Prioritizing action plans to save resources and better achieve municipal solid waste management KPIs: an urban case study

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Abstract:

The management of municipal solid waste (MSW) in cities is one of the most complex tasks facing local administrations. For this reason, waste management performance measurement structures are increasingly implemented at local and national levels. These performance structures usually contain strategic objectives and associated action plans, as well as key performance indicators (KPIs) for organizations investing their resources in action plans. This study presents the results of applying a methodology to find a quantitative-based prioritization of MSW action plans for the City Council of Castelló de la Plana in Spain. In doing so, cause-effect relationships between the KPIs have been identified by applying the principal component analysis technique, and from these relationships it was possible to identify those action plans which should be addressed first to manage public services more efficiently. This study can be useful as a tool for local administrations when addressing the actions included in their local waste plans as it can lead to financial savings.

Keywords: MSW; action plans; KPIs; principal component analysis

1. Introduction

The increasing amount of food waste generated as a direct consequence of excessive production, mismanagement, and wasteful behavior is a challenge when promoting resource efficiency (Facchini et al., 2018). One of the objectives of European policy on waste is to move towards a circular economy (Ferronato et al., 2019). Since the publication of the community waste management strategy in 1989, the implementation of principles for material circularity and waste management has been intensifying (Singh & Ordoñez, 2016). Furthermore, governments around the world have long been committed to developing plans for the sustainable use of resources by strategies that affect waste management (Wilson et al., 2001).

In Spain, these directives have had a direct impact on municipalities, and they have been required to develop local waste management plans and programs (Spain, 2022). These plans establish the conditions and means to manage the waste produced by the activities of a city – with priority on source reduction. These plans and programs are well monitored and managed when an adequate key performance indicator (KPI) grid for assessing, controlling, and improving effectiveness is defined (de Pascale et al., 2021). Additionally, the KPIs are an element of a performance measurement structure that usually includes both objectives and action plans.

When looking at performance measurement (PM) theory and, more specifically, at the best-known and applied PM framework, the Balanced Scorecard (Kaplan & Norton, 1992), organizations interpret their strategic definition (mission, vision, and values) to firstly define their strategic objectives (what to reach) and then define action plans (how the strategic objective will be reached) and KPIs (to indicate whether the strategic objective is being reached). However, public administrations do not usually follow this performance measurement structure. These organizations manage their performance only using KPIs, and when they define the whole measurement structure, they do not apply the tools available to improve effectiveness.

There are many academic works focused on assessing sustainability KPIs (Hristov & Chirico, 2019; Kylili et al., 2016; Pinna et al., 2018; Valencia et al., 2022) including waste management KPIs (Ferreira et al., 2020). However, these works usually only address the tasks of definition and historical data collection for KPIs, and do not carry out a sound analysis of the evolution of the values of the KPIs, nor apply appropriate mathematical techniques to identify additional information for making better decisions. These practices are therefore far from being the most efficient way to proceed. In most cases, the KPIs are usually related (Carlucci, 2010), which means that changes in the values of some KPIs produce changes in the values of other KPIs – and so change the performance of the system. Further, the identification of cause-and-effect relationships between the KPIs makes it possible to prioritize actions plans and improve the effectiveness of the whole performance system structure – as decision-makers can apply actions that enable reaching associated strategic objectives, as well as other resource-saving objectives.

This work refers to a case study in the city of Castelló de la Plana (Spain), and its main contributions are the following: a) it identifies and classifies the principal KPIs for municipal solid waste (MSW) management at the local level in the three dimensions of sustainability; b) it identifies, by applying the historical data collected by the KPI statistical techniques, the main intra and extra dimensional cause-effect relationships between KPIs; c) it prioritizes the action plans, based on these cause-effect relationships, which help optimize municipal resources since it may not be necessary to activate every action plan to reach the KPI targets – and thereby improving the efficiency of local MSW management.

The remainder of this paper is structured as follows: Section 2 provides a background of previous academic works on waste management and performance measurement. The research approach is presented in Section 3, and Section 4 shows and discusses the main results of applying such a methodology to the city of Castelló de la Plana (Spain). Finally, Section 5 provides the main conclusions, describes the limitations of the study, and suggests further research work.

2. Background

Planning in the provision of public services is becoming increasingly frequent, and so the use of indicators to measure performance has also become widely used in the local sphere. Studies have been made on using KPIs in urban design (Mosca & Perini, 2022), transport (Grote et al., 2021), communications (Imoize et al., 2022), wastewater treatment (van Schaik et al., 2021), air quality (Malm et al., 2018) and MSW management (Ferreira et al., 2020).

Focusing on the latter issue, during the last five years there have been more than 3,000 references to KPIs dealing with MSW management. Some of these works focus on a specific perspective of the problem, such as the social (Ibáñez-Forés et al., 2019), the economic (Zhou et al., 2022), or the fractions that have been increasing most rapidly in recent years (Brouwer et al., 2019); while others evaluate the overall efficiency of the system (Amaral et al., 2022). There are also studies that summarize the literature about MSW KPIs and establish commonalities between different countries and years (Deus et al., 2019; Olay-Romero et al., 2020). Some go even further and use literature from other subjects for the development of communication campaigns (de Feo et al., 2019) or educational applications (Pappas et al., 2021).

However, only a few studies (Nemmour et al., 2022) analyze the relationship between indicators for waste management. Although these KPIs are often related, it is important to understand these relationships for efficient decision-making processes (AlHumid et al., 2019; Loizia et al., 2021) as well as in the management of available resources (Stricker et al., 2017).

Several studies can be found that apply statistical techniques to identify KPI cause-effect relationships in MSW management. For instance, (Hatik & Gatina, 2017) used principal component analysis (PCA) to identify similarities between local administrative areas for comparing waste composition; (Callas et al., 2012) defined an indicator of solid waste generation potential in the USA using principal component analysis and geographic information systems; (Liu et al., 2023) assessed soil pollution and identified potential sources of heavy metals with a combination of a spatial distribution and the principal component analysis model. Other studies about waste management use correlation analysis, (Barbudo et al., 2012) for example, assessed the correlation between sulphate content and leaching of sulphates in recycled aggregates from construction and demolition wastes; and (Birgen et al., 2021) developed a data analysis method based on correlations applied to waste-to-energy plants; and (Zhang et al., 2023) recently used correlational analysis to observe how digestion temperature affects the anaerobic digestion of food waste.

Finally, although there are several studies about how to undertake action plans in local waste management plans or programs, most are limited to a descriptive analysis (Asibey et al., 2021) or, at best, they use multi-criteria techniques (Andrade Arteaga et al., 2020; Coban et al., 2018;

Habibollahzade & Houshfar, 2020) that are limited to expert opinions (instead of real data collected by KPIs) and are therefore completely subjective.

Some academic works from other disciplines have discussed identifying and quantifying KPI cause-effect relationships with statistical techniques to improve decision-making processes. For instance, (Rodríguez-Rodríguez et al., 2020a) applied PCA and partial least squares models to draw a KPI cause-effect map for supply chains to improve operational efficiency; (Sanchez-Marquez et al., 2018) used KPI relationships to deal with data uncertainty; (Cai et al., 2009) identified KPI relationships to improve supply chain performance by analyzing iterative KPI accomplishment.

In the context of MSW management, there are no academic works that have applied statistical techniques to historical KPI datasets to identify cause-effect relationships – and then used this information to prioritize action plans within a performance measurement structure. Once this research gap has been highlighted, the next point presents the research approach followed.

3. Research approach

3.1. Research methodology and objectives

This research identifies the main cause-effect relationships among sustainability KPIs by analyzing the evolution of the historical data. Once the meaningful relationships have been indicated, they are projected to the action plan level, and it is then possible to rank these plans and establish which should be activated first to achieve the main KPIs.

The main research objectives are: 1) analyze the historical data collected by a set of sustainability KPIs and find sound cause-effect relationships; 2) establish which are the most important KPIs to be achieved (effect KPIs) within the KPI set; 3) establish the cause KPIs that strongly affect the effect KPIs; 4) identify the action plans that should be activated first to ensure that the effect KPIs are achieved and so save resources.

The adopted research methodology is the case study, which is adequate for the decision-making involved in this research as it can provide answers to ‘why’ and ‘how’ (Yin, 2014). Additionally, as mentioned in other academic works (Lancaster, 2007; Leon et al., 2020), the quantitative approach taken in this research is adequate as it: 1) focuses on establishing causal relationships among variables (KPIs); 2) and presents a study based on the application of statistical techniques (PCA) to find meaningful relationships among KPIs.

3.2. Methodology

Figure 1 shows the methodology developed for this research; the main steps are the following:

- Expert group definition.
- KPIs and action plan selection.
- Data matrix.
- Data analysis.
- Results discussion.

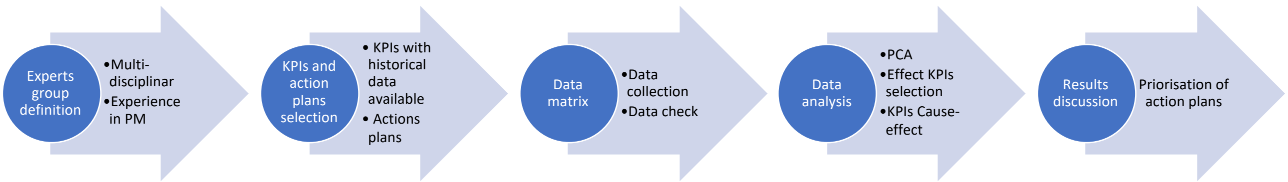

Figure 1. Research methodology

This is a sequential methodology, where the outputs of one phase are the inputs of the following phase (as presented below).

<u>Phase 1. Expert group definition</u>

An expert group is formed of the decision-makers who conduct the phases of the next methodology. The expert group should be both multi-disciplinary and experienced in waste management and performance measurement, mainly dealing with the definition of strategic objectives, KPIs, and action plans.

<u>Phase 2. KPIs and action plan selection</u>

The expert group selects the KPIs and action plans of the performance structure to be included within the study. The selected KPIs must: 1) have collected historical data during some of the previous time periods; 2) be linked to strategic objectives; 3) be grouped into the three dimensions of sustainability: economic (E), social (S), and environmental (ENV).

Phase 3. Data matrix

The data matrix includes the study variables (KPIs) in columns and observations in rows. Each intersection of this matrix contains the historical value of the KPI, which was collected within the period of observation. Additionally, since it is highly likely that KPIs have different collection frequencies, it is necessary to choose a common frequency and bring all the values to that frequency. For instance, the data coming from the KPIs in an annual analysis will be homogenized to an annual frequency, and it is necessary to apply different operations to the data of each KPI (for instance, the simple average) when its frequency is other than annual. The resulting frequency standardized matrix is then used for data analysis. Additionally, decision-makers will assess this data matrix from a global standpoint and may exclude some KPIs that do not have enough recent historical data or present irregularities.

Phase 4. Data analysis

Once that the frequency standardized matrix has been calculated, it is possible to apply a statistic technique to identify relationships between the variables (KPIs in our case). Principal component analysis (PCA) is then applied to identify the main cause-effect among the data matrix KPIs. This technique has already proven its efficiency in analyzing the conjoint evolution of variables (KPIs) and the identification of meaningful cause-effect relationships in the context of this research – such as: the relative lack of historical observations of the variables compared with the number of variables; missing data in some of the time periods; and various measurement units of variables such as monetary (euros), time (minutes, hours, days, etc.) or rates (percentages) (Jackson, 2003; Rodríguez-Rodríguez et al., 2020a; Wold et al., 2001). From the application of the PCA, the expert group will be able to identify the KPIs that are maintaining meaningful cause-effect relationships over time; in other words, changes in the values of some KPIs lead to changes in the values of other KPIs. Once the correlated KPIs have been identified, the decision-makers in the expert group choose which of these KPIs are the most important (effect KPIs) from an organizational point of view (sustainability in this research) and then identify the main cause KPIs associated with these effect KPIs. The main steps to apply are:

- Take the initial frequency standardized matrix (study variables, KPIs, in columns and observations in rows).
- Apply statistical software that supports PCA analysis.
- Decide, regarding the data variability explained, how many principal components to retain for the study.
- Identify the KPIs that are forming each of the retained principal components.
- Define the most important KPIs to be reached (the effect KPIs).
- Identify which are the KPIs (called cause KPIs) that most influence these effect KPIs.

Phase 5. Results discussion

Based on the results achieved in the previous phase, decision-makers will be able to identify the action plans that are associated with the strategic objectives linked to both the cause-and-effect KPIs. They can then establish an activation prioritization of such action plans: firstly, the action plans associated with the strategic objectives linked to the KPIs that have more impacts on the most important effect KPIs; secondly, the action plans associated with the strategic objectives linked to the most important effect KPIs; and thirdly, the remaining action plans associated with the strategic objectives linked to other KPIs. By carrying out this activation prioritization of the action plans, decision-makers will improve the probability of achieving the values of the most important effect KPIs, as well as saving organizational resources when achieving the strategic objectives.

4. Case study

4.1. Case study description

The case study was developed at Castelló de la Plana City Council which had just approved its local waste management plan. Castelló de la Plana is a Spanish Mediterranean city, capital of the province of Castellón, in the north of the Valencia Region, and has a population of 172,589 (INE, 2021). Waste generation in the city exceeds 1.25 kg per resident/day and waste collection is divided into five fractions (glass, packaging, paper & cardboard, biowaste, and mixed MSW) according to current regulations (Spain, 2022). The city also has a network of recycling centers, both fixed and mobile, for depositing specific waste either because of its volume (e.g., household appliances) or its hazardous nature (e.g., engine oils, solvents, X-ray sheets). Finally, it has a small number of specific bins for the collection of cooking oil, textiles, and batteries, respectively. With all these resources, the current separation rate at source is 15.30% by weight of the MSW managed.

Mixed MSW is the majority fraction by weight and is deposited in ‘all-in-one’ containers. These are collected with a rear-loading and side-loading collection service structured in 14 daily routes. Selective biowaste collection is carried out through six routes, with alternative frequencies, and contributes 3.66% of the total municipal weight. For the selective collection of paper & cardboard, which represents 3.59% of the total by weight, the service has three top-loading and one side-loading collection trucks, as is the case with the selective collection of packaging, which contributes 2.36% of the total municipal waste weight. The average collection frequency is three days a week. The fraction with the lowest percentage by weight of the total is glass (2.27%) , whose collection is carried out with top-loading collection trucks once a fortnight.

Regarding the main MSW fractions treatment: packaging, paper & cardboard, and glass are deposited directly at the facilities of the recyclers for sorting. Mixed MSW and biowaste collected in the city are deposited at the transfer plant of a provincial public company that manages the treatment and valorization of these fractions (covering 63% of the province's population). In this plant, bulky and improperly disposed of waste in containers is separated and the rest is compacted for transport to a composting plant. Once the waste arrives in the composting plant, the usual mechanical and biological treatments are carried out. MSW is subjected to various mechanical treatments for the recovery of metals, plastics, paper, etc. The remaining organic matter and biowaste that are collected selectively are aerobically processed through fermentation, maturation, and refining. Due to the age of the facilities, the current rejection rate is near 75% (Reciplasa, 2023) and the final destination is a controlled landfill.

4.2. Case study development

Phase 1. Expert group definition

To apply the methodology, a group of experts was created that included: three senior managers (one from each of the three main MSW management companies in Eastern Spain); two municipal engineers; a PhD engineer from the Universitat Jaume I; two PhDs engineers from the Universitat Politècnica de València; two local political representatives; and four environmental educators from the provincial MSW management board. All decisions were made consensually.

The expert group had four face-to-face meetings within a period of three months.

Phase 2. KPIs and action plan selection

From a performance measurement perspective, the Castelló de la Plana City Council had defined the following elements in its 2022 local waste management plan (Ajuntament de Castelló, 2022):

- 36 strategic objectives.
- 98 action plans
- 36 KPIs.

An informative meeting was first held with the experts to gather data. The main objective was to obtain initial proposals for KPIs and group them into the three dimensions of sustainability. Such a proposal was written and explained by the facilitator and then emailed to the experts. Table 1 presents the description of the 36 KPIs classified into three sustainability dimensions.

Table 1. KPIs description

Indicator	Description	Indicator	Description
E1	Cost of the biowaste collection service per resident and year (€/res.)	S6	Number of public contracts that incorporate sustainability criteria in waste management (unit)
E2	Cost of the container collection service per resident and year (€/res.)	S7	Average time for resolution of complaints in a year (days)
E3	Cost of the paper & cardboard collection service per resident and year (€/res.)	ENV1	Collection service emissions per year (kg CO^2/res.)
E4	Cost of the mixed waste collection service per resident and year (€/res.)	ENV2	Annual water footprint of the waste collection service (liters/res.)
E5	Cost of the glass waste collection service per resident and year (€/res.)	ENV3	Selective collection of biowaste percentage with respect to total household waste (%)
E6	Cost of the mixed waste disposal service per resident and year (€/res.)	ENV4	Selective collection of packaging percentage with respect to total household waste (%)
E7	Cost of the mixed waste transfer service per resident and year (€/res.)	ENV5	Selective collection of paper & cardboard percentage with respect to total household waste (%)
E8	Annual cost of maintenance and cleaning of packaging containers per resident and	ENV6	Selective collection of glass percentage with respect to total household waste (%)

	year (€/res.)		
E9	Annual cost of maintenance and cleaning of paper & cardboard containers per resident and year (€/res.)	ENV7	Percentage of waste collected selectively in the recycling center, compared to the city total (%)
E10	Annual cost of maintenance and cleaning of glass containers per resident and year (€/res.)	ENV8	Emissions from recovery and elimination of biowaste (kg CO^2/res)
E11	Annual cost of maintenance and cleaning of mixed waste containers per resident and year (€/res.)	ENV9	Emissions from recovery and disposal of packaging waste (kg CO^2/res.)
E12	Annual investments for waste management improvement projects per resident and year (€/res.)	ENV10	Emissions from recovery and elimination of paper & cardboard waste (kg CO^2/res.)
E13	Annual investment in awareness campaigns per resident and year (€/res.)	ENV11	Emissions from recovery and disposal of glass waste (kg CO^2/res.)
S1	Number of people participating in campaigns per year (unit)	ENV12	Number of batteries collected selectively per year (kgs/res.)
S2	Number of sanctions applied per year (unit)	ENV13	Amount of vegetable oil collected selectively per year (gr./res.)
S3	Number of complaints received per year (unit)	ENV14	Percentage of complete contribution areas with all the fractions with respect to the total number of collection areas (%)
S4	Number of interactions due to the impact of communication campaigns in social media (unit)	ENV15	Amount of textile waste collected per year (kgs/res.)
S5	Number of adapted containers available for residents with functional diversity per year (unit)	ENV16	Number of uncontrolled waste dumping points in the city

Table 2 describes the 36 strategic objectives and their 98 associated action plans, as well as their link to the KPIs.

The KPIs were then linked with the objectives and associated action plans shown in Table 2.

Table 2: KPIs, objectives, and associated action plans.

Indicator	Objective	Action plans
E1	In five years, do not exceed a 15% increase in the annual cost of collecting this fraction in 2022	1. Study the implementation of new collection systems for which better separation ratios were verified 2. Promote and subsidize home and community composting. 3. Support the financing of a new specific transfer plant for biowaste.
E2	In five years, do not exceed a 25% increase in the annual cost of collecting this fraction in 2022	1. Increase the number of packaging containers and reach the average number for the region. 2. Install a monitoring system for packaging containers by installing fill-level sensors. 3. Promote the use of reusable packaging and bulk products.
E3	In five years, do not exceed a 25five% increase in the annual cost of collecting this fraction in 2022	1. Expand the supply of paper & cardboard containers until reaching the average supply of the region. 2. Install a monitoring system for paper & cardboard containers by installing fill-level sensors. 3. Expand commercial participation in door-to-door collection systems.
E4	In five years, reduce the costs of collecting the mixed fraction by 20%	1. Reduce the number of mixed waste containers to promote the use of separative containers. 2. Homogenize containerization to optimize collection routes. 3. Implementation of payment for the generation of mixed waste.
E5	In five years, do not exceed a 25% increase in the annual cost of collecting this fraction in 2022	1. Expand the supply of glass containers to reach the average supply of the region. 2. Install a monitoring system for glass containers by installing fill-level sensors. 3. Optimization of routes and frequencies of collection of this waste.
E6	In five years, do not exceed the annual cost of disposing this fraction in 2022	1. Implement an electronic container closure and user identification system in certain areas. 2. Optimize the warning system and programming of scheduled and unscheduled bulky waste collection routes. 3. Promote the reduction of waste generation through campaigns and incentives.
E7	In five years, do not exceed the	1. Optimize the distribution, routes, and collection frequencies of this fraction to conduct the

	annual cost of collecting this fraction in 2022	collections when containers are full. 2. Modernize the waste management process at the transfer plant to optimize the system and improve its performance. 3. Study and project an optimal location for a new transfer plant.
E8	In five years, do not exceed a 15% increase in the annual cost of maintenance and cleaning of containers for this fraction in 2022	1. Reduce water consumption by cleaning packaging containers using machinery with water-saving technological solutions. 2. Implement an inspection system for light packaging containers that makes it possible to establish optimal cleaning frequencies. 3. Install an internal temperature monitoring system for packaging containers and an accelerometer to prevent failures.
E9	In five years, do not exceed a 15% increase in the annual cost of maintenance and cleaning of containers for this fraction in 2022	1. Reduce water consumption for cleaning paper & cardboard containers by using machinery with water-saving technological solutions. 2. Implement an inspection system for paper & cardboard containers that makes it possible to establish optimal cleaning frequencies. 3. Install an internal temperature monitoring system for packaging containers and an accelerometer to prevent failures.
E10	In five years, do not exceed the annual cost of maintenance and cleaning of containers for this fraction in 2022	1. Reduce water consumption for cleaning glass containers by using machinery with water-saving technological solutions. 2. Implement an inspection system for glass containers that makes it possible to establish optimal cleaning frequencies. 3. Install an internal temperature monitoring system for packaging containers and an accelerometer to prevent failures.
E11	In five years, do not exceed the annual cost of maintenance and cleaning of containers for this fraction in 2022	1. Reduce water consumption for cleaning biowaste containers by using machinery with water-saving technological solutions. 2. Conduct awareness campaigns on the use of closed bags for the deposit of waste in the container. 3. Introduce container model with fewer mobile elements.
E12	In five years, increase by 10% the resources allocated to investments in I+D+I projects	1. Install door-to-door systems in certain areas of the city for the fractions of biowaste, packaging, paper & cardboard, and mixed waste. 2. Implement positioning and control tools in the vehicle fleet. 3. Plan for the creation of complete collecting areas in industrial areas.
E13	In five years, reach an expense per resident and year of 0.5 euros	1. Carry out at least four campaigns a year on the prevention and separation of waste. 2. Carry out a pilot campaign on the collection of medical waste. 3. Modernization of municipal websites and social networks.
S1	In five years, reach 20,000 annual participants	1. Distribution of materials to promote separation at source. 2. Maintain an environmental education team made up of five members. 3. Improve dissemination of positive results and legal waste obligations.
S2	In five years, do not having exceeded the number of sanctions applied during the year 2022	1. Implement a control system for uncontrolled dumping points (reinforcement with drones). 2. Develop a disciplinary procedure in the new ordinance on waste management. 3. Educate on waste management.
S3	In five years, not having exceeded an increase of more than 10% in complaints received during the year 2022	1. Teach collection drivers about more efficient driving that reduces noise pollution. 2. Conduct campaigns that promote the use of the recycling center against the uncontrolled dumping of large volume waste. 3. Avoid container overflow with adequate containerization and collection frequencies.
S4	In five years, increase citizen participation in social media to 4,000 interactions per year	1. Design a social media communication plan that publishes information on the prevention and separation of waste with a suitable frequency. 2. Update the corresponding sections of the city council website that include information on waste management.
S5	In five years, having adapted 200 containers for people with functional diversity compared to those existing in 2022	1. Detect the locations where there is a need to have adapted containers. 2. Adapt and install at least 200 selective containers for packaging, paper & cardboard, and glass. 3. Improve container renewal frequency.
S6	In five years, reach 30 contracts per year that include sustainability criteria	1. Teach sustainability waste criteria to city council technicians who conduct public bidding processes 2. Design and publish a practical guide on sustainability criteria. 3. Promote sustainability criteria to construction contracts especially focused on waste separation.
S7	In five years, improve the citizen support systems to resolve every complaint within 15 days	1. Implement a procedure for handling complaints and provide the corresponding training to personnel assigned to these tasks. 2. Strengthen coordination between the service concession company and the city council by installing standardized procedures and geolocalization.
ENV1	In five years, not having exceeded a 5% increase in emissions compared to those of 2022	1. Replace 50% of the fleet of diesel and/or gas vehicles with other less polluting technologies. 2. Teach collection drivers efficient driving that reduces emissions. 3. Conduct proper vehicle maintenance and a renovation plan.
ENV2	In five years, have half the annual consumption of drinking water compared to 2022	1. Use of reclaimed water in areas of the city where this network exists. 2. Teach workers water-saving techniques. 3. Optimize cleaning frequencies so that they are carried out only when strictly necessary.
ENV3	In five years, increase the percentage of collection of this fraction by 10% compared to 2022	1. Install an electronic closure system for biowaste containers and user identification in certain areas. 2. Carry out a study on the characterization of biowaste for one year. 3. Design a campaign adapted to the need to reduce improper detections, if necessary.
ENV4	In five years, increase the collection percentage of this fraction by 10% compared to 2022	1. Install at least three mobile platforms in the city center area to deposit the separative fractions. 2. Promote selective collection at events by placing containers and their subsequent collection. 3. Carry out communication and environmental education campaigns for the correct separation of packaging waste.
ENV5	In five years, increase the collection percentage of this fraction by 10% compared to 2022	1. Expand the paper and cardboard waste door-to-door collection system to the entire downtown district, as well as the central area. 2. Strengthen the collection during the annual periods of greatest production by increasing the

		paper & cardboard fraction collection frequencies. 3. Carry out communication and environmental education campaigns for the correct separation of paper & cardboard waste.
ENV6	In five years, increase the collection percentage of this fraction by 10% compared to 2022	1. Implement a door-to-door glass collection system for hotels and restaurants that generate more than 25 kgs per week. 2. Glass waste separation plan at events through the temporary relocation of containers adapted to large producers. 3. Carry out communication and environmental education campaigns for the correct separation of glass waste.
ENV7	In five years, increase the collection percentage in the recycling center by 15% compared to 2022	1. Information campaign on the different locations and hours of the recycling centers through signposting of the locations, billboards, publications on social media and street action. 2. Carry out a campaign on pruning waste that encourages the use of the recycling center for this type of waste. 3. Install a computerized user identification system in the recycling center, which complies with the legislation regarding the collection of home appliances.
ENV8	In five years, do not exceed a 20% increase in emissions compared to those of 2022	1. Implement self-composting in at least 50% of urban gardens, infant and primary schools. 2. Implement self-composting in at least 25% of single-family homes. 3. Develop campaigns to avoid food waste that involve the reduction of biowaste management.
ENV9	In five years, do not exceed a 20% increase in emissions compared to those of 2022	1. Implement the container return system in certain areas of the city. 2. Carry out information campaigns that reduce the number of improper materials collected in packaging containers. 3. Encourage the use of glass packaging.
ENV10	In five years, do not exceed a 20% increase in emissions compared to those of 2022	1. Install cardboard compactors in high production areas of this waste such as industrial estates or shopping streets. 2. Inform large paper & cardboard producers of the schedules and collection points that were defined to optimize collection routes. 3. Establish a circuit between commerce and cardboard manufacturers to promote the circular economy.
ENV11	In five years, do not exceed a 20% increase in emissions compared to those of 2022	1. Optimize the distribution, routes, and collection frequencies of this fraction to carry out collections when the container is full. 2. Promote the refund and return system in hotels and restaurants to optimize the return rate through information campaigns and delivery of materials.
ENV12	In five years, reach an annual amount collected from this fraction of 1kg/res/year	1. Carry out an information campaign through street actions to publicize the locations and importance of separating batteries. 2. Implement a bonus system for the delivery of batteries in the recycling centers.
ENV13	In five years, reach an annual amount collected from this fraction of 200 g/res in a year	1. Study the distribution of oil containers and relocate, if necessary, to reach a coverage of 100% of the city. 2. Carry out an information campaign that includes the delivery of funnels to reach at least 13,000 households. 3. Reinforce the mobile recycling center services.
ENV14	In five years, at least 21% of the locations where there is a biowaste container will be full collection areas	1. Move the necessary containers of packaging, paper & cardboard, glass and mixed waste to create at least 230 complete contribution areas from the locations of the biowaste containers. 2. Implement closed contribution areas with access control for five fractions of waste in residential estates (mixed waste, biowaste, packaging, paper & cardboard and glass). 3. Reduce the number of containers for the mixed fraction.
ENV15	In five years, reach an annual amount collected from this fraction of 4.3kg/res in a year	1. Increase the number of containers until it reaches the average for the region. 2. Design a campaign to promote the use of textile containers for companies that produce this type of waste. 3. Conduct communication and environmental education campaigns for the separation of textiles.
ENV16	In five years, reduce 30% the number of illegal dumping points	1. Increase surveillance through police collaboration. 2. Removal of containers where this problem exists. 3. Promotion of the use of recycling centers.

Phase 3. Data matrix

In this phase, annual data for the 36 KPIs was collected and the resulting data matrix is presented in Table 3, where it is possible to observe the 36 KPIs of the study in rows, observations in columns, and the historical value of these KPI for the years 2017-2022.

Table 3: Historical values KPIs

Indicator	Description	2017	2018	2019	2020	2021	2022
E1	Cost of the biowaste collection service per resident and year (€/res.)	-	-	-	1.77	5.38	5.38
E2	Cost of the container collection service per resident and year	2.48	2.49	2.51	2.71	3.34	4.29

	(€/res.)						
E3	Cost of the paper & cardboard collection service per resident and year (€/res.)	3.22	3.24	3.25	3.15	3.16	3.76
E4	Cost of the mixed waste collection service per resident and year (€/res.)	31.55	31.70	31.86	30.32	29.33	34.71
E5	Cost of the glass waste collection service per resident and year (€/res.)	0.65	0.65	0.66	0.64	0.64	0.75
E6	Cost of the mixed waste disposal service per resident and year (€/res.)	32.00	32.40	33.46	33.17	36.57	38.87
E7	Cost of the mixed waste transfer service per resident and year (€/res.)	5.65	5.72	5.90	5.85	6.45	6.86
E8	Annual cost of maintenance and cleaning of packaging containers per resident and year (€/res.)	0.52	0.52	0.53	0.59	0.77	1.01
E9	Annual cost of maintenance and cleaning of paper & cardboard containers per resident and year (€/res.)	0.52	0.52	0.53	0.51	0.52	0.64
E10	Annual cost of maintenance and cleaning of glass containers per resident and year (€/res.)	0.52	0.52	0.53	0.51	0.51	0.60
E11	Annual cost of maintenance and cleaning of mixed waste containers per resident and year (€/res.)	4.67	4.69	4.72	4.57	4.58	5.42
E12	Annual investments for waste management improvement projects per resident and year (€/res.)	0.63	0.63	0.62	0.62	0.62	0.62
E13	Annual investment in awareness campaigns per resident and year (€/res.)	0.37	0.37	0.37	0.36	0.37	0.37
S1	Number of people participating in campaigns per year (unit)	7651	2704	28,400	663	16,630	17,720
S2	Number of sanctions applied per year (unit)	2	2	0	1	3	15
S3	Number of complaints received per year (unit)	4182	6606	7013	8331	8833	9996
S4	Number of interactions due to the impact of communication campaigns in social media (unit)	38	27	52	2799	2968	2035
S5	Number of adapted containers available for people with functional diversity per year (unit)	25					
S6	Number of public contracts that incorporate sustainability criteria in waste management (unit)	1	3	5	6	11	12
S7	Average time for resolution of complaints in a year (days)	26.5	23.3	25.2	21.7	18.9	17.6
ENV1	Collection service emissions per year (kg CO^2/res.)	7.54	7.89	8.20	8.52	9.14	9.18
ENV2	Annual water footprint of the waste collection service (liters/res.)	22.35	22.17	22.06	23.28	26.43	26.67
ENV3	Selective collection of biowaste percentage with respect to total household waste (%)	0.00	0.00	0.09	1.26	4.11	4.27

ENV4	Selective collection of packaging percentage with respect to total household waste (%)	1.75	1.96	2.16	2.69	2.74	2.74
ENV5	Selective collection of paper & cardboard percentage with respect to total household waste (%)	3.27	3.62	4.06	4.37	4.32	4.15
ENV6	Selective collection of glass percentage with respect to total household waste (%)	2.01	2.06	2.18	2.65	2.37	2.60
ENV7	Percentage of waste collected selectively in the recycling center, compared to the city total (%)	7.55	9.92	9.74	9.37	10.71	9.59
ENV8	Emissions from recovery and elimination of biowaste (kg CO^2/res)	0.00	0.00	0.12	1,64	5.72	4.94
ENV9	Emissions from recovery and disposal of packaging waste (kg CO^2/res.)	0.81	0.92	1.04	1.20	1.31	1.09
ENV10	Emissions from recovery and elimination of paper & cardboard waste (kg CO^2/res.)	0.71	0.80	0.91	0.92	0.97	0.77
ENV11	Emissions from recovery and disposal of glass waste (kg CO^2/res.)	0.24	0.25	0.27	0.30	0.29	0.26
ENV12	Number of batteries collected selectively per year (kgs/res.)	0.08	0.07	0.08	0.06	0.04	0.04
ENV13	Amount of vegetable oil collected selectively per year (gr./res.)	8.26	38.04	101.28	113.06	112.32	86.08
ENV14	Percentage of complete contribution areas with all the fractions with respect to the total number of collection areas (%)	0.00	0.00	0.00	13.48	14.73	18.07
ENV15	Amount of textile waste collected per year (kgs/res.)	2.50	2.53	2.45	2.68	2.98	2.30
ENV16	Number of uncontrolled waste dumping points in the city	25					

The historical data is a highly compact data matrix, where most the KPIs have historical data for all six years of the study. The exceptions are S5 and ENV16 – which although included in the 2022 planning, were only measured in 2017, and so the expert group decided to exclude them from the next phase of data analysis.

<u>Phase 4. Data analysis</u>

The PCA technique was applied to the data matrix, using SPSS v16.0 and following a rotation method of Varimax normalization and Kaiser criterion. Two principal components were then retained for the study as they explained 99% of the data variability – as shown in Table 4.

Table 4: Data variability explained by the principal components

Components	Eigenvalues		
	Total	% of the variance	% Acumulated

1	25,102	73,830	73,830
2	8,898	26,170	100,000
3	1,365E-15	4,016E-15	100,000
4	8,567E-16	2,520E-15	100,000
5	7,750E-16	2,279E-15	100,000
6	6,812E-16	2,003E-15	100,000
7	5,596E-16	1,646E-15	100,000
8	5,157E-16	1,517E-15	100,000
9	4,019E-16	1,182E-15	100,000
10	3,779E-16	1,111E-15	100,000
11	3,145E-16	9,249E-16	100,000
12	2,998E-16	8,817E-16	100,000
13	2,388E-16	7,023E-16	100,000
14	1,992E-16	5,860E-16	100,000
15	1,734E-16	5,100E-16	100,000
16	1,392E-16	4,094E-16	100,000
17	7,346E-17	2,161E-16	100,000
18	5,322E-17	1,565E-16	100,000
19	1,958E-17	5,759E-17	100,000
20	-3,657E-17	-1,075E-16	100,000
21	-4,082E-17	-1,201E-16	100,000
22	-9,379E-17	-2,758E-16	100,000
23	-1,627E-16	-4,786E-16	100,000
24	-1,779E-16	-5,232E-16	100,000
25	-2,016E-16	-5,928E-16	100,000
26	-2,404E-16	-7,070E-16	100,000
27	-3,268E-16	-9,613E-16	100,000
28	-3,514E-16	-1,033E-15	100,000
29	-4,047E-16	-1,190E-15	100,000
30	-4,462E-16	-1,312E-15	100,000
31	-5,073E-16	-1,492E-15	100,000
32	-6,138E-16	-1,805E-15	100,000
33	-7,634E-16	-2,245E-15	100,000
34	-1,352E-15	-3,977E-15	100,000

The two principal components retained for the study are formed by the KPIs, and it is possible to identify which of these two principal components contribute most by making a graphical analysis of the orthogonal situation of the KPIs within the two principal components (see Figure 2).

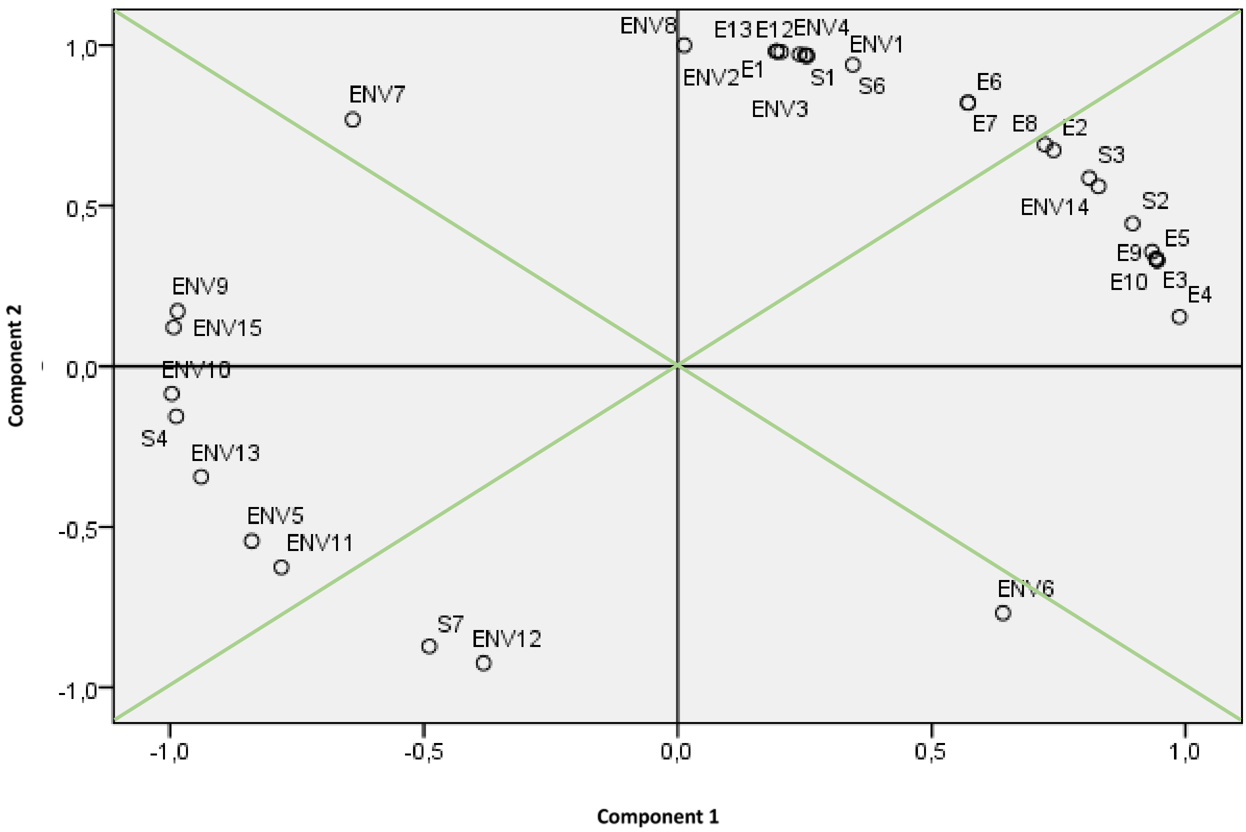

Figure 2. Graphic shows the KPI orthogonal situation within the principal components.

By considering the 45º line from the origin (in green in Figure 2), it is possible to classify an orthogonal distribution of the KPIs into one of the two principal components depending on which principal component is closest. Figure 2 shows how the variables (KPIs) are graphically situated within two principal components: PC1 on the x-axis and PC2 on the y-axis. Each KPI contributes to the formation of the principal components, but they can be classified as more related to one of the principal components than to another depending on the graphical proximity. Two green lines have been added to the graph to make it easier to understand to which principal component each KPI is closest:

- Principal component 1 (x-axis): E2, E3, E4, E5, E8, E9, E10, E11, S2, S3, S4, ENV5, ENV9, ENV10, ENV11, ENV13, ENV14, ENV15.
- Principal component 2 (y-axis): E1, E6, E7, E12, E13, S1, S6, S7, ENV1, ENV2, ENV3, ENV4, ENV6, ENV7, ENV8, ENV12.

The expert group used its experience and knowledge of the organization’s waste management process (past and present) to identify which of the effect KPIs are most important:

- E6: This KPI represents the cost of the mixed waste disposal service per resident and year expressed in €/res. These costs include labor, materials, machinery, and indirect costs of the disposal plant for one year. Once the total cost has been obtained, it is divided by the population registered in the municipality for the year of measurement.
- S1: This KPI represents the number of people participating in each of the environmental awareness campaigns carried out in the city during a year.
- S3: This KPI measures the annual number of complaints received by the council regarding waste management (location, quantity, cleanliness and maintenance of containers, transit of the vehicle fleet, uncontrolled dumping, recycling center services, etc.).
- ENV1: This KPI represents the annual amount of CO^2 emissions (kgs) emitted by the collection services per resident. It is calculated from the sum of emissions (produced by the fractions of mixed waste, biowaste, packaging, paper & cardboard, and glass) and divided by the total population.
- ENV2: This KPI refers to the total volume of fresh clean water used by the waste collection service for cleaning containers and vehicles.
- ENV3: This KPI is the ratio obtained by dividing the annual amount of biowaste collected by the total annual amount of containerized waste collected (mixed waste, biowaste, packaging, paper & cardboard and glass).
- ENV14: This KPI is the ratio obtained from the number of complete (all waste fractions) containerized areas with respect to the total number of points on the public road with single containers (biowaste, packaging, paper & cardboard, and glass).

Once this is done, it is time to identify the main cause KPIs associated with the effect KPIs. Figure 2 shows the symmetric position of the KPIs with respect to the axes and so reveals the groups of KPIs with a higher cause-effect correlation (Jackson, 2003). For the effect KPIs, Table 5 shows the meaningful relationships between KPIs (in columns) and the seven identified effect KPIs and the main cause KPIs (in rows). This Table has been derived by following analytical procedures. Based on the results shown in the previous figure, and following the PCA basis, it is possible to identify the variables that are maintaining some meaningful relationships over time. These variables are those that are grouped around a principal component standing directly together and symmetrically. For instance, regarding the KPI E6 (column 'Effect KPI E6' in Table 5), which is defined as one of the most important KPIs, the KPIs that are closest graphically are:

- Directly: E1, E7, E8, E12, E13, S1, S6, ENV1, ENV2, ENV3 and ENV4.
- Symmetrically: S7 and ENV12.

Table 5. Cause-effect relationships between KPIs.

Cause KPI	Effect KPI E6	Effect KPI S1	Effect KPI S3	Effect KPI ENV1	Effect KPI ENV2	Effect KPI ENV3	Effect KPI ENV14
E1	X	X		X	X	X	
E2			X				X
E3			X				X
E4			X				X
E5			X				X
E6		X		X	X	X	
E7	X	X		X	X	X	
E8	X	X	X	X	X	X	X
E9			X				X
E10			X				X
E12	X	X		X	X	X	
E13	X	X		X	X	X	
S1	X			X	X	X	
S2			X				X
S3							X
S4			X				X
S6	X	X		X	X	X	
S7	X	X		X	X	X	
ENV1	X	X			X	X	
ENV2	X	X		X		X	
ENV3	X	X		X	X	X	
ENV4	X	X		X	X		
ENV5			X				X
ENV10			X				X
ENV11			X				X
ENV12	X	X		X	X	X	
ENV13			X				X
ENV14			X				

The relationships established above show that E8 is the KPI cause with the greatest influence (influencing all seven effect KPIs). After this, the following KPI causes stand out: E1, E7, E12, E13, S6, S7, ENV3 and ENV12, as well as those which influence five effect KPIs (E6, S1, ENV1, ENV2, ENV3). There is a group of KPIs (E6, S1, ENV1, ENV2, ENV4) that influences four effect KPIs and another group of KPIs (E2, E3, E4, E5, E9, E10, S2, S4, ENV5, ENV10, ENV11, ENV13) that influence two effect KPIs. The following phase establishes specific organizational recommendations that arise from this data analysis.

<u>Phase 5. Results discussion</u>

Based on the results achieved in the previous phase, decision-makers were able to identify the action plans that are associated with the strategic objectives linked to both the cause-and-effect KPIs. From analyzing the results of Table 5, the cause KPIs are ranked from more to less influence (measuring this influence as the number of effect KPIs they influence). E8 is the most influential cause KPI, as it influences all seven effect KPIs. This means that the three action plans that are associated with the strategic objective that E8 is measuring (namely, 'do not exceed in five years a 15% increase in the annual cost of maintenance and cleaning of containers for this fraction in 2022') should be activated first, as these action plans will contribute to reaching the strategic objective – as well as those associated with the effect KPIs that E8 is directly affecting:

- E6: cost of the mixed waste disposal service per resident and year.
- S1: number of people participating in campaigns per year.
- S3: number of complaints received per year.
- ENV1: collection service emissions per year.
- ENV2: annual water footprint of the waste collection service.
- ENV3: selective collection of biowaste percentage with respect to total household waste.
- ENV14: percentage of complete contribution areas with all the fractions with respect to the total number of collection areas.

Table 6 shows the action plan prioritization produced when carrying out this analysis for all the identified cause KPIs. Table 6 also shows the main KPI causes identified (E8, E1, E7, E12, E13, S6, S7, ENV3 and ENV12), the KPIs they affect (from the seven identified in the previous phase as the most important to be achieved), and the 25 action plans associated with the strategic objectives of the cause KPIs. These plans are then prioritized in the order of activation.

Table 6: Action plan prioritization

KPI cause	KPI effect	Action plan prioritization
E8	E6, S1, S3, ENV1, ENV2, ENV3, ENV14	1. Reduce water use for cleaning packaging containers by using machinery with water-saving technological solutions. 2. Implement an inspection system for light packaging containers that enables optimal cleaning frequencies. 3. Install an internal temperature monitoring system for packaging containers and an accelerometer to prevent failures.
E1	E6, S1, ENV1, ENV2, ENV3	1. Study new collection systems for better separation ratios. 2. Promote and subsidize home and community composting. 3. Support the financing of a new specific transfer plant for biowaste.

E7	E6, S1, ENV1, ENV2, ENV3	1. Optimize the distribution, routes, and collection frequencies of this fraction to conduct collections when the containers are full. 2. Modernize the waste management process at the transfer plant to optimize the system and improve performance. 3. Study and project an optimal location for a new transfer plant.
E12	E6, S1, ENV1, ENV2, ENV3	1. Install door-to-door systems in certain areas of the city for the fractions of biowaste, packaging, paper & cardboard, and mixed waste. 2. Implement positioning and control tools in vehicle fleet. 3. Plan for the creation of complete collecting areas in industrial areas.
E13	E6, S1, ENV1, ENV2, ENV3	1. Conduct at least four campaigns a year on the prevention and separation of waste. 2. Carry out a pilot campaign on collection of medical waste. 3. Modernization of municipal websites and social networks.
S6	E6, S1, ENV1, ENV2, ENV3	1. Teach city council technicians who conduct public bidding processes about sustainability waste criteria. 2. Design and publish a practical guide on sustainability criteria. 3. Promote sustainability criteria to construction contracts especially focused on waste separation.
S7	E6, S1, ENV1, ENV2, ENV3	1. Implement a procedure for handling complaints and provide the corresponding training to personnel assigned to these tasks. 2. Strengthen coordination between the service concession company and the city council by installing standardized procedures and geo-localization.
ENV3	E6, S1, ENV1, ENV2, ENV3	1. Install electronic closure systems for biowaste containers and user identification in certain areas. 2. Carry out a study on the characterization of biowaste for one year. 3. Design a campaign adapted to the need to reduce improper detections, if necessary.
ENV12	E6, S1, ENV1, ENV2, ENV3	1. Conduct an information campaign through street actions to publicize the locations and importance of separating batteries. 2. Implement a bonus system for delivery of batteries in recycling centers.

Decision-makers will then have available a prioritization of action plans for the whole performance system that have practical and theoretical implications.

Practical implications

The main aim of any performance measurement system is to ensure that the defined strategic objectives are reached in the most efficient way. The proposed methodology provides a novel and efficient approach for MSW decision-makers because it identifies – with the application of objective rather than subjective analytical procedures – the order of activation for action plans associated with strategic objectives. It enables reaching all the defined strategic objectives by activating some of the action plans in the performance measurement system and this can provide the organization with notable resource savings. However, like all performance measurement systems, this approach must consider some specific points from a practical point of view:

- Exogeneous variables/events and how they affect the performance measurement system in the present and future. There are some interesting academic works discussing this point but the approaches are always subjective, as we do not know the future and to what extent external changes will affect future developments/performance.

- As a result of the application of this methodology, some actions plan may not be activated. This will result in cost-savings for the organization, but it is necessary to ensure that all the defined strategic objectives for the period (usually one year) are reached despite the activation of fewer action plans. Otherwise, the application of this methodology will mean that an organization achieves short-term cost savings, but compromises the achievement of other sustainability strategic objectives.
- Additionally, it is necessary to keep in mind that an effective follow-up should be carried out in the short-term to ensure that the activation of these analytically chosen action plans is truly helping achieve all the defined strategic objectives of the performance measurement system.

The application of this methodology provided the Castelló de la Plana city council with an order of activation for its 98 action plans. The council was recommended to first activate the 25 action plans associated with the strategic objectives of the cause KPIs. This will make it possible to achieve the meta values of the cause KPIs they are associated with for strategic objectives – as well as those associated with the effect KPIs. With the initial activation of these 25 action plans, the city council can later check whether it is achieving the meta values of both cause-and-effect KPIs. If so, it would not need to activate the action plans associated with the strategic objectives of the effect KPIs (whose estimated cost is €3.2m for 2022) and the funds could be used elsewhere within the city council. If it is necessary to activate some of the action plans associated with the strategic objectives of the effect KPIs, the council would still save some money if it does not need to activate all of the plans. Therefore, the activation times of the action plans should follow Table 6 and have control and check points.

Theoretical implications

It is well known that numerous aspects (operational, economic, environmental, and social) should be considered for the optimization of MSW systems from collection to ultimate disposal (Teixeira et al., 2014). KPIs are an important tool for evaluating performance, but they provide only partial productivity measurements. Without an appropriate aggregation metric, an analysis of KPIs may result in misleading conclusions about MSW service performance (Ferreira et al., 2020). For this reason, standardized methods – such as life cycle assessment (Feiz et al., 2020), life cycle costing, cost-benefit analysis, risk assessment, eco-efficiency analysis, and social life cycle cost (Allesch & Brunner, 2014) – have frequently been used. In addition to these standardized methods, multi-criteria analysis has become increasingly used in recent years (Andrade Arteaga et al., 2020; Coban et al., 2018; Habibollahzade & Houshfar, 2020) for finding relationships between performance elements. However, multiple-criteria decision analysis always harbors doubts about the subjectivity of expert opinions or about the selection of KPIs (Amaral et al., 2022).

This case study has presented the results of applying a methodology for prioritizing waste management action plans which has proven effective in similar approaches found in the literature (Cai et al., 2009; Rodríguez-Rodríguez et al., 2020b; Sanchez-Marquez et al., 2018) and could become an efficient tool for MSW management. The methodology enables objectifying decision-making since it is based on employing historical data from a wide variety of parameters to establish cause-effect relationships using statistical analysis. Combining KPIs further removes bias in evaluation (De La Barrera et al., 2016), especially when appropriate correlations have been defined for contributing to synergistic decision-making (Papamichael et al., 2022).

The potential limitations of this study are mainly that it is applied to just one waste management organization, and that the results of following the suggested action plan order of activation are unavailable (which would have shown to what extent the intended resource savings are produced). This is relevant because the MSW performance measurement system is multi-dimensional and, as was observed by (Parekh et al., 2015): “the performance of some indicators is influenced by the performance of other indicators, similarly to how the cost of transportation does not only depend on manpower, machinery, spare vehicles but also depends on distance to landfill site, mode of operation i.e., departmental, contractual or public private partnership mode”. This means that the recommended actions must always be followed up.

5. Conclusions, limitations, and future research work

This paper has presented the results of applying a methodology to prioritize the waste management action plans of the Castelló de la Plana City Council in Spain. Such a methodology is based on the performance structure of strategic objectives, action plans, and KPIs – and their structural relationships. For the study, 36 KPIs were classified into three sustainability dimensions and six years of historical values were gathered. The main cause-effect KPI relationships were identified by applying principal component analysis, and once the most important effect KPIs were identified, the main cause KPIs were indicated. Finally, a prioritized list of 25 action plans (linked to the cause KPIs via the strategic objectives) that should be activated first (from a total of 98 action plans) was produced. Activating these plans first will ensure that their values are reached, as well as the values of the chosen effect KPIs. Following this order of activation enables the city council to save resources, as the values of the effect KPIs can be achieved without activating some (or all) of the action plans linked via the strategic objectives.

Future work could include the application of other statistical techniques to find KPI cause and effects (such as factor analysis or partial least squares) and other implementations of the methodology to improve and generalize its use for any MWS organization.

6. Data availability statement

The data that supports the findings of this study are available from the corresponding author [H.M.-S.] on request.

7. Acknowledgments

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