Behavioral Insights Into Waste Management in Smart Cities

SUSTAINABILITY AND WASTE MANAGEMENT ARE SOME OF THE BIGGEST CHALLENGES OF OUR TIME. IN ORDER TO FIND LASTING SOLUTIONS, WE MUST USE TECHNOLOGY TO BUILD BETTER SYSTEMS AND INFRASTRUCTURE, AS WELL AS SPREAD AWARENESS OF THIS ISSUE AND INSTIL A SENSE OF CIVIC RESPONSIBILITY IN SOCIETY

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We find ourselves in the 4th Industrial Revolution, and the technological advances that oftentimes leave us in awe can also make us question whether human development is progressing at the same pace. Worrying about the role of humanity in a world dominated by technology is an important and justifiable question. But, instead of thinking of technology as a threat to humanity, could we instead consider it as something that, if used correctly, could complement us and enhance our abilities to do good? There is no better place to put this question to test than in cities, for it is in these hubs of civilization where we find the most social, economic, political and cultural interactions which are at the center of human development. Nowadays, the concept of smart cities is gaining traction in academia as well as in the public and private sectors. Smart cities use all available technology and resources to implement strategies targeting innovation, social cohesion, sustainability, and connectivity in a city. In essence, smart cities deal with finding solutions today for the problems that we know will be of even bigger consequence in the future.

One of the most challenging matters of our time is that of sustainability, and particularly the challenge of waste management and resource efficiency. Everywhere we go, sustainability demands our attention. Politicians and activists tell us that we must take responsibility for future generations by caring for the environment. However, in most cases, people are not aware of the systems that are in place for this purpose. We are also unaware of certain behavioral biases that affect our individual choices surrounding waste generation, sorting and recycling, as well as reuse (OECD et al., 2017).

For these reasons, finding solutions to the challenge of waste management is one of the main objectives of smart cities. Upon research of the academic literature available on this topic, it is noted how many technologies and systems have already been developed in smart cities for this purpose. Most noticeable is the research surrounding the use of could-based technologies, or Internet of Things (IoT), for the development of Decision Support Systems (DSS) that maximize the efficiency of waste collection trucks in smart cities, resulting in a reduction of carbon emissions and a significant increase in cost-effectiveness (Medvedev et al., 2015). Important advances have especially been made in European and Nordic countries. Finland leads the way by implementing both waste management

Material consumption in cities will increase to around 90 billion tons by 2050

systems and waste reduction education programs, incentivizing resource efficiency through a circular economy and ensuing in around 93 percent of the waste segment being reused (Surapaneni et al., 2018). However, novel technologies and waste management systems have also been put into action on a smaller scale in other countries.

Having highlighted the systems and processes developed to tackle this challenge, the importance of behavioral insights for reaching these objectives must not be overlooked. The assertion that individual behaviors and biases are key factors in finding pivotal solutions, and that these solutions can be upscaled with the use of technology, is where the motivation for combining smart cities and behavioral economics resides in this paper. While there is no denying that a strong administration network is key for an efficient waste management process, obtaining desirable results can only be achieved through the spread of a subjective civic sense and education on the idea of waste segregation (Surapaneni et al., 2018).

THE CHALLENGE OF WASTE MANAGEMENT

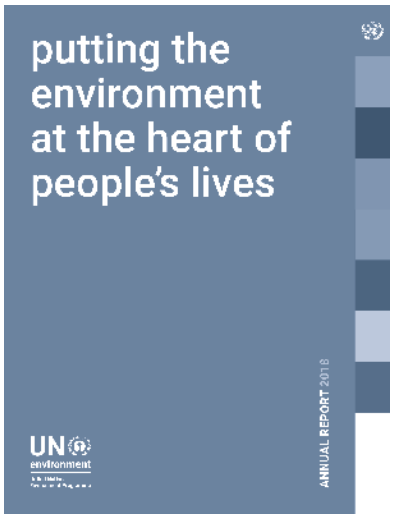
In this paper we will deal sustainability and, more specifically, waste management. We will first explain what this issue consists of in general terms and in relation to cities, and then proceed by analyzing it from two different perspectives: firstly, from the problems forth by ineffective systems in cities (which is where smart city solutions can make a contribution), and secondly, from common behavioral biases which hinder the progress in waste management (offering an opportunity for behavioral economics to provide possible solutions).

We have chosen to analyze this challenge from these two perspectives because we believe that these are the main paths through which a long-lasting solution could be found. Also because we cannot truly reach any meaningful results if one of these two parts is erring: sound infrastructure and systems pave the way for better and more efficient practices, yet without tackling the biases and heuristics that affect individuals' behavioral decision making, the best advances may be rendered meaningless. Similarly, it is not difficult to imagine that tackling those biases and heuristics without investing in technological progress is simply suboptimal. Without one or the other, it would be much more difficult to make any progress.

Waste management will have a great impact on future generations and it deals with a number of challenging issues

SUSTAINABILITY AND WASTE MANAGEMENT IN CITIES

Cities will undoubtedly face many challenges in the coming years due to growing population and our increase in resource consumption. The United Nations Environmental Programme (UNEP, 2018) estimates that 66 percent of the population will live in cities by the year 2050, in contrast to around 54 percent at the present. What this implies is an addition of about 2.4 billion people to the global urban population, which will inevitably lead to an expansion of existing urban environments or the creation of new ones. We must also consider that, even though cities use less than 2 percent of the Earth's surface, it is in these urban centers that more than 75 percent of the natural resources available globally are consumed. The UNEP also estimates that the material consumption related to cities will increase to around 90 billion tons by 2050 in comparison to 40 billion tons in 2010. Some of these resources include primary energy,



raw materials, fossil fuel, water, and food (UNEP, 2012).

What results from these changes in population and resource consumption is that cities will likely experience challenges related to growth, performance, competitiveness and residents' livelihood (McKinsey & Company, 2013). Rapid urbanization will have an effect on and even deteriorate liveability challenges in relation to waste management, scarce resources, air pollution, and traffic congestion that cause human health concerns, and decaying public infrastructure (Washburn et al., 2009).

Having described the context, we must explain what we understand by sustainability before discussing waste management in particular. First of all, it is important to establish the scale with which we will assess a system in terms of sustainability (Allen & Hoekstra, 1993). What this means is that sustainability on a global scale is different from sustainability on an urban scale, and thus they require different types of actions. Furthermore, even though it is difficult to hold a single definition of

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sustainability in the urban scale, there are certain characteristics that are commonly used when referring to urban sustainability. These characteristics can be divided into three categories or dimensions of sustainability: environmental (ex. reduction of the use of non-renewable resources), economic (ex. economic vitality and diversity), and social (ex. intergenerational equity) (Maclaren, 1996).

Waste management falls in all of these three dimensions. It deals with theconsumption and management of resources and is produced by many economic activities. Also, waste management is an issue that will have a great impact on future generations, and the root of the problem can be tracked down to certain behaviors in the general population which impede any significant progress around better waste management practices.

In essence, we can understand waste management as "all the activities that are required to manage waste from the point of collecting the waste to recycling andmonitoring" (Conserve Energy Future, 2020). More specifically, waste management's characteristic activities include:

(a) collection, transport, treatment and disposal of waste, (b) control, monitoring and regulation of the production, collection, transport, treatment and disposal of waste and (c) prevention of waste production through in-process modifications, reuse and recycling. (United Nations Statistics Division, n.d.).

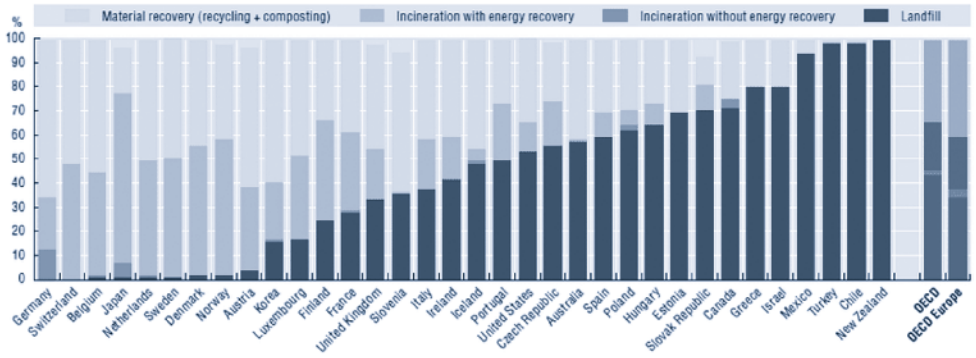
In addition, waste management demands dealing with "a number of challenging issues, for instance, balancing objectives between promoting recycling and protecting consumers against harmful chemical substances in recycled materials; insufficient data collection; quality aspects related to recycling; energy recovery of waste; and waste prevention" (Bourguignon, 2015).

When poorly managed, waste contaminates the world's oceans, clogs drains, causes floods, transmits diseases through breeding of vectors, increases respiratory conditions through airborne particles through the burning of waste, harms the animals that consume waste, and their ecosystems, and affects economic development by, for example, reducing tourism. As we can see, these effects prove that waste management is an issue that concerns everyone all over the world, and therefore requires urgent action from all levels of society (Kaza et al., 2018).

While there are many challenges related to waste management, as we have just stated, one of the main matters in question is that of "promoting recycling while making sure consumers are protected from toxic substances which can be found in waste" (Bourguignon, 2015), as well as the high cost of adding effective waste management systems, especially in cities of developing countries.

As an example of a case of poor waste management, we could look at the city of Santiago, Chile, where unregulated dumping and "informal rubbish dumps" are common (Environmental Issues in Chile, 2020). According to a report published by the OECD (2015), 99 percent of Chile's municipal waste disposal or recovery shares were composed of landfills, with only the remaining 1 percent representing material recovery (recycling and composting). We can observe this information in

FIGURE 1. Municipal waste disposal and recovery shares, 2013 or latest.



Source. OECD (2015).

the figure 2 below. One of the main sources of pollution in the world, there are many reasons why landfills are a problem, including toxins, greenhouse gasses, and leachate (all which contaminate earth, air, and water).

In order to address these issues, smart cities have emerged as a possible solution by, for instance, building clear and transparent structures of urban systems, which are simple, responsive and adaptable with the use of technology and design methods (ARUP, 2010). However, it is important to remember that having efficient systems in place is not enough. In order to achieve success in waste management, these systems must go hand in hand with a sense of civic responsibility that permeates the whole ofsociety in which they operate.

WASTE MANAGEMENT SYSTEMS AND SMART CITY ALTERNATIVES

The issues we have just mentioned are far from new and have in fact have gained much attention in recent years. However, the systems implemented so far have been ineffective in finding efficient and durable solutions. Some of the most common approaches in the past have been based on the 4Rs of the waste hierarchy, namely: reduction, recycling, reuse, and recovery.

However, in most cities, especially in those of developing countries, not enough attention has been paid to the implementation of proper waste management systems. It is most common to find waste disposal practices that include open dumps, incineration, and composting, all practices that cause great harm to the environment and increase public health risks that can result in disease epidemics, among other things.

One of the main reasons for the lack of progress with this issue is the high cost of adding waste management systems in cities. Researchers from the World Bank (n.d.) have cited waste management as "the single highest budget item for many local administrations in low-income countries," describing how, for them, it accounts for almost 20 percent of the municipal budgets, on average. This is calculated under the assumption that "basic solid waste management systems covering collection, transport, [communication, control, and employment] and sanitary disposal in low-income countries cost $35 per tonne at a minimum and often much more" (Kaza et al., 2018). In contrast, solid waste management represents more than 10 percent of municipal budgets in middle-income countries, and about 4 percent in high-income countries, depending on each country's case. Because resources and capacity for planning are limited, sustainable waste management is usually in a complicated position, as issues such as clean water, education and health care are normally higher in priority for local administrators. As a result, poor waste management has dire and disproportionate effects on the poor (Kaza et al., 2018).

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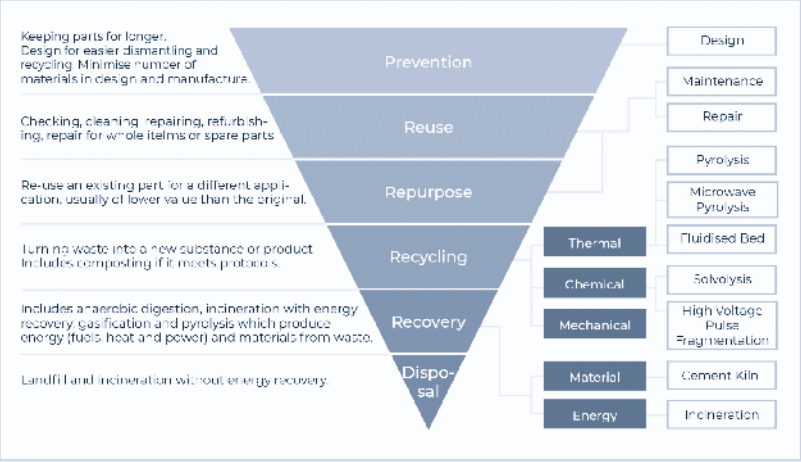
Additionally, "waste management data are critical to creating policy and planning for the local context" (Kaza et al., 2018). In order to create appropriate plans and select the right management methods for future generations, local governments need information on how much waste is being generated and the types of waste generated. With this knowledge, administrators can "design systems with a suitable number of vehicles, establish efficient routes, set targets for diversion of waste, track progress, and adapt as waste generation patterns change" and "realistically allocate budget and land, assess relevant technologies, and consider strategic partners, such as the private sector or nongovernmental organizations, for service provision" (Kaza et al., 2018).

Smart city literature notes how the technologies implemented in these settings can and are contributing to improving waste management systems. Research from Falconer and Mitchell (2012) has observed that smart cities adopt expandable solutions that use information and communications technology to "boost efficiency,

FIGURE 2. Waste management hierarchy: shows the hierarchy of management of wastes in order or preference, starting with prevention as the most favorable to disposal as the least favorable option.



Source: Bax & Company (n.d.)

decrease costs and improve quality of life." In this manner, it can be seen how smart cities directly deal with the matters of the high cost of building these systems, as well as the inefficiencies of the systems already in place, with the use of scalable technologies.

More precisely, some common solutions provided by smart cities are:

• Asset management, meaning the efficient tracking of their waste containers with the use of smart sensors located in waste bins and empowered with Internet of Things (IoT) technology in order to provide live updates on the information of the assets. Smart bins are an example of this solution, which we will discuss more in detail in the first case study in the next section.

• Citizen management, which implies involving citizens in the waste management process. This can be done with mobile applications, through which local governments can communicate with their citizens and work together with them to have a cleaner and more sustainable city by way of education on waste management practices and raising awareness of the harmful effects of ignoring this issue. This solution will be dealt with in our second case study in the next section.

On this note, we will now discuss common behavioral biases and how these are roadblocks in the way of achieving better waste management practices. This way, we hope to show that citizen awareness and behavior is an essential part in the attainment of this objective; even the best technologies and the biggest budgets are of no use without civic cooperation.

BEHAVIORAL CHALLENGES RELATED TO WASTE MANAGEMENT

As we have previously mentioned, waste management approaches in the past have aimed at tackling the 4Rs of waste management: reduction, recycling, reuse, and recovery. Reduction can be achieved through longer-living products or packaging-free goods. The reuse of products can be facilitated by simplifying repairs with eco-designs.

The determinant to obtaining desirable results resides in spreading a subjective civic sense and education on the idea of waste segregation among the general population

And reusing and recycling waste materials can be an incentive to discard and sort waste properly. However, there are multiple cognitive biases that affect our individual behavior and choices around waste generation, sorting, recycling, and reuse (OECD et al., 2017). Israeli psychologists Daniel Kahneman and Amos Tversky introduced the term 'cognitive bias' in the 1970s to describe people's "systematic but purportedly flawed patterns of responses to judgment and decision problems" (Ramachandran, 2012). This research approaches a bounded rationality perspective to understand human judgment by describing how people deviate from rationality and instead make seemingly irrational decisions.

Researchers from the Organization for Economic Cooperation and Development point out three main biases that affect individuals' behavior around this issue:

1) The first one is described as the "status quo bias," whereby consumers naturally opt for standard or default options. For example, an individual whose phone is broken might generally find it easier to replace said phone by buying a new one instead of repairing it, in which case its lifespan would be extended.

2) The second bias could be thought of as a "mental effort avoidance bias" and it revolves around incorrect waste sorting and recycling caused by the "unintuitive design of waste bins." The authors argue that the waste bins' design is "often the by-product of complex waste sorting

regulations; thus, correctly sorting waste requires a conscious effort rather than an automatic, effortless act" (OECD et al., 2017). In our first case study in the next section, we will also discuss an initiative that is currently being carried out in the city of Pamplona with digital waste bins, which also directly takes measures about this bias.

3) Finally, certain social behaviors have been found to influence littering. A clear instance of this are "attitude-behavior gaps," by which individuals "do not recognize correct waste disposal as a necessary civic duty". Another example is when individuals miscalculate both the personal and public consequences of littering. Lastly, we have "negative social norms," which can also be thought of as the "herd mentality bias." An example of this is how individuals can be incentivized to litter if they see everyone else doing so (OECD et al., 2017).

Nonetheless, despite the fact that we must become more aware of our biases and work through them in order to have better waste management practices, not everything is in the hands of the consumers. There are also several market features that are a hindrance to the implementation of policies based on the 4Rs and complicate consumers' minimization of waste generation and maximization of reuse and recycling.

For example, there is an obvious information asymmetry between producers and consumers with respect to a product's lifespan and repair possibilities (OECD et al., 2017). Also, "consumers rarely receive feedback regarding the amount and type of waste they generate" when it comes to household waste generation. In this line, it is also difficult to link waste generation to the cost of waste collection by the municipality.

However, despite the challenges presented by these market features, taking behavioral insights into account "can contribute to shaping resource efficiency and waste management policies in several ways" (OECD et al., 2017). Researchers from the OECD have suggested that designing waste bins in a more intuitive way could ease household recycling efforts. They also recommended that door-to-door waste collection in transparent bags could make recycling more noticeable, thus helping activate social norms in this context.

The behavioral insights to waste management practices we have reviewed so far have focused on "framing and simplification of information" and "changes to the physical environment." While policies implemented with these insights have generated considerable action, for example, of encouraging the reuse and repair of products, literature reviews suggest that there have not been many interventions with the aim of reducing waste generation or incentivizing correct waste sorting in households. A reason for this may be that it is considerably difficult to monitor changes in parameters such as waste volume, number of trash bags filled, or weight, since most waste is generated at homes. The same goes for tracking households' sorting and recycling patterns. A significant obstacle in the way of the application of behavioral insights to this policy area might be the lack of observability that surrounds waste disposal choices. Although these are certainly impediments to better waste management, we believe that this challenge can best be addressed by incentivizing recycling and sorting in households through easily accessible information and education campaigns on the basics of waste sorting regulations. In this way, not only will correct waste sorting and recycling require less of a conscious effort from individuals, but they will also develop a sense of civic duty, commitment and responsibility to this end.

Certain social behaviors influence littering. For example, not recognizing that it is a civic duty. Waste management and many other challenges require the collaboration of all so that we can find lasting solutions

There are many approaches to put this forward, such as a project developed in the Netherlands in 2010 where six behavioral interventions related to social norms were tested through a field experiment. The results of said project indicate that descriptions with simplified information as well as negative incentives (ex. penalties) and generating commitment and consistency were the interventions with the most significant effects on the project. These successful interventions resulted in a reduction in littering frequency by almost 50 percent in each of these cases (Dijksterhuis & Van Baaren, 2010).

CONCLUSIONS

In this paper we have argued that waste management is a problem that concerns us all and that requires everyone's attention in order to find a solution. The literature reviewed serves as proof of the consequences that this issue can have if we do not work on finding viable solutions in the near future. Furthermore, we have studied how this is no simple task not only because of the challenges related to putting sound infrastructures in place, but also because of the behavioral biases, of which we are mostly unaware, that hinder any significant progress in this respect. Taking one step forward, we conducted two case studies in order to observe these practices in reality.

Through the literature reviewed,

Governments should consider both the technological and the behavioral aspects when drafting and implementing waste management policies

we have gone over a broad and holistic view of some solutions to the challenge of waste management found in the intersection of smart cities and behavioral economics. By doing this, we hope to have helped readers understand that, while we cannot deny the importance of a strong administration network for an efficient waste management process, the determinant to obtaining desirable results resides in spreading a subjective civic sense and education on the idea of waste segregation among the general population. We would also like to add that governments and authorities should take into consideration both approaches mentioned throughout this paper when planning and implementing waste management policies in order to arrive at optimal results, as the policies that consider the complexity of the human spectrum that are likely to be most successful. In conclusion, it is worth highlighting that the world we live in is the result of our daily decisions. Reality is contingent upon human cooperation. Waste management and so many other challenges today require everyone's collaboration so that we can find durable solutions. Ordinary people have the power to change the world through their actions, and so it is in our hands to take responsibility for our future ●

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