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Designing Waste Management Systems in the City of The Future

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1 ABSTRACT

Each year people on the planet produce tons of waste. The more urbanised a country is, the more residues it produces. Its management is one of the most expensive services to municipalities and in many countries, it is still one of the main concerns. Many environmental and health problems are associated with poor waste management practices and the absence of circular economy approaches. Moreover, traditional waste management systems are designed from a waste production perspective. The process is focused on the collection of the produced waste, system coverage of it across the urban territory and its expansion. The prevalent way of thinking is still: out of sight, out of thought. Fewer efforts are put into transforming solid waste management in the direction of having a material or resource flow. Often municipalities work in silos and for this reason, solid waste is regarded as an independent process, acting on its own, designed and operated individually. Although there are many overlaps that the operation can have if it is planned in an integrated manner.

The paper presents solid waste management (SWM) regarding this integrated perspective, highlighting the synergies that could be achieved with other sectors such as mobility and logistics. It describes what can be understood under material circularity from an SWM perspective and how the principles and ideas described in the paper can be integrated into the urban planning of future cities ensuring that the waste is handled as a valuable resource.

Keywords: Solid waste management, Circular economy, Zero waste, Reuse model

2 NEED FOR CHANGING THE TRADITIONAL WAY TO DO IT

2.1 Urban Waste Crisis

Rapid urbanisation and exponential population growth are undeniably significant phenomenon since the past century. The world population is expected to increase from 7.9 billion in 2021 to 9.9 billion by 2050 (IISD's SDG Knowledge Hub, 2020) and more than two-thirds of the world population is predicted to live in cities. The World Bank (2020) indicates that nearly 7 out of 10 people will live in cities. Similarly, another alarming trend that is in direct proportion to urbanisation is global waste production. Currently, total solid waste annually generated in the world is estimated to be around 7 to 10 billion tonnes and as of 2016, 2.01 billion tonnes of municipal solid waste is generated (Kaza et al., 2018). Here, according to Kaza et al (2018), municipal solid waste refers to waste generated by residences, commercial enterprises and institutions. Other wastes such as industrial, medical, electronic, and construction and demolition waste are not considered to be municipal solid waste.

Kaza et al's (2018) What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 report indicates that global waste is estimated to increase by 70% by 2050 and it is also expected to surpass the population growth. According to this World Bank report, the global average of waste generation was 0.74 kilograms per person per day in 2016 and the United States has the highest average of waste generated with a per capita of 2.21 kilograms a day. Furthermore, COVID-19 has caused serious disruptions in the way waste is generated and healthcare waste is said to have monumentally increased due to the pandemic (Das et al., 2021). The pandemic has further instigated an unprecedented increase in the consumption of single-use products mainly plastics and experts call for a zero-waste approach and stress on the need to shift from a linear to a circular economy (Sarkodie and Owusu, 2020).

These alarming trends in waste generation in urban areas is a universal issue. Urbanisation coupled with population growth in cities is the driving force behind the increase in the amount of waste generated. Moreover, solid waste challenges concern people, municipalities, and cities alike, affecting them and the environment in multiple ways. SWM is especially a major challenge for municipalities of fast-growing cities and is also undoubtedly one of the most expensive services offered. The way waste is collected, treated and disposed of in cities requires utmost attention and the problems related to this pose a great challenge to cities and municipalities worldwide. Poor and improper solid waste management not only can cause various health, environmental, and social challenges but also influences pollution levels in cities. Greenhouse gas such as carbon dioxide and its equivalent generated from the way solid waste is treated and disposed of, are expected to rise from 1.6 billion tonnes in 2016 to 2.6 billion tonnes by 2050 annually (Kaza et al., 2018).

Waste management practices, quantities and quality of solid waste generated vary significantly due to demographics and socio-economic variables (Boateng et al., 2016) and in rural and urban areas, developed and developing countries. More developed and industrialised countries tend to have a better waste management system in place but at the same time, high-income countries produce more waste per capita and consume more goods. According to the World Bank estimate, in 2016, developed nations such as the United States, Canada, Australia and Germany's annual waste generation per capita per day is greater than 1.5 kilograms. Whereas, in several developing countries of Africa, Asia, and South America this number ranges from 0 to 0.99 kilograms.

In 2016, countries of East Asia (mainly China) and the Pacific region collectively generated the highest amount of waste globally. However, according to the 2018 World Bank report, there will be a shift in this trend. Waste generation in especially low-income countries is projected to be incremental. The fast-growing nations of Sub-Saharan Africa, South Asia, and the Middle East and North Africa are estimated to at least double the amount of waste generated by 2050 (Kaza et al., 2018). Furthermore, urban waste generation and its composition are closely linked with changing incomes of rapidly urbanising and industrialising cities. The composition of municipal solid waste ranges from organic and metal to paper and plastic waste. This composition differs among low-income and high-income countries. While most of the waste generated in low-income countries is organic waste, packaging waste forms the bulk of waste generated in high-income countries since people in cities rely on packaged and industrialised products. Overall, these statistics indicate that the urban waste crisis is a universal challenge.

Further, it is essential to take political issues into account, as urban waste is mainly exported to other local authorities with which agreements need to be reached. On a macro level, developed countries generally export waste to developing countries. To tackle the movement of hazardous waste among nations, nearly 180 countries worldwide and the European Union joined the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal that entered into force in the year 1992. On a micro level, urban waste may be collected from one authority that oversees the waste collection and exported to other local authorities that provides services for processing. The World Bank report indicates that there are different administrative and operational models across municipalities. An issue arises when the municipalities have different viewpoints and priorities in managing waste. To address this issue of differences among municipalities and other agencies, a common platform is required to efficiently coordinate decisions and regulate the management.

2.2 Traditional Waste Management Systems

In most countries, the principal aim of local administrations is to get rid of waste to not disturb the cities' landscapes. If its management works "well" it is not given much attention or resources. Hence, systems are traditionally designed from a waste production perspective. Efforts are put especially on the collection to keep the waste out of sight and consequently out of mind. This applies particularly to developing but also emerging countries, which grow at a very fast rate making it hard for them to keep the pace in the expansion of the system on par with the waste increase. Often the waste is informally deposited on the street and arbitrary dumpsites appear in cities. When cities have a problem in managing their waste, it becomes immediately visible and gets worse day by day. Uncontrolled waste management can easily become dangerous as it gets mixed with hazardous or/and medical waste not only for people involved in collecting disposing of waste such as waste pickers but also for the environment as it causes air pollution and soil contamination. In this sense, what tends to become a priority is to get it out of the way by collecting it, but sustainability is usually not considered.

The administration is usually one of the reasons for the deficiencies in waste management systems as it is not handled as such a relevant matter. In many cases, the planning and operation take place in an isolated form and not necessarily in coordination with other sectors such as energy, agriculture or mobility. In addition to this, the systems vary among high-income and low-income countries. Waste management in cities is generally supervised by local entities such as municipalities. Globally, 216 cities reported a dedicated solid waste management department, whereas 21 cities do not have a dedicated department and this information is unknown in 131 cities (Kaza et al., 2018). Since solid waste management requires an inter and transdisciplinary approach, most often cities struggle to coordinate comprehensively to address any issues that might occur. The World Bank studies indicate that municipalities mainly take a decentralised approach in managing their waste. Furthermore, a recent trend in cities suggests that municipalities are increasingly collaborating with the private sector and public-private partnerships to efficiently manage their waste. For example, many municipalities in Indian cities have employed private contractors for the transportation of municipal waste (Sharholy et al., 2008). In addition, inter-municipal cooperation, as a partnership between two or more municipalities established for waste management is a notable example that has gained acceptance in Europe. This cooperation between municipalities is beneficial because it may increase efficiency, reduce costs, and aid in reaching economies of scale. Coordination is the key to successful partnerships. Few European countries such as France, Spain, Italy, and the Netherlands have inter-municipal cooperation to manage waste (Kolsut, 2016) that has resulted in productive waste management systems.

Forms of the so-called Smart Waste Management can be found today in many developed cities. The term is applied to a type of management that uses technology to increase efficiency. This is allowed through intelligent routes for the trash collectors, the avoidance of both unnecessary trips and congested streets but also the use of mobile applications to better inform the citizens about the service provided. The implementation of this type of management uses different types of devices such as Global Positioning System sensors and ultrasonic level sensors, machine-to-machine connectivity and have the potential to reduce time in the collection processes and the costs.

Recycling systems are widely applied worldwide but the global recycling rate reflects how poorly the systems are implemented in general. The recycling rate is used as an indicator to measure progress in many countries. Firstly, the recycling rate is measured as the percentage of waste recycled from total generated waste. However, Hotta et al (2015) highlight that this indicator is defined and calculated differently among different nations especially in Asian countries due to the existence of the informal recycling sector. Due to these varying methods to measure recycling rates, it is harder to draw parallels. In 2019, the EU generated 502 kg of municipal waste per capita and recycled only 48% of its waste (Municipal waste statistics - Statistics Explained, 2021). In addition, compared to its European counterparts, Germany performs the best in the world, topping the list with the highest municipal waste recycling rate of 66.7% (Eurostat data 2019). Whereas, according to the OECD report (2015), among the 34 OECD nations, Chile and Turkey are the worst performing countries when it comes to municipal waste management with a recycling rate of merely 1%. Another significant result stated in the report is that New Zealand comes at the bottom of the list that disposes of all its municipal waste in landfills. This suggests that be it a high-income or low-income country, recycling rates are not uniform across continents. A different approach and smart innovative solutions are required, and much work needs to be done to address challenges that affect recycling rates.

2.3 Next level Circularity

Circularity or also notably known as the circular economy is an emerging concept that refers to a sustainable model of production and consumption of products and services across multiple industries. Based on several definitions of circular economy, Geissdoerfer et al (2017, p.759) comprehensively define the circular economy as a "regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops."

Globally, the current and conventional model in consumption of goods follows a linear model of 'take-make-dispose' (MacArthur 2013). This linear approach causes depletion of non-renewable resources and is a threat to the environment. In contrast to this, the circularity model consists of a closed-loop approach. That is to say, the model is sustainability-driven which reduces the consumption of resources and generates less waste. In this case, waste is considered a valuable resource rather than an issue. It can be said that this is the best method to manage waste. Furthermore, the circularity model could result in the reduction of carbon emissions, greenhouse gas emissions and waste streams. The MacArthur Foundation's report 'Towards the Circular Economy' (2013) presents that implementation of the circularity model could lower materials consumption by 53% by 2050. Considering the trends in waste production and management systems, it is evident that a well-informed integrated change is urgent and crucial.

The process of using resources to make materials and materials to make products requires high amounts of energy. Worrell et al. (2016) highlight that nearly 25% of global CO2 emissions is produced due to materials production. Consequently, waste generation and greenhouse gas emissions are inevitable by-products of material production. Although on a global scale, greenhouse gas emissions from waste management are less than 5%, it is still crucial for a system change since materials consumption and production patterns are influenced by the growth of cities. Cities in the future with serious intentions of reducing their negative impact on the environment and consciously using resources and pursuing sustainable operation and ways of doing should aim for what we call here a "Next Level Circularity". The concept of next level circularity demonstrates the change in a systems perspective. It highlights that to avoid and minimize waste production to the furthest extent, the systems should be looked at through the lens of materials perspective. Recyclable material systems should be designed to achieve material circularity. Nevertheless, to practice this type of circularity, cities must implement measures and specific frameworks such as Ecological public procurement policies, Local production, repair, reuse and recycle initiatives, Eco-design principles in the built environment, Bio-intensive urban agriculture, Energy generation from biomass, Innovation in water and waste management systems, Infrastructure solutions for e-mobility and low-energy districts.

2.3.1 Material Pact

Packaging materials are an important contributor to municipal solid waste. Concerns about packaging waste, particularly plastic packaging, and its negative and long-term environmental effects are growing. Despite increased concern over plastic pollution, plastic manufacturing and consumption are expected to continue to increase in the next decades (MacArthur 2013). Numerous variables, including governmental and legal changes, there is a growing concern about food and packaging waste, environmental pollution, and global demand for food and energy resources. All these influences the development of sustainable packaging that is made from renewable and environmentally friendly materials, as well as sustainable waste management options at the end of product life.

The Material Pact can be defined as a network of initiatives that brings together all relevant parties on a national or regional level to create solutions for a circular economy for packaging materials. Each initiative is directed by a local organisation and brings together governments, corporations, and residents around a shared vision and a set of ambitious local goals. Redesign and innovation may help to eliminate redundant and problematic plastic packaging. Before plastic was invented many products such as vegetables, soaps and other items were sold without any packaging and this was a norm in selling products. Today packaging is predominant and overused not only for practical reasons but also used for special design purposes and other unnecessary motivations. A shift in behavioural change can be achieved by awareness-raising campaigns and encouraging more conscious consumers.

For instance, packaging and the use of plastic, in general, should be regulated by the local administration. In this sense, the usage of plastics can be clearly defined, and only certain plastics must be allowed in the fabrication of packaging. The material pact regulations and guidelines are designed aiming that every plastic packaging is reusable, recyclable, or compostable and only used when and if needed; reuse is promoted instead of single use. According to its characteristics, especially its recyclability, the following materials can be recommended:

NYLON 6 - A potential inspiration source as a material with infinite closed loops Nylon 6, the most popular nylon grade, is a polymer built up by synthesising caprolactam, its monomer building block. Polyethylene Terephthalate (PET) - is one of the most important commercially consumed polymers; it is an increasingly conventional material like paper, wood, metal and glass in a variety of applications.

Polylactic Acid - Polylactic Acid commonly known as PLA, is a polymer made from renewable resources. Contrary to other thermoplastics which are petroleum-based, some of the raw materials used for PLA's production include corn starch, tapioca roots, sugarcane. Its properties, however, are comparable to other plastics in the industry. These characteristics and consumers' desire to use a less impactful material have triggered its rapid entrance into the plastic market as a competitive commodity.

Compostable Packaging - Fully compostable packaging should be prioritised. Companies can be incentivised to its design and its local production. Examples of materials for this are mycelium (roots of mushrooms) that can be then composted at home or in the local facilities.

Edible Packaging - Edible food packaging is a sustainable type of packaging that is designed to be eaten or can biodegrade efficiently like the food it contains. Edible packaging comes in many forms and is constantly being improved and innovated to be made from many different types of substances. Already different types of edible packaging are available for different types of food e.g., edible coffee cups in the market.

2.3.2 The Reuse Model

Innovative reuse models, enabled by digital technology and altering consumer preferences, can unleash significant benefits. Reuse is defined in the British Standard and International Organisation for Standardisation, as well as in EU regulations, as shown in Table 1.

Table 1. Definitions of reuse and reusable packaging in standards and directives.

Standards and Directives	Definitions
BS EN 13429: 2004 Packaging reuse [11]	**Reuse**: operation by which packaging, which has been conceived and designed to accomplish within its life cycle a minimum number of trips or rotations, is refilled or used for the same purpose for which it was conceived, with or without the support of auxiliary products present on the market enabling the packaging to be refilled: such reused packaging will become packaging waste when no longer subject to reuse **Reusable packaging**: packaging or packaging component that has been conceived and designed to accomplish within its life cycle a minimum number of trips or rotations in a system for reuse
Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives [12]	**Reuse**: any operation by which products or components that are not waste are used again for the same purpose for which they were conceived
Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 Establishing a framework for the setting of ecodesign requirements for energy-related products [13]	**Reuse**: any operation by which a product or its components, having reached the end of their first use, are used for the same purpose for which they were conceived, including the continued use of a product that is returned to a collection point, distributor, recycler, or manufacturer, as well as the reuse of a product following refurbishment
ISO 18603: 2013 Packaging and the environment—Reuse [16]	**Reuse**: operation by which packaging is refilled or used for the same purpose for which it was conceived, with or without the support of auxiliary products present on the market enabling the packaging to be refilled **Reusable packaging**: packaging or packaging component that has been designed to accomplish or proves its ability to accomplish a minimum number of trips or rotations in a system for reuse
BS 8001: 2017 Framework for implementing the principles of the CE in organisations [23]	**Reuse**: operation by which a product, component, or material can be used again without requiring any reprocessing or treatment

Table 1: Definitions of reuse and reusable packaging in standards and directives (Muranko et al., 2021).

These definitions emphasize a systemic and performance-driven approach to reuse, as they refer to the presence of a reuse system, auxiliary products that facilitate reuse, a minimum number of reuse rotations or trips, and the fact that reusable packaging eventually becomes waste and must be recycled. Reuse is not new to the consumer and was certainly there before as common practice before plastic in packaging was invented, but it is an emerging practice. For example, Bronze Age archaeological discoveries have shown repair activity on broken or abandoned pottery in Greece and the reconditioning of bronze and iron razors for reuse across Europe. Records of public actions in late 18th-century European countries, e.g., the Netherlands, show that various second-hand household products, such as kitchen utensils, were commonly bought for reuse (Muranko et al., 2021). With the increased interest in reuse, reuse model frameworks have gradually appeared in the literature. Just like the circular economy approach, reuse can mitigate negative environmental consequences induced by the intense mining, manufacturing, distribution, use, and disposal of packaging, including waste accumulation and contamination of the air, water, and land (Pardini et al., 2020).

Shifting consumer preferences have in some countries enabled a new paradigm of creative reuse that can yield major benefits, such as digital technology and changes in user preferences. Such models can aid in delivering a superior user experience, tailor products to each user's unique demands, gain insights about users, solidify a brand's identity, streamline operations, and save money.

Also reusing materials created by a refurbishing process is an operations technique that involves slowing the flow of materials by extending the product utility. In the waste pyramid, reuse is followed by recycling, which has become a very popular and very common practice. Reuse however should be prioritised and preferred as it allows for lower ecological and carbon footprint. The reuse system has three main elements, namely the re-user behaviour, reusable product and finally the reuse-enabling infrastructure.

The models can be sequential and/or exclusive reuse models (Muranko et al., 2021). Exclusive reuse involves a product that is repeatedly used by a single user throughout the product's lifetime for the same purpose for which it was intended, as well as using and enhancing reuse-enabling infrastructure (Muranko et al., 2021). In this model, the user owns the reusable items, retains ownership of the product, and is accountable for recovery, continued use, and recycling after the product has been retrieved for re-introduction into the consumption phase. For an item to be considered as recovered, its functionality must be re-established, and a person or organisation must be prepared to use it. The item can then be reintroduced into the cycle of 'utilisation-recovery-preparation'. An example is durable cloth sanitary towels (e.g., Bloom and Nora), which are composed of a consumable (an absorption layer) and a facilitator (structural layer), both of which are reusable. The consumables of products belonging to this model are typically made of non-perishable materials (e.g., fabrics) that are durable enough to withstand multiple uses. Various examples of the reuse model can be seen in Fig. 1.

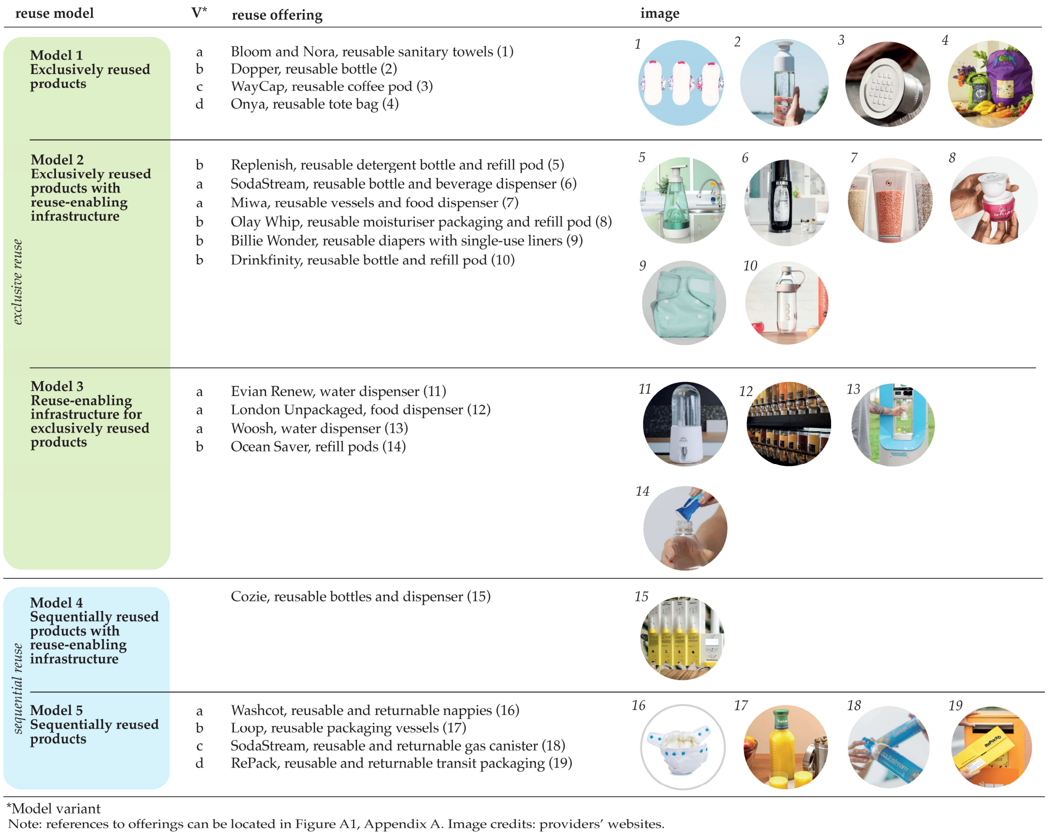

Fig. 1: Various examples of the Reuse model (Muranko et al., 2021).

Sequential reuse is a product use behaviour in which a reusable product is used consecutively by multiple users throughout the product lifecycle for the same purpose for which it was created and with the help of reuse-enabling infrastructure (Muranko et al., 2021). When sequential reuse models are implemented, the user has access to a reusable product. The user is responsible for returning the reusable product to the provider, who is then responsible for returning it for reuse and recovery, and on return to the consumer. The 'Utilisation-Recovery-Preparation' is a cycle of steps the manufacturer uses until the consumer does not return the product, when the reusable product is no longer fit for use, or when the provider decides to discontinue making the product. Reuse models can provide a database with the information needed to determine if a reuse offering suits the needs of the target audience and their technological, infrastructural, and financial capacities. This model is commonly used in-store dispensers used to refill skincare products into parent reusable, returnable vessels and refill pods such as SodaStream.

2.3.3 Sustainable Packaging

In addition to proper packaging design, sustainable packaging involves the creation and usage of packaging that is more sustainable. To meet the changing consumer demands, manufacturers must also adopt newer life cycle inventory (LCI) and life cycle assessment (LCA) methods, which will assist them to employ packaging that has a lower environmental impact and ecological footprint (Lee et al., 2005). To see all the design, choice of materials, processing, and life cycle, the package needs additional in-depth study and documentation. Sustainable packaging must meet the functional and economic needs of the present without jeopardizing the ability of future generations to satisfy their requirements. Instead, considering sustainability to be an end state, it should be regarded as a continual process of improvement. There are several regulations on both business and consumer levels when it comes to sustainable packaging. Some requirements must be put in place by law while others are up to the discretion of packagers. Investors, employees, management, and customers can have a direct impact on corporate choices and help create environmentally friendly company policies.

The main goals of sustainable packaging are:

(a) Convenient and functional product protections, safety, and regulatory compliance.

(b) Low-cost packaging: The less expensive, the better, because the lesser it is, the more one is willing to use it.

(c) Foster a long-term commitment to both human and environmental health.

In addition to the goals, the factors for designing sustainable packaging that must be taken into consideration are reusability, recycling rate, water and energy usage, use of renewable resources, and atmospheric factors. Sustainable packaging describes a range of approaches that meet multiple sustainability criteria, with little or no impact on the environment and its resources (PWC Plus 2019).

3 MATERIAL CIRCULARITY IN THE CITY OF THE FUTURE

Many infrastructural and management factors are involved in transforming the urban environment into smart communities. Technology or infrastructure is only one component of this transition; the collection of suitable data to define smart solutions, as well as the changes in consumer behaviour driven by smart solutions, are two other pillars of future smart cities (Esmaeilian et al., 2018). To address the problem of waste management, a new approach to waste collecting and treatment is required but most important for its overall planning and the general concept people have about waste needs to change. In future planning, the talk should not be anymore about waste management but rather material circularity systems. The system should from the very beginning consider the whole product life cycle and the vision of the entire process should be clear. This means that once a product is designed, its end and the process behind needs to be clear. Conscious and responsible planning should aim for a waste-free city in which waste is avoided at all times and if any, it is then minimized and converted into resources for other systems. In general, to become a zero-waste smart city, three approaches are required: waste avoidance, effective waste collection, and ultimately, effective value recovery from collected waste.

Fig. 2: Smart Waste Management System (“Solid waste clipart 5 » Clipart Station,” n.d.)

3.1 Cross-sectorial planning to ensure synergies and cost-efficiency in the city of the future

This approach is something that cannot be achieved through isolated planning. Synergies within municipality departments but also with producers and the industry, in general, must be established. Material circularity can only be implemented in coordination and alignment with many other urban planning sectors and in many cases also demand regional coordination. From the production perspective, this should be implemented in alignment with the economic department, or authorities responsible for regulating the products available in the market and its local production. Aiming to make sure that the defined policies as the producer responsibility principle are respected and that products are designed in the best possible way by following the circularity approach. For this reason, strong coordination with the commercial and industrial sectors is crucial. From another perspective, aiming more to a full recovery of nutrients, the alignment with the

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wastewater sector to combine solid waste treatment with sludge treatment is relevant. Further the process of food waste into compost is the most effective when coordinated with local food production and agricultural activities that demand it.

Besides in a city that allows for new planning or some restructuring, the coordination with mobility and logistics offers great potential for adding efficiency in the process and reducing costs. For instance, in new planned cities, the waste collection should be done using the most efficient and less contaminating technologies. Whenever possible underground systems shall be chosen, and the infrastructure used for waste collection should be carefully planned together with the infrastructure needed for the city mobility and logistics. Future cities will ideally be planned to envision and prioritise shared mobility systems as well as mobility as service approaches. Ideas for this type of mobility include the use of Automated Guided Vehicles that run on magnetic surfaces, the same that can be used for multiple purposes. In this scenario, the car as we know it does not have a place nor the streets as we are used to. The infrastructure created is then planned for being used for a variety of services and purposes, so it would be the tunnels built for the transport of the waste to the collection and treatment facilities, which at the same time can be used for package deliveries and others. The selection of the exact system will depend on the location and density of the community; in higher density areas preference will be given to the pneumatic system for waste collection for reduced carbon footprint and better efficiency. In general, the integration of the different systems, urban services and its infrastructure must be the norm and always prioritised. This applies also to the type of vehicles used, the software, and the hardware employed in the implementation. The coordination guarantees efficiency and reduction of costs at all levels. Regarding the treatment, the proximity principle should be applied to facilitate the local reuse as well as unnecessary transport.

The aim in future cities should be to create a holistic, economic industrial and social framework that seeks to have a city that is not only efficient but also and essentially waste-free. For this, apart from creating the appropriate regulations, creativity, and tech-savviness are necessary as they can encourage people to incorporate more environmentally friendly measures. In this sense, technology can be a great help when facilitating people, the correct handle of their residues. Blockchain has proven to be an ideal player in initialising digital tokens. Blockchain solutions can also help to reduce the ecological ruin prompted by waste in general. Well-designed applications also help in delivering relevant information, such as collections hours, the right use of containers, containers locations, among others. Depending on the needs, this can be complemented with advanced solutions such as smart bins that not only do compacting to increase the capacity of the container but also help with the sorting. They can be especially helpful in tourist places, where the local administration does not have the opportunity and enough time to train the "temporary user" of the services. Finally, gamification and different forms of incentives can bring the right push and motivate the users in the right way to make them part of the solution. Incentives offered can be a great motivation for people to dispose of their waste in the right manner. The incentives can be in the form of monetary rewards that can be exchanged for kilometres of public transport or entrance tickets to certain amenities, discounts for local shops, and other services. Also, the possibility to see people's progress along the time can be motivating and even more if there is a competition component added, for example among different users, blocks of houses, companies or schools. Many options could be chosen for each specific context, but the combination of the right tools is what can make the difference.

4 CONCLUSION

Since waste is mostly looked at as waste nowadays, meaning, waste is looked at as a valueless and useless entity, cities must realise the potential waste has and must tap into this resource just like any other. The amount of waste generation will only continue to rise with rapid urbanisation and population growth. With waste generation on the rise, poor waste management practices can be dangerous to health, environment, and the costs will be higher to repair the damage than prevent. The consequences can have long negative effects as continuing polluting land, air and water. The existent pressure on the availability of resources and the environmental consequences of linear consumption systems are pushing models of the circular economy. The global landscape and crisis warrant urgent, smart, and sustainable actions.

Ideally, the challenges require a shift in the way waste is treated and generated right from its nascent stage. Materials and products must be designed to last longer and in such a way that they can be utilised in the circularity loop, before even having to refurbish them or recycle; products and material lifecycle must be prolonged, and materials seen as nutrients circulating in safe and healthy metabolisms. Cities and municipalities need to take a holistic approach to evaluate urban waste and synergies among responsible stakeholders are essential to implement sustainable waste management systems. This can only be achieved through an integrated solution with the help of laws, regulations and a good mix of incentives and the help of adequate technology. Socio-environmental-technical understanding of urban solid waste is necessary (Gutberlet, 2017) but more importantly, the synergies it has with other sectors is key in delivering smart and innovative solutions that are closely linked with environmental and economic outcomes. Therefore, there is a clear need for a paradigm shift in the way urban waste is managed globally.

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