest extent possible”.

A sound material-cycle society with that meaning is generally called a circular economy so that this paper hereafter uses the term of circular economy.

The World Bank (2018) warns that the world is expected to generate 3.4 billion tons of waste annually

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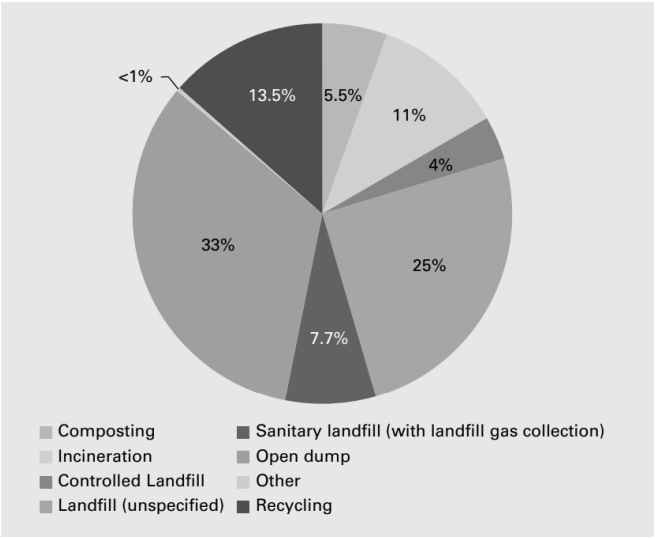
by 2050, increasing drastically from today's 2.01 billion tons[3]. Among the various kinds of waste, the United Nation Environment Programme especially warns about plastic waste saying that the rate of plastic production has grown faster than that of any other material since the 1970s and if this trend continues, the global production of primary plastic is forecasted to reach 1,100 million tons by 2050[4].

It would not be a big issue if the waste is well managed in an environmentally safe manner. More than half of the global waste, however, is open dumped (33%) or landfilled (30.7%). Only 13.5% is recycled and 5.5% composted (See Fig. 1).



Source: World Bank, *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050* (Overview, Figure O.6), 2018

Fig.1 Global Waste Treatment

In a circular economy, the 3Rs (Reduce, Reuse, Recycle) are highlighted and the 3Rs need to involve all sectors on a supply chain from suppliers, manufacturers, distributors, retailers, and customers. Governments also have an important role in this matter. The Sustainable Development Goals (SDGs) that were adopted by the United Nations as global goals in 2015 stress the reduction and recycling especially in the 12th goal -Responsible Consumption and Production-. It says that encouraging industries, businesses, and consumers to recycle and reduce waste is important as it points out that the efficient management of natural resources is essential to achieve the desired goal. One of goal targets is to achieve an environmentally sound management of chemicals and all waste throughout its life cycle and significantly reduce their release to air, water, and soil in order to minimize their adverse impacts on human health and the environment. Another

target is to substantially reduce waste generation through prevention, reduction, recycling and reuse[5].

Waste management is crucial not only to conduct the 3Rs in a circular economy but also to achieve the SDGs. Some practices in developed countries including Japan, the United States, and European countries could be a benchmark for the rest of societies in the world. The currents practices, however, are not efficient enough to enjoy the economies of scale since they have been done in each local area, for instance, in Japan. As Yoon (2011) pointed out waste chain management should be more focused by all sectors as the necessity of the chain management in reverse logistics[6].

A number of research papers on waste management have attempted to provide information and direction in this area but with little emphasis on an integrated framework for waste chain management including all sectors. This paper, therefore, provides an overview of an integrated waste chain management by identifying an integrated framework and addressing considerations that must be taken into account by all sectors. Section 2 discusses the integrated framework associated with the waste chain management while relevant aspects of the framework are also discussed. Section 3 introduces a case study demonstrating the master plan for Parkes, New South Wales, Australia where different types of waste treatment facilities are planned for an immediate implementation within the next few years. Section 4 concludes the paper with further research on the waste chain management.

II. Integrated Framework for Waste Chain Management

1. Concept of Waste Chain Management

Waste, as a material, is one of the byproducts that needs to be handled by a company or as part of a manufacturing process. This waste is also subject to removal and transportation which is often called reverse logistics. For decades, companies have tried to manage all materials in a chain system with other business partner companies to make the flow and stock of materials more efficient, and this is called supply chain management.

Accordingly, in this section, the concept of waste chain management is identified while associated logistics and supply chain management have been defined; similar terms including closed loop supply chain are explained in papers such as "*Closed Loop Supply Chain Management and Reverse Logistics -A Literature Review*" by Raj Kumar and Satheesh Kumar (2013)[7].

a. Logistics and Reverse Logistics

Logistics in business or distribution does not have a united definition since the term logistics evolved from military terminologies. In Japan, logistics is sometimes considered as a synonym of physical distribution. The definition by the Council of Supply Chain Management Professionals (CSCMP) is most

referenced. According to CSCMP, logistics is “the process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements”. This definition includes inbound, outbound, internal, and external movements [8].

Logistics aims at supplying the right product to the right place at the right time in the right quality at the right cost, which is called 5Rs. Logistics needs to manage six primary functions to supply goods to customers in an efficient and effective manner: transport, storage, packaging, handling, processing, and information.

CSCMP also defines reverse logistics as “a specialized segment of logistics focusing on the movement and management of products and resources after the sale and after delivery to the customer. It includes product returns for repair and/or credit” [9].

The general movement of goods in logistics flows from a seller to a buyer but the movement in reverse logistics flows back from the buyer to the seller. Reverse logistics starts after delivery when the goods need to be returned. The term reverse logistics has been used in recalling defective goods, but it has expanded its meaning to handling waste from manufacturing, distribution, logistics activities, and after consumption.

Logistics has been improving its system to expedite all process to respond to customers quickly from the 1980s. Sellers and transport companies try to shorten the lead time as customers want to get what they want immediately. Meanwhile, reverse logistics does not necessarily require a short lead time. Since the goods in reverse logistics -generally waste and defected goods- are not valuable, companies naturally want to treat them in the cheapest way possible. That may induce inefficient or inappropriate management of waste. We have discovered the value in the reuse and the recycle of waste when they are managed properly, and waste management is essential in a circular economy.

b. Supply Chain Management and Reverse Supply Chain

Supply chain is a metaphor used to represent all the individual companies, functions, procedures from the point of origin to the point of consumption. Supply chain management (SCM) covers across companies including suppliers, manufacturers, wholesalers, and retailers. The term SCM was first used to describe a more comprehensive view of what it took to meet customer demands [10].

CSCMP says SCM is “an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model”. It points out that SCM “encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers” [11].

As mentioned above, waste management plays an important role in a circular economy and waste needs to be managed in a chain system. The term reverse supply chain or reverse chain has used in the past two decades. According to Guide and Van Wassnhove (2002), reverse supply chain is "the series of activities required to retrieve a used product from a customer and either dispose of it or reuse it" [12]. Yoon (2011) defines reverse chain as a serious of processes from discharging, collecting and transporting, processing, to final disposing or recycling [13].

c. Waste Chain Management

The term of reverse in reverse logistics and reverse supply chain indicates the direction of the material movement. The material in reverse logistics and reverse supply chain does not necessarily mean waste as there are flows of returning goods and defective goods that will eventually be shown in logistics or in a supply chain. That is the reason why we need to clarify a specialized segment of waste management as a chain system.

Therefore, this paper uses the term "Waste Chain Management" referring to the series of activities required to manage all waste in supply chains from discharging to the final disposing including recycling and getting energy from waste (See Fig. 2).

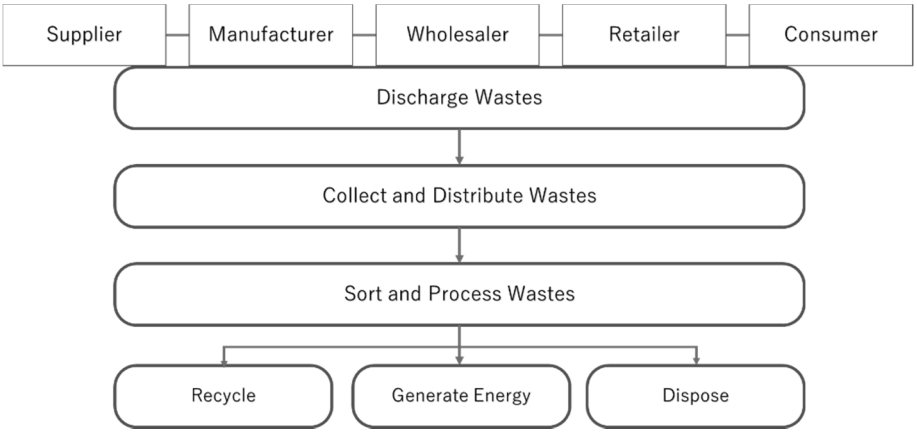


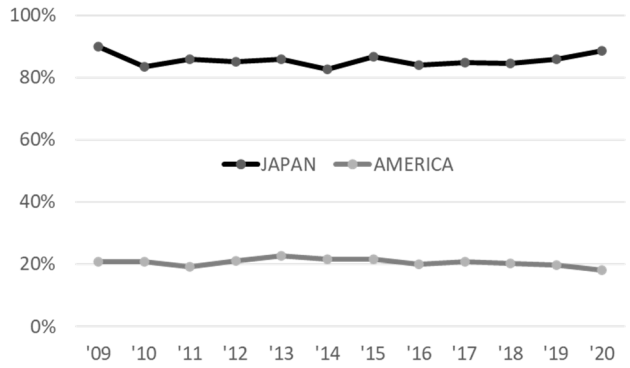
Fig.2 Waste Chain Management

2. Activities in Waste Chain Management

An integrated framework of waste chain management needs to provide all activities that must be done in the system. This section, therefore, describes the activities as mentioned above.

a. Discharge

Waste chain management starts with discharging waste. All economic units such as all industries, offices, shops, and households need to discharge all waste in an appropriate manner. This first step has a big effect on the whole waste chain management. For example, since Japan enacted the *Law for Promoting of Sorted Collection and Recycling of Containers and Packaging* in 1995, PET bottles, for instance, are separately discarded and collected for recycling. According to the Council for PET Bottle Recycling of Japan, as shown in Fig. 3, the recycle ratio of PET bottles in Japan has trended around 88% over the past decade (89% in 2009, 88.5% in 2020) while in America it is around 19% (20.9%, 18.0% respectively) [14].



*Note) Recycled PET bottles÷Sold PET bottles×100%

Data) Council for PET Bottle Recycling of Japan

Fig. 3 Recycle Ratio of PET Bottles*

b. Collection and Distribution

All waste should be properly collected in an efficient and an environment-friendly way. Collected waste needs to be transported to facilities for inspection, sorting, and disposition. The facilities mean places of waste collection that store waste temporarily and waste process centers where the above activities are done. The process centers may be in various places as waste processing can be done in several tiers. In addition, processed waste moves on to recycling facilities or energy generation plants. Those facilities should be located as a network for efficient waste chain management.

c. Sort and Process

All waste needs to be inspected to check for any hazardous waste firstly when they are collected and secondly in the collector's place when they are sorted for the next facility. This is the same as all cargo are

inspected at every inbound movement and outbound movement in a supply chain. Once arrived at process centers, waste needs to be sorted to the next targeted resource type, for instance plastic waste can go either to be recycled plastic or to go through oilification process or to be incinerated to generate electricity.

For example, PET bottles in Japan are collected on behalf of local governments, then are stored in a pressed shape after inspection. After transported to a process center, the bottles are inspected and sorted by color to be transformed as a recycled resource for other industries such as a material for clothes. Then, sorted bottles are broken down into smaller bits before being washed. Finally, PET bottles, as recycled material, go back into a supply chain. Meanwhile, when the collected PET bottles are expected to be recycled PET bottles, the waste bottles are processed in chemical resolution[15].

d. Recycling

The next activity is recycling. The most important goal of waste chain management is recycling. From the discharge of waste to processing collected waste, all those activities are to obtain resources and go back to suppliers or/and manufacturers in supply chains. Once the waste is created in a supply chain, recycling is an important key to the successful implementation of a so-called closed loop supply chain. Furthermore, when a supply chain is connected to other supply chains, for example a supply chain of a beverage industry and a supply chain of an apparel industry as mentioned above, a circular economy can be reached sooner.

Many companies in the fashion industry appeal to consumers that their products are made with recycled textiles that are collected and processed in their supply chain. In a circular economy, companies let their waste from their supply chain feed new products in other supply chain. Food waste help agricultural industry such as farming and dairy by providing recycled animal feed and fertilizers. Those cases will be commonly seen in a circular economy.

e. Energy Generation

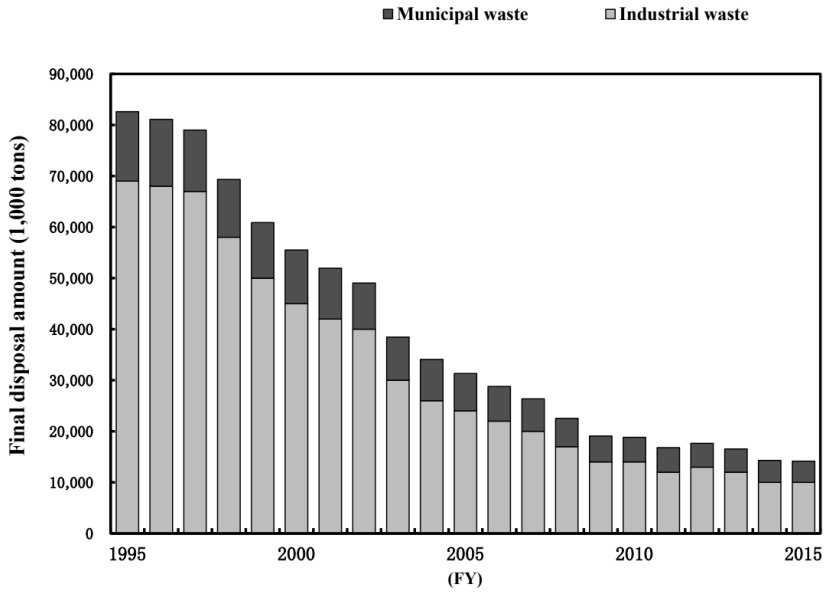
Energy from waste is also an important recycled resource. The term “Energy from Waste” has quite often been highlighted recently in the energy industry field and academic field. Incinerating waste generates electricity or steam. Environment assessment would be essential to control greenhouse gas emission when incinerate waste. In addition to electricity, oilification would be another recycled energy. Plastic waste generates oil through chemical process or pyrolysis and the oil turns into fuel after refined.

f . Final Disposal (Landfill)

The last step is landfill. One third of global waste is being landfilled as mentioned above. However, according to the Japan Waste Network, landfills in Japan have dramatically decreased through waste

management[16] (See Fig. 4). And as of 2020, only 2.4% of Japanese industrial waste is disposed[17]. That implies the importance and necessity of waste management even though the analysis was done only with industrial waste.

Some economies have also tried to get gas from landfills. Carbon dioxide, however, makes up over 90% of landfill gas along with methane gas. More analysis must be conducted, and environment assessment is essential in the final disposal as well.



Source: Japan Waste Network 『Waste Management in Japan ~Rules and Figures~』, 2018, p41

Fig. 4 Trends of Landfills in Japan

3. Sectors in Waste Chain Management

All sectors in a supply chain need to be involved in the waste chain management and authorities must get involved to introduce measures and regulate private sectors. This paper, therefore, addresses the roles and responsibilities of each sector for waste chain management.

a. Government

Government as an authority, plays an important role in establishing relevant policies and regulations. A waste management system by any entity private or public should therefore be connected to such environment policies and regulations. Government also needs to coordinate and control all the activities in order to make the system effective and efficient. Moreover, environmental assessment and seeking public opinion should

be solicited by the government directly or indirectly. It would be necessary for government to educate the private sector about the waste management.

b. Waste Generator

As mentioned in Section 2, waste chain management starts with discharging waste. All economic units generate and discharge waste. Most importantly, the waste generators should endeavor to reduce waste. Then they need to discharge waste in response to the rules that government has set up.

Waste is divided into some categories based on the waste classification system. Japan, for example, classifies waste into i) municipal waste and ii) industry waste while in Australia they generally are divided into 1) municipal waste, 2) commerce and industry waste, and 3) building and demolition waste.

Among the waste generators, some companies such as suppliers and manufacturers in the apparel or the automobile industry may establish their own recycling system in house, but that does not mean their system is efficient enough to continue their ways. It is not only because that the amount of waste from one company is not enough to enjoy the benefits of scale economics but also that the recycling is not their core business.

c. Logistics provider

Logistics providers in a waste chain management collect and transport waste as well as distribute recycled products where applicable. Waste, in general, is collected by licensed contractors in accordance with the waste classification system. Logistics providers have responsibilities of building an efficient and environment friendly transport system and reporting their activities. They also temporarily store the collected waste in their facilities before they distribute the waste to process plants or energy plants.

d. Process plant

Processing waste is an important key to obtain recycled resources and energy. In a process center, waste is sorted, washed, shredded, or chemically treated to be turned into recycled resources. Even though the waste collector could provide these services, only a few large facilities are capable of providing such processing activities in order to be economically viable.

e. Energy plant

Waste can be turned into electricity, oil, steam, and gas in energy plants by various treatments. Energy plant should be built in compliance with environmental laws and regulations. Especially, an energy generation facility incinerating waste must have a carbon capture device to stop emitting carbon dioxide.

4. Considerations for the Integrated Framework

This section so far has structured an integrated framework. This section now addresses five considerations for the framework.

a. Aim of waste chain management

First, waste chain management needs to clarify its aim as any other system does. The aim of waste chain management can vary such as maximizing the volume of recycled materials or generating more energy from waste by incinerating all waste. Local governments often conflict with each other so that a collaborative management system must be considered, or a federal government should get involved in designing a national waste chain management.

b. Category of waste

Categorizing waste is key to create an efficient waste chain management system. There are some ways to categorize waste. Japan, for example, divides into general waste and industrial waste. Industrial waste is 20 types of waste that are on the list of the *Waste Management and Public Cleansing Act* such as sludge, metal scrapes, rubble, and animal excrement. General waste is also divided into general waste from businesses and general waste from households. The latter is categorized into burnable waste, non-burnable waste, recycling waste (paper, PET bottle, cans, etc.), and often packaging materials. Some countries, for instance Korea, put food waste on the category to recycle organic waste for animal feed or organic fertilizer.

In order to increase the amount of valuable resources such as recycled materials and energy through the waste chain management, the category of waste needs to be linked to the converted resource. The quality and quantity of each category also need to be considered to achieve the aim of the waste chain management.

c. Network

In waste chain management, the network is critical to achieving the system objectives as it is a key component within a supply chain. The network is made up of nodes connected by links that is consequently correspond with transport modes. The nodes are all places of the economy units in a supply chain such as factories, distribution centers, processing centers, transport facilities, shops, and houses. The waste is created in the nodes and transported to the other nodes. For example, waste from houses moves to collectors' facilities and to waste processing centers or energy plants.

The location of the nodes forms the network. The number of nodes generally decreases along the waste management activity phase. In other words, a few processing centers and energy plants treat the waste discharged from a huge number of houses. The greater the number of centers and plants in waste management

system, the shorter the distance waste is transported. But this case would not take advantage of the scale economics. It can be inferred that the number and the location of the centers and the plants should be strategically decided by the government.

d.Transport

Waste is firstly collected and transported by trucks in general cases. Once collected into bulk cargoes, they move further to processing centers and energy generators, and the mode of transport could be via mass transport such as trains and ships. Waste transport does not require a high-speed shipment, so trains and ships are better modes of transport for environment and efficiency purposes. Inter-modal transport, therefore, should also be considered.

e.Environment Assessment

The waste management system pursues a sustainable society so that the system needs to be environmentally friendly. Prior to the phase of processing and incinerating, in addition to the transport system, an environment assessment must be conducted.

III. Case Study of Parkes, Australia

Establishing a waste chain management system should start with a master plan in order to achieve its goals and objectives through effective procedures. The master plan should be designed by a government since waste management involves land use and infrastructure. All waste management activities of economic units are required to follow the guideline of the master plan. This section, from the viewpoint of the government's role, introduces the case of Parkes, New South Wales, Australia which has just started to establish a Special Activation Precinct encompassing a waste chain management scheme.

1. Profile of Parkes

Parkes is a town in the Central West region of New South Wales (NSW), Australia, about 360 km west of the Sydney CBD and 300 km north-west of the Canberra CBD. Parkes encompasses a total land area of about 5,900 km^2 with a population of about 14,500 (2021). Parkes is predominantly rural, with more than two-thirds of the population living in the township of Parkes. Rural land is used largely for agriculture, particularly sheep grazing and crop growing, with some cattle grazing, copper and gold mining, and forestry[18].

In 2006, Parkes Shire Council, with approval from the State Government, rezoned 516 hectares for the development of the Parkes National Logistics Hub with an additional reserve of over 100 hectares. The

Parkes National Logistics Hub has been designed for 24 hour, seven days per week operation of a multi-modal transport facility.

Source: Parkes Shire Council Website[19)]

Fig.5 Location of Parkes

Parkes' unique central location at the crossroads of the nation's North-South Newell Highway and the East-West transcontinental rail line puts 80% of Australia's population within reach overnight. Parkes is the first inter-modal center for road trains to the west from Sydney. In addition, the new inland rail connecting Brisbane to Melbourne will intersect with the East-West rail line at Parkes. That means Parkes is set to be Australia's largest inter-modal site. (See Fig. 5)

2.The Special Activation Precinct Project in Parkes

In October 2018, the NSW government announced the establishment of Special Activation Precincts in Parkes to support the delivery of its 20-Year Economic Vision for Regional NSW. A Special Activation Precinct is a dedicated area identified by the NSW Government to bring together planning and investment to drive jobs and economic activity. Parkes is the first Special Activation Precinct that covers an area of 4,800 hectares. It is strategically located three km west of the Parkes township at the crossroads of the Australian rail freight network with expected business development and employment growth opportunities. The precinct takes advantage of the existing east-west rail corridor (Sydney to Adelaide and Perth) and the inland rail from

Brisbane to Melbourne, as shown in Figure 5.

The precinct consists of six sub-precincts which allow a range of land uses including freight and logistics, agribusiness and value-add agriculture, enterprise and manufacturing, intensive livestock agricultural, and resource recovery and recycling. The NSW government says that the sub-precincts are tailored to the strategic environmental impact and economic development aspirations and embed strong sustainability and circular economy principles.

The scope of project includes 1) lease or purchase of site within the Parkes precinct, 2) build, own and operate the facilities, 3) waste supply to the facilities, including sourcing and transport, 4) sale of recovered materials, 5) disposal or treatment of residual waste, and 6) sale and purchase of energy off-takes.

It is noticeable that the process will provide the opportunity for the private sector to collaborate with the regional government of NSW by submitting innovative proposals for the project. Currently, two proposals have been accepted including a plastic recycling plant (AU$260million) to process 200,000 tons of plastic and a facility for "Energy from Waste" to generate electricity for about 30,000 households.

The regional NSW government in 2020 designed "The Parkes Special Activation Precinct Master Plan" including performance measures, matters for consideration and preparation of the delivery plan. The master plan describes the vision and principles for the precinct, provides detailed land use provisions by sub-precinct, and provides performance criteria for environmental considerations like air quality, noise, biodiversity, and water management. The master plan also predicts that the precinct will become an inland port, transferring export ready goods to every major city and freight center in Australia. The project will provide opportunities for new industries in agriculture, freight and logistics, manufacturing, energy and resource recovery and transport to co-locate. The government claims that the Parkes Special Activation Precinct will be a true eco-industrial park, setting new benchmarks for efficient management and environmental performance standards in energy, waste, water, climate resilience and emissions[20].

3. Implications of the Parkes Case

The Parkes case discusses the roles of government on waste management. The NSW State Government established an agency named "Regional Growth NSW Development Corporation" to deliver place-based projects in regional NSW. Its mission is to create sustainable places for regional NSW communities. The agency supports investors through faster approval processes and infrastructure development.

The Parkes Special Activation Precinct Master Plan was made by the regional NSW government (Department of Planning, Industry and Environment) which led all process including the technical study process and community and stakeholder engagement based on the guideline of the State Environmental Planning Policy and approved by the Minister for Planning and Public Spaces. Under the master plan, the

delivery plan was prepared by the government agency. The master plan identifies the vision, aspirations, and principles for the precinct while the deliver plan identifies site-level development controls and provides detailed strategies and plans.

As this paper points out the importance of the location and the network, the regional NSW government designated the sustainable logistics hub in Parkes where provides the best network of mutli-modal transport (modes and links) and facilities (nodes) in various industries including waste recycling facilities. The government also controls the land use while it welcomes private sector's contribution.

Waste management in Japan is often criticized as an inefficient system even though the Japanese government has structured legislative framework for waste management since the *Waste Sanitation Law* in 1900. It is because that each local community has established its own municipal management system and that waste is managed separately based on the waste classification. According to the data from the Japanese Ministry of the Environment, there are 1,251 facilities[21] for municipal waste and 1,124 facilities[22] for industry waste, as of 2020. This does not let the management system enjoy the benefits of economies of scale. It is not simple to rebuild a regional waste chain management since municipals already have their own system and there would be conflict among the communities.

IV. Conclusion

As the World Bank points out, developing countries have major issues on waste management and they must adopt an integrated waste management system. If some of the best practices can be benchmarked, the impact of global waste issues will be mitigated in a quicker and more efficient way.

This paper identified the integrated framework of waste chain management with activities that have to be conducted in the system and addressed the considerations. The case of Parkes, Australia has also been discussed to emphasis the importance of the government's role and master planning exercise as part of the development of a waste chain management. Further research will address relevant activities in detail with support of empirical evidence.

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