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Evaluating municipal solid waste management performance in regions with strong seasonal variability

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ABSTRACT

The evaluation of municipal solid waste (MSW) services using management systems (ISO 9001, ISO 14001, and OHSAS 18001) is important for improving the quality of such services. In this study, we prioritize and select performance indicators (PIs) for MSW service evaluation and organize them in a Balanced Scorecard (BSC) tool. The tool is applied for the period 2008–2011 to the public administration organization responsible for waste management in Loulé Municipality, Portugal, a region characterized by strong tourist seasonality. MSW management priorities are well established through EU directives and the application of PIs should allow service objectives to be quantified, including reducing the production of waste, increasing the quantity of recyclables, improving clients' satisfaction with the service, improving workers' motivation, decreasing the quantities of waste in landfills, and reducing service costs. The results indicate that the use of indicators and BSC tool can assess the strategic objectives of the organization and monitor its performance over time. The overall BSC assessment ratings were 51.7%, 66.1%, and 70.1% for 2009, 2010, and 2011, respectively, indicating an improvement in overall service performance over time. The results demonstrate that monitoring seasonal variations of PIs in tourist regions is important since these variations can help to explain annual changes in the factors affecting waste services management, their impacts on overall service quality, and the best time for measures to be applied. Based on this case study, the BSC can effectively contribute to improvements in the quality and cost of MSW services in areas characterized by strong seasonal variations in population and waste.

1. Introduction

Many technical departments within public organizations face responsibilities that go far beyond the strict technical component of their work. Public solid waste management is a paradigmatic example, as its planning and daily management should also reflect social, environmental, and financial sustainability concerns, as dictated by law (EU, 2008; MAOT, 2011). Such complex management requirements are better handled if supported by tools for assessing the overall system performance (Machado and Moy, 2003), including administrative, financial, legal, and planning aspects. There are five strong motivations in the waste sector for developing a framework for performance evaluation (Schübeler et al., 1996; Coelho and Alegre, 1997), which are to: (a) encourage the service's improvement, (b) comply with regulations, (c) specify verifiable strategic objectives, (d) regulate technical and operational activity, and (e) support the decision-making process. A framework is intended to improve overall performance, to assess the sustainability of the system, and to improve the quality of the service provided to users. Therefore, such a framework should cover not only operational aspects, such as the handling, transfer, transport, separation, processing, and disposal of waste, but also aspects that transcend immediate perceptions, such as awareness campaigns, coding of waste handling containers, optimization of collection circuits, and contextual and geographic features.

Performance indicators (PIs) are simple measures, easy to interpret, accessible, and reliable for monitoring various types of systems including waste management services (United Nations, 2007). PIs reflect the critical factors in key areas where action and investment are needed, assisting decision-makers in service system design, planning, monitoring, evaluation, and priority- and goal-setting (Perotto et al., 2008, Hermann et al., 2007). PIs provide valuable information for assessing the efficiency and effectiveness of processes, activities, and the service systems themselves, and as such constitute a valuable tool for supporting decision-making and strategic planning (Matos et al., 2004; O'Regan and Ghobadian,

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2005; Micheli and Manzoni, 2010). One of the best-known conceptual frameworks based on PIs is the Balanced Scorecard (BSC). It is a flexible management tool well suited to the specific characteristics of the public sector, while preserving the advantages of a modern public management focused on results (Pienaar and Penzhorn, 2000). The BSC can be used as a measurement system, as it is a strategic management and communication tool.

Waste management in seasonal tourist regions is a difficult challenge since the quantities and composition of the generated waste show marked intra-annual variability. Seasonal variability makes it difficult to establish the necessary waste management programmes and facilities aimed at waste prevention and recycling (Ariza et al., 2008). In addition, the deterioration of environmental quality and the increase of waste production in tourist areas are problems that have been recognized in various different countries (Gidarakos et al., 2006; Ariza et al., 2008; Gómez et al., 2009). For example, Ariza et al. (2008) reported that the amount and composition of waste and litter production along beaches in Costa Brava (Spain) varied during the summer as a consequence of beach use and cleaning practices. Waste management systems in such areas should benefit from the development of conceptual management frameworks based on PIs. Although several authors have studied the production and composition of municipal solid waste (MSW) in areas under strong seasonal variation (Sterner and Bartelings, 1999; Gidarakos et al., 2006; Gómez et al., 2009; Boldrin and Christensen, 2010), they have not provided complete management tools.

The present investigation selects, prioritizes, and tests PIs for MSW management in a tourist area with marked seasonal variations in population and waste production, and applies the BSC tool to the municipal service responsible for the management of MSW in that area. Results for the selected PIs are critically discussed within the BSC framework with reference to the waste management organization's performance.

2. Methodology

2.1. Study area

The municipality of Loulé is located in Algarve, southern Portugal, and occupies an area of 765 km^2 in which about 70,600 people live permanently (INE, 2011). Over the years, the population in this coastal area has increased, and it is now characterized by a very strong seasonal variation driven mainly by tourism, the main economic activity. The seasonal population includes an additional 32,700 inhabitants (as estimated by the municipality using water consumption records) over the four-month-long tourist high season extending from June to September (the remaining months are considered as low season). The municipality's waste management system covers 100% of the territory and includes solid wastes and recyclable materials. The handling, collection, and transportation of municipal mixed solid wastes (residential, commercial, and institutional) to the controlled landfill are the responsibility of the municipality, coordinated by the Division of Hygiene and Urban Solid Waste (DHURS). An independent state-owned company (ALGAR, S.A.) is responsible for the handling and collection and of recyclables, including paper, glass, plastic, metal, batteries, and green waste. The DHURS shares with ALGAR, S.A. the responsibility for public perceptions of waste separation and correct disposal (i.e., responsibility for ensuring favourable public attitudes towards recycling). In Portugal, MSW management follows a strategy based on the principles of sustainability, mainstreaming, integration, equity, and participation, as part of the Public Administration.

2.2. Indicator development

In the first PI development phase, data were collected based on the following management systems already in use by the DHURS: (a) the Integrated Quality and Environmental Management Systems (IQEMS) that comply with the requirements of ISO 9001 and ISO 14001, and (b) the Hygiene and Safety at Work Management System (HSWMS) according to the reference standard OHSAS 18001. The Individual Performance Appraisal implemented in Loulé Municipality has been also used by the DHURS for improving the motivation and satisfaction of its workers, promoting continuous improvement of both individual and collective performance.

The PI set was built from the PIs used by the DHURS under IQEMS and HSWMS, as well as from the indicators imposed by the Portuguese Regulatory Authority for Water and Wastes (ERSAR). Some indicators were developed internally (i.e., within the DHURS), and are hereafter referred to as "internal" PIs to differentiate them from the "external" PIs. This first set of indicators obtained from both internal and external sources contained PIs that reflected human, environmental, financial, infrastructural, and operational resources. This initial list was very extensive (57 indicators), some of which were either redundant and/or difficult to measure and assess.

2.3. Indicator prioritization and selection

In a second phase, PIs were prioritized and selected to reduce the number of indicators in the first set to a more efficient set. The methodology used for PI selection was based on engagement with stakeholders through workshops and interviews. Workshops were made quarterly with all selected stakeholders until a consensus among them was reached. In these workshops, the vision, mission, and values of the DHURS were defined, and a SWOT analysis (strengths, weaknesses, opportunities, and threats) was performed (Mendes et al., 2012). Moreover, individual stakeholders were interviewed, and the usefulness and relevance of each indicator from the initial list (57 indicators) in meeting the DHURS's strategic objectives were discussed and evaluated. Stakeholders were selected considering the roles of different stakeholder groups in influencing the strategy of the organization (Contreras et al., 2008), with two group classes: internal and external stakeholders. As mentioned by Bezama et al. (2007), stakeholders have diverse preferences and goal achievement expectations, and therefore it is important to analyse their different expectations for strategic decision support. Internal stakeholders are those who are directly responsible for the DHURS's activities and who are involved in its management, monitoring, and evaluation. These include the mayor, town council, the director of department, the chief of division, and other division staff (Mendes et al., 2012). External stakeholders are those who can influence the DHURS's activities but have no direct responsibilities, and include the population (both residents and visitors), central administration (Portuguese Environment Agency (APA) and ERSAR), courts, the media, and suppliers of goods and services. The number of internal and external stakeholders was ten, five in each group to retain parity between them. The final set of PIs established at the end of the stakeholder engagement process constitutes the set used in the BSC framework.

The prioritization of PIs for the BSC was based on significance weights attributed to each indicator (Table 1), and the overall significance (OS) value for each indicator was calculated using a weighted sum (Eq. (1)).

$$OS_i = \sum_{j=1}^{s} \sum_{k=1}^{3} C_{ijk} \times w_{ijk} \qquad (1)$$

Table 1
Significance classification used for PI prioritization.

k	Classification (C_k)	Significance weight (w_k)
1	A – Very important	3
2	B – Important	2
3	C – Less important	1

where C_{ijk} is the counts of each classification index k attributed to indicator i by stakeholder j, according to Table 1, and s is the number of stakeholders.

OS varies between a minimum of 10 and a maximum of 30. The central value of the interval plus one (21) was the value considered to separate low from high overall significant indicators. Hence, PIs with $OS > 21$ were considered as very relevant and included in the final set. This straightforward method was compared to another where both the mean (m_i) and the ratio of the standard deviation (sd_i) to the mean (coefficient of variation, CV_i) of the classifications were considered. In this case, indicators fulfilling the following criterion are included in the final set:

$$m_i > \frac{1}{s}\sum_{j=1}^{s} OS_{ij} \quad \text{and} \quad CV_i < \frac{1}{s}\sum_{j=1}^{s}\frac{sd_{ij}}{m_{ij}} \tag{2}$$

Only PIs with $m_i > 2.1$ and $CV_i < 0.4$ were selected on the basis of Eq. (2).

These two methods provide similar results if the probability density of the significance classifications is uniform or symmetrical, but different results when positively or negatively skewed (Tables S1 and S2). Even though the statistically based (second) method may be more scientifically robust, the first is easier to communicate and easier for non-experts to understand, and is therefore preferable if the methods provide similar results.

2.4. Indicator application and testing

Data were collected for the selected PIs for Loulé municipality for the period 2008–2011. The BSC was implemented as described in Mendes et al. (2012), with the management assessment calculated for each of the four years using Eq. (3). The year 2008 was used as the reference period against which subsequent years were compared.

$$\textit{BSC overall assessment} = \sum(\textit{PI performance level in each objective} \times \textit{PI objective weight}) \tag{3}$$

where *PI performance level in each objective* is determined according to defined targets and classes of performance (excellent, fulfilled, risk zone, not fulfilled) as presented in the study of Mendes et al. (2012), and *PI objective weight* is the weight of the different perspectives in contributing to the overall assessment. In this study, the original BSC perspectives proposed by Kaplan and Norton (1992) were used, namely *clients*, *internal processes*, *learning and growth*, and *financial*. The weights of the different perspectives in contributing to the overall assessment were 25% for the *client perspective*, 50% for the *internal processes perspective*; 15% for the *learning and growth perspective*, and 10% for the *financial perspective*, as used by Mendes et al. (2012).

2.5. Statistical tests

Student's two-tail t-tests were conducted to determine whether the averages of two samples were significantly different, under the null hypothesis of equal means. The hypotheses tested were internal vs. external stakeholders, and high vs. low seasons for the different PIs.

3. Results and discussion

3.1. Indicator development, prioritization, and selection

The exhaustive set of 57 PIs is presented in Table S1 (Supporting Information). These PIs were obtained from the different management systems implemented in the DHURS: IQEMS, HSWMS, ERSAR, and Internal. The classifications assigned by the stakeholders, as well as the overall significances (Eqs. (1) and (2)) for each PI, are presented in the same table. In the process of building the set of PIs, all relevant stakeholders should be included as they may reflect different sensitivities. This was the case here with internal and external stakeholders assigning significantly different classifications to the PIs: internal stakeholders with an overall OS mean of 13.1 ($sd = 1.5$), and external stakeholders with an overall OS mean of 7.7 ($sd = 1.7$) ($t(124) = 19.2$, $p < 0.05$).

The PIs selected according to the methodology described above are summarized in Table S2 (Supporting Information) and Table 2. It should be noted that the different management systems studied have indicators with different nomenclature, but in practice the objectives and the implementation of these indicators are the same. For example, the indicator *molok cleaning* from IQEMS and the indicator *containers cleaning* from ERSAR, indicate the same process, so they were grouped as representing one PI for the BSC, named *equipment cleaning* (Table S2).

The comparison of PI selection methods from Eqs. (1) and (2) is presented in Table S2, where it becomes clear that in this case both produce similar results. There are only two PIs, *Mixed waste handling capacity* and *Performance assessment index*, which were accepted by the overall significance method (Eq. (1)) but rejected by the statistically based method (Eq. (2)). Given the similarity of the results from the two methods, and the simplicity of the first, the set of PIs chosen using the overall significance method was used.

The resulting final set contains 24 PIs associated with strategic management, reflecting the objectives in the different perspectives of the BSC. In the *clients perspective*, the PIs measure expectations of users regarding the service of waste collection and transport. In the *internal processes perspective*, PIs measure how management operations (operational, hygiene and safety, environmental and social, human resources, and innovation processes) are integrated, and whether they are efficient and productive for sustainable development and service quality. In the *learning and growth perspective*, PIs measure continuous performance improvement, combining human capital and organizational information, and enhance personal satisfaction. Finally, in the *financial perspective*, PIs measure the financial integrity and stable development of the organization through compliance and budget optimization.

The final set of PIs (Table 2) was monitored annually, with results being analysed and compared, and standardized reports of indicator evolution were produced for analysis.

3.2. Indicator application and testing

Twenty-four indicators were used in the BSC assessment, the results for which are reported in Table 3. Table 3 also presents the effort made by DHURS in data collection for the selected PIs for the years since the BSC was implemented in 2008. The "BSC information completeness assessment" is defined as the ratio of the number of indicators with data to the total number of BSC indicators (24). In 2011, all the indicators were able to be calculated. Therefore, the first benefit from implementing the BSC system was the establishment of procedures for collecting and systematizing information. For public administration this represents an added value, because information is usually at hand but not easily accessible, and is often too raw for direct use.

Table 2
The final set of PIs, their units of measurement, and methods of quantification, distributed by BSC perspectives according to the strategic management of the DHURS.

Perspective	Objective	PIs, units, and method of calculation
Clients	CP.1. Meet the citizens	CP.1.1. Citizens satisfaction index (%) = $\frac{(\text{No. of questionnaires with GOOD} \times 1 + \text{No. of questionnaires with REASONABLE} \times 0.6 + \text{No. of questionnaires IMPROVE} \times 0.3)}{(\text{No. of questionnaires carried out} - \text{No. of NO OPINION questionnaires})} \times 100$ (4)
Internal Processes	IPP.1. Comply with the national strategy for waste	IPP.1.1. Landfill (%) = $\frac{\text{Mixed solid waste}}{\text{Municipal waste produced}} \times 100$ (5)
		IPP.1.2. Solid waste production per capita (kg/cap day) = $\frac{\text{Mixed solid waste produced}}{(\text{Resident population/reference period})}$ (6)
		IPP.1.3. Recycling rate (%) = $\frac{\text{Recyclable waste produced}}{\text{Mixed solid waste produced}} \times 100$ (7)
	IPP.2. Improving the operational services	IPP.2.1. Equipment cleaning (−) = $\frac{\text{Disposal equipment sanitized semi-buried}}{\text{Disposal equipment installed semi-buried}}$ (8)
		IPP.2.2. Written response to complaints and suggestions (%) = $\frac{\text{Complaints and suggestions}}{\text{Responses to complaints and suggestions}} \times 100$ (9)
		IPP.2.3. Use of the handling capacity (kg/equip year) = $\frac{\text{Mixed solid waste produced}}{\text{Handling equipment installed}}$ (10)
		IPP.2.4. Vehicle park utilization (km/vehicle) = $\frac{\text{Distance travelled by waste collection vehicles}}{\text{No. of vehicles used for waste management collection}}$ (11)
	IPP.3. Productivity evaluation	IPP.3.1. Vehicle park capacity (kg/m^3 year) = $\frac{\text{Mixed solid waste collected} + \text{Odd-dimension waste}^{(1)}\text{ collected}}{\text{Installed capacity of waste collection vehicles}}$ (12)
		IPP.3.2. Dimension of full-time staff (workers/10^3 t) = $\frac{\text{Personnel assigned to the waste management service}}{\text{Mixed solid waste collected} + \text{odd-dimension waste}^{(1)}\text{ collected} \times 10^3}$ (13)
		IPP.3.3. Mixed waste disposal capacity (l/inhab.) = $\frac{\text{Volume of disposal equipment installed}}{\text{Resident population}}$ (14)
	IPP.4. Reduce non-renewable resources and greenhouse	IPP.4.1. Energy resource use (l/t) = $\frac{\text{Fuel consumed}}{\text{Mixed solid waste collected} + \text{odd-dimension}^{(1)}\text{ waste collected}}$ (15)
		IPP.4.2. Emission of greenhouse gases (kg CO_2/t) = $\frac{CO_2\text{ emissions from waste collection vehicles}^{(2)}}{\text{Mixed solid waste collected} + \text{odd-dimension waste}^{(1)}\text{ collected}}$ (16)
	IPP.5. Optimize the life cycle of waste	IPP.5.1. Waste separation rate for recycling (%) = $\frac{\text{Separation of waste per type of waste (glass, plastic, metallic)}}{\text{Recycles waste collected}} \times 100$ (17)
		IPP.5.2. Yard waste recovery rate (%) = $\frac{\text{Yard waste sent to organic recovery}}{\text{Yard waste produced}} \times 100$ (18)
	IP.6. Minimize accident risks	IPP.6.1. Work accidents (number/100 workers year) = $\frac{\text{Accidents at work}}{\text{Personnel assigned to the waste management service}}$ (19)
	IPP.7. Promote awareness	IPP.7.1. Awareness actions (%) = $\frac{\text{Awareness actions performed}}{\text{6 awareness actions planned in a 3 years period}} \times 100$ (20)
	IPP.8. Develop projects/services	IPP.8.1. Projects/services implementation (number/year) = No. of projects and services planned and implemented (21)
Learning and Growth	LGP.1. Increase motivation and attendance	LGP.1.1. Absenteeism (%) = $\frac{\text{Missed work days}}{\text{Working days} \times \text{Personnel assigned to the waste management service}} \times 100$ (22)
	LGP.2. Developing skills	LGP.2.1. Total training hours (h/workers year) = $\frac{\text{Hours of training assisted}}{\text{Personnel assigned to the waste management service}}$ (23)
	LGP.3. Increase the performance evaluation	LGP.3.1. Performance assessment index (%) = $\frac{(\text{No. of assessed with Relevant} \times 1 + \text{No. of assessed with Fit} \times 0.6 + \text{No. of assessed with Inadequate} \times 0.3)}{\text{Total assessed}} \times 100$ (24)
Financial	FP.1. Meet and optimize the budget	FP.1.1. Waste disposal cost (€/t) = $\frac{\text{Costs of waste disposal in landfills}}{\text{Municipal waste going to landfill}}$ (25)
		FP.1.2. Total costs (€/year) = Sum of total annual costs (26)
		FP.1.3. Annual revenue (€/year) = Sum of annual waste-related tax revenues (27)

(1) Odd-dimension wastes are the urban wastes with large or awkward dimensions (such as beds, mattresses, and furniture) that cannot be placed in containers.
(2) CO_2 emissions were calculated according to the requirements of the National Regulator ERSAR (ERSAR and LNEC, 2012), in which CO_2 emissions $= \sum_{i=1}^{t} FC_i \times PCI_i \times 0.99 \times FE_i$, where i is the fuel used; FC_i is the i fuel consumed (t); PCI_i is the energy of the i fuel (GJ/t); 0.99 is the carbon oxidizable fraction in the fuel; and FE_i is the emission factor of the CO_2 (kg CO_2/GJ).

Table 3
Evolution of selected indicators from 2008 to 2011 and BSC overall assessment.

Perspective	Indicator	2008	2009	2010	2011
Clients	CP.1.1. Citizens satisfaction index (%)	72.00	62.50	83.10	85.40
Internal processes	IPP.1.1. Landfill (%)	92.00	90.60	89.62	89.46
	IPP.1.2. Solid waste production per capita (kg/cap day)	2.08	1.98	1.93	1.73
	IPP.1.3. Recycling rate (%)	7.22	7.95	8.53	9.50
	IPP.2.1. Equipment cleaning (–)	3.38	2.84	3.06	3.87
	IPP.2.2. Written response to complaints and suggestions (%)	–	–	–	66.67
	IPP.2.3. Use of the handling capacity (kg/equip year)	–	13,469.86	13,136.19	14,603.85
	IPP.2.4. Vehicle park utilization (km/vehicle)	28,963.33	23,978.91	23,739.36	22,255.08
	IPP.3.1. Vehicle park capacity (kg/m^3 year)	520.44	493.71	444.75	390.43
	IPP.3.2. Dimension of full-time staff (workers/10^3 t)	1.91	1.96	2.01	2.24
	IPP.3.3. Mixed waste disposal capacity (l/cap)	68.91	72.48	72.70	63.83
	IPP.4.1. Energy resource use (l/t)	5.47	5.38	5.67	6.03
	IPP.4.2. Emission of greenhouse gases (kg CO_2/t)	14.49	14.25	15.02	15.98
	IPP.5.1. Waste separation rate for recycling (%)				
	Glass	45.67	44.15	41.50	42.66
	Paper and card	37.41	38.26	37.75	38.41
	Packaging	13.48	15.59	16.92	16.10
	Batteries	0.00	0.01	0.02	0.01
	Wood	3.44	1.99	3.81	2.83
	IPP.5.2. Yard waste recovery rate (%)	48.75	63.77	62.60	55.71
	IPP.6.1. Work accidents (number/100 workers year)	–	0.05	0.06	0.04
	IPP.7.1. Awareness actions (%)	100	100	100	100
	IPP.8.1. Projects and services implementation (number/year)	2	6	5	5
Learning and growth	LGP.1.1. Absenteeism (%)	–	5.44	4.53	5.42
	LGP.2.1. Total training hours (h/worker year)	4.14	2.72	0.57	18.07
	LGP.3.1. Performance assessment index (%)	–	–	–	76.09
Financial	FP.1.1. Waste disposal cost (€/t)	34.65	35.17	34.50	38.08
	FP.1.2. Total costs (€/year)	–	–	–	4,058,527.82
	FP.1.3. Annual revenue (€/year)	–	–	2,286,277.68	2,344,721.03
BSC overall assessment (%)		–	51.70	66.05	70.05
BSC information completeness assessment		(17/24)	(20/24)	(21/24)	(24/24)

For the years 2009, 2010, and 2011, the BSC overall assessment values were 51.70%, 66.05%, and 70.05%, respectively (Table 3). This increase over time in BSC value reflects the overall improvement made in the waste management service of the municipality and the efforts made in data collection, despite the negative variation in some PIs. For example, IPP.1.1. (*landfill*) and IPP.1.2. (*solid waste production per capita*) decreased over the years (as recommended by EU), despite the values being far from national and EU targets; conversely, IPP.4.2. (*emissions of greenhouse gases*) increased during the same period. The lack of information from the *learning and growth* and *financial* perspectives negatively influenced the BSC overall performance assessment, as these perspectives were below the target objectives. This was related to the difficulties in transmitting and sharing information between municipal staff. There is still much room for improvement in cooperation between staff and other departments, requiring the involvement of all stakeholders, through internal standardization procedures. It is also necessary to develop internal mechanisms in the municipal organization that allow faster access to information by stakeholders.

Some PIs were selected for discussion to illustrate the applicability of the BSC approach to a public waste service in a tourist region. The PIs were selected due to their variability between the high and low seasons, and because they exemplify our methodology and results obtained, and are discussed in turn below.

Statistically significant differences were found in the mean values of all PIs for which monthly data for high and low seasons are available ($t(46)$; $p < 0.05$), with the exception of *yard waste production*, *yard waste recovery*, and *batteries recovery*. These three indicators are not expected to show seasonality as they do not depend strongly on population size fluctuations.

The PI *solid waste production per capita* (IPP.1.2.) provides information about the quantities of MSW produced per day per inhabitant, which can be aggregated over longer periods, such as per year or per season. This PI derives from the *internal processes perspective* (Eq. (6) in Table 2). Results show a decrease in both total MSW production and daily waste production per capita between 2008 and 2011 (Fig. 1). Per capita productions are, nonetheless, about 20% above the national values in the same period, which varied between 1.39 and 1.40 kg/cap day (APA, 2011). There was a significant difference in total waste production between the high season ($m = 6{,}245{,}482$ t, $sd = 973{,}736$ t) and low season ($m = 4{,}456{,}885$ t, $sd = 481{,}593$ t) ($t(46) = 8.56$, $p < 0.05$). Lower per capita amounts of waste were obtained during the high season than during the low season (Fig. 1a). This may be attributed to the different consumer and disposal behaviours of tourists compared with local inhabitants (e.g., Cierjacks et al., 2012), which is supported by the recycling rates presented in Fig. 2a. There is a much less-marked fluctuation in the per capita production of waste (Fig. 1a), which decreased, for the yearly aggregated data, from a value of 1.78 kg/cap day in 2008 to 1.49 kg/cap day in 2011, becoming close to the national value. The rate of decrease was 4.4%/year (3.3%/year for the high season, and 4.9%/year for the low season). The reduction may be due to the increase in recycling rate and/or greater citizen awareness regarding waste minimization issues (see below).

Results from the PI *recycling rate* (IPP.1.3. from the *Internal processes* perspective) are presented in Fig. 2. This PI was obtained from the quotient of the recyclables produced and the total MSW produced per year or per season (Eq. (7), Table 2). Fig. 2a shows an increase in the recycling rate during the high season. This increase may be due to the seasonal population recycling more and/or the proportion of recyclable materials as a percentage of total waste is higher during summer. The first possible reason is not, however, supported by the data, as the low season resident population has a demonstrated commitment to waste minimization, as indicated by a higher year-by-year rate of decrease in per capita production of

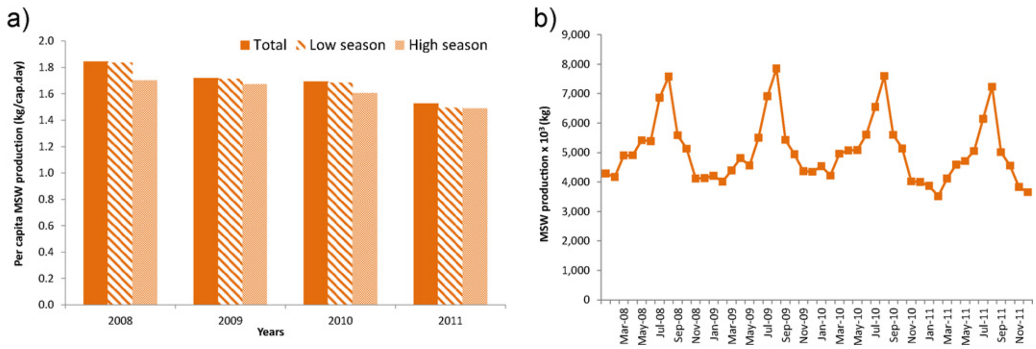

Fig. 1. Changes over time in (a) solid waste production per capita PI and (b) mixed solid waste production.

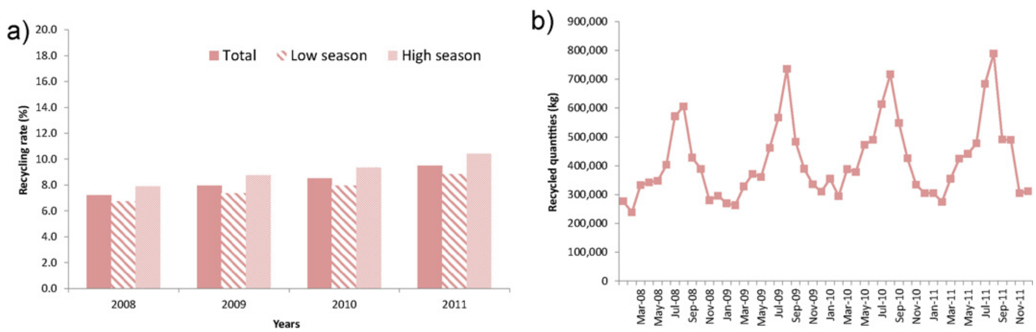

Fig. 2. Changes over time in (a) recycling rate PI and (b) quantities of recyclables.

MSW, when compared to the high season per capita value (Fig. 1), while the rate of increase in recycling is very similar (7.1%/year and 7.0%/year for high and low seasons, respectively). Consequently, we assume that the high proportion of recyclables in the total waste is the main reason for the observed increase in the recycling rate during summer periods, which could result from a combined effect of consumer and disposal behaviour in both the resident and tourist population during the hot season, when packaged food and liquids are consumed more frequently. The difference is statistically significant between high (m = 640,833 t, sd = 131,782 t) and low season (m = 404,445 t, sd = 75,151 t) ($t(46) = 7.93$, $p < 0.05$).

These results regarding recycling provide two relevant pieces of information for waste management: (i) As the local resident population has a similar environmental awareness to the visiting (tourist) population, similar perception campaigns can target both populations; and (ii) the handling capacity for recyclables is growing at an annual rate almost twice of that of the decrease of handling of non-recyclables (7.0%/year and 4.4%/year, respectively). As such, the MSW system may have already attained its maximum effort in terms of handling and collection equipment, as recyclables are not the responsibility of the municipality. Future gains in service quality and cost reductions can now be better attained by management practices, focusing more on operational procedures and population perceptions of recycling than on equipment.

Yard waste recovery rate (IPP.5.2) (Fig. 3) is the quotient of the yard waste (including cut grass, leaves, and branches from houses and golf courses) sent to organic recovery and the yard waste produced from recovery (Eq. (18), Table 2). This PI has a seasonality dependent on vegetation growth, with most of the waste being produced during spring and autumn. However, the difference was not statistically significant between high (m = 55,753 t, sd = 51,585 t) and low season (m = 42,630 t, sd = 30,242 t) ($t(46) = 1.11$, $p = 0.27$). These wastes are transported by the producers or by the state-owned company, ALGAR, S.A., to recovery centres. This PI indicates clearly that there is still much room for improvement both in biological recovery of the waste and in the consistency of the recovery system. Some of the resources now available as a consequence of the decrease in the volume of MSW handled may be used to improve this indicator in the near future.

Vehicle park utilization (IPP.2.4.) presented in Fig. 4 shows the distance travelled by the waste collection vehicles (Eq. (11), Table 2). Since the number of waste handling/disposal equipment and vehicles does not change during a year, this PI indicates collection efficiency. As supporting information, the total distance and

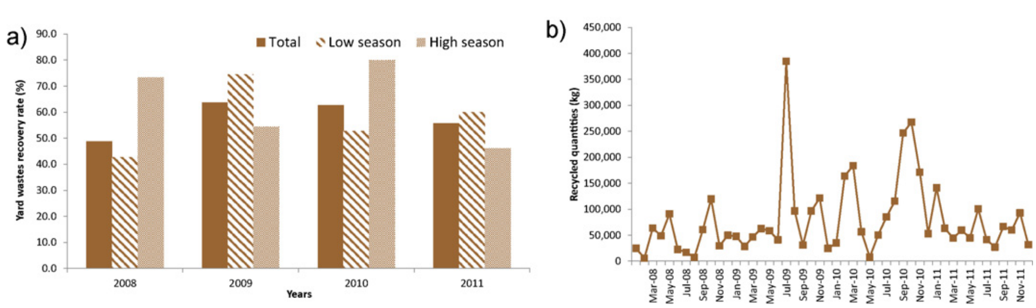

Fig. 3. Changes over time in (a) yard waste recovery rate PI and (b) recycled yard materials.

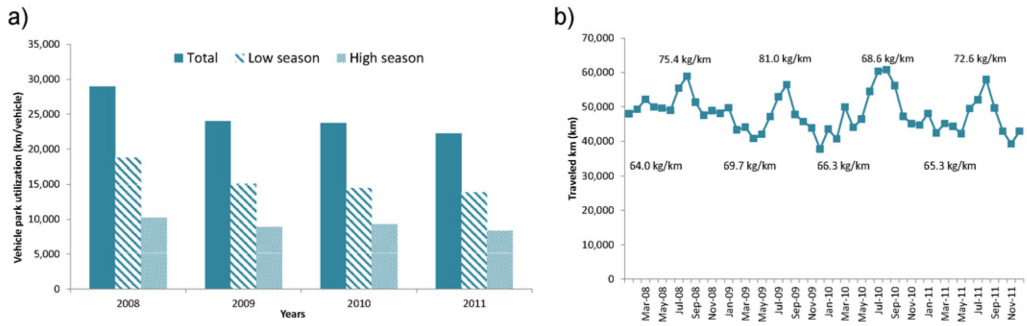

Fig. 4. Changes over time in (a) collection fleet utilization PI and (b) distance travelled by the collection fleet. In (b), MSW quantities (kg) transported per distance travelled (km) are shown.

the amount of waste collected per km travelled by the collection fleet is provided (Fig. 4b). During summer, the number of kilometres made per vehicle increases until the collection capacity equals the handled volume. There was a significant difference in distance travelled between high (m = 53, 753 km, sd = 4477 km) and low seasons (m = 45,299 km, sd = 3506 km); $t(46) = 7.17$, $p < 0.05$. Route optimization might help make these values converge, improving efficiency, in particular during the low season.

Finally, *waste disposal cost* (FP.1.1.) was analysed and compared to the distance travelled to collect the wastes (Fig. 5). The *waste disposal cost* PI reflects the costs associated with the fees charged for disposing of waste in the controlled landfill, managed by ALGAR, S.A. All collected wastes that are not diverted to recycling share this destination (Eq. (25), Table 2). Fee values depend on the nature of the waste, and vary annually upon approval by the Ministry of the Environment. The waste disposal cost varied only slightly between 2008 and 2010, but increased in 2011 (Fig. 5a) due to an increase in the value of the fees. Disposal costs and travel costs (€ spent in fuel) constitute the two main expenditure items, with the latter being on average 38% larger than the former (Fig. 5b). This difference increases during the low season to 45% and decreases to 25% in the high season, in accordance with the aforementioned lower travel efficiency for the low season. This indicates that improved efficiency during collection by means of fewer travelled km, or more fuel-efficient vehicles, will have a higher impact on operational costs than will a proportional reduction in the amount of landfilled waste. Overall costs were significantly higher during the high season. Mean travel costs were 247,858 € (sd = 35,220 €) and 209,088 € (sd = 30,358 €) for high and low seasons, respectively ($t(46) = 3.95$, $p < 0.05$). Mean disposal costs were 200,826 € (sd = 29,381 €) and 145,136 € (sd = 14,873 €) for high and low seasons, respectively ($t(46) = 8.77$, $p < 0.05$).

This practice of continuous PI measurement and analysis gives ongoing information for the evaluation of waste management, which provides insights into best management practices within the organization. In addition, PIs can be used to measure the impact of tourism on the waste management system and, as a consequence, to develop the measures necessary to cope with the increased population during the high season, while maintaining a high quality of municipal services, promoting recycling, and reducing the amount of waste produced.

Some other indicators selected for the BSC are not directly affected by seasonality, including indicators from the *clients* and *learning and growth* perspectives. However, these PIs are important in the overall assessment of the organization's management, since the satisfaction of clients and the motivation of municipal staff are essential for waste service management.

Recycling awareness actions started in 2008 and were performed as planned through to 2011 (IPP.7.1, in Table 3). In the same period, *recyclables recovery rate* (IPP.5.1) increased (Figs. 1 and 2, and Table 3), indicating that awareness actions may have been successful in reaching target populations. This correlation between awareness actions and PI value increase is also seen in the results for *yard waste recovery rate* (IPP.5.2) for which no awareness action was undertaken, and as a consequence no positive evolution in the indicator was observed (Fig. 3 and Table 3). Despite the improvement in recycling, rates still lie below national and EU targets, which are (EU, 2004; MAOTDR, 2007): >60% for glass, paper and card, and packaging; and >15% for wood. The municipality will need to reinforce its commitment to increasing the population's perceptions of recycling if it is to achieve a faster convergence to target values in the near future. The increase in IPP5.1 will have a strong impact on the other PIs associated with production, recycling, and handling/collection services and on the overall management. The distance travelled per vehicle (IPP.2.4.) when above a certain threshold may place waste collection efficiency at risk due to the increased frequency of mechanical breakdowns. Previous records indicate the need to reduce the indicator value. Results from the BSC show that acquisition of two more vehicles was reflected in an improvement of the indicator during the first two years (2008, 2009); however, in the second period (2010, 2011), despite the acquisition of two other vehicles, the indicator decreased (Table 3 and Fig. 4b). Clearly, other actions are needed; for example, route optimization, in particular during low season. Improvements in IPP.2.4 will positively influence indicators related to vehicle park capacity, energy use, emission of greenhouse gases, and costs.

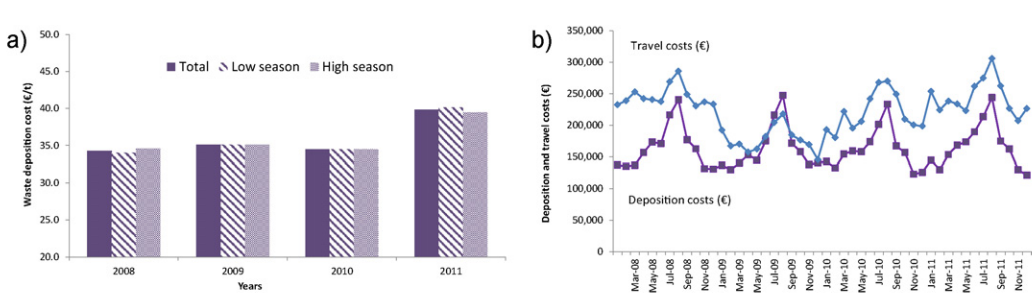

Fig. 5. Changes over time in (a) waste disposal cost PI and (b) disposal costs (€).

4. Conclusions

This paper proposed a method for the prioritization, selection, and testing of performance indicators for municipal solid waste (MSW) management in tourist areas with marked seasonal variation in population, based on the Balanced Scorecard (BSC) approach. The method was applied to the municipal service responsible for the management of MSW in Loulé Municipality in Algarve, Portugal. The development of the PI system was gradual, starting with a large number of indicators and finishing with a smaller set more focused on the organization strategy. The initial set contained 57 PIs, which were obtained from different management systems already implemented in the DHURS. Twenty-four PIs were included in the final set after applying the prioritization and selection procedures, part of which involved stakeholder input. These PIs were associated with strategic management, reflecting the objectives in the different BSC perspectives.

The results indicated that the BSC tool can assist in the management of municipal waste management in tourist areas with strong seasonality. An example is the optimization of the waste collection fleet and travelled routes, which were shown to be less efficient during low season, as vehicles repeat routes from the high season but collect lower volumes of waste. In addition, the population has responded favourably to recycling awareness campaigns. Tourists' recycling habits were similar to those of the resident population, which reduces the need to diversify recycling awareness actions targeted at these two populations.

The BSC overall management assessment demonstrated that improvements have been made in the waste management service of Loulé Municipality. The BSC constitutes a strategic management and communication tool, allowing the articulation, integration, and development of a regulatory management performance. It makes use of synergies between management systems implemented inside the organization with the purpose of analysing the development of management practices, and the effectiveness of environmental, financial, social, operational, and human resources processes. In particular, this research shows that monitoring waste management through using PIs in the framework of the BSC tool can be successfully applied to organizational performance in municipal waste management services in areas characterized by strong seasonal variations in population and waste.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecolind.2013.02.017.

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