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Assessment of Circular Economy Implementation in Municipal Waste Management Through Performance Indicators and Citizens' Opinion in a City in Western Greece

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Abstract: Municipal solid waste management (MSWM) is an advantageous subject for implementing circular economy (CE) strategies. In this context, the waste generation and waste collection steps of MSWM in the third largest Greek city (Patras), in western Greece, were evaluated according to the proposed CE indicators. Public opinion and knowledge on CE in MSWM were also evaluated in a small sample of citizens from the Municipality of Patras (207 individuals) through a questionnaire survey. Results showed that (a) the CE performance indicators objectively assessed circularity in MSWM; (b) Patras fared better than Greece and EU in some indicators [waste generation (kg per capita × year), food waste generation (kg per capita × year)] and worse in others [food waste composting (% *w*/*w*), WEEE recycling (kg per capita × year)]; (c) citizens have not adopted CE practices in their waste management; and (d) there is a clear reluctance to change practices in older individuals. Based on these results, some recommendations for improvement were made. These results may aid in delineating existing conditions in MSWM in large eastern Mediterranean cities and contribute to the transition toward a reduction in waste disposal and an increase in material reuse.

Keywords: municipal solid waste management; circular economy; performance indicators; public opinion; Greece

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1. Introduction

The concept of a circular economy (CE) has gained increasing attention from policymakers, industry, and academia in the last decade [1–3], contributing to sustainable development. Moreover, the circular economy concept is associated with certain Sustainable Development Goals (SDG 6, SDG 7, SDG 8, SDG 12, and SDG 15), proving their strong interrelation.

Kirchherr et al. [4] noted 221 recent definitions of CE, indicating that the CE concept has been interpreted and implemented in a variety of ways thus far. The CE concept envisions a closed-loop system where resources are continuously recovered, recycled, and reused, in contrast to the linear "take, make, dispose" approach. The goal of the CE is to encourage responsible and periodical use of resources. The two main aspects of CE are to lower material intake and minimize waste generation [5,6]. In addition, the 3Rs—reduce, reuse, and recycle—are highlighted in most of the CE literature [7,8]. By focusing on the cyclical flow of materials, energy, and resources within the system, Chen et al. [9] pointed out that the circular economy deviates from the linear model and is based on the fundamental principles of reduce, reuse, recycle, and recover. Therefore,

the way that societies produce, use, and manage resources should fundamentally change as a result of the shift from a linear to circular model.

CE principles can be applied to all stages of solid waste management (SWM), encompassing paradigm shifts in waste generation, collection, and the recuperation of materials and energy as well as in final disposal. SWM contributes strongly to the transition to a CE [10,11], with mutual benefits between CE and SWM [12]. Ghisellini et al. [13] noted that it is crucial to include circular economy concepts into waste management to reduce the negative environmental effects of conventional linear models and to open up new economic opportunities. By incorporating the CE principles into waste management procedures, environmental issues are addressed and the groundwork for a more resilient and sustainable future is deployed [14].

Certain European Union (EU) policies that have been incorporated into various national laws provide tools and incentives consistent with the circular economy concept. The EU Waste Framework Directive highlighted a five-level waste hierarchy that establishes an order of preference for managing and disposing of waste, with prevention (product non-waste) as the first priority strategy, followed by preparing for reuse, recycling, recovery, and disposal. The European Commission fostered the new circular economy action plan (CEAP) in March 2020, with its primary objective to ensure less waste [15].

Aiguobarueghian et al. [14] explored outstanding case studies that integrated sustainable waste management and the adoption of CE principles. They highlighted the examples of Copenhagen and Amsterdam, which have adopted the circular economy's waste management concepts, resulting in a notable decrease in landfill disposal and an increase in recycling rates. D'Adamo et al. [16] explored the relationship between MSWM and CE models across European countries where their systematic literature review revealed a focus on quantitative models adopting reuse and recycling within MSWM, leading to circular practices. Allevi et al. [17] proposed a waste management model in a circular economy framework in twelve (12) municipalities in the Lombardy Region in Italy. Their study concluded that the amount of recyclable waste collected increased when the municipalities were actively involved and deployed policies that induced citizens to ameliorate the waste-sorting process. New and exciting opportunities are also on the way with regard to adapting the tools for waste sorting, waste recycling, and final disposal; for example, the use of artificial intelligence in smart bins and for waste-sorting robots as well as an improvement in waste logistics [18] such as the routing of collection vehicles [19].

Focusing on Greek legislation, the initial attempt to regulate MSWM at the national level, based on the principles of CE, can be found in the current National Waste Management Plan (2020–2025) [20], and especially in Law 4819/2021 [21], which introduced PAYT, the separate collection of recyclables, and green points (GPs), among others. Previous research in northern Greece showed that these goals are overly ambitious and that the current situation of Greek MSWM needs significant baseline improvements [22]. As such, the objective of this paper was to evaluate the circularity of MSWM in the third largest Greek city (city of Patras) through selected performance quantitative indicators and the citizens' perception. This research will aid in understanding the current problems and challenges that Greece and similar European countries with historically high landfilling rates face regarding circularity implementation in MSWM. Some points of interest may also be raised, and possible solutions may be deduced from this investigation.

2. Materials and Methods

2.1. Study Area

2.1.1. Regional and Municipal Characteristics

The city of Patras belongs to the prefecture of Western Greece, which covers 8.6% of the total land area. This is the fourth largest prefecture; Patras is the largest city within the prefecture, belonging to the prefectural unit of Achaia, which is also the most populated prefectural unit out of the three [23]. As in most Greek areas, there is population shrinkage within the prefecture with fewer births than deaths [24] and most residents falling into the 50–59 age group. There are also more men than women in the prefecture (50.2 vs. 49.8%, respectively) [23].

The prefectural unit of Achaia is approximately in the middle of the prefecture, with the Gulf of Patraikos and Gulf of Korinthiakos as the northern boundaries and the Ionian Sea as the western boundary, with a total area of 3274 km^2, out of which 60% is mountainous terrain [25]. The city of Patras (Patras municipality) accounted for 215,922 permanent citizens in 2021, a slight increase from the census of 2011 (213,984 permanent citizens) and in stark difference to the national decrease of 3.1% between 2011 and 2021 [23]. The city is further divided into five municipal units (Patras, Vrahaika, Mesatis, Paralia, Rio) from the merger of individual municipalities in 2010 [26]. The city functions as an urban pole for the western part of Greece, especially after the construction of the Rio-Antirio Bridge; its port is of significant national value and the city has also benefited from the improvement in the big road axes that run along western Greece. The University of Patras and a science park operate within the city, and industrial and manufacturing activities are also present [27]. Finally, the city acts as a tourist destination due to its rich culture and heritage.

2.1.2. Local MSWM Plan Characteristics

The local MSWM plan should inexorably follow the requirements of the regional and national MSWM plans and their updates. In turn, the regional, and especially the national MSWM plan that is superseded every five years by a new one, follow the updates of relevant EU mandates such as the updated Waste Framework Directive 2018/851/EU [28], the updated Landfill Directive 2018/850/EU [29], and the updated Packaging of Waste Directive 2018/852/EU [30]. All of these directives have a substantial impact on recycling and disposal actions on municipal waste [31]. The directives are incorporated in national law mainly in the form of decrees, and in many cases, the decree is identical to the original directive. A more thorough analysis of the intercalating requisites in MSWM for Greece set by EU legislation can be found in [32]. Regarding recycling, the public non-profit entity Hellenic Recycling Agency is responsible for the alternative (non-landfill) management of waste as well as for the design and planning of programs for reduction [33]. It is thus responsible for supervising the collective system for alternative management for packaging waste (HERRCO), which comprises local authorities (municipalities) through their central union as well as enterprises that import or produce packaged goods [34]. HERRCO was created to satisfy the legal obligation of Greece as an MS to effectively recycle packaging waste, as laid out in the original Packaging of Waste Directive (94/62/EC) [35] and its amendment 2018/852/EU [30] The collection of packaging waste is substantiated through the "blue bin" scheme [36], which collects plastic, aluminum, paper (and glass), along with the "blue bell" scheme that collects glass, the "yellow bin" that collects paper only, and the "red bin" that collects metal only. The MSWM plan currently in force [20] and in its amendment in 2023—[37]) sets ambitious goals for the recycling of packaging waste and other kinds of recyclable waste, reuse, and landfill minimization. Furthermore, a Greek law that came into force in 2021 radically changed municipal waste collection and advocates for recycling schemes [22] that have yet to be established. In this context, a local MSWM

plan for the whole Municipality of Patras was drawn and ratified in 2023 [38]. As in other relevant documents, the plan must describe the current situation in detail, showcase the time-dependent goals, cite the agreed upon actions, their time schedule and cost, and propose additional measures. Some characteristics of the local MSWM plan are depicted in the Supplementary Materials. Some other characteristics of the current situation, as laid out in the plan, are shown here. In brief, non-recycled waste (the "green bin" scheme) containing both biodegradable and non-biodegradable waste is landfilled in the sanitary landfill "Xerolakkas", which furnishes the municipality along with other neighborhood municipalities. A recycling facility (Maintenance Sorting Centers for Recyclable Materials, MSCRM) also operates in the same site, and sorts the package waste from the "blue bin" scheme [36] and where all other singular waste packaging schemes [32] end up. The landfill is at its end of life and is supposed to be replaced by a new one at the "Floka" site. A biodegradable waste processing plant will also be built there so that landfilling of the biodegradable portion will be minimized, and only the finally processed waste (remnants from the biodegradable waste processing plant) will be landfilled [38]. These actions are yet to be completed.

Since subsequent performance indicators used [39,40] rely heavily on waste separation, data on the collection and storage facilities are shown in the Supplementary Materials.

2.2. Performance Indicator Selection and Calculation

Since the MSWM of the municipality was evaluated exclusively for its circularity, established indicators were chosen, based on the data in [39,40]. These indicators have been developed to establish a general framework for monitoring circular economy implementation in the EU and can be further divided according to the subsector they describe: (1) production and consumption, (2) waste management, (3) (use of) secondary raw materials, and (4) competitiveness and innovation [39]. Eight indicators out of a total of ten and their subdivisions were selected (Figure 1). The final selection of the inclusion/exclusion indicator was based on (a) the relativeness to MSWM and (b) availability of data for evaluation. Data for the calculation of the indicators were extracted from EUROSTAT (see references in Section 3), the Greek Electronic Waste Registry [41], the previous National WM Plan [42], the 2011 and of 2021 censuses [23], and the local MSWM Plan [38]. In brief, the methodology included the mining of the most recent data from the most reliable source. Whenever data were older but more reliable, these data were chosen. Whenever local data were available, these were chosen over the national data. The population of the municipality was extracted from the official census campaigns.

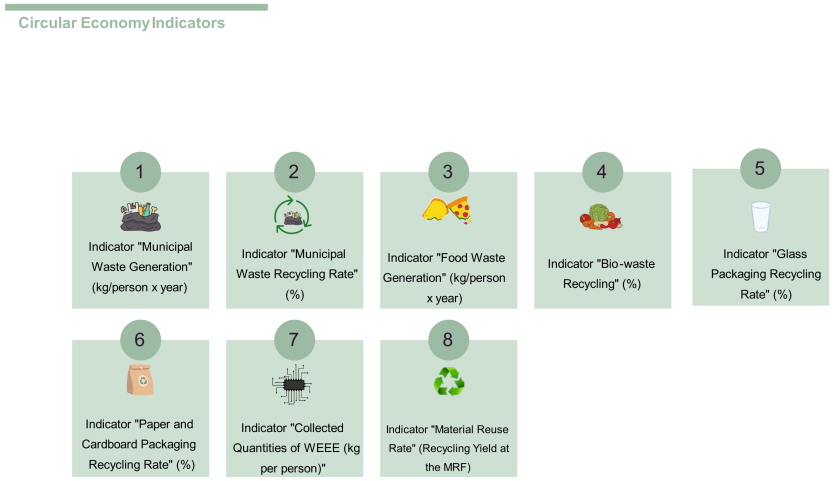


Figure 1. The CE performance indicators selected to be calculated for the Municipality of Patras.

2.3. Questionnaire Design and Application

A small public opinion campaign for the citizens of the Municipality of Patras took place in November 2024 through a convenience sample, as in previous relevant research from our colleagues [36,43,44], mostly through personal interviews. A small number of responses were also obtained through social media distribution. A total of 207 citizens responded to all questions. For the interview respondents, there was minimal interaction with the interviewer unless clarification was needed, and the answer sheets were pooled on the spot. The questionnaire consisted of Part A with six questions on demographic characteristics and Part B with fourteen closed-end questions examining the relationship of the sample with MSWM and their knowledge regarding CE. Several questions were ranked using a five point Likert scale (1 "not at all" to 5 "very much"), one question was answered on a yes/no basis, and three questions on a preference ranking basis. A GDPR declaration preceded all questions. At the beginning of Part B, the circular economy concept was explained in layman's terms in approximately 60 words (Supplementary Materials). After the collection of all responses, the data were coded and transferred initially to Microsoft Excel 2007 (Microsoft, Washington, DC, USA) and later to SPSS 28.0 (IBM, Armonk, NY, USA).

2.4. Statistical Analysis

Descriptive statistics were depicted in charts. In cases where very few respondents belonged to a certain group (e.g., "very much"), the data were pooled with the former or latter group (e.g., "much"). For questions 1, 2, and 4 to 9 in Part B, a chi-square assessment was performed to test for significant differences attributable to the sex or age group. Whenever needed, to satisfy the minimal requisites for the robustness of the test, pooled answers (e.g., "very much" and "much") were deemed necessary. Whenever the chi-square analysis showed significant differences between groups, as a whole ($p < 0.05$), post hoc tests were also performed. This was conducted with the use of z-scores from contingency tables, which were then transformed into *p*-values [45] through SPSS functions. To correct for type I errors, a Bonferroni correction was applied on the critical *p*-value through a multiplication of 0.05 $\times$ the total number of multiple comparisons

3. Results

3.1. Calculation and Comparisons of CE Performance Indicators

The main input data for the calculation of the CE indicators for the Municipality of Patras were extracted from its local MSWM plan [38] and are shown in Table 1A,B.

Since no data on the separate waste streams within the "blue bin" are available, the relative percentages of plastic, paper, glass, metal in the "blue bin" were calculated from the tons projected for the year 2020 nationally from the previous National SWM plan [42]. The percentages were calculated as follows: 50.2% paper, 20.9% plastic, 12.2% metal, and 11.3% glass. In other words, it is expected that almost 50% of the collected recyclable waste in the "blue bin" belongs to the paper/carton category, roughly 12% is metal waste, and so on. Some recent data are also available for western Greece through the (updated) Regional SWM plan [46] that showed the following results: 45.6% paper, 23.1% plastic, 11.4% metal, and 12.2% glass of all recycled packaging material, but it was unsure as to whether these were from the "blue bin" scheme or from the sum of all alternative collections ("blue bell", "yellow bin, etc.). Since real data for glass-only and paper-only were available for Patras for 2020, their combination with the data from previous the National SWM plan [42] was chosen.

The indicators selected are shown in Table 2 and depict a comprehensive picture of MSWM in the municipality. Total waste generation fluctuated for the years 2017–2020 but

was lower in every case than both the EU and the national values. The same was true for biodegradable (food) waste, which was quite a bit lower than the national value for Greece for 2019. However, the total waste recycling was low, mirroring the low rates for the whole of the country; this was even lower than the national average value of 18.1%. Glass package recycling was better while paper recycling was worse than the national average value. The municipality scored low in two indicators: food composting, which was non-existent for the year 2019, and WEEE recycling, which was much lower than the national average.

Table 1. (**A**) Data on MSW collection in the municipality for 2017–2020 in tons. (**B**) Data on the MSW composition in the municipality for 2019 in tons.

(**A**)

Year	Mingled Waste ("Green Bin")	Recyclable Waste ("Blue bin")	Garden Biodegrad-ables	Voluminous Waste	Glass ("Blue Bell")	Paper/Carton	WEEE	Landfilled Total	MSW Total
2017	81,228.66	8507.50	4693.68	-	438.78	-	5.1	85,922.34	94,873.72
2018	81,432.70	9477.25	6261.33	398.85	476.55	-	2.9	88,092.88	98,049.58
2019	82,127.50	10,453.75	8762.54	476.63	553.15	-	2.36	91,366.67	102,375.93
2020	80,413.33	10,510.90	7966.25	617.48	467.7	14.65	6.65	88,997.06	99,996.96

(**B**)

Waste Stream	Quantity (t)	Composition (% *w*/*w*) *
Biodegradable kitchen waste	35,488	35%
Biodegradable garden waste	10,238	10%
Oils and fats	1414	1%
Paper/carton	21,638	21%
Plastic	14,470	14%
Metal—Fe	1887	2%
Metal—Al	1004	1%
Glass	4277	5%
Clothing material	2285	2%
Wood	3267	3%
Voluminous waste	2213	2%
WEEE	2213	2%
Hazardous waste	111	0%
Other	1873	2%
Total	**102,376**	**100%**

* rounded to first non-decimal.

Table 2. CE indicator values for the Municipality of Patras, Greece and the EU for recent years.

No.	Name	Unit	Year			
			2017 [a]	2018 [a]	2019 [a]	2020 [a]
1	Waste generation	kg/per capita × year				
EU			500	500	505	520
Greece			504	515	524	499
Patras			443	458	478	467

Table 2. *Cont.*

No.	Name	Unit	Year			
2						
EU	Total waste recycled	% (*w*/*w*)	46.3	46.4	47.2	48.7
Greece			18.9	20.1	21.0	18.1
Patras			9.4	10.6	11.2	11.6
3						
EU	Food waste generation	per capita × year			128	
Greece					191	
Patras					166	
4	Food waste recycling	% (*w*/*w*)				
EU				34		
Greece				11.5		
Patras				0		
5	Glass package recycling	% (*w*/*w*)				
EU					75.6	
Greece					29.9	
Patras					39.8	
6	Paper recycling	% (*w*/*w*)				
EU					82.1	
Greece					84.6	
Patras					24.2	
			2020	2021 [b]	2022 [b]	2023 [b]
7						
EU	WEEE recycling	kg/per capita × year		11		
Greece				5.98		
Patras					0.06	0.05
8						
Patras	MSCRM efficiency	% (*w*/*w*)	52.58	57.65	56.35	56.80

[a] Population of the 2011 census (213,984 inhabitants) [23]; [b] Population of the 2021 census (215,922 inhabitants) [23]; data from [38,41,42,47–51], personal communication with the Municipality of Patras.

3.2. Demographic Characteristics

Some of the characteristics of the sample and its comparison with the municipality census are shown in Table 3.

Furthermore, the age categories ratios in our sample were 27% for 18–12 y, 28% for 26–45 y, 27% for 46–65 y, and 18% for >65 y, however, data at the level of the municipality (different classification ranking than ours) showed a representation of 25.3% for older people (for 60 years and above) [52].

The respondents also wrote down the municipal units or municipal communities (further division of the municipalities according to [26]) of their place of residence, as shown in Figure 2.

Table 3. Comparison of the demographic characteristics of the respondents with the municipality census of 2021 (data from [52]).

Parameter	Municipality of Patras 2021 Census	Sample
Sex ratio		
Male	49.1%	48%
Female	50.9%	52%
Education status		
Until primary school	24%	12%
Until secondary school (3 y)	11.1%	7%
Until secondary school (6 y)	32.9%	30%
University and post-graduate	22.92%	51%
Marital status		
Single	44.6%	36%
Married	44.1%	43%
Divorced	4.7%	10%
Widowed	6.5%	11%

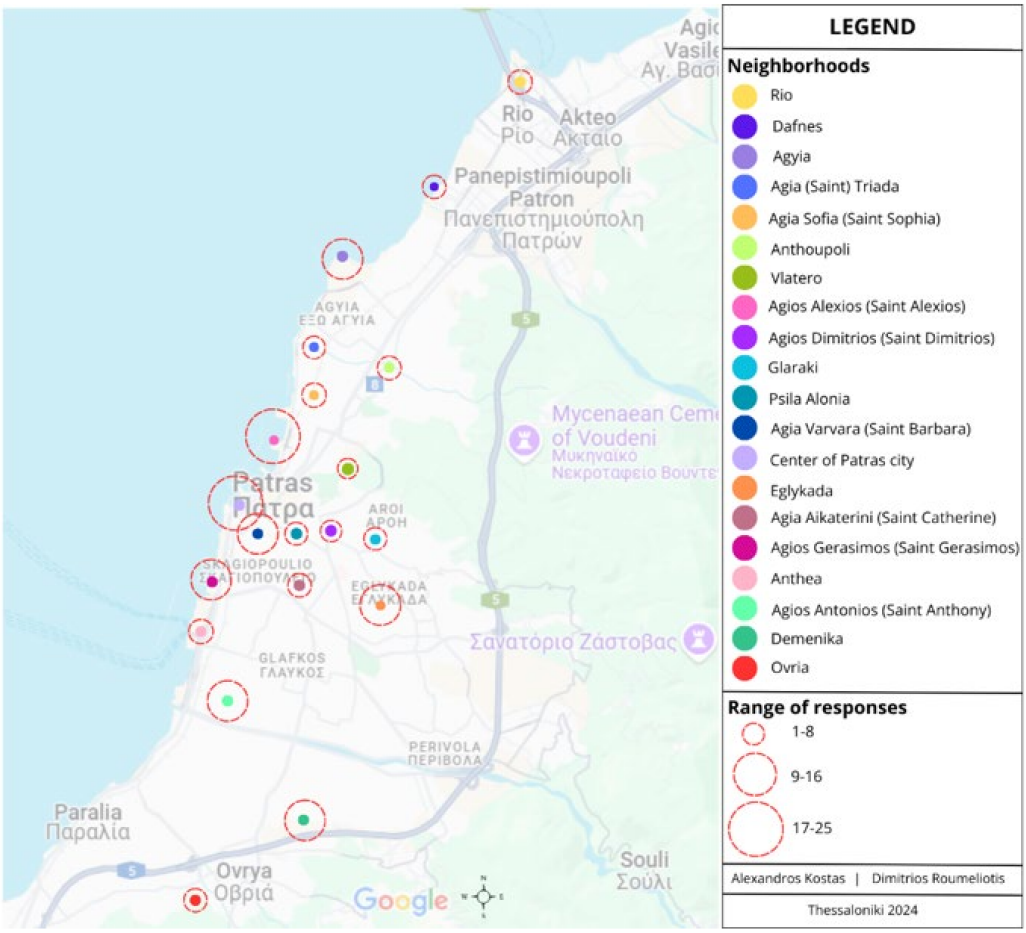
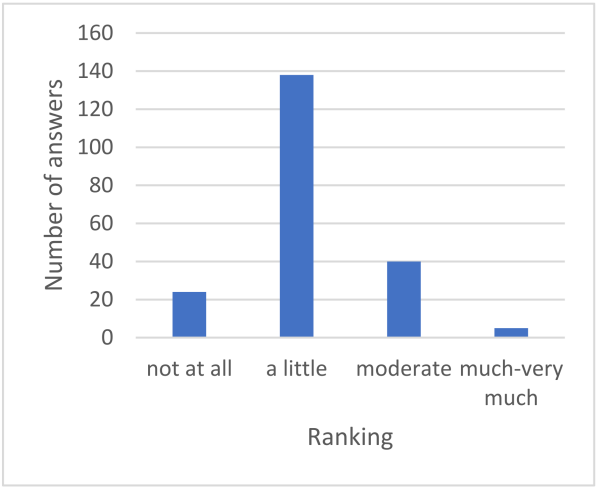


Figure 2. Relative distribution of the respondents' place of residence.

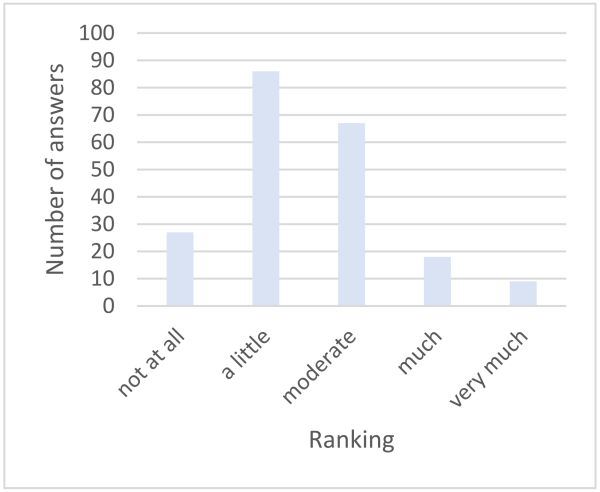
3.3. Respondents' Opinion and Statistical Analysis

The answers are visualized in Figure 3. Respondents gave generally uniform answers in Part B, specifically on the application of CE in MSWM in their municipality. Regarding Question II1, "In your opinion, is your Municipality capable in MSWM?", the responses were overwhelmingly lukewarm ("a little" was the most common response). In Question II2, "How much do you recycle?", most replied "a little", however, many also replied "to a moderate extent". In Question II3, on how people in total recycle in your family, most answered "two people", most probably the husband and wife, while in Question II4, "How much do you actively try reducing municipal waste generation?", most respondents did not really consider reducing waste production in their everyday life. In Question II5, "Do you actively use recycled/reused products in everyday life?", the answers mostly fell into the "a little" and "moderate" categories, while some respondents acknowledged that they were not actually aware of whether they performed this action or not. The general knowledge question (Question II6) on whether the respondents were familiar with the notion of CE, as described at the beginning of Part B, showed that they had some knowledge of this term ("moderate" was the most common answer), while some individuals were also very familiar with the term. The respondents also had a significantly high opinion of CE in terms of social advancement and environmental protection (Question II7). They also valued a lot the citizens' contributions toward MSWM (Question II8), possibly through participatory planning, though not directly hypothesized. They did not believe that the municipality encourages this participation (Question II9), but some of them (45%) were aware of the mobile application Sense.City (https://sense.city/), which promotes participatory planning at the level of the municipality. In essence, the application helps the user to upload photos and report problems pertaining to municipal waste collection, roadworks, water and sewage collection systems, and the illumination of public spaces in real-time. Out of this percentage, 39% rarely used it, while 35% had never used it.

Regarding ways that the citizens could actively apply CE in everyday life, the most popular option out of the four given was directly linked to waste minimization (Question II12) ("waste recycling"). Furthermore, application of reward recycling was also considered the most impactful way to mobilize citizens to apply CE (Question II14), while CE-targeted education in secondary schools was chosen as a quite effective education and dissemination activity (Question II13). See also the Supplementary Materials.



(**A**)



(**B**)

Figure 3. *Cont.*



Figure 3. Number of answers in each category. (**A**) Question II1, (**B**) Question II2, (**C**) Question II3, (**D**) Question II4, (**E**) Question II5, (**F**) Question II6, (**G**) Question II7, (**H**) Question II8, (**I**) Question II9, and (**J**) Question II10.

For chi-square comparisons in relation to sex, for questions 1, 2, and 4 to 9, pooling the answers belonging to Likert scale "1" and "2" or "4" and "5" was deemed necessary, for individual questions. For questions 7 and 8, pooling of answers belonging to Likert scale "1", "2", and "3" was deemed necessary. For all questions, there was no statistically significant difference between the men and women ($p \geq 0.05$).

For the chi-square comparisons in relation to age, for questions 1, 2, and 4 to 9, pooling of answers belonging to Likert scale "1" and "2" or "4" and "5", or "3", "4", and "5" was deemed necessary for individual questions. When the overall significant differences were found, post hoc tests were additionally performed as described in Section 2.4. The results are shown in Table 4.

Table 4. Cross-tabulation results in relation to age group. (**A**) Question II1, (**B**) Question II2, (**C**) Question II4, (**D**) Question II5, (**E**) Question II6, (**F**) Question II7, (**G**) Question II8, and (**H**) Question II9.

A (II1)

		Value	**Df**	**Asymptotic Significance (2-Sided)**
Pearson Chi-Square		25.069 [a]	6	**<0.001**
Groups		Not at all	A little	Moderate/Much-very much
Age	18–25			0.00214
	26–45			
	46–65			
	>65	0.00120		

[a] 1 cell (8.3%) had an expected count of less than 5. The minimum expected count was 4.29; critical *p*-value after Bonferroni correction: 0.004166; Red background: counts more than expected in the null hypothesis.

B (II2)

		Value	**Df**	**Asymptotic Significance (2-Sided)**
Pearson Chi-Square		53.723 [a]	9	<0.001
Groups		Not at all	A little / Moderate	Much-very much
Age	18–25			
	26–45			
	46–65			
	>65	0.0000		

[a] 2 cells (12.5%) had an expected count of less than 5. The minimum expected count was 4.83; critical *p*-value after Bonferroni correction: 0.0031; Red background: counts more than expected in the null hypothesis.

C (II4)

		Value	**Df**	**Asymptotic Significance (2-Sided)**
Pearson Chi-Square		47.022 [a]	9	<0.001
Groups		Not at all	A little / Moderate	Much-very much
Age	18–25			
	26–45			
	46–65			
	>65	0.0000		

[a] 0 cells (0,0%) had an expected count of less than 5. The minimum expected count was 5.00; critical *p*-value after Bonferroni correction: 0.0031; Red background: counts more than expected in the null hypothesis.

Table 4. *Cont.*

D (II5)					
		Value	**Df**		**Asymptotic Significance (2-Sided)**
Pearson Chi-Square		13.392 [a]	9		0.146
Groups		Not at all	A little	Moderate-Much-very much	Not aware
Age	18–25				
	26–45				
	46–65				
	>65				
[a] 1 cells (6.3%) had an expected count of less than 5. The minimum expected count was 3.93.					
E (II6)					
		Value	**Df**		**Asymptotic Significance (2-Sided)**
Pearson Chi-Square		37.622 [a]	6		<0.001
Groups		Not at all/A little	Moderate		Much-very much
Age	18–25				
	26–45				
	46–65				
	>65	0.000			0.00137
[a] 0 cells (0.0%) had an expected count of less than 5. The minimum expected count was 9.65; critical *p*-value after Bonferroni correction: 0.0041; Red background: counts more than expected in the null hypothesis; Blue background: counts less than expected in the null hypothesis.					
F (II7)					
		Value	**Df**		**Asymptotic Significance (2-Sided)**
Pearson Chi-Square		34.543 [a]	6		<0.001
Groups		Not at all/A lit-tle/Moderate	Much		Very much
Age	18–25		0.00137		0.00373
	26–45				
	46–65		0.00270		0.00032
	>65				0.00014
[a] 1 cells (8.3%) had an expected count of less than 5. The minimum expected count was 4.29; critical *p*-value after Bonferroni correction: 0.0041; Red background: counts more than expected in the null hypothesis; Blue background: counts less than expected in the null hypothesis.					
G (II8)					
		Value	**Df**		**Asymptotic Significance (2-Sided)**
Pearson Chi-Square		28.272 [a]	6		<0.001
Groups		Not at all/A lit-tle/Moderate	Much		Very much

Table 4. *Cont.*

G (II8)				
		Value	**Df**	**Asymptotic Significance (2-Sided)**
Age	18–25			
	26–45			
	46–65			
	>65		0.0001	0.0001

[a] 1 cells (8.3%) had an expected count of less than 5. The minimum expected count was 4.29; critical *p*-value after Bonferroni correction: 0.0041; Red background: counts more than expected in the null hypothesis; Blue background: counts less than expected in the null hypothesis.

H (II9)				
		Value	**Df**	**Asymptotic Significance (2-Sided)**
Pearson Chi-Square		14.426 [a]	6	<0.025
Groups		Not at all	A little	Moderate/Much/Very much
Age	18–25			
	26–45			
	46–65			
	>65			

[a] 0 cells (0.0%) had an expected count of less than 5. The minimum expected count was 5.18; critical *p*-value after Bonferroni correction: 0.0041.

It is clear from the comparisons that even though sex did not play a significant role in the notions and opinions, the age category did. This was evident despite the following. Due to the limited number of participants, we had to pool answers, and by doing so, the distinguishing power was lessened; we also applied a conservative approach in our post hoc analysis. In Question II1, "In your opinion, is your Municipality capable in MSWM?", young people were more forgiving; more than expected answered "moderate/much/very much". On the contrary, people of more than 65 years of age answered "not at all" to a greater extent than the other age groups. In Question II2, "How often do you recycle?", again, more than expected, people aged more than 65 years replied "not at all". This was also mirrored in Question II4, "How much do you actively try reducing municipal waste generation?". In Question II5, "Do you actively use recycled/reused products in everyday life?", no age differences were found. On the general knowledge question (Question II6) of whether the respondents were familiar with the notion of CE, as described at the beginning of Part B, only very young people seemed to be exceptionally aware. On the contrary, people in the oldest age group seemed to be the least aware. It is also worth noticing that in this age group, people had a significantly lower faith in CE as a driver for social advancement and environmental protection (Question II7). The acceptance of participatory planning in MSWM was also age related for the older generation in contrasting and competing ways (Question II8). No age differences were found for Question II9.

4. Discussion

Some important outcomes may be highlighted from the above-mentioned results for Patras, the third largest Greek city.

The selected indicators depict a mixed situation for the municipality, which struggles to encompass sustainable practices in MSWM, as occurs across the whole of Greece. For example, as shown in the National SWM plan of 2020 [20], there were very low rates of

recycling from separate collection and from mixed waste (16.5% and 21.6%, respectively) for Greece. Landfilling remains the option of choice for solid waste management (78.4% of waste was landfilled in 2018), while there is almost no waste to energy waste transformation nationally [53,54], except for medicinal waste [55]. As such, it is more imperative than ever to optimize the first, rather than the last steps in MSWM such as waste minimization and material recycling.

There seems to be a downward trend to MSW production for the country in relation to previous years, which may also be due to the extended economic austerity [56]. It is generally acknowledged that economic development drives an increase in MSW volume [57] and that financial prosperity is mostly just a demand-side factor that creates more recyclable materials [58]. Patras seems to have produced less MSW than the national average in the last years, but many factors may have led to this result. In any case, financial recession is not a way to achieve CE in MSWM because (a) waste minimization is reversible when the recession ceases to exist, and (b) less money will be allocated toward the appropriate management of waste by the public and private sectors [59]. Food waste generation is also suppressed in relation to Greece, which is a promising marker, but not suppressed in relation to the EU average. Food waste is an important concern in modern Western societies, but the social drivers that may contribute to increased food waste in Greek households are only now beginning to be investigated [60,61]. Citizens in the Prefecture of Western Greece are quite aware of the problem, according to recent research, but are not the most aware when compared to the whole country [61]. On the other hand, food waste management is very rudimentary in the municipality since no composting is undertaken. This is an ongoing problem in the country, with attempts to compost in some municipalities taking place mainly in the greater Athens area as well as pilot schemes with a finite duration [62–64]. However, centralized or home-based composting is one excellent way to apply CE in MSWM. Recycling performance was mixed, with some indicators better than others. One of the worst performances was in WEEE recycling which is a waste stream with ever increasing volumes and detrimental environmental effects [36]. In the EU, only about 3.5 Mt/y of the total 12 Mt/y produced are properly recycled [65], and this recycling process is not ideal for the personnel involved [66]. In other countries such as China, WEEE management is slowly being shaped under set policy frameworks [67]. The drop plan to shops that the municipality follows does not seem to work; other schemes in the Greek city of Volos with drop-off points did not work in the past either [36]. It is also likely that this plan does not work for bulky WEEEs because the customer must travel to the drop-off point, which may work for smaller appliances. It has also been shown from previous research that these appliances may be kept in the houses (sheds, basements, etc.) for an undisclosed amount of time [36] The new Greek Law 4819/2021 [21] mandates the incorporation of GPs in all local WM plans. These are designated areas where specific waste streams (e.g., paper, WEEEs, batteries, clothes, green, and bulky waste) will be collected, but their construction has not been finalized in most Greek cities, so this is another drawback. Furthermore, it is very common in Greece that many socially marginalized groups are involved in "grey recycling" such as people from the Roma community [68]. This causes deleterious effects to their health because they do not have the facilities for proper dismantling. It also negatively affects the environment as well as the sustainability of any official WEEE recycling scheme due to the lack of sufficient WEEE input. This is a reality that must be accepted; steps should be taken to address the existence of informal scavenging, incorporate legislative and policy measures, and formally engage these communities [69] to achieve circularity in WEEE recycling.

Regarding the social knowledge and acceptance aspect of our research, the sample of interviewees was more balanced in terms of the sex ratio than past research [22,44],

however, more educated people answered the questionnaire than the general census, which has also happened in past research [44]. As such, these results may mirror a "best case" scenario of people of higher educational status who will probably be more knowledgeable on waste management and environmental protection [70]. It is also important to note that older people are more difficult to reach with the tools used here (a "snowball" technique was mainly used for reaching the respondents), and a "young bias" may be acknowledged as a caveat [61]. Taken together, the prevailing situation may be worse than that depicted through the present survey.

The citizens were generally positive to the notion of CE and to its application in MSWM, and they approved the use of CE concepts such as municipal waste reduction; however, there was a repeatedly wary and distrustful disposition toward governmental bodies [44,71] and a general malaise toward frank change at the personal level, which was clearly age-related (i.e., older individuals were more obstinate to the alterations proposed). This contrasts with a large sample in northern Greece on PAYT, GPs, and RC acceptance, where younger people were more indifferent than people aged 56–65 years [22]. However, the present questionnaire was focused differently—specifically on CE and its application to MSWM along with the insertion of mobile apps for this cause. Young people are more familiar with the concept of CE and are accustomed to similar terms being ingrained in the spirit of the time, so in the present research, the results were more promising regarding young consumers.

The main conclusions of the above-mentioned findings were supported by interviews with the managers of the municipality MSWM. The interviewees highlighted—from the point of the much-maligned policy enablers—some common factors of discontent including bureaucracy, counterproductive mingling of regional, ministerial, and national jurisdictions, aging infrastructure, lack of financial resources, lack of public engagement, and a lack of knowledge in the general public. Environmental education has been identified as the basis for environmental citizenship and the main contributor toward pro-environmental behaviors [72] by experts and public alike.

The limitations of the present research include various methodological and practical constraints; regarding the indicators' calculation, the validity of the data used was directly correlated to the validity of the input data in the local MSWM plan. Furthermore, we assumed specific percentages of the "blue bin" waste streams based on previous national data. For the survey performed, the sample was quite small; the sex ratio was balanced to the national census for Patras, however, education status was not. The inherent subjectivity on how people mark their actions and dispositions when answering a questionnaire should also be considered. This was also encumbered with the fact that older people may not be acquainted with the term of CE as it was briefly described here, even if they unknowingly apply some aspects of it, for example, older people usually waste less food than younger people [73]. Nevertheless, the unfamiliarity of the older Greek generation with the CE term is of some value as a standalone finding. Finally, the pooling of data for statistical analysis has inexorably led to decreased sensitivity. Future work on the matter should include a stratified questionnaire sample of more diverse characteristics that will also include questions on specific examples of circularity in MSWM as well as analysis of up-to-date data on MSWM, possibly from the upcoming NSWM plan under preparation from the Ministry of Environment.

For the city of Patras, some recommendations on updated policy and on plans and programs specific to waste collection may include:

- Immediate implementation of the PAYT programs as laid out in Law 4819/2021. All necessary infrastructure (i.e., alternative collection systems) should also be put in place.

- Intensive promotion of home composting that will include a comprehensive educational campaign and the donation of a significant number of home composters. Set up of a division within the mayoral waste management department, that deals exclusively with this activity.
- Set up of the envisaged GPs at prominent sites in the city.
- Revision of the local MSWM plan so that it includes key performance indicators and important milestones.
- Rigorous changes in the WEEE collection scheme that includes two-way information flow between the Mayor and Hellenic Recycling Agency, the intensification of information campaigns, increase in collection points, amelioration of services for bulky WEEE, and social inclusion actions for the Roma community.
- Promotion of the Sense.City application and/or the establishment of a similar application exclusively for reporting problems in waste collection and illegal dumping, help with bulky waste, aid with common questions, and queries for municipal waste.

5. Conclusions

The ongoing pursuit toward a cleaner and safer environment, social equity, and economic growth can only be achieved through a visionary strategy focused on circularity in production and consumption that fosters resource efficiency, waste valorization, and end-waste minimization [74]. In this context, CE implementation in MSWM in a large city in Greece was evaluated in recent years with the aid of performance indicators. The indicators showed a situation with room for improvement; while waste production and food waste production were fairly suppressed, indicators for recycling and material reuse generally fared worse. Citizens of a younger age were more familiar with the notion of CE while people in the oldest age group seemed to be the least aware, had a significantly lower faith in CE as a driver for social advancement and environmental protection, and a significantly lower opinion on management authorities. When getting to brass tacks, there was some recycling activity among the citizens but not a conscientious intent to minimize waste or to use items from recyclable materials. A mobile application that promotes interaction on MSWM in the city was known by almost half of the interviewees, but was rarely used. Intensive changes in MSWM at the local, regional, and national levels are urgently needed for Greece in order for the country to achieve the ambitious goals set in the amendments of waste-related EU directives.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su17052265/s1, Table S1: Focal points of MSW generation; Table S2: Current programmed waste stream itineraries; Table S3: Total units and type of waste collection and storage facility itineraries; Figure S1: Ranking of predetermined answers in Part B of the citizens' questionnaire; File S1: Questionnaire translated into English.

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the present work. However, we confirm that all procedures performed in this study followed the guidelines of the Declaration of Helsinki. Any measures for personal data protection were also taken according to the DPO instructions.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. A GDPR complying statement was included in the first page of the questionnaire and can be found in the Supplementary Materials. Participants that filled in the questionnaire agreed with the terms and conditions laid out in the statement. Participants could withdraw at any time and their responses would not be recorded.

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Abbreviations

The following abbreviations are used in this manuscript:

CE	Circular economy
CEAP	Circular economy action plan
GPs	Green Points
HERRCO	Hellenic Recovery Recycling Corporation
MSCRM	Maintenance Sorting Centers for Recyclable Materials
MS	Member state
MSWM	Municipal solid waste management
PAYT	Pay as you throw
SDGs	Sustainable development goals
SWM	Solid waste management
WEEE	Waste of electric and electronic equipment

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