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Enhancing Waste Governance through Dynamic Performance Management

An analysis of the Sicilian Waste System

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Abstract

This thesis aims to show how to enhance the waste governance through dynamic performance management. Particularly it analyzes the Sicilian waste management system and identify possible political leverage upon which to intervene in order to improve the performance of the whole system. During the last decades, waste management emerged as a critical problem for both national and local governments. A main driver of waste production has been recognized in the increasing population size, as well as the in urbanization of big cities and changes in consumption habits. The management of waste – as a global concern – requests that local communities and regional government are ready to effectively tackle such a wicked problem. This concern is the motivation of this research. Therefore, the work would offer a contribution to improve the waste governance and to support policy-maker in adopting a more integrated approach to waste management.

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Chapter 1 – Research Background

1. Introduction

In Limits to Growth, Meadows, Meadows, Randers, and Behrens (1972) argued that the usage rates (in 1972) of the earth's finite material and energy resources (non-renewables) could not continue without any limit. Raw materials are being used at a faster rate than they are being replaced. Therefore, some – urgent – alternatives need to be found. The result of Limits to Growth was the raise of the concept of sustainable development. Management disciplines – waste management field too – have been dramatically affected by such a concern. Thus, waste management has become an issue of growing global concern as urban populations continue to increase and consumption patterns change. Among other global issues, communities and national government are facing: health problems; urgent mounting environmental implications associated with garbage disposal, particularly in developing countries; growing solid-waste collection and supply scarcity. These phenomena affect waste management, while the availability of new technologies is offering opportunities for tackling them and turning waste into a resource.

Urbanization has increased in speed and scale in recent decades, with more than half the world's population now living in urban centers (Tacoli, 2012). By 2050, urban dwellers probably will account for 86% of the population in developed countries and 64% of the population in developing countries (UNPD, 2012a). Rapid urban population growth has resulted in several land-use and infrastructural challenges, including regional solid-waste management infrastructure.

Both national and municipal governments often have insufficient production capacity or funding to meet the growing demand for solid-waste management services (Tacoli, 2012). Indeed, as two recent reports have highlighted (World Bank, 2012; UN-HABITAT, 2010), solid-waste management is the largest budget item for many cities. In developing countries, open dump sites are the most common method of disposing of waste (World Bank, 2012). Dumping of mixed waste occurs alongside open burning, grazing of stray animals and pollution of surface and groundwater by hazardous substances such as leachate and gas (UNEP, 2011).

Landfill sites continue to represent one of the most serious environmental threats in several European countries (Raco et al., 2013). In Italy, cities such as Naples and Palermo have experienced extended waste-management crises (Mazzanti et al., 2012). New communication tools and technology options such as waste-to-energy (or energy from waste) offer possible strategies forward. The waste management ranks the most preferable solution to the least preferable. This rank is now used globally as a communication tool to remind that preventing waste through efficient use of resources and raw materials is the best option. Re-using discarded goods without reprocessing or remanufacture is assumed to provide greater savings in resource consumption and to that is given priority over recycling (Wolsink, 2010).

Increased scarcity of natural resources and the consequent rise in commodity prices have influenced the demand for recycled products. The resource value of waste has become an important driver in many developing countries today and provides a livelihood for the urban poor (Habitat, 2010). Recycling materials such as paper, glass, and plastics, as well as composting and digestion of bio-waste, become the next preferable option. Aerobic (with oxygen) composting of Municipal Solid Waste

(MSW) avoids the formation of methane associated with anaerobic conditions. The method is less complex and less costly (World Bank, 2012).

The world market for municipal waste, from collection to recycling, is worth an estimated US $410 billion a year (Chalmin & Gaillochet, 2009). However, only a quarter of the 4 billion tons of municipal waste produced each year is recycled or recovered (Chalmin & Gaillochet, 2009).

Figure 1 shows the municipal waste recycling rates in the European Union in 2010 compared with 2001 As the radar chart indicates, recycling performance has improved in most European countries.

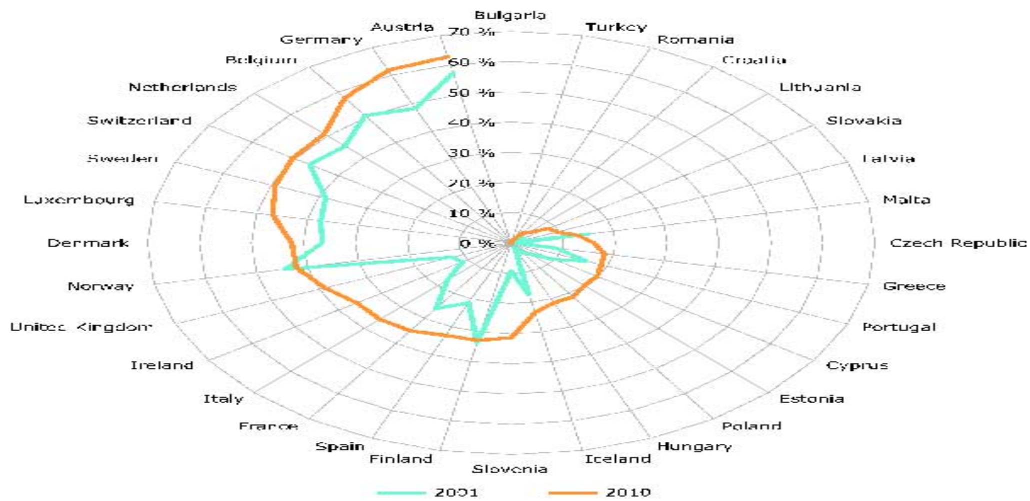


Figure 1 Municipal waste recycling rates in 32 European countries, 2001 and 2010 (EEA, 2013)

In a report assessing the economic implications, recycling had a turnover of EUR 32 billion in 2004, and increased by almost 100 per cent to a minimum of EUR 60 billion in 2008 in the European Union countries (EEA, 2011). From 2000 to 2008, employment growth in the recycling sector increased 7 per cent each year, with an overall increase of 45 per cent. Recycling generated more jobs at higher income levels than other forms of waste management in European countries (EEA, 2011). The general increase in recycling of municipal waste reduced the percentage of municipal waste landfilled (EEA, 2013).

These evidence opens a room for a discussion around a better understanding of the process behind waste management processes and policies. In this context, the job of public management scholars is to investigate how public sector organizations together with the private sector and communities, may collaborate within the framework of governance.

2. Public Administration reforms: an overview

During the last twenty years throughout the western economies, governments initiated a profound process which was aimed at reforming the public sector. Different streams of reforms tried to tackle the financial shortage as well as the budget shrinking of public sector organizations, at central and local levels too. Therefore, public sector reform has been a common experience across the world despite its different forms and focus (Pollitt & Bouckaert, 2011). This process of reform was supported by the spread of a set of ideas focused on dysfunctions of public sector organizations. These ideas were driven by the diffusion of new theories and movements such as new institutional economics, the public choice theory, the transaction cost theory, and the principal-agent theory.

Management model of public sector organizations have passed through three dominant modes: from the classic management model known as Old Public Administration to the managerial model termed as "New Public Management" (Hood, 2001). This latter stream of movement evolved during the last twenty years from an institutional perspective towards an inter-institutional one (Bouckaert, Peters, & Verhoest, 2010). Indeed, recent research on public management has focused on Public Governance as management model to improve inter-institutional outcomes.

Governance is here understood as "the way in which stakeholders interact with each other in order to influence the outcomes of public policies" (Bovaird & Löffler, 2009: 6). Studies on Governance mainly conducted a debate with a reference position that the "rules and institutions for the authoritative organization of collective life" (Donahue, 2002: 1) cannot preserve the classical notion of the State. They are formulated and reformulated as complex interactions which involve actors from both civil society, the private players, and public sector organizations.

Within the conceptual framework of Governance, multiple actors come together into several policy fields. By taking a more normative perspective, the challenge for both public management scholars, and policy makers is to define how these interactions should themselves been operationalized in order to facilitate good governance.

This chapter provides a broad overview of recent governance debates in waste management highlighting the main areas of convergence and divergence observed within up-to-date publications. Such a debate is then used to explore main management issues related to the integrated waste management system.

2.1 The path towards Governance

The first stream of changes in public administration came after the ideas and experiences matured by the Anglo-Saxon countries which have been labeled as New Public Management (NPM) (Christensen & Lægreid, 2007; Dunleavy & Hood, 1994; Hood, 1991; Hood, 1995; Larbi, 1999; Pollitt & Bouckaert, 2011).

The paradigm shift from old classic administration to NPM brought philosophies and tools of business organizations inside the public sector. NPM is a product of neo-classical economics and particularly of rational/public choice theory (Niskanen, 1971) with a focus on intra-organizational processes and management (Ostrom & Ostrom, 1971).

By the end of the '90s, public governance has shifted the root of the public-sector reforms (Borgonovi, 2002: 38-41) into organizational sociology and network theory (Haveri, 2006; Osborne, 2006), and particularly in the work of Ouchi (1980) Powell (1990), Tsai (2000), and in the organizational studies of Williamson (1981).

Such a shift is particularly important because it has extended the scope of public administration. By Governance, public sector management model/theory concerns with outcomes, and indeed, it takes an inter-organizational focus than does the output and intra-organizational accent of the NPM (Bovaird & Löffler, 2009).

The academic and political debate around the size of public intervention within the economy, on one side, and the increasing scope of societal needs satisfied by the welfare state, on the other hand, has produced a discussed landscape of governance studies.

Governance has been used as an umbrella term. Within the public management literature, there is a wide area of approaches – termed as "governance" or as "public governance" – which locates a long-standing theoretical debate in the field.

In the attempt to devise a meaningful definition of governance, authors as well as scientific institutes come up with several of explanations of governance.

- Governance is the exercise of political power to manage a nation's affairs (World Bank, 1989: 60)
- Governance comprises the traditions, institutions and processes that determine how power is exercised, how citizens are given a voice, and how decisions are made on issues of public concern (Canadian Institute on Governance).
- Governance is the way in which stakeholders interact with each other in order to influence the outcomes of policies (Bovaird & Löffler, 2009: 7).
- The pattern or structure that emerges in a socio-political system as a "common" result or outcome of the interacting intervention efforts of all involved actors. This pattern cannot be reduced to [the outcome produced by]

one actor or groups of actors in particular (Kooiman, 1993: 258).

- Governance as "self-organizing inter-organizational networks" that function both with and without government to provide public services (Kickert, 1993: 199).
- Governance is "about managing networks." Governance as "minimal state, socio-cybernetic system and self-organizing networks" (Rhodes, 1997: 53).
- Frederickson (1999: 702) argued that "public administration is steadily moving [...] toward theories of cooperation, networking, governance, and institution building and maintenance."
- Salamon (2002) used governance to put emphasis on the collaborative nature, on the reliance on the wide array of third parties in addition to government to address public problems and pursue public purposes.
- A holistic approach to governance where outcome/outputs of policy programs are a function of environment, users, activities, structures and managerial role (Lynn Jr, Heinrich, & Hill, 2001).

For at least the last twenty years – from late 1990s till now – governance has been a prominent subject in public management studies (Frederickson, 2009: 283), with manifold roots of interest (Bovaird, 2005) owing to a considerable prior theoretical and/or ideological baggage (Osborne, 2006: 381).

As political scientist, Kjaer (2004) illustrates the variety of definitions of governance by contrasting the work of Rhodes (1997), Rosenau (1995) and Hyden (1999).

Governance relates to self-organizing, inter-organizational networks characterized by interdependence, resource-exchange, decision making process, rules of the game, and significant autonomy from the state (Rhodes, 1997: 15).

Global governance is conceived to include systems of rules at all levels of human activity – from the family to the international organization – in which the pursuit of goals through the exercise of control has transnational repercussions (Rosenau 1995: 13).

Governance is the stewardship of formal and informal political rules of the game. Governance refers to those measures that involve setting the rules for the exercise of power and settling conflicts over such rules (Hyden 1999: 185).

An explanation for the diversity in definitions that these quotations illustrate is that the definitions come from divergent sub-fields of social and political science.

Rhodes (1997) takes the perspective of public administration scholar, and he points out the reforming process which occurred in public sector organizations. Rosenau (1995) highlighted the need to tackle global problem, while Hyden (1999) have adopted governance as a mean to enable diplomacy and engage theories of third world development.

In the field of governance other publications have focused geography, sociology and economics that have enriched the construct by paying attention to efficiency in governing matters, as well as by emphasizing the effect of public policy on society and community.

Pierre and Peters (2000) have examined the differences between the "old" central government and the "new" governance in influencing social and economic developments. By analyzing formal and informal associations particularly through networks, they distinguished that the government through the political-institutional system steers society and public policies; while governance takes a "society-centric", perspective which focus on the ability of society to govern itself.

The literature on governance seems to have devoted considerable attention to the methods and mechanisms that might facilitate generating satisfactory decisions among several stakeholders through negotiation and deliberation. Such a debate stimulated the discussion upon power and interests in governing and decision making processes and practices (Kjaer, 2004).

In outlining public governance, scholars did not focus only on results, as they did in NPM. They have rather stressed interaction, coordination, and outcomes that citizens as stakeholders aim to achieve (Bovaird & Löffler, 2009: 3-12). As Kickert (1997: 735) remarked: "in public governance, interaction with the socio-political environment plays an important part. It is not merely an internal organizational matter, [...] Public governance is the "management" of complex networks, consisting of many different actors from the national, provincial, and local government, political and societal groups, pressure, action and interest groups, societal institutions, private and business organizations. The management of such public networks is a form of external government steering."

Notwithstanding differences and alternative definitions of governance, there are critical perspectives that question whether such a broad term can be useful in developing a coherent analytical framework (Marinetto, 2003). Several authors call for application of the conceptual models of governance (Kjaer, 2004) to grasp the capability of state to manage an increasingly complex world.

The challenge for research on governance therefore is to preserve the theoretical foundation of the concept, whilst attempting to develop empirical understanding within a specific field.

2.2 Waste Governance

Recent studies of environmental and sustainability issues are embracing and reframing the notions of governance to understand the complex processes of policy making and implementation in such a field (Adger, Brown, Fairbrass, Jordan, Paavola, Rosendo et al., 2003; Bulkeley & Betsill, 2005; Bulkeley & Mol, 2003; Newig & Fritsch, 2009; Priscoli, 2004). These studies aim to recognize the importance of a coordinated governance in policy-making, by trying to encompass the role of both public and private sector, as well as community organizations at local level.

By taking the perspective of governance one may consider not only technical matters, but also the social, cultural, political and economic contexts and networks that are involved into waste management.

Waste management is considered a global challenge (Greenpeace, 1993) where the developments in recycling technologies are creating new global opportunities for managing waste' flows. Indeed, almost all western countries have national waste management plans especially European Institutions have issued waste policy statements. At both national and local level, waste management systems are witnessing overlapping areas among public and private actors, and indeed the private sector has increased its share in delivering waste services. Waste governance is becoming intertwined through public private partnerships and networks of waste organizations.

From the perspective of the academic debate, the analysis of waste governance is increasingly variegated. Fagan (2004) has highlighted the role of network in waste management issues. The network approach recognizes as its core the growing flows of interactions between cultures, societies and economies through the world. This point recommends a move of many aspects of management of waste from local to global and vice versa (Dirlik, 1999).

Parto (2005) has developed an institutional analysis of waste. Such an analysis is pretended to considers the driving forces in waste management systems. The author proposed a clear institutionalist analysis of waste management, moving from the idea that by analyzing the structures of waste governance, namely the institutions which intervene on the policy process, it is possible to have a better understanding of the policy outcomes. In other words, he asks: why do some places achieve higher volume of waste produced, while others have a higher level of recycling?

The analysis of Parto (2005) contrasts with Fagan (2004) because the first focuses on the actions of the institutions, while the analysis of Fagan (2004) is aimed to bring society into the technical field of waste management. According to Parto (2005), waste policy analysis is an activity that is not possible to perform "without addressing issues of governance and accounting for the role of institutions" (Parto, 2005: 2).

Besides networked and institutional analysis of waste there are also other approach which have sought to expand these conceptual boundaries (Myers, 2005).

Myers (2005) has added geographical and conceptual diversity to waste governance analyses, by adopting a political ecology framework. Despite the criticism, Myers have moved forward by investigating the interactions among a city program developed by United Nations and selected cities in Africa. His innovation came from the change of perspective, which has moved from networks, or institutions towards four themes: economic, environmental, political and cultural sphere.

His work looked at the triadic elements of governance: the structures and practices (the how), the level of rationalities (why), and the outcomes achieved by the governing process (what). Such an approach has paid attention to social science themes in a field which was traditionally dominated by purely technical assessment of environmental costs and outputs.

The major contribution of Myers (2005) – which links back to Pelling (2003) – is the idea that the aptitude of both society and government changes the way in which waste is perceived. It can be a resource, or hazard, or simply disregarded. The interactions of these perceptions with the structure of governance, such as the bureaucracy or institutions, influence the decisions and the outcomes of waste governance.

Albeit the differences among these approach to waste governance, there are some overlapping areas. Networking, institutionalism and political ecology share common ideas. All approaches have used qualitative methods to capture their relative fundamental aspects of waste governance. Moreover, they have identified a variety of actors in waste governance system. Lastly, the political ecology of waste (Myers, 2005) supports the idea that ecology, culture, and management techniques should be brought together in the political field and therefore in the decision-making process in order to evaluate the outcomes of governance.

2.3 Framing waste governance from a sustainable outcome-based perspective

To analyze waste governance from a sustainable outcome-based perspective, a multidisciplinary approach is required (Guerrero, Maas, & Hogland, 2013; Marshall

& Farahbakhsh, 2013; Morrissey & Browne, 2004). In waste governance, environmental and economic issues are highly intertwined. Framing and understanding the long-term effect of policies on the wider-system performance is crucial for a sustainable approach to waste management.

Davies (2008: 158) conceptualized the relationship between governance and environment as nature-society relations, which also includes the "roles and responsibilities of actors and institutions". The perspective of governance "allows for consideration not only of technical matters or scientific analyses, but also of the social, cultural, political and economic contexts and networks" (Davies, 2008: 15).

Sustainability is clearly defined by Diesendorf (2000: 23) as the end point of sustainable development, which correspond to "types of economic and social development that protect and enhance the natural environment and social equity." It was the World Commission on Environment and Development which published its report (1987) to put the concept of "sustainable development" into the public debate.

The concept was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987: 43). However, there is no unanimously approval on the concept of sustainability. Within waste governance studies, sustainability has been described as a socio-political construct, which is different from the definition provided in the Brundtland (1987) report. Indeed, it has become common in the language of governance, but it has led to alternative approaches towards its core meaning: from an eco-centric to an anthropocentric view. Such an alternative has led to contradiction to what should be considered the utmost solution in terms of sustainability (Kaika & Swyngedouw, 2000).

This flaw was clearly recognized by Swyngedouw and Heynen (2003: 901). The authors stated that "there is no such thing as an unsustainable city in general. Rather, there are a series of urban and environmental processes that negatively affect some social groups while benefiting others." Therefore, a sustainable program can be compromised by conflicting beliefs, leading to consensual conclusions that potentially move away from original sustainable policy intentions.

Today, societies and communities ask that waste management should be not only safe, but must also be sustainable. According to this political request, sustainable waste management must be:

- economically affordable;
- socially acceptable;
- environmentally effective.

Figure 2 The three dimensions of Sustainable Development (Adapted from McDougall, White, Franke, & Hindle, 2008: 3)

As figure 2 shows, policy-makers must consider each dimension equally, otherwise the whole system will become unbalanced (McDougall, White, Franke, & Hindle, 2008: 3).

Traditionally, the waste management system was managed mainly according to an economic concern, which took over the other aspects of the service. In the last ten years, environmental matters have acquired increasing attention and become more prominent in the political debate. Social aspects of waste management have an influence on the decision-making process, however few research have investigated how to measure it (Nilsson-Djerf, 1999). Environmental issues in waste management can be characterized into two streams: conservation of resources and pollution of the environment.

To connect the above-mentioned pillars, it is necessary that waste management system adopts the perspective of sustainability. To this end, it is necessary to understand those main issues which affect waste management. This is a prerequisite to embody the concept of sustainability within the integrated waste management system.

3. Classification of waste and management issues

Following the discussion on alternative approaches in waste governance, it is worth to define the key terms, relevant concepts, and management issues related to waste management. Waste may be understood as unwanted or unusable materials, which come from industry and agriculture as well as businesses and households. It can be liquid, solid or gaseous in nature and hazardous or non-hazardous depending on its location and concentration (Girling, 2005).

Waste are considered either unusable materials or can be understood as a source of value. Such diversity emerges when different countries and communities are compared. (Scanlan, 2005), or even because of a different approach in treating waste (zero waste approach vs. supporter of energy from waste).

How unusable products are collected and recycled into valuable commodities, who undertakes these practices and under what conditions, are increasingly important questions which deserve to be investigated (O'Neill, 2000).

During the 19th and 20th centuries, western countries have developed a waste legislation to tackle the need of a more precise definition of waste. Such a legislation has had managerial, financial, and legal implications for public organizations and communities too.

Definition of waste have been developed at various institutional levels. For example, the 1975 EC Waste Framework Directive (75/442/EEC 1975) defined waste as any substance or object which is discarded or which will be discarded. This definition has been amended on several occasions to finally comprise “any substance or object set out in Annex I which the holder discards, or intends to discard, or is required to discard” (Waste Framework Directive 2006/12/EC). Table 1 lists the categories of waste.

Table 1 Categories of waste (adapted from European Union 2006, L114/15)

Q1	Production or consumption residues not otherwise specified below
Q2	Off specification products
Q3	Products whose date for appropriate use has expired
Q4	Materials spilled, lost or having undergone other mishap, including any materials, equipment, etc., contaminated as a result of the mishap
Q5	Materials contaminated or soiled as a result of planned actions (e.g. residues from cleaning operations, packing, materials, containers, etc.)
Q6	Unusable parts (e.g. reject batteries, exhausted catalysts, etc.)
Q7	Substances which no longer perform satisfactorily (e.g. contaminated acids, contaminated solvents, exhausted tempering salts, etc.)
Q8	Residues of industrial processes (e.g. slags, still bottoms etc.)
Q9	Residues from pollution abatement processes (e.g. scrubber sludges, baghouse dusts, spent fillers, etc.)
Q10	Machining or finishing residues (e.g. lathe turnings, mill scales, etc.
Q11	Residues from raw materials extraction and processing (e.g. mining residues, oil field slops, etc.)
Q12	Adulterated materials (e.g. oils contaminated with PCBs etc.)
Q13	Any materials, substances or products who use has been banned by law
Q14	Products for which the holder has no further use (e.g. agricultural, household, office, commercial and shop discards, etc.)
Q15	Contaminated materials, substances or products which are not contained in the above categories
Q16	Any materials, substances or products which are not contained within the above mentioned categories

Besides categorization of waste, management scholar and practitioners have discussed about recycling and recovery, minimization and prevention. Such a debate has a meaningful implication for policy-making since it defines how waste management system works. Such a perspective is of primarily importance for the purpose of this work.

Waste prevention has been defined as a “technique, process or activity that either avoids or eliminates waste at its source" (Crittenden & Kolaczkowski, 1995). Waste prevention can be either applied to consumers and producers by intervening on the production process and the product lifecycle (reuse of products, fixing of products).

All the waste management discourse focuses on measures such as composting, recycling, energy recovery and landfill. These are practices dealing with various category of materials classified as waste.

Over the recent decades, the debate around waste management has ended up in two approaches to waste management: the waste hierarchy and the integrated solid waste management (Clift, Doig, & Finnveden, 2000). The first approach, which is portrayed in figure 3, suggests ranking waste management activities from most to least desirable options in terms of environmental or energy benefits. This benefits span form conserving resources, minimizing air and waste pollution, to protecting health and safety. The waste hierarchy emerged in the 1970s as result of the rising pressure given by environmental organizations that criticized the dominance of the "only" disposal methods practiced as waste management philosophy.

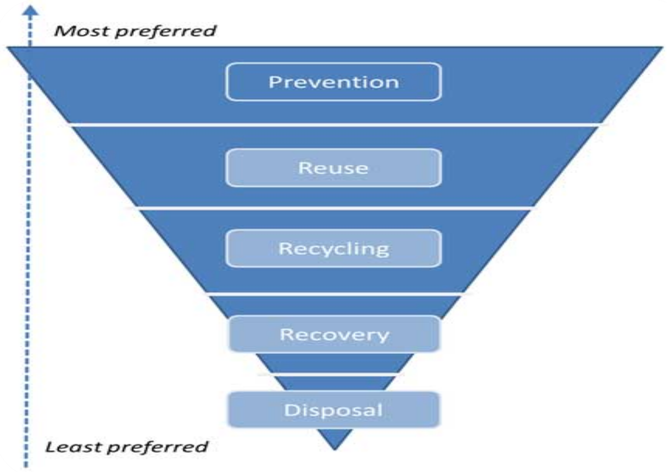


Figure 3 Waste management hierarchy (UNEP, 2011)

As Gertsakis and Lewis (2003: 3) (2003: 3) remarked "the waste management hierarchy is a concept that promotes waste avoidance ahead of recycling and disposal. The shortened version of the hierarchy, "reduce, reuse, recycle" is frequently used in community education campaigns, and has become a well-recognized slogan for waste reduction and resource recovery and disposal. Such an innovative perspective claimed a more differentiated system for managing various types of wastes. As the analysis of solid waste management carried out by Boyle (2000: 517) remarked "the lack of waste management policy and co-ordination; the lack of hazardous waste management; concerns regarding local policy" are some of the issues organizations face in dealing with waste.

The waste hierarchy can be understood as a blueprint which has been adopted, with slight modifications, by governments in almost every western country. For the European countries, the waste management hierarchy is not conceived as a legal tool. It is rather a conceptual mechanism. Due to its nature, such a framework has been used as a justification, in some countries, for adopting at a slower pace the most desirable waste management steps. In other words – as Price and Joseph (2000) noticed – some countries have required more time to move from landfill to energy recovery and recycling, they have rather paid attention to the more politically challenging issues of “demand management.”

On the contrary, other authors (White, 1993; White, Dranke, & Hindle, 2012) criticized the hierarchy model, by placing waste management issues within a linear progression model which tries to consider a sustainable development perspective. They started from the idea that disposal (which represents the slightest favorable solution), in some cases, may become the preferable option when the impact of the recycling and re-using presents higher costs in terms of both environmental and financial resources.

Within this stream of thoughts, the current hierarchical model of waste management is critically discussed. This approach would be replaced by a holistic perspective that assesses the overall environmental burdens and economic costs of and for the whole system.

Integrated waste management system “combines waste streams, waste collection, treatment and disposal methods, with the objective of achieving environmental benefits, economic optimization and societal acceptability. This will lead to a practical waste management system for any specific region” (McDougall et al., 2008: 15).

Originally a systems approach to waste management was firstly proposed in 1962 by Lynn, Logan, and Charnes (1962). They described this approach as “viewing the problem in its entirety as an interconnected system of component operations and functions.” With this “early-stage description”, the authors recognized the complexity of waste management. Therefore, systems analysis and mathematical modelling started to be adopted in order to optimize waste management operations and strategy development.

A second stage in the evolution of the integrated waste management system was produced in 1978 by the American analyst R.M. Clark within the US Environmental Protection Agency. He stated that "Management methods, equipment, and practices should not be uniform across the country since conditions vary, and it is vital that procedures be varied to meet them." This concept neglected the uniform applicability of the hierarchical approach to waste management.

The last and most important contribution on the integrated waste management system was realized by the Economic Commission for Europe in 1991. The Commission defined the integrated waste management system as a "process of change in which the concept of waste management is gradually broadened to eventually include the necessary control of gaseous, liquid and solid material flows in the human environment."

The benefits of adopting an integrated waste management system approach – as they are suggested – seem to be manifold:

- certain problems can be more easily approached while considering many other aspects of waste management;
- capacity and resources are more likely to be efficiently used thanks to economies of scale, which depend on the equipment and the level of infrastructural developments;
- it is possible to balance costs across the whole waste system, as well as the participation of actors from public, private and civil society in appropriate roles

(UNEP 2005: 8).

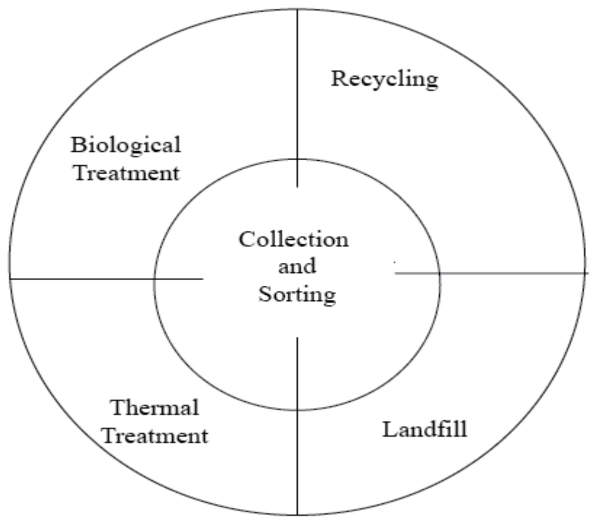


Figure 4 The elements of Integrated Waste Management (McDougall, et al.: 25)

The language of integration asserts that management options may address a "practical" problem without being locked in the hierarchical implications of waste treatment.

The integrated waste management system has received support from both governments and the private sector due to its pragmatic approach. However, the results have been controversially discussed since they are a way to continue with the most environmentally damaging practices instead of adopting seriously waste prevention practices, a position expressed by the zero-waste movement (Zero Waste New Zealand, 2003).

In waste governance, the relationship between performance and environmental agendas is particularly complex and this goes back to the questions raised in *Limits to*

Growth by Meadows et al. (1972). Facing the challenges related to the increase in waste production which is unavoidably associated with the economic growth of our communities is a priority for management scholars and municipal decision-makers. Therefore, the aim of this research in waste governance may not disregard the sustainability of current waste governance approaches.

4. What are the implications for policy making?

Managing waste is a complex task that requires changes in consumption and waste production patterns, appropriate technology, organizational capacity, and co-operation among a wide range of stakeholders (Zarate et al., 2008). Data on waste management should be collected, although complete and reliable data are extremely difficult to obtain (Wilson et al., 2012). Regional and national governments can help filling data gaps by developing waste data strategies, and by ensuring that statutory reporting requirements are met. Research institutions and universities have a role to play finding cleaner, greener ways to process waste and discovering viable methods to produce energy from waste.

There is also an on-going need to develop regional and national waste-management plans. A democratic process of formulating municipal solid waste goals is essential to determine the actual needs of citizens, and allows decision-makers to prioritize limited local resources according to the emerging requirements (Marshall & Farahbakhsh, 2013). Waste management solutions in one region might not be appropriate elsewhere. For example, some Waste-to-energy (WtE) techniques (i.e. the process of generating energy in the form of electricity and/or heat from the primary treatment of waste) might be more appropriate in developed or middle-income countries, while in developing countries, composting organic waste and biogas capture may be more useful to deal with waste in organic matter. Large-scale investment in a specific technology, such as WtE, might also lead to technological “lock-in” narrowing options in the future. Guidelines also exist for how to generate national waste management strategies (UNEP and UNITAR, 2013).

Ultimately, waste management presents an opportunity, not only to avoid the detrimental impacts associated with waste, but also to recover resources, realize environmental, economic and social benefits and to take a step on the road to a sustainable future. Decision-makers need to be well informed in order to develop integrated waste-management strategies tailored to the needs of citizens (Guerrero et al., 2013). When informed decisions about waste management are made waste can even provide economic value.

Waste management has not always been a priority for local and national policy makers and planners, especially in developing countries (Marshall & Farahbakhsh, 2013). Other issues with a higher social and political urgency might take precedence and leave little budget for waste issues (Memon, 2010). Thus, in many cities around the world, effective policy measures have been elusive and the resources invested in the sector inadequate (Konteh, 2009). National governments can make a critical contribution by making waste management a national priority. They can also ensure the availability of skills, knowledge, and capacity to effectively implement waste management programs, especially at the local level, helping to turn garbage into a resource.

5. Research design

The aim of this research is to explore innovative performance management approaches with the intent to effectively improve the waste management system at regional level by increasing the current differentiated collection rate of waste as provided for European and national legislation. Particularly, such a goal can be pursued also by fostering the inter-organizational conditions and mechanisms such as collaborative governance focused on recycling protection of the environment.

5.1. Research objectives and questions

The main goal of the thesis is to show how a dynamic performance management may support policy-makers to improve the performance of the waste management system.

To this end, the research particularly focuses on two aims:

- to discuss main managerial issues of the Integrated Waste Management system;
- to show how a dynamic performance management may support policy makers in designing the public service offered by the Sicilian Region for the collection, disposal and recycling of regional solid waste in terms of efficiency, effectiveness and social satisfaction.

This research explores the above objectives that can be summarized into the following research questions:

1. What are the main factors (economic, political, social, organizational) that limit the implementation of the integrated waste management system?
2. Which policies/actions are requested to make the integrated waste management system more efficient and sustainable?
3. How may a dynamic performance management approach contribute in increasing

efficiency and effectiveness in the waste management process?

In order to assess the effectiveness of dynamic performance management applied to waste management, this research develops a case study based on the Sicilian Region.

This case can offer a deep understanding of the dynamics that characterizes the waste management system since it characterized by:

- a weak coordination between regional department and municipalities;
- a system fragmentation due to a high level of municipal autonomy in delivering the service;
- a low degree of infrastructures;

By applying a dynamic performance management approach to the case under investigation, is therefore possible to support public decision-makers with insights on how to sustainably improve the performance of the waste management system.

5.2 Methodology and research strategy

Public Management is a wide field of scientific interest, which includes analyses of public institutions, agencies, local government and the management of local areas.

This work builds on the findings of explanatory studies into a research area which aims to "bridge the gap between Systems Dynamics and its applications in public sector organizations, with a precise focus on performance management" (Bianchi, 2016: vii). To this end, the research applies the dynamic performance management framework by developing a case study focused on the Sicilian Region.

As many studies prove (Bianchi, 2016; Bianchi & Rivenbark, 2014), applying System Dynamics to Performance Management may support public managers to trace those value drivers that have led to a given performance level over time. In doing so, it contributes in enhancing the diagnosis process that enables them to put in place policies and strategies oriented to fill the gap between the actual and the target performance value (e.g., the gap between actual and desired recycling rate).

Dynamic performance management allows one to identify casual relationships between key performance variables (end-results and performance drivers) and strategic resources within the system, it will be possible to improve performance. The use of conceptual and simulation models may provide powerful insights for policy-making.

Furthermore, the above mentioned “instrumental” view allows decision-makers to identify end-results and performance drivers that support decision makers to understand how strategic resources allocation may affect performance. Therefore, this perspective aims at defining a set of measures regarding both performance drivers and end-results.

The system under observation is characterized by a high level of dynamic complexity due to organizational, economic, political, and legislative issues. Therefore, the adoption of this approach may discover effective policy levers which enable organizations to improve the performance of the waste management system. Dynamic performance management entails a case study research strategy to understand how public governance may improve the performance of Integrated Waste Management system of the Sicilian Region.

Through a case study one may understand qualitatively – by using multiple source of evidence – the phenomenon under study, detect dynamics and frame the impact of causal factors on the system’s performance of the Sicilian waste management system.

Case study is “a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence" (Robson, 2002: 178). By mentioning Berg (2001: 225) "case studies may focus on an individual, a group, or an entire community and may utilize a number of data technologies such as life histories, documents, oral histories, in-depth interviews, and participant observation". Yin (2013) also put emphasis on the importance of context, adding that, within a case study, the boundaries between the phenomenon being studied and the context within which it is being studied are not clear. The case study strategy has a considerable ability to generate answers to the questions "what and how" (Lewis, Thornhill, & Saunders, 2007: 139). The benefits of the case study method lie in its ability to open the way for discoveries (Shaughnessy & Zechmeister, 1985), indeed research based on case study aim to investigate specific issues. Moreover, when a research assumes a deductive-inductive approach, a case study may enable theory testing. "A well-constructed case study strategy allows to challenge an existing theory and provide a source of new research questions" (Lewis et al., 2007: 140). A single case study "can easily serve as the breeding ground for insights and even hypotheses that may be pursued in subsequent studies" (Berg, 2001: 231).

A single case may be used for a unique or a critical case or even for the opportunity to analyze a new phenomenon. Multiple cases often used when there is a need to generalize – as large degree as possible – the findings, while holistic vs. embedded, relates to the researcher position in respect to the unit of analysis. Case study research strategy seems to diminish the comparability and the replicability of the findings because a single unit seems unable to provide a large degree of generalizability. A single case study "can easily serve as the breeding ground for insights and even hypotheses that may be pursued in subsequent studies" (Berg, 2001: 231).

5.3 Research boundaries: the Sicilian waste collection system

During the last twenty years, the Italian waste collection system has changed. Reforms have introduced methods, such as selection and differentiation of garbage for recycling. Quite often, the Sicilian Region has been interested by waste emergencies (Council of Ministers, order N.2983 of 31.5.1999), causing relevant problems of public order and serious risks to public health. Sicilians produce about 6500 daily tons of waste. The largest part ends up in landfills and only the 18% is collected, conferred, and disposed as differentiated waste. Therefore, during the last years the emergency boosted because of the discontinuity of the numerous organizational and management conflicts involving the various actors at regional, provincial and municipal level, and of the lack of implementation by the multiple measures provided for the European Union, the State and the Regional Government. The Sicilian waste management system is experiencing organizational criticalities, such as the presence of landfills with increasingly collapsing basins and the involvement of criminal organizations (Europol, 2013; Germani, Pergolizzi, & Reganati, 2015). Specifically, the involvement of organized crime in the management of regional solid waste, as well as in public procurement for the construction of infrastructure or even in the acquisition of equipment and vehicles, is realized through the illegal trafficking of waste. The illegal trafficking of waste is characterized by the continued and indiscriminate disposal of waste in illegal landfills, particularly located in abandoned mines and in caves.

Hence, for this purpose, and based on the conditions that have characterized the last years of the Sicily's waste management, this research aims to provide possible suggestions for performance improvement by fostering the strategic learning process of decision-makers. The research will develop a case study regarding the Sicilian Waste Management system, which is analyzed according to a dynamic performance management approach.

5.4 Thesis structure

Four chapters structure this doctoral thesis. Chapter 1 illustrates the research project, it draws the background and provides an orientation to the research questions, focus and design. The chapter also reviews the existing body of literature in the field of public management, by following the evolutionary pattern the management models of public sector organizations. In doing this task. the chapter illustrates how these paradigm shifts have affected performance management systems of public sector organizations with a specific focus on Waste Governance. It also introduces two traditional approach to waste management and describe the implication of sustainability for waste management.

Chapter 2 argues the argues the need of a Dynamic Performance Management to support the integrated waste management system. The chapter dives into the concept of sustainability within the waste discussion by conceptualizing performance according to an integrated waste management perspective. It also presents the pillars of the methodology and motivates the rationale behind the research strategy adopted to conduct the study. On this regard, chapter 2 review a selection of relevant publications that applies system dynamics to waste management issues.

Chapter 3 present the case study on the Sicilian Waste management system and focuses on the system dynamics modelling activities. Indeed, the chapter details the model purpose through PHPI method and illustrates the model structure. It also comments the behavior the model is able to produce. Chapter 3 ends with the limitations and a short policy conclusion.

The last chapter research closing remarks summarize main arguments of the thesis at the end of the work.

Chapter 2 – Supporting sustainable Integrated Waste Management through Dynamic Performance Management

1. Introduction

New Public Management (NPM) reforms have brought into public sector a new approach in delivering public services to communities. Such an approach has been focused on introducing market mechanisms and outsourcing through different forms of governance (Doherty, Horne, & Wootton, 2013; Torres & Pina, 2002).

Through a variety of governance approach, such reforms were aimed at improving performance in the provision of public services, which was primarily meant as an increase in service quality, and lower costs. Therefore, governments – especially at local level – started to look new ways for deliver and assess the value they produce. To this end, performance management systems become a crucial tool (Bouckaert & Halligan, 2007) – "the ultimate challenge" (Arnaboldi, Lapsley, & Steccolini, 2015) – for the public sector to establish performance achievements (Ammons, 2014; Ammons, 2013) and accountability of governmental organizations (Bianchi & Rivenbark, 2014).

This chapter supports the idea of a holistic approach to the integrated waste management by describing how collaborative governance may support both regional and local level in achieving the sustainability of the system. Therefore, it explores main characteristics of a sustainable approach to waste management and connects them to the concept of performance. To this end, the research proposes dynamic performance management – an approach which blends system dynamics with performance management system – as a method to improve the performance of the integrated waste management system. Lastly, the chapter ends with a brief overview of core elements of the system dynamics methodology and its application to waste management issues.

2. A holistic approach to the integrated waste management

Sustainable practices to protect the environment and natural resources from further – and continuous – degradation is putting higher pressure on policy makers, especially in the field of waste management. Main issues are connected with environmental and financial performance. Traditional collection and disposal methods are still adopted and valid waste management options, however they do not seem to be enough to address urgent issues and to achieve sustainability in such a system. During the last years – as discussed in chapter 1 – two approaches have been prevailing. One focuses on reducing the environmental impact of waste through a priority action scale, while the other one adopts a more pragmatic approach which combine different strategies. The common goal of both approaches is to achieve the sustainability of the system at both environmental and financial level.

To build and maintain an environmentally and economically sustainable waste management, it requires major changes in a way that the system is designed for this purpose. Indeed, quest often regulation of waste management is a matter of national and/or regional level while the implementation is a task of local governments. Alike the infrastructures to run the service can be owned by private organization and their capacity development is not under the responsibility of the same institution which must protect the environment and the health of citizens. Therefore, policy coordination at different level of a system which shows inter-connection and interdependencies among resources and performance is a big challenge for the waste governance.

In a context like this, it is necessary to re-think and re-design the system. Introducing innovation and change within a waste management system could cause higher costs – for a part of the system – in the short term because the implementation of the new process. Unless a systemic view point is adopted such trade-offs do not allow policy-makers to assess the outcomes of a new policy.

Adopting a holistic view may give to the system significant benefits.

- Decision makers may have a broader view of the waste management process which enables a more informed strategic planning process, rather treating waste stream distinctly.
- Environmental burdens can be accounted for the whole system. Looking at the environmental costs of one part of the process may results in an increase of the environmental cost somewhere else in the system.
- Both the unit and whole system must endeavor to match the costs with the income.

A holistic approach is a key perspective to fully implement the role of the integrated waste management system, since it allows one to assess the overall environmental burdens and the economic costs associated with the whole system (McDougall et al., 2008).

The integrated waste management system must play a role in reducing the waste produced with a strategy aimed at preventing, as well handling the amount of waste which is produced within a community.

Societies inevitably produce waste and solid waste management in the past was aimed at counteracting the effects on public health. Currently, less waste and the implementation of an effective system for managing the waste are the needs that societies must undertake.

The sustainability of the system can be achieved only when a certain community starts producing "more from less" including less natural resources, less pollution and waste (Hurlem, 1987). The new era of green consumption (Elkington & Hailes, 1988) seems to drive societies towards these goals. Indeed, a new generation of light-weighted products or refillable packaging started to be produced by industries (Hindle, White, & Minion, 1993).

The reduction of waste is at the top of the waste management hierarchy. If one adopt an integrated waste management approach, the reduction may be a prerequisite to effective manage the waste. The reduction of the source will affect the volume of waste to handle for the entire system. What is then required is an effective way to manage such a volume in a way that less natural resources and less pollution are generated.

Figure 5 illustrates and compares the role of waste prevention and the role of the integrated waste management system. The outputs of the integrated waste management system are energy and raw material which can be used as inputs in the production process rather industries continue to deploy natural resources.

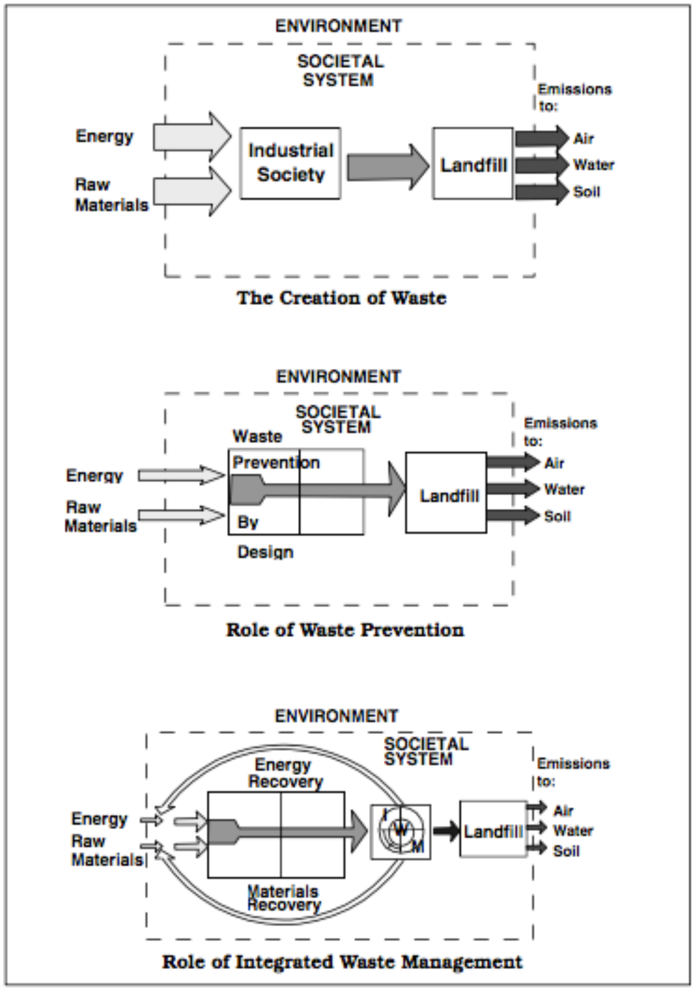


Figure 5 The role of the integrated waste management system (McDougall et al., 2008: 17)

As for the governance of an integrated waste management system, in order to improve the sustainability of the system, there's a need to cope with the complexity of the system.

Integrated waste management is a complex task involving various types and categories of waste. Technological handling techniques, solutions and treatment options show a great multiplicity of approaches, and some outputs can be re-used (Eriksson & Bisaillon, 2011). Waste management involves many diverse stakeholders involved and a large variety of supplier (e.g. workforce, equipment), users (e.g. citizens and firms), and markets for system outputs (e.g. energy, compost). The complexity of these interconnected systems indicates that an holistic perspective is crucial for understanding system dynamics over time (Rojo, Glaus, Hausler, Laforest, & Bourgeois, 2013).

A sustainable approach to the waste management is characterized by to be environmentally effective, economically affordable, and socially acceptable (Nilsson-Djerf, 2000). To this end, an holistic approach to integrated waste management must be tailored to local environmental, economic, political/social priorities and – according to good governance principles – involve stakeholders in decision-making (Garnett & Cooper, 2014; Joseph, 2006).

3. Sustainable Waste Management

A sustainable system for waste management must be compatible with the environment (reducing the burdens or the environment), reasonable under the economic profile (the costs of the system must be sustainable for the citizens, the community and the governments), and socially acceptable (meaning that the organizations should build trust with people and organizations involved in these issues).

Sustainability is a long-term goal. It implies trade-offs in time and space and involves a strategic management to keep the environmental, economic, and social dimensions in balance. Deciding the break-even point of balance between environmental sacrifice and cost of the service has an impact on the level of social acceptance.

Sustainable waste management requires that the system is integrated, market oriented, flexible and socially acceptable. The meaning of the term integrated waste management is hardly to be completely defined. A system is integrated when its collection system includes material recycling, treatment of organic materials, thermal treatment, energy recovery and landfill. In using any of these methods, the system should also be market oriented regarding the outputs – namely waste managers must build a market for the outputs (Morrissey & Browne, 2004). A third characteristic of a sustainable integrated waste management system is the flexibility (Parkes, Lettieri, & Bogle, 2015). The system must achieve social, economic and environmental targets and at the same time, be able to change over time and region by region, according to these goals (McDougall et al., 2008).

Research and practice have found that integrated waste management system should be arranged at regional level. Such a scale allows the system to benefit from economies of scale (White, 1993) coming from sharing disposal facilities and infrastructures. Scaling the system requires implementation at local level where local authorities should intervene on this process, particularly to increase efficiency and implement changes. In order to operate effectively and achieve sustainability in waste collection, the participation of the community is also necessary. People must understand their role in Waste Management System and co-operate with the local authorities for making the system works correctly.

A strategy to increase participation in recycling schemes relies on communication and education. When the system needs changes, effective communication may inform citizens of the benefits of the new system connected to the three dimensions of sustainability. Such communication may increase the probability that changes will be accepted, and good public support and participation depend on the perception people have of the waste management facilities. Having a good participation is of big importance for the entire system, because it has an impact on planning and management too.

A sustainable integrated waste management system has a net of operations which present a high degree of interconnections. Collection methods influence the ability to recover raw materials, or the possibility to produce energy. To this end, it is necessary to approach the integrated waste management system from a holistic perspective, where the system as whole should be economically, environmentally and socially sustainable. This means that the system should aim for being environmental effective, economic affordable, and be able to reduce environmental burdens and drive costs out.

Table 2 presents a synthetic overview of the main characteristics of a sustainable waste management system.

Table 2 Designing a sustainable solid waste management system (McDougall et al., 2008: 22)

Aim for the following:	Environmental effectiveness: Economic affordability:	reduce environmental burdens drive costs out
The system should be	Integrated	in waste materials in sources of waste in collection methods in treatment methods anaerobic digestion composting energy recovery landfill recycling
	Market oriented:	materials and energy must have end uses and generate income
	Flexible:	for constant improvement
Take care to:	Define clear objectives:	
	Design a total system against those objectives Operate on a large enough scale.	
Never stop looking for improvements in overall environmental performance and methods to lower operating costs	Remember that there is no perfect system.	

Collection of Municipal Solid Waste is usually a service provided by local authorities even though they can contract out this service to private companies. The relevance of looking at the whole system may overcome the limitations that may arise in a system where a municipality or a private company only has the control of the waste handling within its operation. This bounded view of the system may cause the inability of decision-makers to perceive and understand the effects of their decision in the long run, or the impact of current policies on other organizational units (Simon, 1957). Other phenomena which may affect decision makers embedded in the dynamic and complex waste management system may be correlation heuristics (Cronin, Gonzalez, & Sterman, 2009), habit, routines, rules of thumb (Sterman, 2000) and incrementalism (Lindblom, 1959; Quinn, 1980).

A holistic approach – by taking the perspective of the whole system – may be a good way to improve the performance of the integrated waste management system because it "considers the full range of waste streams to be managed and views the available waste management practices as a menu of options from which to select the preferred option based on site specific environmental and economic considerations" (Morrissey & Browne, 2004: 298).

4. Conceptualizing performance in the waste collection sector

The concept of performance has been investigated by several authors. The prevailing literature defines performance as a multifaceted construct (see chapter 1 section 2.3). A well-known definition of performance states that "Performance is what the organization hires one to do, and do well" (Campbell, McCloy, Oppler, & Sager, 1993: 40-41). However, the multidimensionality of performance entails to measure/manage different perspectives of results. As Bouckaert and Halligan (2007: 16) have shown, the full extent of performance can be measured in terms of economy, efficiency, effectiveness, productivity, and trust. Indeed, organizations – especially those delivering public services – can measure either the resources deployed and the efficiency in using them, the volume of output, the impact of such a volume, and, even, the cost-effectiveness. Measures of trust are able to capture how outcome, outputs, and inputs build consensus around organization's policies and decision rules.
Other authors have conceptualized performance by differentiating the quality of action, as a measure of output; from the quality of the achievement, as a measure of an outcome (Dubnick, 2005; Sonnentag & Frese, 2002; Van Dooren, Bouckaert, &

Halligan, 2015). Such a differentiation can be framed also by considering that a public organization can perform well in achieving internal targets, but these results may produce a poor impact on socio-economic context. Indeed, an important distinction allows one to identify an internal and an external effectiveness (Bianchi, 2004): the first one is a comparison between objectives and associated results; the second captures the ability to meet public needs (Ammons, 2014).

The debate around the efficiency and effectiveness in public service delivering is a hot topic within the public management literature. Outputs and efficiency in the public sector are inadequate concepts (Van Dooren et al., 2015) since the primary goal of public organizations is not the maximization of profits (Bouckaert & Halligan, 2007), it is rather to increase collaboration and inter-institutional performance (Bouckaert et al., 2010).

Several scholars have put their efforts on exploring and understanding weather the governance system may have an impact on efficiency (Moore & Hartley, 2008; Rossignoli & Ricciardi, 2014).

The governance theory/model as proposed by (Bovaird, 2005; Kooiman, 1993, 2003; Osborne, 2006) explores the relationships between the organization(s) responsible for delivering the service and the network of stakeholders. Within this net of interdependencies, the interests and the needs of the actors involved may vary and these variations are reflected in decisions, which produce an impact on performance at both organizational and inter-institutional level.

In exploring both theoretical relationships and empirical evidence on the impact of governance forms on organizational performance, Skelcher (2008: 3-23) found that "the governance-performance causality is complex […] Change in governance arrangements *per se* do not cause changes in organizational performance. But where they involve greater organizational autonomy, they do motivate changes in management that can have a positive effect on organizational performance."

Several theories (e.g., agency theory, stewardship theory, and stakeholder theory) explained the role of governance, whereas others, in determining performance, referred to the ownership structure (public choice theory, property rights theory, transaction cost theory, and industrial organization theory).

The Public Choice Theory (Niskanen, 1971; Ostrom & Ostrom, 1971) stated that governance experiences its own agency problems where publicly owned companies are relatively less efficient than private ones because in publicly owned companies the managers put their own goals before company efficiency.

The property rights theory (Alchian, 1965) assumes that ownership leads to greater efficiency because owners are motivated to perform efficiently due their own best interests in doing so; particularly private sector organizations.

The theoretical debate has been supported by empirical studies which indicates that private sector participation in public services has generally improved efficiency. Such a statement supports the role and the relationship between governance and performance.

Performance itself can influence the governance arrangements (Skelcher, 2008: 14). The implicit assumption in public services reform initiatives, stating that "changes to governance arrangements will impact positively on performance outcomes" must be proved through performance measurement systems.

Taking a holistic perspective helps decision makers to focus on the interplays between the different parts and levels of the system (at local and regional level too) and understand how these aspects may affect integrated policies in the long run (Bianchi, 2010). Therefore, the governance of an integrated waste management system needs to be enhanced through an approach which supports policy-makers in framing the outcome for the integrated system, and thus providing them with proper lenses for interpreting such phenomena. The implementation of proper designed performance management systems may provide a set of tools which enable decision-makers to define, monitor and achieve goals compatible with a sustainable development perspective (Bianchi, 2016: 52).

Traditionally, performance management and measurement systems have been designed in a static way which do not allow decision-makers any cue about future – possible performance development. “These systems seem to have fallen short of expectations. Such practices are essentially based on financial models and static reporting; they are focused on an organizational sphere, implying a lack of linkage between outputs and outcomes. They also imply that achieved results are primarily assessed in relation to the effects produced by decision makers on their own institutions” (Bianchi, 2016: 20)

To this end, performance management systems need to be enhanced using System Dynamics methodology. This is the domain of dynamic performance management (Bianchi, 2016: 16)

5. Dynamic performance management to enhance sustainability in the integrated waste management system

At the core of dynamic performance management, there is the instrumental views of performance, which provide a framework to assess performance sustainability.

Dynamic performance management is an approach that matches traditional performance management methods and techniques with System Dynamics modeling (Bianchi, 2002, 2012; Bianchi, 2016). Based on a learning-oriented approach, dynamic performance management may support decision makers to frame better the policy-makers involved in a policy field (i.e. the relevant system) and to design sustainable policies concerning outcomes.

Dynamic performance management moves from synthesis to analysis and is a conceptual framework based on three layers: end-result, performance drivers, and strategic resources.

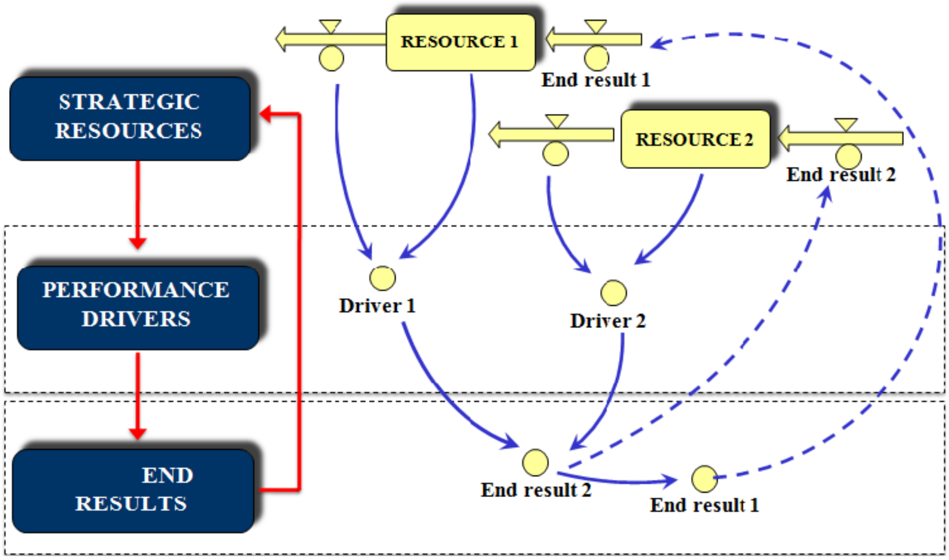


Figure 6 The dynamic performance management framework (Bianchi, 2016)

The first step in applying dynamic performance management is the identification of end-results (both outcomes and outputs). If the first step in applying the *instrumental view* is the identification of end- results, the second phase requires recognizing performance drivers. Performance drivers compare the actual performance in terms of efficiency, productivity, and effectiveness in the use of the set of strategic resources against a benchmark: for instance: *skills/desired skills* affect service delivery failure rate; *actual service time/expected users waiting time* affects the users' satisfaction; the number of *administrative tasks/ administrative tasks threshold* affects *the costs per paperwork.*

As a third step, dynamic performance management supports decision-makers to outline the policies to adopt in order to affect the strategic resources (i.e. the stocks of tangible and intangible factors to build-up and deploy together with others) that will influence performance drivers, and through them the end-results, which will feedback on the strategic resources making policy sustainable (Bianchi, 2016).

In complex governance settings, such as waste management, immigration or health care, strategic resources are rarely managed or controlled by the same institution (e.g. municipality, hospital, ministers); they are rather managed by the different organizations and players. Dynamic performance management may support each organization in a network in identifying how it may contribute to the achievement of wider outcomes in the relevant system (Bianchi, 2016; Bianchi, Bovaird, & Loeffler, 2017; Bivona & Cosenz, 2018).

As Bianchi (2016) stated: "the instrumental view implies that alternative means for improving performance be made explicit. In this regard, it is necessary to identify both end-results and their respective drivers. To affect such drivers, each responsibility area must build up, preserve, and deploy a proper endowment of strategic resources that are systemically linked to each other."

End-results provide endogenous sources of accumulation and/or depletion of resources which are strategic for the performance e.g. cash flow accumulates into the bank account; the rate of the problem solved at customer services depletes the backlog of problems to be solved.

End-results are flows which capture both output and outcomes, and they can be modelled as in-and-out flows of strategic resources. Strategic resources can be classified in physical resources referring to the ones which can be purchased on the market (inventory, employee, capacity), and resources generated by management (internal) routines (reputation, organizational climate, skills, solvency) that can be obtained only through efficiency or effectiveness of operations.

This section has described the dynamic performance management, next section will illustrate the building block of System Dynamics. This simulation methodology is at the core the Dynamic Performance Management. When this conceptual framework is blended with a methodology able to handle the dynamic complexity of the system, performance management systems may provide decision-makers with proper lenses to develop a more comprehensive – and dynamic – perspective of performance determinants.

6. Managing complex problems: System Dynamics methodology

This work contributes to a research field which aims to "bridge the gap between Systems Dynamics and its applications in organizations, with a focus on performance management" (Bianchi, 2016: vii) with a specific emphasis in the public sector. This research agenda is known as "System Dynamics for performance management".

System Dynamics may play a role in addressing public sector issues. "Despite the high applicability to public policy problems, System Dynamics is currently not utilized to its full potential in government policy making" (Ghaffarzadegan, Lyneis, & Richardson, 2011). System Dynamics may enhance performance management systems, indeed as it has been remarked a "mechanistic approach to planning & control systems design and implementation have often generated an illusion of control and a risk of manipulation in goal setting and performance evaluation" (Bianchi, 2010: 364). Other authors highlighted the presence of a number of unintended effects generated by the introduction of formal P&C systems in the public sector (Boyle, 1999; Christensen & Lægreid, 2007).

System Dynamics is a methodology developed at MIT (Cambridge, USA) by Jay W. Forrester in the late fifties. System Dynamics methodology is considered a methodology to investigate the non-linear behavior of complex systems which takes also in to account the mental models of decision makers. Specifically, System Dynamics modelling can be understood as a methodology to the study and investigate complex systems where multiple feedback mechanisms among key variables of the system exist. These feedbacks make the system variables interact each other.

System Dynamics models are based on a non-linear feedback view of systems (Forrester, 1969: 108). Such a view can be *external* when the model frames "cause-and-effect relationship underlying the relevant system's behavior, from a point of view that may go by far beyond that each of the involved players may take" (Bianchi, 2016: 18); or *internal* when it "focuses the wide relevant system by primarily taking the observation point of one of the players (or institution) affecting the system's behavior" (Bianchi, 2016: 18).

Therefore, by using System Dynamics, decision makers can develop conceptual maps that allow them to understand how and why key variables of a system behave over time and how to act on the most valuable leverage points to alleviate the causes of complex problem, or to manage the system toward the desired direction. According to Bianchi, System Dynamics differs from traditional methods of analysis because, based on the comparison between the simulation models and the reality, it "allows the decision makers to continuously review the assumptions previously made to extrapolates keys of interpretation that allow to understand and deal suitably with the complexity of the phenomenon observed" (Bianchi, 2009). On this regard, simulations aim at showing how the system reacts to the adopted policies. Such insightful comprehension enables decision-makers to get confidence with the root of the problems that characterizes the system under analysis.

The use of the System Dynamics methodology involves different steps which can be summarized as follow:

- identification of a problem;
- development of dynamic hypotheses and causal maps to explain the cause of the problem and conceptualization of the model;
- analysis of the model to verify whether it can fit the historical data observed in the real world;
- design alternative policies to alleviate the problem or to manage the system towards the goals;
- implementation of the policy.

Thanks to the flexibility of the methodology, System Dynamics is suitable for analyzing the dynamic configurations of complex systems – i.e. what kind of behavioral patterns they generate over time. System Dynamics is grounded on a basic assumption according to which these patterns arise from the endogenous causal structure of the system analyzed. Causal structures are determined by physical or social constraints, goals, rewards and pressures that make a system's agents (more generally, system's structures) behaving in a certain way (Meadows, 1980).

The perspective of System Dynamics model is endogenous. This means that modelers tend to include and expand relevant structures that may be responsible for causing a certain behavior. This perspective implies that model are closed chains of causal relationship: the "feedback loops". System Dynamics models are made up of several feedback loops connected.

System Dynamics models can be built according to two kinds of representation: causal loop diagrams (CLD) and stock and flow diagrams (SFD). The first is a qualitative and aims at focusing on the causal relationship among the variables. The other one is quantitative and aims at emphasizing the physical structure of the system being analyzed, allows one to quantify system's variables, the casual relationships among them and to run simulation.

System Dynamics models are developed through structures made up of causal circuits between the variables of the system under investigation. The basic elements, determining the dynamic structures, are the feedback loops. Roughly, a feedback loop can be defined as a closed chain composed of two or more variables that affect each other (Sterman, 2000) These different causalities allow to understand the mechanisms behind a given phenomenon, highlighting the drivers and levers of intervention that can be used to influence the state of the system. The relationships among the variables that form these causal circuits can be distinguished in:

- Direct relations. In this type of relationships, graphically indicated by the symbol "+", to an increase / decrease of a variable corresponds to an analogous increase / decrease of the linked variable;
- Indirect relations. In this type of relationship, graphically indicated by the symbol "-", the relation is opposite: to an increase / decrease of a variable corresponds decrease / increase of the linked variable;

If the multiplication of the signs within a loop determine a positive sign, it is a reinforcing loop. In this case, the combination of the variables displays a "+" dominance which means that their interactions cause the observed phenomenon to show a trend of exponential growth or exponential decay. If the multiplication of the signs within a loop determine a negative sign, it is a balancing loop. In this case, the combination of the variables displays a "-" dominance which means that their interactions eventually cause the observed phenomenon to show a trend of gradually balancing dynamic till an equilibrium point at a certain time is reached.

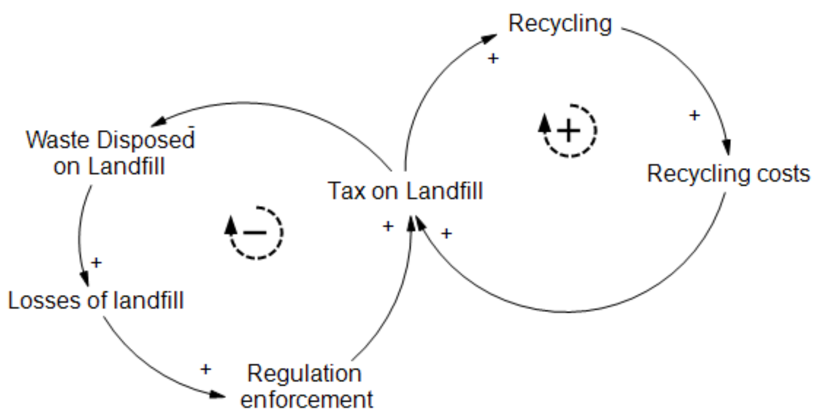


Figure 7 A Causal loop diagram showing a reinforcing loop and a balancing loop

Figure 7 shows two feedback loops: a reinforcing loop and a balancing loop. In this example, if the quantity of waste recycled increases, the recycling costs increase as well, leading to raising taxes on landfill, which reinforce the quota of waste recycled. This is a reinforcing loop, which allows the system to increase the recycled quota. On the other side, a reduction in the amount of waste disposed into landfill, in turn, causes a loss of landfill, and all other conditions being equal, a raise in taxes on landfill. This is a balancing loop which synthetizes a decay process in the waste disposed into landfill.

6.1 The qualitative modelling approach

According to System Dynamics principles, the qualitative approach is oriented to the identification of the systemic relationships of a given phenomenon to understand the functioning of the system. Coyle remarks that, when dealing with a high level of uncertainty qualitative analysis can be useful not less than a full scale quantitative modeling approach (Coyle, 2009). In such a situation, an inference diagram can be enough to provide useful suggestions and insights to decision makers. Such a model presents causal analysis of the phenomena under study through a feedback approach, however it does not provide simulation output. In System Dynamics, the qualitative analysis is realized through the elaboration of a specific type of model called Causal Loop diagram (CLD). CLD are graphical maps showing the causal structure of a system. A CLD allows to map explicitly the causal relations between the variables and to identify which feedback mechanisms are produced by the dynamic behavior of the variables of system under investigation. CLD's have proven to be extremely effective instruments (Sterman, 2000) since they:

- provide a graphical description of the problem investigated;
- allow to represent, in a straight and effective way, the assumptions over the dynamics of an investigated phenomenon;
- highlight the fundamental feedback mechanisms among the variables related to the investigated phenomenon;
- allow to bring to the surface mental models of the decision-makers involved;
- facilitate the process of communication and knowledge-sharing between all actors involved;

Since no simulation occurs when using CLD, their use is just useful to understand the cause-effect relationships as well as the feedback loops in the observed system. CLD's may be constructed also by using the same symbols of "Stock and Flows" diagrams to combine increase the understanding of the contribution of each variable in the system under analysis.

6.2 Quantitative modelling approach

In the System Dynamics methodology, the quantitative analysis is performed by using a type of model called 'Stock and Flow diagram' (from now SFD). More specifically, quantitative models allow one to obtain a simulation of the dynamics that characterize the system under analysis. This requires a preliminary initialization of the variables involved.

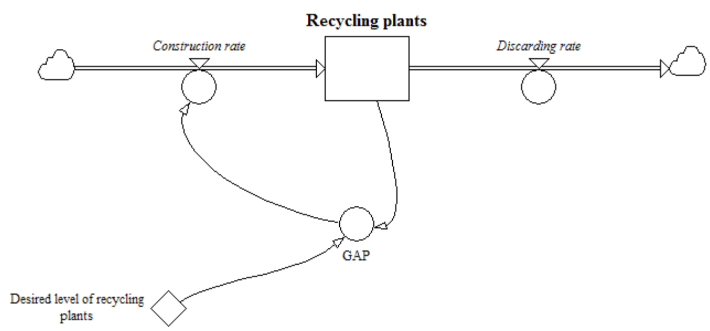


Figure 8 A simplified version of a quantitative simulation model (stock variable in bold, flow in italic, auxiliary variable in capital letters and constant variable)

Figure 8 shows the four variables types that are used to build a quantitative simulation model:

- stocks represent the level of accumulation of a given variable;
- flows increase / deplete the material accumulated in a stock variable;
- auxiliaries are used to make intermediate quantifications and calculations significant.
- constant variables are used to include parameters into the model. These values are inserted in these variables and no changes occur during the simulation.

6.3 Application of System Dynamics to waste management

The number of publications on System Dynamics review as well as the number of paper presented at System Dynamics conference, prove that the application of such a methodology to waste management issues is an effective method to investigate structural problems in this field.

The following literature review considers the works published in the System Dynamics Review (including conference proceedings).

A first article presented at the 1994 edition of the International System Dynamics Conference, held in Sterling, Scotland was developed by Sliwa (1994). In his work, he addressed the problem of solid work in Puebla (Pue, Mexico). He found that the solid waste collection and recuperation could be converted from a resource consuming to a resource generating problem. He also discovered also a reinforcing loop which shows how municipal budget assigned to cleaning services links the profit of the companies with a decrease of waste contamination in Puebla.

Sudhir, Srinivasan, and Muraleedharan (1997) presented a "system dynamics model which captures the dynamic nature of interactions among the various components of the urban solid waste management system in a typical metropolitan city in India. The model provides a platform for debate on the potential and systemic consequences of various structural and policy alternatives for sustainable urban solid waste management system."

Marrone and Montemaggiore (2002) analyses the case of Amia Spa, the municipal waste management company of Palermo, Italy. They built a qualitative model was built with the aim to support Amia's managers in understanding the structure of their competitive system, particularly "the new market segments the company will serve."

Kum, Sharp, and Harnpornchai (2004) through a simulation addressed the question of solid waste recovery policies in Phnom Penh City (Cambodia) through small scale composting promotion. Their simulation result found that waste recovery through small-scale composting and informal recycling cannot contribute significantly to the waste diversion without other supporting policies.

Ulli-Beer, Andersen, and Richardson (2004) presented a comparative policy analysis drawing on the System Dynamics Solid Waste Management model that is based in a feedback perspective on human behavior. The policy experiments they performed shows that “combinations of interventions altering personal and contextual factors are crucial for policy compliance and for designing robust recycling initiatives especially under uncertain and adverse conditions in the system.”

Olaya and Torres (2010) developed a conceptual article through which they aim to present an “option to systematically help to guide the selection of key variables integrating quantitative and qualitative analysis.”

A first stages of conceptualization process initiated within the scope of an action research project in the field of waste and residual resource management in a large urban center of a low-income country, was developed by Escalante (2012).

Cai and Liu (2013) built up a model to investigate municipal domestic waste and its effect on environmental pollution.

With MUWAIT (MUnicipal WAste management in ITaly) Di Giulio, Migliavacca, Durante, Torelli, and Giuliani (2013) simulate technical aspects as well as revenues and costs associated with waste disposal and potential energy savings which could be generated by waste.

A system dynamics model was developed to analyze (Dace, Bazbauers, Berzina, &

Davidsen, 2014) the policy mechanisms that promote packaging material efficiency in products through increased recycling rates within the EU's long-term objective to become a recycling and resource effective society.

A system dynamics model was developed by Rodriguez, Escalante, and Rubiano (2016) to simulate different public policies of Bogota (Colombia) government. As the authors stated "the model results establish that the recoverers play an important role in the system, and that their income depends largely on the sale of material to the industry and less on the government subsidy for recycled materials."

As the research illustrated above remark, System Dynamics is an approach that by explaining causality and simulating policies' effect on system's behavior over time allows researcher to asses system's performance sustainability and trade-offs in time and space. As a consequence, System Dynamics when connected with performance management may support policy makers in improving coordination between those public and private organizations which intervene in the governance of the waste management system.

7. Implications and closing remarks

The shifts of paradigm in public administration theories makes public governance a good mode of management for delivering public services. However, current implementation of such a model shows some weaknesses when an inter-institutional system need to be managed. In the context of Sicilian Region, the performance of the waste management system need to investigated through an approach which allow one to understand how to manage the system complexity. The system need to be enhanced in a way that the waste governance is able to manage shared resources in order to improve the outcomes of the system. Waste governance – linking regional and local level –may address such need by adopting a holistic view to the integrated waste management system In this way performance management systems support the implementation of public governance for waste management.

Dynamic performance management allows organizations' decision maker to combine the external to the internal perspective of performance when framing the outcomes of inter-institutional systems. Such an approach, by explaining causality of performance and simulating policies' effect on system's behavior assess performance sustainability and trade-offs in time and space. As a consequence, dynamic performance management improves coordination between the public and private organization which are responsible for delivering the service and it fosters the relationship between political and managerial level.

The next chapter develops a case study in which an outcome-based dynamic performance management approach was used to frame the waste governance system of the Sicilian Region. In particular, the analysis address the need of collaboration among organizations involved in delivering the service and through a simulation model provides insights for policy making.

Chapter 3 – Case Study: the Sicilian waste system

1. The evolution of Waste Management regulation

Disposing of urban waste is a problem everywhere; as an economy expands, refuse increases with a potential damage for present and future generations. Often, eliminating one source of pollutants creates other negative externalities. Therefore, government globally recognized the need of an integrated plan for waste management.

The European waste management regulation is based on the directive 75/442/CEE, which provides a definition of waste, distinguishes between "refuse" and "dangerous refuse", and requires a management plans for each European Country. In Italy, is the DPR. 915/82 that regulates waste treatment; this law asks regions to produce a plan for treating waste within their territory.

The European directive enforced national governments to intervene in order to increase recycling quota and reduce the amount of waste produced. However, Italian regions did not adopt any management plans and this lack of implementation caused inefficiencies in the public service delivering and opportunities for illegal businesses.

By the end of '90s the European strategic guidelines were approved and a new debate grew up, which produced the so called "Ronchi decree". Such a law, has set concrete target to be achieved by the end of 2002. Regions must separate and recycle 35% of the waste produced. The goal should be achieved according to the strategic priority defined by the law. The priorities are the following:

1. A considerable reduction of waste achievable by involving the producer

responsibility in the life cycle of goods. Other tools can be clean technologies, and tax associated with amount of waste produced.

2. Promoting a reuse of goods.
3. Fostering recycling of original parts and/or materials that can be reused to produce new products (e.g. plastic, paper and glass).
4. Improving the recovery of waste through processes which implies chemical, thermal or physical transformation of original goods (bio-gas, compost and fuel).

The "Ronchi decree" both considering intra and cross differences among regions, confirmed regions as authorities responsible of the regulation through which defines the management alternative to deliver the waste service. This decree promoted the creation of Optimal Territorial Areas (ATO) based on the territory of provinces. The assumption behind the creation of the ATO is the capability to provide appropriate services rather than a single national system.

In January 1999 (with Decree No. 2983), the Italian Prime Minister was concerned about the disposal of solid urban waste in Sicily and declared the state of emergency, which was even extended to the special category of waste. The "Priority Action Plan for Waste Emergency in Sicily" (P.I.E.R.) was approved with the Commission Order No. 150 of July 25, 2000. Such an act identified a list of measures to tackle the emergency (the initial length was set at twenty-four months). The goal was to make Sicily an autonomous region to what regards waste treatment. The plan recognized all the waste facilities available in Sicily and set targets for recycling. Moreover, through the plan new recycling plants to treat the organic and the dry waste, have been installed. However, the Commission Order n.3190 of March 22, 2002 replaced the production of Waste Derived Fuel with the waste-to-energy ratio of the dry fraction.

And in the subsequent Commission Order No.488 of 11 June 2002, in the annexed "Guidelines for the Separate Collection", in view of the introduction of the waste-to-energy facility, noted: "*There is therefore no need to subdivide the territory into ATO and sub ATO at the service of the Waste Derived Fuel plant system, and extend ATOs and sub-ATOs to the integrated management of differentiated collections (dry and wet material) to integrated waste management, ie management of the residual fraction downstream of separate collection [...]*."

Lastly, the Sicilian Region adopted a waste management plan with the Commission Order No. 118 of December 18, 2002. With this brand-new plan, the region identified 27 ATOs, but it created problem in implementing the national guidelines.

2. Issues in implementing the "Ronchi decree"

In Italy was the "Ronchi decree" to provide stimuli to change both political and people sensitivity toward environmental issues, and to set deadlines and goals for the waste management system at regional scale. Notwithstanding the challenging goals of the decree, Regions experienced difficulties in starting and running ATO's activities mainly because politicians sought to appoint their political partners in these organizations and municipalities perceived such organizations as counterparts. These factors caused lack of collaboration, lower trust among municipalities, reluctance to share equipment, staff members, employees, facilities, difficulties to define shared standard of services, and lastly higher costs of the service. Moreover, the presence of a highly-politicized board of directors of ATOs determined that activities were subjected to the requirements of politics rather being oriented to reaching management targets. Although some ATOs were well-governed and they were able to provide a service quality level close to the Italian baseline, the Sicilian Regional Law n. 9 of 2010 quitted ATOs. This law outlined the "Integrated Waste Management and Reclamation of Polluted Sites", reduced the number of ATO (from 25 to 10), and enforced each Municipality to establish consortia to run the service: the so-called "society for the regulation of waste management service" (SRR).

The new regional waste plan at the article n.9 sketched the "Differentiated Waste Management Guidelines". The purpose of such an article was to encourage the integrated home waste collection and stimulating the system towards the achievement of the minimum standard of recycling as expected by the European and national legislation. The targets for the system were the following:

- 20% of separate collection and 15% of material recovery by the end of 2010;
- 40% of separate collection and 30%material recovery by the end of 2012;
- 65% separate collection and 50% material recovery by the end of 2015.

The new plan also limited waste production by encouraging reuse, recycling and recovery of waste through the implementation of targeted promotional campaigns to draw attention towards recycling and pollution. From a service management perspective, municipalities have to provide the service within their territories through Optimal Collection Area (ARO) by adopting in advance an Intervention Plan which respects the principles of differentiation, adequacy and efficiency in service delivering. Indeed, the article n.5 paragraph 2-ter of the Regional Law, as modified on 29 December 2012, stated that *"[...] the municipalities in single or associate form, as permitted by D.Lgs. 18.08.2000 n. 267, and without additional costs for public finance, following the drafting of an action plan, with its mandatory specifications* *and economic framework for expenditure, consistent with the Plan of Environment and approved by the Regional Energy and Public Services Utility Bureau, Regional Water and Waste Department, can proceed to the organization and management of the garbage sweeping, collection and transport of […].”* With this article the waste management system shifted from a system based on ATOs towards a system which is based on SRR. Even though the name of the organizations has changed over time, it seems that the principles introduced by the “Ronchi’s decree” have not changed.

3. Case Background

The Sicilian Region with a population of approximately of 5 million is one of the biggest region in Italy. Sicily is characterized by highly and irregularly urbanized cities and rural village with completely different lifestyle. Indeed, within the region the urban waste production and composition changes substantially if one compares the countryside against cities. Sicilians generate two millions ton of waste each year and the volume has not increased over the last five years. The flow of urban waste in Sicily is divided into two main sets: recycled and not recycled. The stream of waste is managed from collection, through intermediate facilities (composting and recycling), to ultimate disposal (landfills).

According to the law, the collection and disposal service of urban waste can be contracted out to a private organization, provided by a “in house” organization, or through a public private partnership. ATOs, as well as Municipalities may choose one of these forms to deliver the service. The organization running the service is responsible for a comprehensive operation of street cleaning, urban waste collection, transportation and disposal at landfill sites, repair and maintenance of the waste storage facilities, dustbins, infrastructure and resources (staff, mobile equipment, vehicles and plant). In a nutshell, it has to manage all the operation composing the waste cycle.

In the year 2015, Sicilian produced over two and half million tons of waste, which means almost five hundred kilograms per capita each year. The territory of Palermo produces almost one third of the total amount of waste produced in the island. The percentage of waste recycled in the region is around 13% which means 60 kilograms per capita each year.

Figure 9 shows the dynamics of waste produced and recycled in Sicily from 2010 to 2015. The amount of waste produced has slightly decreased over the last five years (grey line) while the flow of waste recycled has vaguely increased during the same time span (blue line). As a result, a small improvement in recycling performance – from 9% to 13% – there was from 2010 to 2012 (green line).

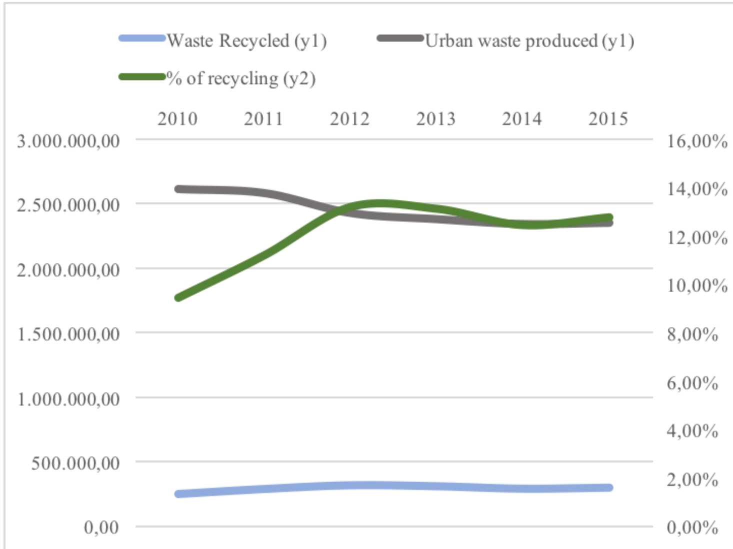


Figure 9 Dynamics of waste production and recycling in Sicily from 2010 to 2015 (Elaboration on data provided by Ispra)

The same pattern can be observed in figure 10. The waste production rate per capita (black line) decreased and recycling rate per capita (green line) shows a small increase and then it flattened.

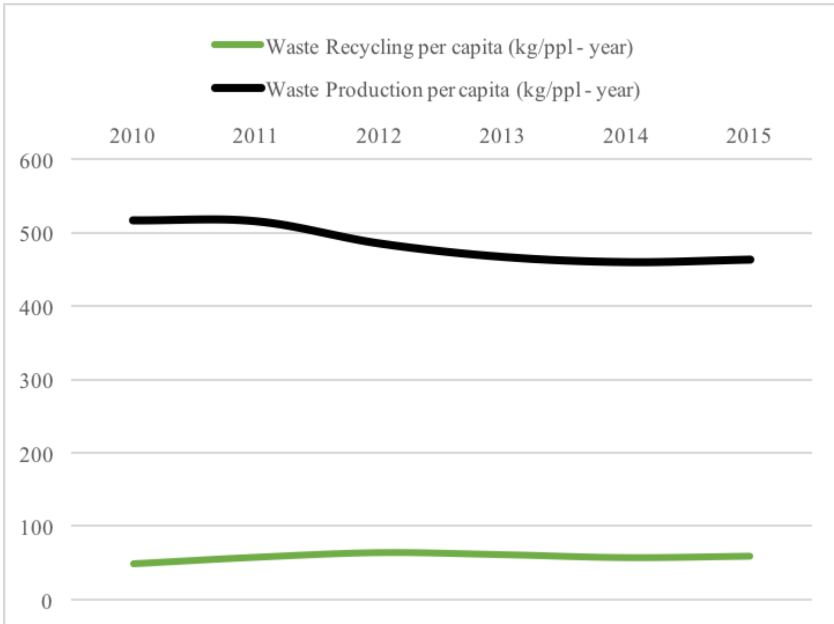


Figure 10 Dynamics of waste production and recycling PER CAPITA in Sicily from 2010 to 2015 (Elaboration on data provided by Ispra)

These data are not encouraging at all and the situation may appear eve worse if Sicilian waste performance is compared with national figures. The region with the higher recycling rate is Veneto scoring 68,8 %, followed by the Trentino Alto Adige with 67,4%. Both regions perform above the European targets for the 2012. Calabria has the most growing rate of recycling rate, while the highest value of recycling rate per capita is achieved by Emilia Romagna with 369 kilograms per year. Sicily is the only Italian region which does not go beyond the threshold of 100 kilograms per person per year.

Observing data at sub-regional scale only two provinces does not achieve 10% of recycling rate: Palermo with 7,8% and Siracusa with 7,9%. The highest value in Sicily is registered by Trapani with 24% and Caltanissetta with a recycling rate of 20%. Table 3 shows waste production at sub-regional scale for the year 2015. Data are ordered according to performance value in the recycling rate.

Table 3 Waste production and recycling rate at sub-regional scale for the year 2015 (elaboration on data provided by ISPRA)

Province	Population	Waste production (t)	Waste production per capita	Waste recycled	Recycling rate
Trapani	435.765	209.396	480,5	50,695	24,3%
Caltanisetta	271.758	111.452	410,1	23.020	20,7 %
Ragusa	320.226	138.750	433,3	20.586	14,8%
Catania	1.115.535	528.790	474,0	77.645	14,7%
Agrigento	445.129	205.623	461,9	28.942	14,1%
Enna	169.782	60.913	358,8	6.595	10,8%
Messina	640.675	308.299	481,2	31.106	10,1%
Siracusa	403.985	193.771	479,6	15.273	7,9%
Palermo	1.271.406	593.199	466,6	46.255	7,8%

The recycling performance of almost all Sicilian province is remarkably poor since all territory are below 30% of recycling rate, with negative consequences on the cost of the service, the tax paid by households, and on the achievement of environmental targets. Within the recycling rate several categories of waste are include. Table 4 reports the fraction differentiation rate per waste category: bio-waste, paper and glass has the higher value.

Table 4 Recycling rate per category of waste for the year 2015 (elaboration on data provided by ISPRA)

Category of Waste	**Quantity (t)**	**Weigh (%)**
Bio-waste	117.705,8	39,2%
Paper	84.943,8	28,3%
Wood	15.209,9	5,1
Metal	2.168,4	0,7%
Plastic	23.148,0	7,7%
RAEE	6.354,8	2,1%
Selective	286,8	0,1%
Textile	2.490,1	0,8%

Glass	33.734,8	11,2%
Furniture and equipment	12.736,9	4,2%
Others	1.606,9	0,5
Total	**300.386,3**	100%

Data on waste production, composition and recycling are the product of the way in which the waste management system is structured. To understand how to improve performance at regional scale it is necessary first to frame how the waste management system works and after spot main management issues. The next section dives into the state-of-the-art of waste management system in Sicily.

4. Waste management in Sicily: current state ad main issues.

In the year 2015, almost a fraction of 83% of the total waste produced have been disposed to landfill. Sicily currently has 11 working landfills: two are located in the territories of Palermo, Trapani, Catania and Agrigento, only one landfill in Caltanissetta, Ragusa, and Siracusa. Picture 11 locates these landfills on the map of Sicily according to province boundaries.

Figure 11 Geographical position of landfills in Sicily (elaboration on waste registry data)

By analyzing waste production data one may notice that in Sicily on average each citizen dispose to landfill 384 kg of garbage each year. Such a value is three times higher if compared with national average, which is about 124 kg per person per year. Regarding the recycled fraction, during the year 2015 Sicily has treated 170.683 tons of bio-waste which represents an increase of 5,5% if compared with 2014 performance. Indeed, from 2011 to 2015 Sicilian Region has authorized 3 bio-waste treatment plants and currently there are 15 working plants in the whole Region. However, the non-recycled fraction until 2014 was completely disposed to landfill without any pre-treatment. In 2015, a mechanical biological treatment (MBT) plant have been installed and started to work. This plant treated 1.271.826 tons of waste (+264% over the 2014 value). MBT system is a type of waste processing facility that combines a sorting facility with a form of biological treatment such as composting or anaerobic digestion. MBT plants are designed to process mixed household waste as well as commercial and industrial wastes. Figure 12 shows a simple flow chart for the MTB process which relates to a group of solid waste treatment systems.

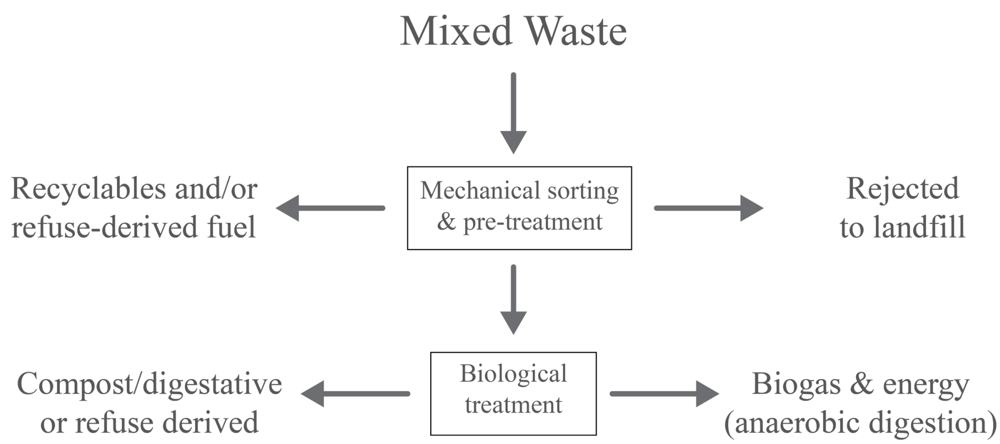


Figure 12 Mechanical biological treatment flow chart

These systems enable the recovery of materials contained within the mixed waste and facilitate the stabilization of the biodegradable component of the material. The sorting component of the plants typically resemble a materials recovery facility. This component is either configured to recover the individual elements of the waste or produce a refuse-derived fuel that can be used for the generation of power. However, Sicily still disposing a fraction of 24% of the waste produced to landfills without any preliminary treatment or separation.

The stabilization and the continuous reduction of biodegradable waste disposed to landfills – against which an MBT plant is an effective solution – are among the most important strategic goals of the European Union (2008/98/CE). Table reports strategic goals and key dates for achieving them according to the EU directive 99/31/CE

Table 5 Strategic goals for the member states of the EU and time horizon for achieving it

Time horizon of the target	**Target**
Short term (by 2008)	173 kg of waste/capita- year
Medium term (by 2011)	115 kg of waste/capita-year
Long term (by 2018)	81 kg of waste/capita-year

At national level the total amount of recyclable waste disposed to landfill is equal to 4.691.277 tons (28% of the total production of waste). Currently only 11 Italian regions are above the target fixed for the 2018. Sicily, among others, is far away from this goal since the amount of biodegradable waste disposed to landfill is equal to 230 kg per capita per year. To achieve such a goal, Sicilian Region has to improve waste management system performance. Recycling of bio-waste is crucial for reducing tons of waste to dispose to landfill. Indeed, Italian most Performing regions have recycling facilities allowing they to effectively implement an integrated waste management system. On this aspect, Sicily has a lower degree of either capacity installed and there are no investments planned for the next future. This current state of the system is recognized as a main cause of the bad performance in recycling.

5. Sketching the Dynamic Performance Management chart of Sicilian Waste management system

The Dynamic performance management perspective of the waste management system of the Sicilian Region emphasizes three-layers: from end results back to strategic resources, through performance drivers. In this way, the chart frames the causal relationships behind recycling performance and supports policy-makers in identifying the value chain from a systemic perspective.

Figure 13 synthetically profiles the dynamic performance management chart for the Sicilian waste management system. Waste recycling rate is the major end-result for two main reasons: it synthetizes system performance and adversely influences the waste disposal rate to landfills.

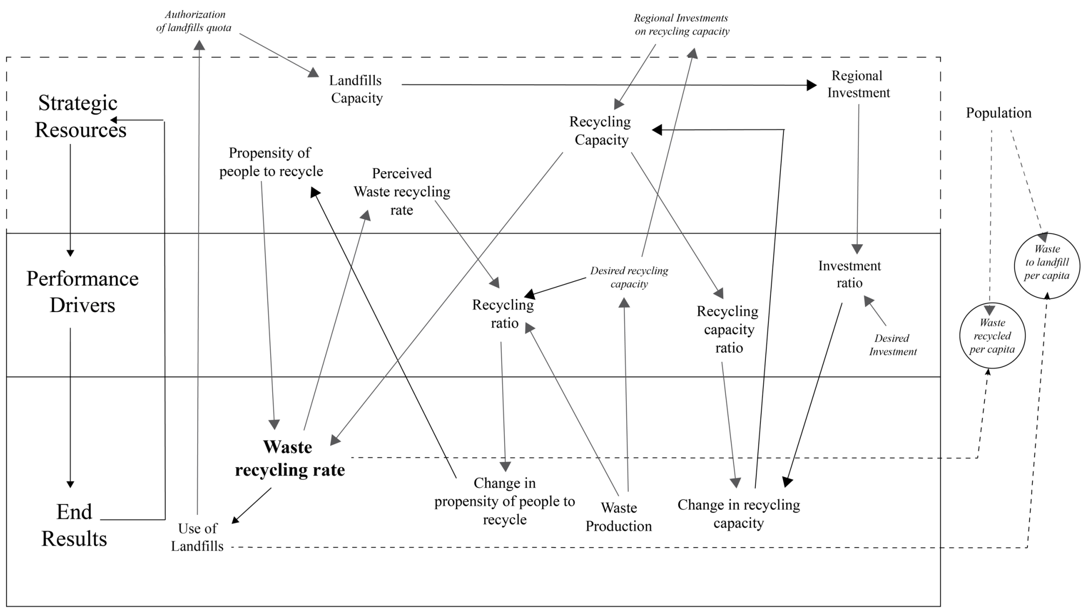


Figure 13 The dynamic performance management chart for the Sicilian Waste management system

The waste recycling rate is directly[1] affected by two resources, people's propensity to recycle and the available recycling capacity: upon these two resources regional policy-makers have to intervene if they want to improve recycling and reduce the use of landfills.

The recycling capacity can be increased through regional investments in capacity which is also pushed up by the recycling capacity ratio, as a measure of the relative pressure on this waste treatment method. In order words, the investments in recycling capacity should be increased to match the desired recycling capacity, which in turn, is updated on the basis of even more challenging recycling targets. On the other side, the "change in people propensity to recycle" which updates the strategic resource "people propensity to recycle" is affected by the weight of recycling over the total waste produced, namely the performance driver "recycling ratio". This causal

[1] The direct link is an assumption of the model since the implementation part is outside the boundaries of this model.

connection highlights how people changes their willingness to recycle when system's performance and costs of the services reflect their efforts.

The "waste recycling rate" affects the "use of landfills", indeed a lower recycling rate increases the amount of waste to be disposed to landfills; it leads the administration to expand the authorized quota of regional landfills. Such a policy, on one hand increases the available waste treatment capacity, however, on the other side, reduces the regional investment on "recycling capacity."

To conclude the analysis, the dynamic performance management chart also includes two performance indexes: the "waste disposed to landfill per capita" and the "waste recycled per capita". These two indexes can be adopted to measure performance of the Sicilian Waste management system.

The analysis carried out through dynamic performance management has shown how such an approach provides a powerful method to enhance performance management according to a sustainability perspective. Main insights – emerging on the role that dynamic performance management can play in improving waste governance – can be associated with its support for decision makers in: i) framing trade-offs associated with the policy design; ii) understanding the process through which strategic resources accumulate and/or deplete; iii) figuring out which policy levers affect performance drivers; iv) providing measures for performance drivers. Indeed, to conclude the analysis it is important to underline trade-offs affecting Sicilian Waste management system. This analysis can be developed through a causal loop diagram which offers a clear picture of regional waste management policies. As figure 14 shows, current waste policies are characterized by the adoption of short term solution, rather than pushing the system towards the achievement of long term goals.

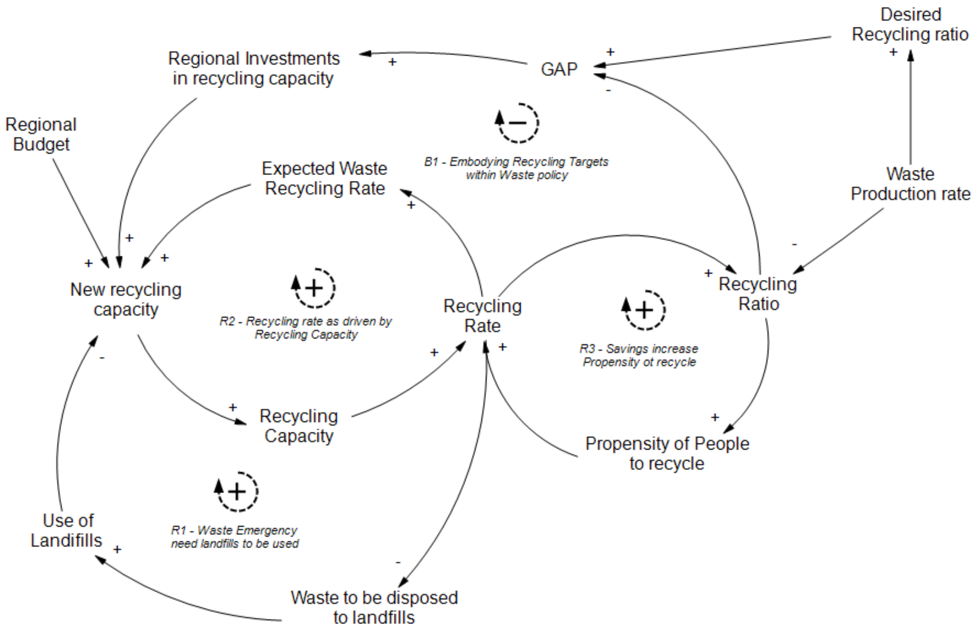


Figure 14 Framing trade-offs in policy design through causal loop diagram

Particularly, the loop R1 labelled “Waste emergency need landfills to be used” describes how the regional policy makers have managed the system during the last 10 years. Poor recycling performance increases the waste to be disposed to landfills – assuming a constant waste production – which in turn implies more use of landfills and therefore lower financial resources for the Sicilian region to invest in planning new recycling capacity. Such an emergency reinforces the use of landfills as way to treat waste since it absorbs the financial resources to plan new investments. Moreover, this phenomenon bolsters the poor performance in recycling. Indeed, as the loop R2 maps, the lower is the recycling capacity, the lower recycling performance will be due to an even lower expected recycling rate by waste manager (in terms of tons of recycled waste collected at kerbside and particular waste services used by citizens). The loop R3 drives down the people propensity to recycle as a result of the poor performance in recycling. A lower recycling ratio does not allow waste management organizations to save money from the recycling and they are called to increases the cost of the service due to the higher use of landfills. This third reinforcing loop strengthens the other two loops worsening recycling performance. To counteract such a negative spiral, regional policy makers have to set a desired target for recycling against which compares the current performance and try to fill the gap by planning and prompting the required recycling capacity over a consistent time horizon. Through the policy described by the loop B1 it is possible to embody recycling target within regional waste policy and try to accomplish the environmental goals.

The causal analysis is a first step in advancing the dynamic performance management chart into a model able to simulate. The dynamic performance management chart supports in identifying effective leverage points for performance improvement, while the causal analysis maps and describes underlying phenomena behind performance. These two steps set the ground for assessing through a simulation model the research hypothesis at the base of this work. The following section is devoted to that task.

6. A dynamic approach to design the integrated waste management system

One of the main benefits of adopting a dynamic approach to analyze the waste management system is to enrich the outcome-oriented view of performance, with a deep understanding of the development of such a system over time. The combination of both provides a holistic understanding of the causal connections between structure and behavior, which eventually helps in addressing real cause of problems.

This section of the work unfolds the simulation model by illustrating relationships between variables through stock and flow diagrams. Behind relationships there are mathematical equations which allows the model to run numerical simulation, a complete list of equations is enclosed in annex 1 at the end of the thesis. This section is devoted to comment causal relationships between variables.

The model aims to simulate the dynamics of main variable of the waste management system for the Sicilian Region from 2010 till 2016 with the purpose to provide policy insights as source of possible future improvements from 2016 to 2020.

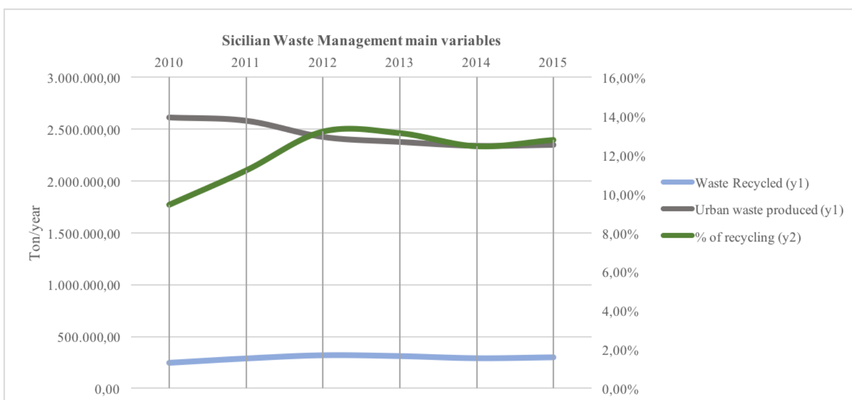
Main variables targeted by the system dynamics model are:

- waste recycled which represents the flow of waste recycled per year by the Sicilian waste management system;
- waste disposed to landfill per capita which captures the quantity of waste disposed to landfill after being collected compared to population size. This waste flow is neither recycled nor treated through mechanical-biological plants (MBT).

Waste recycled is a flow variable consisting in an end-result for the entire system. An improvement of recycling will increase the performance of the Sicilian system and at the same time reduces the quantity of waste disposed to landfill, reinforcing performance. Waste disposed to landfill per capita is a performance indicator for the waste management system, indeed it is used as performance target by the European Union (see table 5).

The purpose of the model is here illustrated by adopting the **PHAPI** technique which is used in System Dynamics methodology to easily explain a phenomenon. **PHAPI** is the scientific method used to understand the roots of problems, **P** stands for identifying the problem through a reference mode. **H** is the hypothesis about the system structure that may be responsible for the problematic behavior, and it infers from the theoretical perspective adopted. **A** is the analysis of the model response to structure tests. Finally, **P** is policy design or operations research, and **I** is implementation. The PHAPI of the system dynamics model of the Sicilian waste management system is presented in table 6.

Table 6 The purpose of the model explained through PHAPI method

Problem	The recycling rate (blue line) for the Sicilian region from 2010 to the end of the 2015 has been quite stable. Indeed, in six years the net change in the amount of recycling rate has been about 50,000 ton of waste recycled per year. Over the same time horizon, the percentage of recycling (green line) has increased due to a reduction in the total amount of urban waste produced (grey line). 
Hypothesis	The recycling rate depends on both the propensity of people to recycle and the capacity of the waste management system to effectively recycle the different categories of waste. These elements are highly connected. People will recycle more if the cost of the service drop over time. To reduce service costs the system should dispose to landfills less and less tons of garbage, in a way that the Sicilian waste system saves money and redistributes those savings to citizens.
Analysis	Recycling rate is a flow that depends on the recycling capacity of the regional system. The recycling rate diminishes the flow of waste to be disposed to landfill.

	Based on the weight of waste recycled over the total amount of waste produced in the Sicilian region (i.e. recycling ratio) the system should plan to build and prompt recycling capacity in order to support citizens to accomplish the environmental goal.
Policy	The model captures how the waste system is managed in the Sicilian region. The base run explains that as long as the system rest on landfill capacity, waste performance – in terms of recycling – cannot be improved. Moreover, people willingness to recycle may diminish even below the current recycling capacity if recycling does not lead to savings for the system as whole and for citizens too. Alternative policies to improve recycling performance, rather may set regional budget to out to: • Increase recycling capacity by building new plants and reduce over time the need of landfill; • Switch the system towards a more intense and effective use of a mechanical and biological process to treat waste in order to reduce – primarily – the bio-waste disposed to landfill as well as increase the recycling quota. The model structure has been used to compare current policy focused on landfill capacity with the two above mentioned policies. Then, an improved system performance has emerged, and this indicates that the suggested policy may produce a sustainable outcome improvement in the long-term.
Implementation	The model was designed to frame the relationships between system capacity and waste management system performance. To implement the two policies, additional hypothesis and analysis are required, especially the model should be substantially changed in order to replicate the characteristic in the management model of each ATO at sub-regional level. Implementation issues, especially with regards to financial implication of the two policies, may be part of further research.

Figure 15 portrays the full stock-and-flow model of the Sicilian waste management system. The model frames the building blocks of the Sicilian waste Management system, and as highlighted in the picture 15, it contains six sectors:

1. Waste production;
2. Waste flow management;
3. Recycling capacity;
4. Mechanical-biological treatment capacity;
5. Landfill capacity;
6. Regional Policy.

Sectors are interconnected, but for making clear the purpose of the structure, each sector of the model is described in turn.

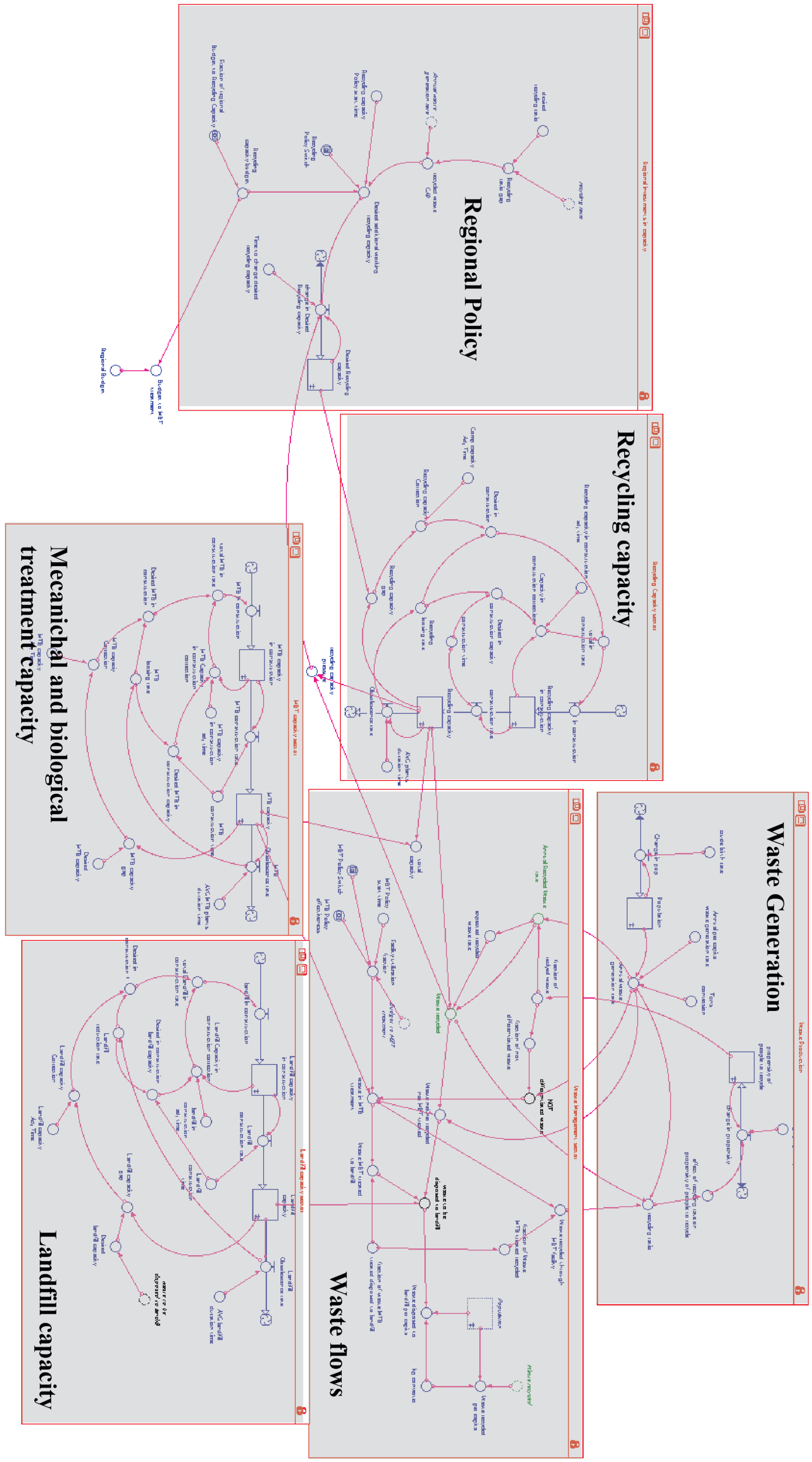


Figure 15. An overview of the sectors composing the stock-and-flow model of the Sicilian Waste management system

6.1 Waste production

The waste production sector captures the basic dynamics underlying the production of waste. The production of waste is manly driven by human activities; thus, the development of population is at the core of the sector. The stock of population develops according to a crude birth rate taken as a parameter of the system.

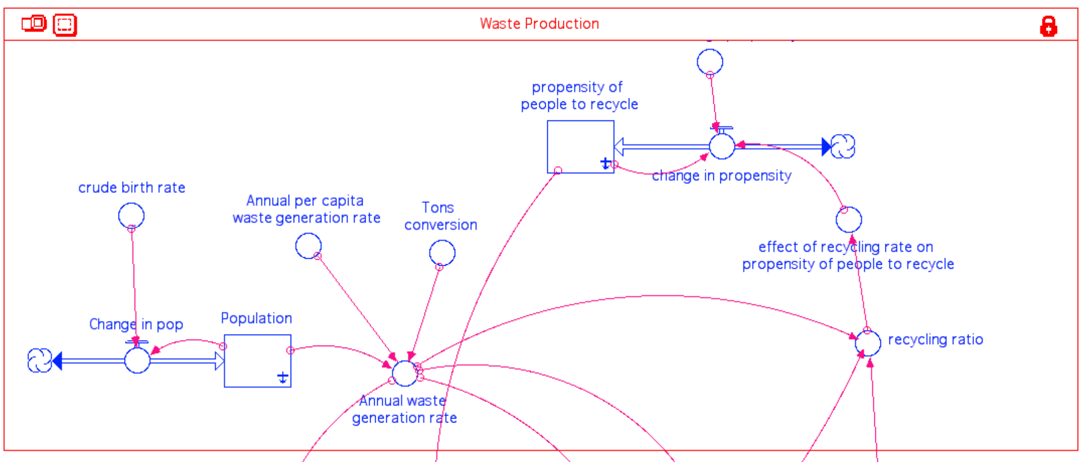


Figure 16. The waste production sector

People produces waste and the annual waste generation rate is calculated by multiplying population size by the Annual per capita waste generation rate. In this way, the model determines the annual amount of waste measured in tons per year. The purpose of this sector is to determine the flow of waste which must be collected by the organizations responsible for delivering the service.

6.2 Waste management sector

The annual flow of waste produced by Sicilians is managed by the system through three main stream: recycled, treated through MBT plant (only after 2012), or disposed to landfills. As the figure 17 shows the annual Recycle waste rate represents the demand of recycling which is somehow expected by decision makers (such an expectation is based on historical data). To fulfill the demand for recycling, the organizations involved in this service employ recycling capacity. However, such a capacity is enough to satisfy the actual demand. The remaining waste is basically disposed to landfills, only a small fraction is recovered or correctly disposed to landfills after a mechanical-biological treatment. Therefore, the variable “Waste to be disposed to landfills” captures the volume of waste per year which are finally disposed. These tons of garbage were produced as not differentiated and were just collected and disposed as they are. A strategic goal for the waste management system is to reduce such value in order to achieve European union targets.

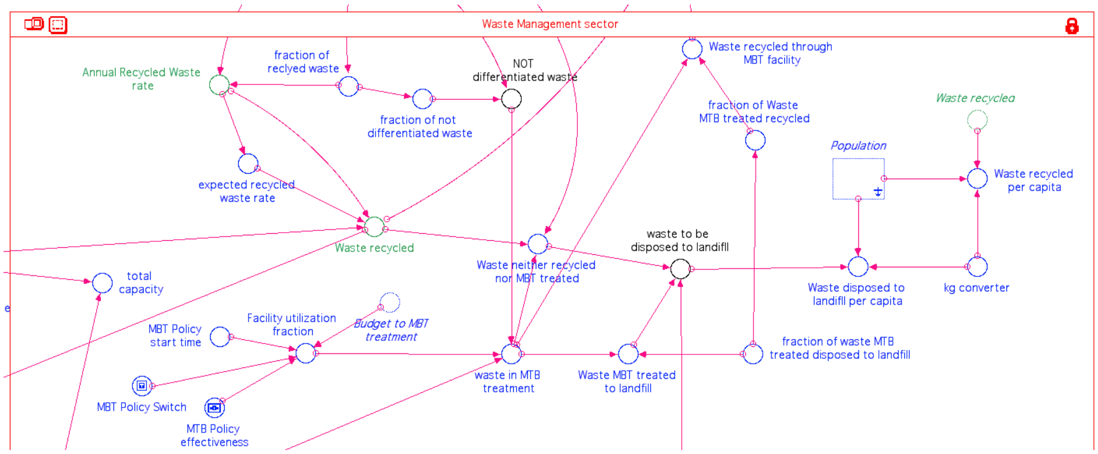


Figure 17. The waste management sector

6.3 Waste Management System capacity: Recycling, MBT and landfill sector

System capacity is represented as a stock management structure (Sterman, 2000) with an installed capacity, a desired level of capacity and a work in progress stock. The goal of such a structure is to progressively adjust the installed capacity according to the desired level. In this case, the desired level of capacity and the current level of installed capacity correspond to the actual level of capacity utilized by the waste management system. In other words, for base run simulation system capacity is in an equilibrium condition.

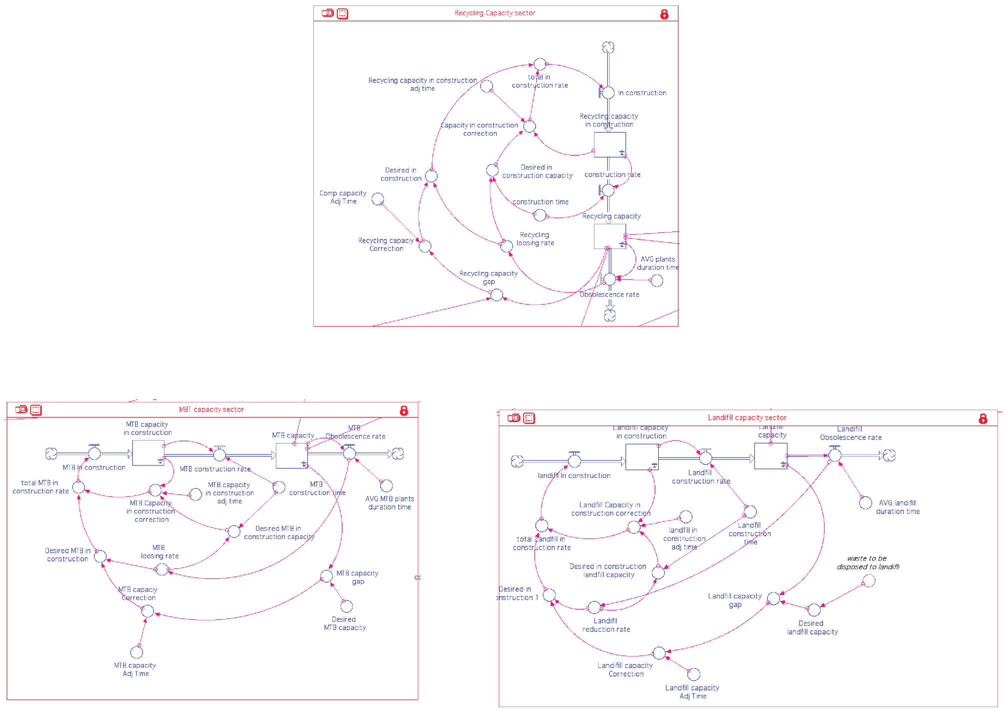


Figure 18 Recycling, MBT, and Landfill capacity

For recycling the available capacity is equal to the amount of waste recycled and the same is for the MBT plants. Lastly, the model determines desired landfill capacity based on the perceived need by the system which can expand or diminish the annual quota for each landfill. The model endogenously increases landfill capacity if necessary to dispose waste as the Sicilian regional administration does in authorizing a higher quota.

6.4 Regional Policy sector

The regional policy sector, basically connects the actual performance of the system with the decision to expand recycling capacity. For the base run such a feedback does not work since at regional level there are no investment planned in expanding the recycling capacity.

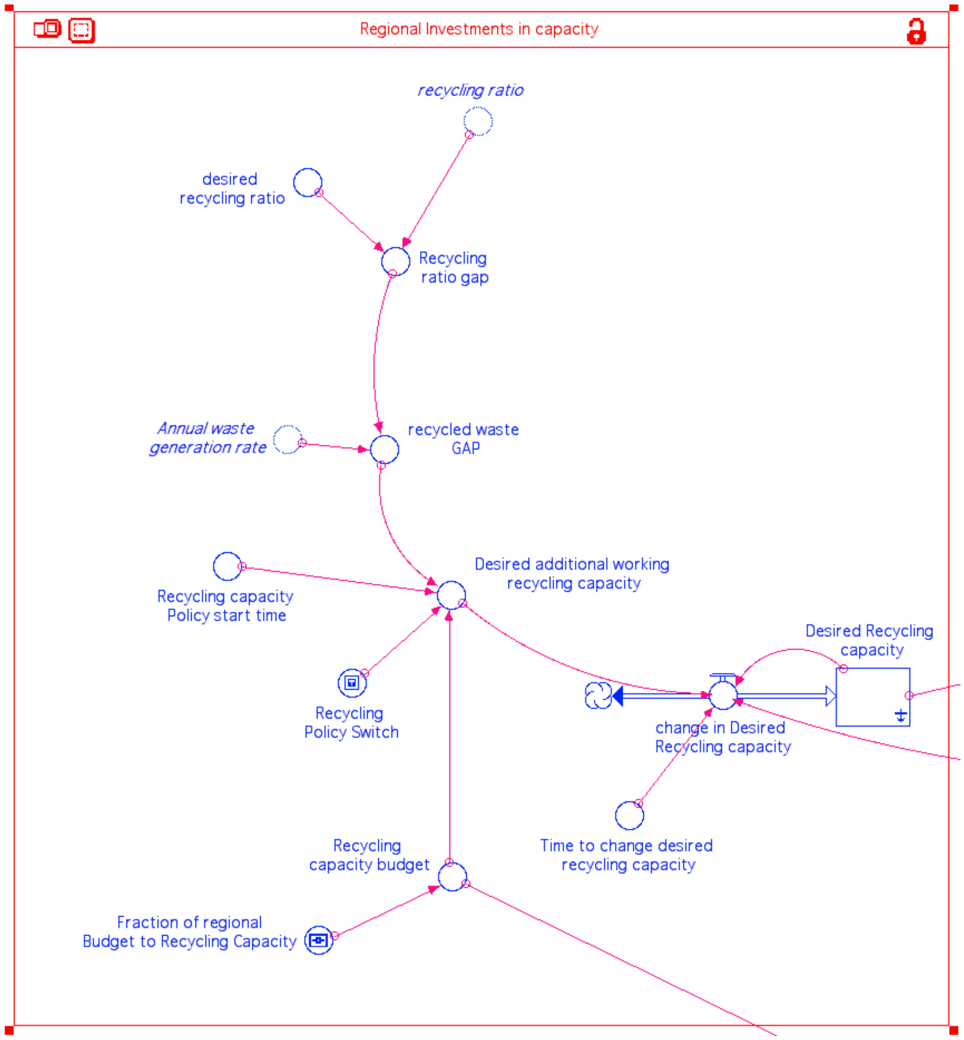


Figure 19 The regional policy sector

The model takes into account such a decision rule and indeed the desired level of recycling capacity can be also determined as result of a comparison between the current recycling ratio and the target level. This strategy – commented in the next section – is at the core of a policy designed to improve the recycling rate and reduce the amount of waste disposed to landfills.

7. Simulation output: base run and policy comparison

To conclude the case study analysis, this section presents simulation outputs. In particular, at first the base run is compared with real data in order to evaluate the capability of the model to fit historical patterns (from 2010 to 2016); secondly, two alternative/complementary policies are commented with the aim to assess their effectiveness to improve system's performance over an expanded time horizon (from 2016 to 2020).

Figure 20 compares the base run of the model with data. The model output seems to fit the historical behavior significantly. Simulation results provide an explanation of the waste management system performance. From the graph, it emerges that current policies have not improved recycling rate over the last 6 years. According to the analysis developed in section 3 and 4 of this chapter, increasing recycling capacity is a main issue which is not addressed by policy-makers. Regional investments and regulation policy have been focused primarily on landfills quota as only mean to tackle "Sicilian waste emergency." In order to improve waste performance, local policy-makers would have tackled some structural aspects which are connected with the management of waste flow. In other words, qualify waste treatments. However, during the last 6 years only one mechanical-biological treatment plant has been constructed and put to work. No other relevant investment has been planned. The following section will present two possible/complementary policies aimed at addressing such a problem.

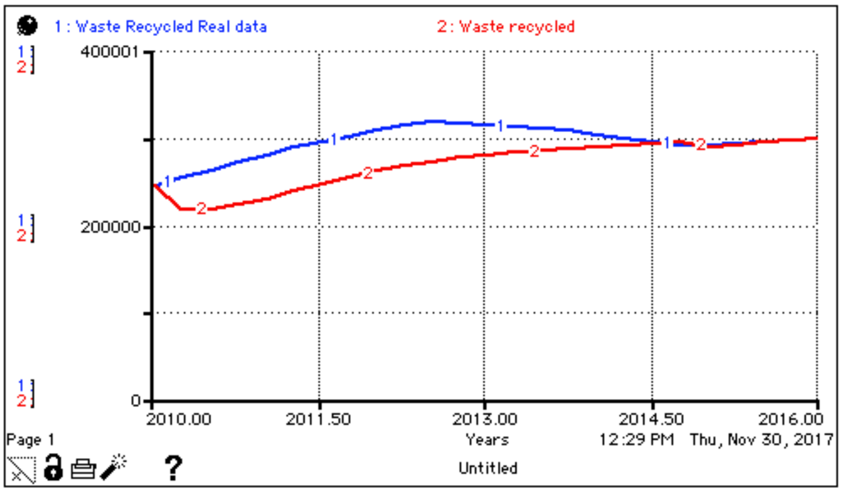


Figure 20 Waste recycled real data (line 1) compared with simulation output (line 2)

The model can also be used to simulate alternative policies: to this end an interface has been designed, through a control panel the model allows policy-makers to interact with it by using simple input devices and a friendly graphical user interface. Using these tools the model can run under different conditions and simulation output changes accordingly. This feature is particularly important for questioning decision-makers mental models and to support a double loop learning approach to planning.

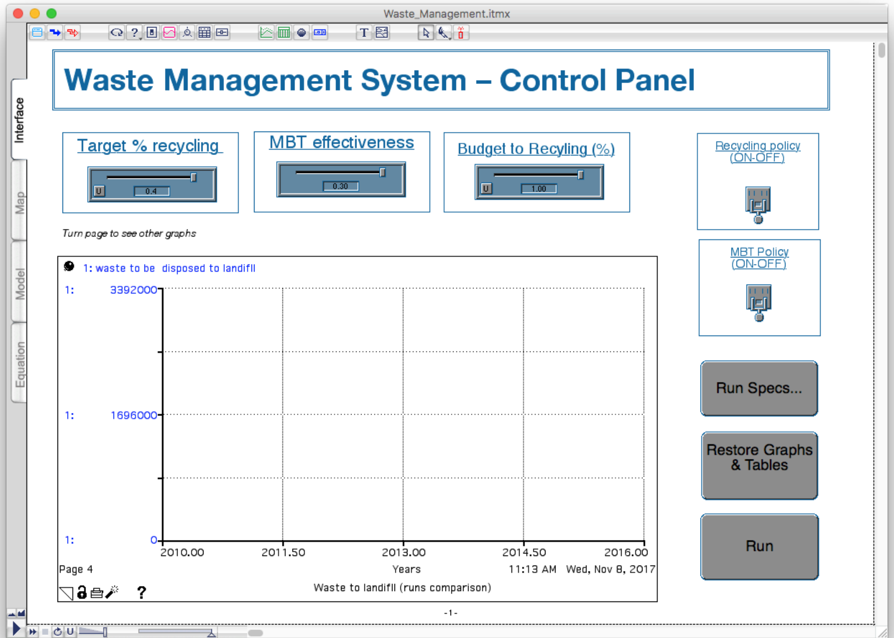


Figure 21 The control panel of the System Dynamics model

Two policies have been designed specifically to improve performance of Sicilian waste management system. Basically, both policies target the recycling rate by increasing system capacity.

A first policy focuses on the recycling capacity, connects current performance on recycling with the decision to increase recycling capacity. Regional policy-makers have to set a desired target level of recycling ratio (measured in % of recycling), which is compared to the current recycling ratio (the weight of the waste recycled over the total waste produced). The emerging gap in recycling can be filled by offering to citizens a higher system capacity to recycle in a way that savings emerging from the additional recycling can be used to sustain people propensity to recycle. For this policy, the model allows one to set up a start time and a percentage of the regional budget, as figure 22 shows.

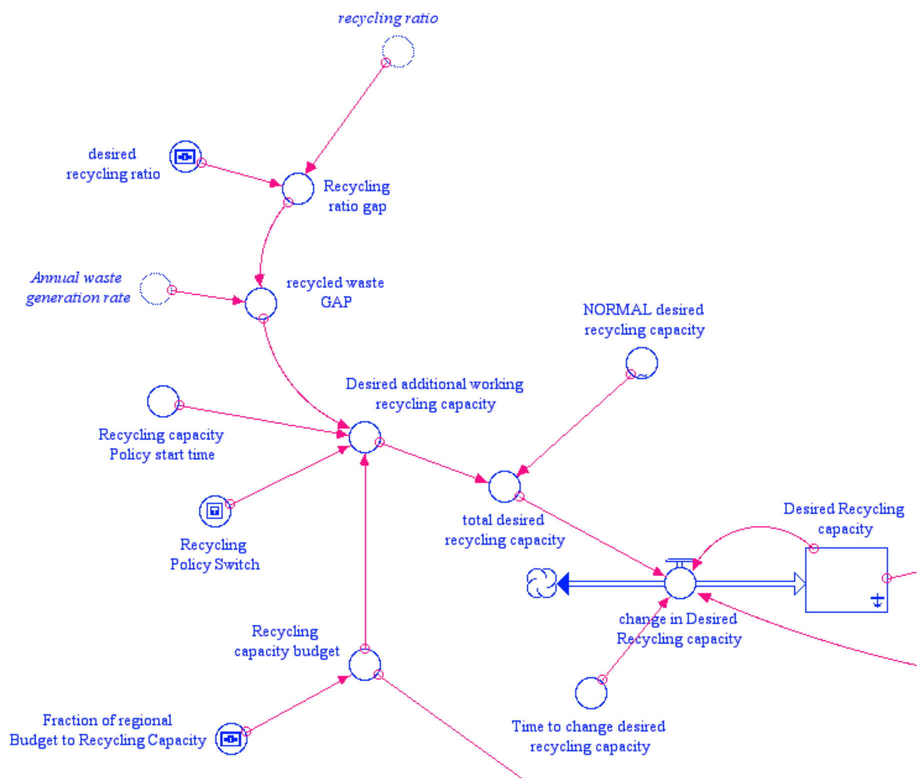
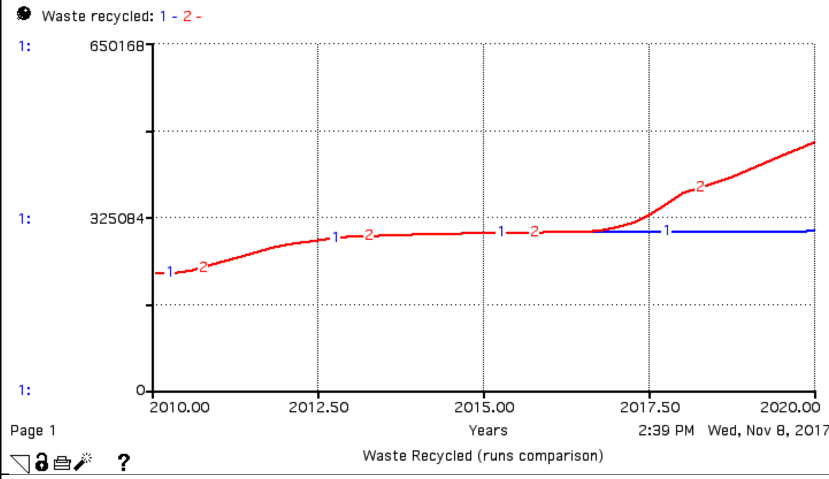
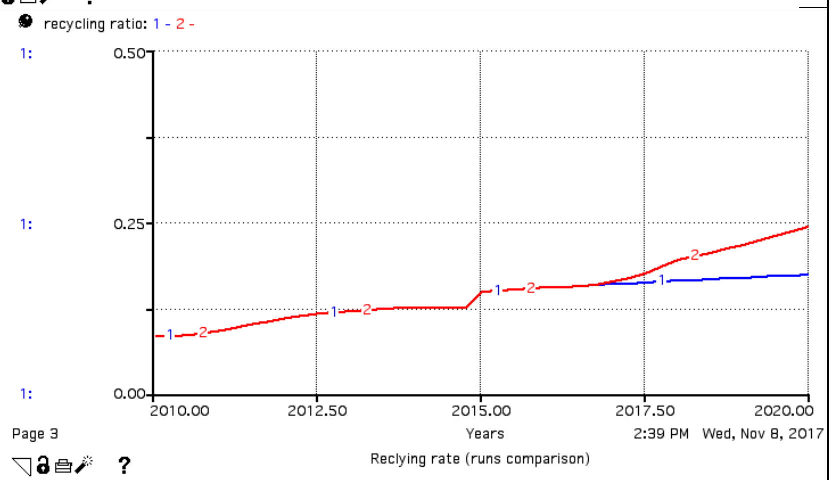
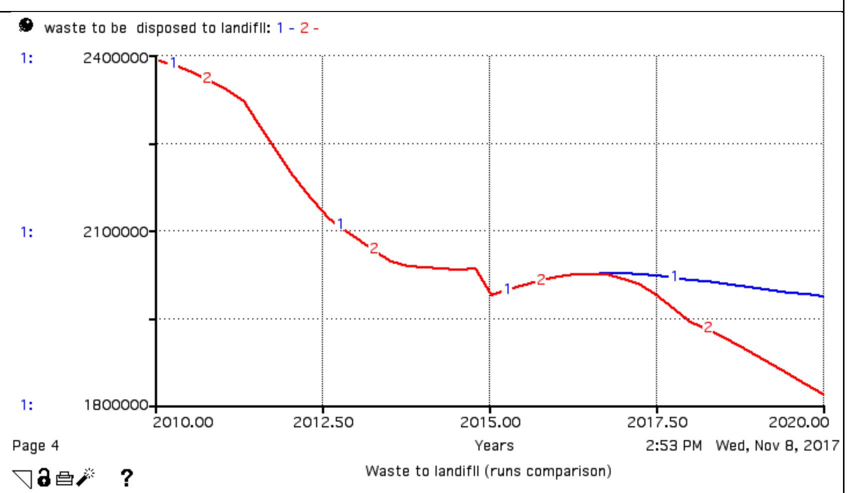


Figure 22 The formation of desired recycling policy

This policy assumes that all the regional budget is used to increase the system recycling capacity and it comes from an interview with a manager of the Department of Water and Waste of Sicilian Region. During the interview, he said "a big issue of Sicilian waste management system is the need of additional recycling capacity which is not enough to close a cycle for any waste category. Only by closing the cycle it is possible to save money and reduce the cost of the service for citizens."

<table>
<tr><th>Policy Parameters</th><th>Simulation Output</th></tr>
<tr><td>Target recycling 40%

Budget to recycling
100%</td><td>
</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td></td><td>
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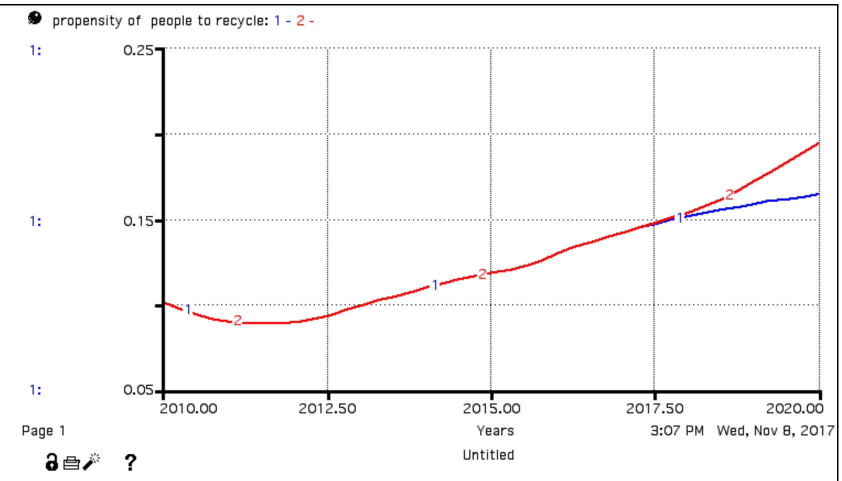


Figure 23 Comparison of simulation runs (from 2010 to 2020): no policy (line 1) vs. policy 1 (line 2)

As figure 23 shows this policy improves system performance: the recycling rate increases and therefore the recycling ratio increases as well. The amount of waste disposed to landfill (the third graph of figure 23) decreases. These improvements are made possible by an increased capacity of the waste management system to deliver a more dense and widespread service along the whole Sicilian region. In addition, people propensity to recycle increases thanks to the savings obtained by closing the lifecycle for certain category of waste. This phenomenon reinforces the capability of the system to deliver a better service.

A second policy option adds to the recycling capacity the possibility for the system to increases the effectiveness of the MBT plants. This policy assumes that regional regulation may allow organizations to use MBT treatments for a larger category of waste. Thanks to such a policy, they can produce energy out of waste and correctly dispose biological waste to landfills. As figure 25 shows this policy start by default in the year 2015 which is the time when the MBT plant begins to work. The MBT plant has an initial effectiveness meaning that it is not completely used for treating a large variety of waste, indeed the policy effectiveness will impact on that by increasing such working capacity of the plant.

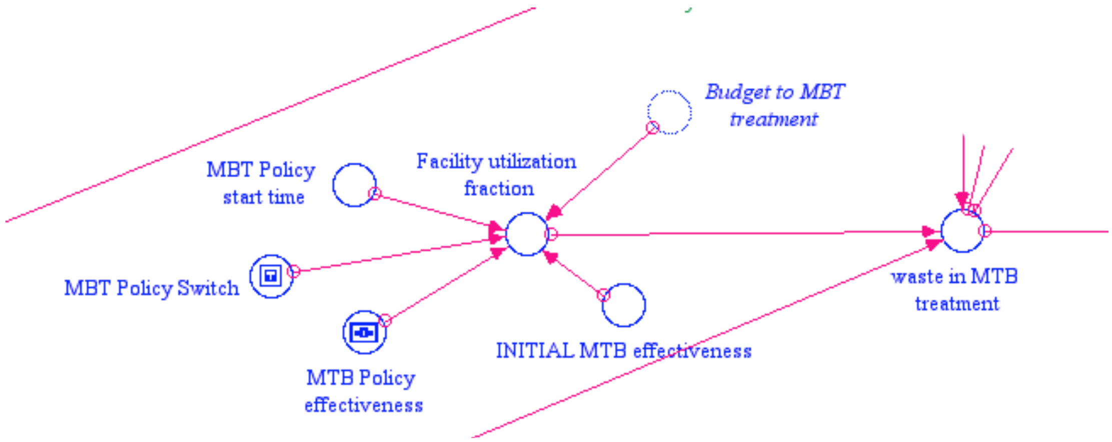


Figure 24 MTB policy structure

This second policy is conceived as complementary to the first one since it has the same goal. However, both policies share the same regional budget. Thus, the higher the recycling budget (close to 100%) is, the lower the budget assigned to MBT capacity will be. A low budget for the MTB plant limits the capacity effectiveness.

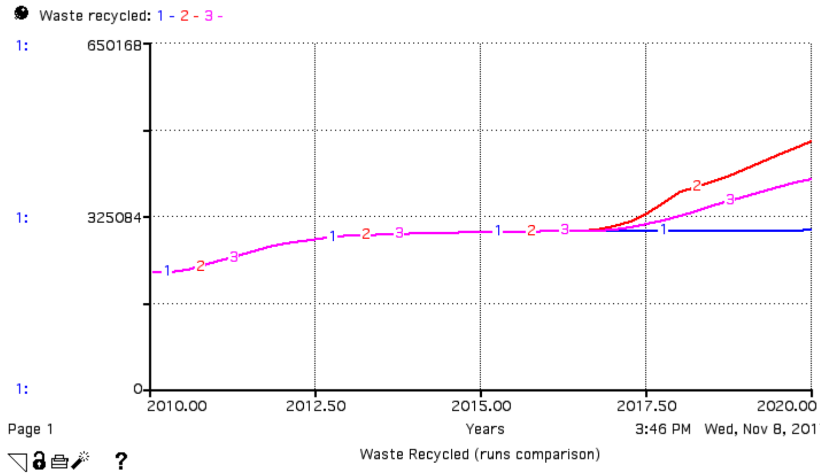
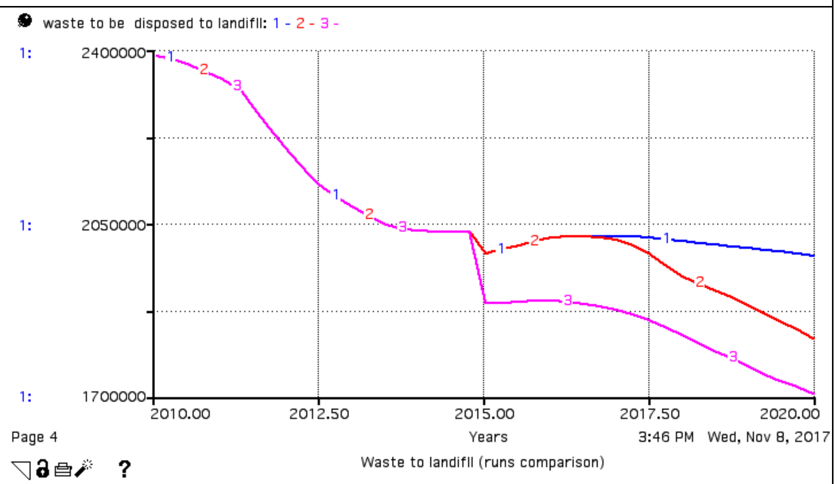
Policy Parameters	Simulation Output
Target recycling 40% *Budget to recycling 50%* *Budget to MBT 50%* *MBT effectiveness 30%*	
	

Figure 25 Policy runs comparison (2010 - 2020): no policy (line 1) vs. policy 1 (line 2) vs policy 2 (line 3)

This second policy shares the budget between the two policy levers. By looking at the recycling rate it seems that policy 2 is less effective than policy 1, however this policy decreases the flow of waste which is disposed to landfill and support Sicilian Region to achieve European environmental targets (focused on the reduction of bio-waste disposed to landfill). Therefore, policy 2 seems more suitable for the case of Sicily. In addition to that, policy 1 assumes that all waste is correctly recycled by citizens and – unfortunately – this is not a complete reliable assumption. Moreover, if the system adopts two policies it may deliver more integrated solutions to manage the waste stream. Indeed, a system is integrated when it is able to prompt systemic and feasible solution to manage the waste stream and it keeps into account that its sustainability implies to well-balance economic affordability, social acceptability, and environmental effectiveness.

8. Limitations of the model

A number of limitations affects the waste system model. To carry out quantitative modeling of complex systems shortcomings must be accepted. In this case, major limitations arose in the modeling process. Even though many sources of information may help the researcher in eliciting the causal structure, in suggesting appropriate parameters estimation, initial value, and non-linear relationships, there may be a lack of confidence for some of them. These are the classic problem of modeling, especially when a systemic perspective is adopted at a high level of aggregation as it the case of the Sicilian region to what regards the waste management system. Find longitudinal data for the model variables is a time-consuming task, and most of the time an impossible one, due to database fragmentation or inconsistency between data sources. Therefore, the simulation outputs can be compared with real data only for a limited number of variables.

Soft variables even if well operationalized rely upon the robustness of qualitative research strategies, as well as the process of describing decision rules through mathematical equations, and the process of drawing/estimating non-linear functions.

The research needs to feedback its findings to the local area decision-makers and requires further disconfirmatory analysis which may improve the structure and the behavior it produces. Lastly, the model does not address implementation issues which of course may have an impact on the findings of the research. Particularly, the research may be further advanced into an analysis of possible improvement of efficiency and effectiveness of the whole waste management process.

9. Conclusions

This chapter develops a case study focused on the waste management system of the Sicilian region. For achieving the purpose of this study, it frames such a system through a System dynamics model. The simulation model worked for a clear purpose: it has framed the waste management system of the Sicilian region it and has explained how it is possible to improve system performance. To this end, two policies which targets system capacity to recycle have been designed. Simulations have increased the understanding of the performance determinants and have helped in assessing the suitability of the results.

The simulated policies give insights into a feasible strategy: a well-balanced approach to close the lifecycle of certain waste categories and increase the effectiveness of MBT plants through administrative regulation may produce an integrated and sustainable system. In addition to that, it may help the Region to achieve performance targets.

Research concluding remarks

During the last decades, waste management emerged as a critical problem for both national and local governments. A main driver of waste production has been recognized in the increasing population size, as well as the in urbanization of big cities and changes in consumption habits. The management of waste – as a global concern – requests that local communities and national government are ready to effectively tackle health problems; environmental implications of garbage categories, illegal disposal of waste, growing solid-waste collection and supply scarcity. These phenomena affect the standards and the processes through which governments deliver waste collection and disposal services. As a result, new approaches to waste management arose. Indeed, management innovations together with the availability of new technologies may represent a way to deal with such a challenge and – hopefully – to turning waste into a resource. Therefore, the aim of this doctoral thesis was to show how dynamic performance management may support regional waste governance in implementing an integrated approach to waste management.

From a public management perspective, over the last decade the traditional model of public service delivering has been progressively dismissed in favor of management tools and techniques borrowed from private organizations. Native concepts of the private sector such as users' satisfaction, performance, effectiveness, efficiency, were also included within the scope of the organizations devoted to collect waste. These innovations have followed the evolutionary pattern of the management model of public sector organizations. Waste management organizations have either witnessed such a shift of management paradigm.

In such a context management issues arose at two levels. From a theoretical point of view, the hierarchical model which has dominated waste management experiences from early 50's has been replaced by an integrated approach to waste treatment. On the same line, sustainability studies have been progressively included into the waste management debate. Recycling and reuse of waste in association with prevention of waste production represent solutions against the scarcity of resources. Increased scarcity of natural resources and the consequent rise in commodity prices have influenced the demand for recycled products. Recycling materials such as paper, glass, and plastics, as well as composting and digestion of bio-waste, become the most preferable option.

From a policy making perspective, municipal governments often have insufficient production capacity or funding to meet the growing demand for solid-waste management services. Therefore, landfill may represent a viable solution, even though it is one of the most serious environmental threats in several European countries (Raco et al., 2013). For instance, Italian cities such as Naples and Palermo have experienced extended waste-management crises (Mazzanti et al., 2012), which have been managed without tackling structural causes.

Managing urban waste is a wicked issue for most European and developing countries. Expanding economies drain environmental resources and produce more waste with a potential damage for present and future generations. Often, eliminating one source of pollutants (i.e. burning plants) creates other negative externalities. An integrated plan is necessary for a well-balanced waste management approach.

Hence, taking into account the above-mentioned conditions, this research has developed a case study regarding the Sicilian Waste Management system. Such a context has been analyzed according to a dynamic performance management approach. Such an approach has provided policy insights and suggestions for performance improvement by fostering the strategic learning process of decision-makers.

In order to manage performance, the waste governance should frame the results of the waste system as a multidimensional concept which includes economic, social, and environmental target. Performance management systems may support the organizations responsible for delivering the waste service only if they adopt an integrated approach to waste management. Therefore, waste governance can manage shared resources in a way that economic and environmental sustainability is enhanced. In achieving this, both understanding causality behind performance and mapping the accumulation and depletion processes of resources are crucial tasks. They involve the management of complexity, particularly when wicked issues are tackled. Regional policy makers may address these challenges by matching performance management systems with System Dynamics models.

Dynamic Performance Management helps waste governance in mapping (i.e. framing the system), planning and measuring/evaluating performance improvement, and – eventually – undertaking corrective actions. Dynamic performance management supports decision- makers in framing performance, understanding causal explanations of the structure underlying results and outlining a strategic plan to achieve the desired objectives.

This thesis has illustrated how Dynamic Performance Management can be used to enhance waste governance through the promotion of integrated waste management solutions. Particularly, the research aimed to provide a method to frame the system and a framework through which regional policy-makers can understand causal relations behind performance. In applying Dynamic Performance Management to the waste governance of the solid urban collection system for the Sicilian region, several benefits of using system dynamics modelling were identified that can play an important role in improving the quality of waste performance for the entire region. The identification of a trade-off occurring in both time and space that is linked with a shift in the mind-set of regional decision-makers at political level (see figure 14). This wished behavioral change will imply a move from the current and emergency-oriented choice to the adoption of sustainable long-term oriented strategies. In other words, from landfills based system to the planning of new recycling capacity. These shift is associated with a possible future for the entire regional system. Such a strategic turn can be properly supported through the comprehension of the accumulation and depletion of strategic resources as results of an alternative mix of action on different policy levers, that determines how performance drivers affect end-results.

Moreover, Dynamic Performance Management also can help decision-makers with establishing strategic goals for the entire system, and supporting them in focusing their attention on selecting relevant targets and on measuring associated performance through indexes. Dynamic Performance management does not represent an ultimate solution, it is an important tool in decision makers' hand which may address crucial factors behind performance in a way that critical inter-organizational changes are promoted thanks to the identification of major issues of the waste management system.

Annex 1 – list of equations

Equations of variable are listed according to the sector they pertain to

Landifill capacity sector

Landifill__capacity(t) = Landifill__capacity(t - dt) +

(Landfill__construction_rate - Landifill__Obsolescence_rate) * dt

INIT Landifill__capacity = 2500000

INFLOWS:

Landfill__construction_rate =

Landfill_capacity_in_construction/Landfill__construction__time

OUTFLOWS:

Landifill__Obsolescence_rate =

Landifill__capacity/AVG_landifill_duration_time

Landfill_capacity_in_construction(t) = Landfill_capacity_in_construction(t - dt)

+ (landifll_In_construction - Landfill__construction_rate) * dt

INIT Landfill_capacity_in_construction =

Desired_in_construction_landfill_capacity

INFLOWS:

landifll_In_construction = total_Landfill_in_construction_rate

OUTFLOWS:

Landfill__construction_rate =

Landfill_capacity_in_construction/Landfill__construction__time

AVG_landifill_duration_time = 10

Desired__landfill_capacity = waste_to_be__disposed_to_landifll

Desired_in_construction_1 =

Landfill_capacity__Correction+Landifll__reduction_rate

Desired_in_construction_landfill_capacity =

Landifll__reduction_rate*Landfill__construction__time

Landfill__construction__time = 1

Landfill_capacity__Adj_Time = 3

Landfill_capacity__gap = Desired__landfill_capacity-Landifill__capacity

Landfill_Capacity_in_construction_correction =
(Desired_in_construction_landfill_capacity-
Landifill_capacity_in_construction)/landfill_in__construction_adj_time
landfill_in__construction_adj_time = 2
Landifill_capacity__Correction =
(Landfill_capacity__gap/Landfill_capacity__Adj_Time)
Landifll__reduction_rate = SMTH1(Landifill__Obsolescence_rate,2)
total_Landfill_in_construction_rate =
Desired_in_construction_1+Landfill_Capacity_in_construction_correction

MBT capacity sector

MTB_capacity(t) = MTB_capacity(t - dt) + (MTB_construction_rate -
MTB__Obsolescence_rate) * dt
INIT MTB_capacity = IF(time<2012)
Then(0)
Else(Desired__MTB_capacity)
INFLOWS:
MTB_construction_rate =
MTB_capacity__in_construction/MTB__construction_time
OUTFLOWS:
MTB__Obsolescence_rate = MTB_capacity/AVG_MTB_plants_duration_time
MTB_capacity__in_construction(t) = MTB_capacity__in_construction(t - dt) +
(MTB_In_construction - MTB_construction_rate) * dt
INIT MTB_capacity__in_construction =
Desired_MTB_in_construction_capacity
INFLOWS:
MTB_In_construction = total_MTB_in__construction_rate
OUTFLOWS:
MTB_construction_rate =
MTB_capacity__in_construction/MTB__construction_time
AVG_MTB_plants_duration_time = 10
Desired__MTB_capacity = IF(time<2012)

Then(0)

Else(1185524)

Desired_MTB_in_construction =

MTB_capaciy__Correction+MTB__loosing_rate

Desired_MTB_in_construction_capacity =

MTB__loosing_rate*MTB__construction_time

MTB__construction_time = 1

MTB__loosing_rate = SMTH1(MTB__Obsolescence_rate,2)

MTB_capacity__Adj_Time = 1

MTB_capacity__gap = Desired__MTB_capacity-MTB_capacity

MTB_capacity__in_construction_adj_time = 1

MTB_Capacity__in_construction__correction =

(Desired_MTB_in_construction_capacity-

MTB_capacity__in_construction)/MTB_capacity__in_construction_adj_time

MTB_capaciy__Correction = (MTB_capacity__gap/MTB_capacity__Adj_Time)

total_MTB_in__construction_rate =

Desired_MTB_in_construction+MTB_Capacity__in_construction__correction

Recycling Capacity sector

Recycling_capacity(t) = Recycling_capacity(t - dt) + (construction_rate -

Obsolescence_rate) * dt

INIT Recycling_capacity = 293000*.75

INFLOWS:

construction_rate = Recycling_capacity_in_construction/construction_time

OUTFLOWS:

Obsolescence_rate = Recycling_capacity/AVG_plants_duration_time

Recycling_capacity_in_construction(t) = Recycling_capacity_in_construction(t -

dt) + (In_construction - construction_rate) * dt

INIT Recycling_capacity_in_construction = Desired_in__construction_capacity

INFLOWS:

In_construction = total_in__construction_rate

OUTFLOWS:

construction_rate = Recycling_capacity_in_construction/construction_time

AVG_plants_duration_time = 10

Capacity_in_construction_correction = (Desired_in__construction_capacity-Recycling_capacity_in_construction)/Recycling_capacity_in_construction_adj_time

Comp_capacity__Adj_Time = 1

construction_time = 1

Desired_in_construction = Recycling_capaciy__Correction+Recycling__loosing_rate

Desired_in__construction_capacity = Recycling__loosing_rate*construction_time

Recycling__loosing_rate = SMTH1(Obsolescence_rate,2)

Recycling_capacity__gap = Desired_Recycling__capacity-Recycling_capacity

Recycling_capacity_in_construction_adj_time = 4

Recycling_capaciy__Correction = (Recycling_capacity__gap/Comp_capacity__Adj_Time)

total_in__construction_rate = Desired_in_construction+Capacity_in_construction_correction

Regional Investments in capacity

Desired_Recycling__capacity(t) = Desired_Recycling__capacity(t - dt) + (change_in_Desired_Recycling_capacity) * dt

INIT Desired_Recycling__capacity = 293000

INFLOWS:

change_in_Desired_Recycling_capacity = ((Converter_1-Desired_Recycling__capacity)/Time_to_change_desired_recycling_capacity)*recycling_capacity_pressure

Converter_1 = desired_recycling_capacity+Desired_additional_working__recycling_capacity

desired__recycling_ratio = 0.4

Desired_additional_working__recycling_capacity = IF(TIME<Recycling_capacity_Policy_start_time)

THEN(0)
ELSE(recycled_waste__GAP*Recycling__Policy_Switch*Recycling__capacity_budget)
Fraction_of_regional_Budget_to_Recycling_Capacity = 0.5
recycled_waste__GAP = Annual_waste__generation_rate*Recycling__ratio_gap
Recycling__capacity_budget =
Fraction_of_regional_Budget_to_Recycling_Capacity
Recycling__Policy_Switch = 1
Recycling__ratio_gap = desired__recycling_ratio-recycling_ratio
Recycling_capacity_Policy_start_time = 2015
Time_to_change_desired_recycling_capacity = 2
desired_recycling_capacity = GRAPH(TIME)
(2010, 246508), (2011, 289151), (2012, 320525), (2014, 312364), (2015, 291649), (2016, 300386)

Waste Management sector

Annual_Recycled_Waste__rate =
Annual_waste__generation_rate*fraction_of__reclyed_waste
expected_recycled__waste_rate = SMTH1(Annual_Recycled_Waste__rate,1)
Facility_utilization__fraction = IF(TIME<MBT_Policy__start_time)
THEN(0)
ELSE(0.5+(MTB_Policy__effectiveness*MBT_Policy_Switch*(1+Budget_to_MBT_treatment)))

fraction_of__reclyed_waste =
MAX(fraction_of_waste_recycled_real_data,propensity_of__people_to_recycle)
fraction_of_not_differentiated_waste = 1-fraction_of__reclyed_waste
fraction_of_waste_MTB_treated_disposed_to_landfill = 0.6
fraction_of_Waste_MTB_treated_recycled = 1-
fraction_of_waste_MTB_treated_disposed_to_landfill
kg_converter = 1000
MBT_Policy__start_time = 2015

MBT_Policy_Switch = 1

MTB_Policy__effectiveness = 0.3

NOT__differentiated_waste =
fraction_of_not_differentiated_waste*Annual_waste__generation_rate

total__capacity = MTB_capacity+Recycling_capacity

Waste_disposed_to_landifll_per_capita =
(waste_to_be__disposed_to_landifll/Population)*kg_converter

waste_in_MTB__treatment =
MIN(NOT__differentiated_waste*Facility_utilization__fraction,MTB_capacity*
Facility_utilization__fraction)

Waste_MBT_treated__to_landfill =
waste_in_MTB__treatment*fraction_of_waste_MTB_treated_disposed_to_landf
ill

Waste_neither_recycled_nor_MBT_treated = Annual_waste__generation_rate-
Waste_recycled-waste_in_MTB__treatment

Waste_recycled = IF(expected_recycled__waste_rate>Recycling_capacity)
THEN(Recycling_capacity)
ELSE(min(Recycling_capacity,Annual_Recycled_Waste__rate))

Waste_recycled__per_capita = (Waste_recycled/Population)*kg_converter

Waste_recycled_through__MBT_facility =
waste_in_MTB__treatment*fraction_of_Waste_MTB_treated_recycled

waste_to_be__disposed_to_landifll =
MIN(Landifill__capacity,Waste_MBT_treated__to_landfill+Waste_neither_recy
cled_nor_MBT_treated)

Waste Production

Population(t) = Population(t - dt) + (Change_in_pop) * dt

INIT Population = 5051075

INFLOWS:

Change_in_pop = Population*crude_birth_rate

propensity_of__people_to_recycle(t) = propensity_of__people_to_recycle(t - dt)
+ (change_in_propensity) * dt

INIT propensity_of__people_to_recycle = 0.1
INFLOWS:
change_in_propensity =
(effect_of_recycling_rate_on_propensity_of_people_to_recycle-
propensity_of__people_to_recycle)/time_to_change_propensity
Annual_waste__generation_rate =
(Population*Annual_Waste_generation_per_capita)/Tons__conversion
effect_of_recycling_rate_on_propensity_of_people_to_recycle =
SMTH1(recycling_ratio,1)
recycling_ratio =
(Waste_recycled_through__MBT_facility+Waste_recycled)/Annual_waste__generation_rate
time_to_change_propensity = 1
Tons__conversion = 1000
Annual_Waste_generation_per_capita = GRAPH(TIME)
(2010, 517), (2011, 516), (2012, 485), (2014, 467), (2015, 460), (2016, 463)
crude_birth_rate = GRAPH(TIME)
(2010, -0.0096), (2012, -0.0006), (2015, 0.0187), (2018, -0.0006), (2020, -0.0035)

Not in a sector

Budget_to_MBT_treatment = Regional_Budget-Recycling__capacity_budget
recycling_capacity_pressure = Waste_recycled/Recycling_capacity
Regional_Budget = 1
fraction_of_waste_recycled_real_data = GRAPH(TIME)
(2010, 0.0944), (2011, 0.11), (2012, 0.13), (2014, 0.131), (2015, 0.125), (2016, 0.128)
Waste_Recycled_Real_data = GRAPH(TIME)
(2010, 246508), (2011, 289151), (2012, 320525), (2014, 312364), (2015, 291649), (2016, 300386)

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