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Sustainable urban perspectives through waste indicators evaluation.

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Abstract

Human Activities are considered among the main production of any kind of pollution. The paper focuses on the evaluation and the assessment through the DPSIR model of the existing practices, procedures and results obtained in order to determine whether the Municipal Solid Waste (MSW) management implemented in three major Municipalities in the Urban Area of Greece in Attica Prefecture and consist from Municipalities of Nea Smirni, Vyronas and Piraeus, could be considered viable and sustainable. The evaluation indicated that MSW in Greek cities has reduced over the last years, also suggesting a steady downward trend, which could be considered consistent with that of the per capita incomes in Greece due to the extended economic austerity, while at the same time the recycling indicator seems to optimize. The results are very useful for policy makers, local authorities to take actions related with the target set from circular economy strategy as well as the targets set from United Nations Development Program

Keywords: sustainability indicators, solid waste management, DPSIR, waste strategies, circular economy, sustainable urban development

Highlights

- Measuring environmental performance through Indicators model (DPSIR)
- Adoption of the target set from circular economy, UNDP in local level
- Economic impact in the framework of waste management in Urban Areas
- Evaluation of the most significant aspects of sustainability in Urban Areas

1. Introduction

The technological development and improvement of living standards through the global economic prosperity of the past decades have developed massive needs for goods and products (Amvrosiou et al. 2017; Zavali and Theodoropoulou 2018), resulting in several environmental impacts such as the greenhouse effect, climate change, reduction of natural resources, *etc.* (Baumgartner 2011; Kyramargiou and Vardopoulos 2019). Those damages arose from the lack of a proper institutional framework as, until recently, our society ignored the dangers of prosperity and did not hold the necessary ecological consciousness (Zorpas 2014), as well as the need to satisfy the increasing products and services consumption (Lebel and Lorek 2008; Lawson et al. 2016) of the growing urban influx (Kammen and Sunter 2016).

In addition, more than 245 billion tonnes of waste per year are produced from commercial activities in Europe (Eurostat 2019a). Moreover according to the projections of the World Bank (2018) the average waste production per citizen in the developed countries may reach 2.1 kg/day by 2025. Thus, waste management nowadays, and in particular sustainable municipal waste management is considered one of the most social and significant issues, which is often an element of conflict between social and political aspects especially in local level (Miller and Spoolman 2008). Due to its particular nature, managing most of the matters associated, lies in the cooperation of all social partners and the broader scientific consensus (Grodzińska-Jurczak et al. 2006). The use of a rational and sustainable waste management strategies (covering prevention, reuse, recycling, energy recovery, *etc.*) involves the co-operation of the local and regional competent bodies while at the same time, it should be governed by the requirements of the national environmental policies and legislation (Eriksson et al. 2005; Zorpas et al. 2015a, 2017, 2018; Poulos et al. 2018). Therefore, sustainable solid waste management is a multidimensional and multidisciplinary subject to be addressed by the local and regional authorities.

Waste in simple terms result from any kind of consumption and any kind of production process, while any time a simple item is disposed of then a whole new set of impact is involved treating it. Taking into account the sources of waste, those can be divided into several groups: municipal solid waste (MSW) (including household and commercial), industrial waste (including numerous activities such as manufacturing -light and heavy-, refinery, chemicals mining, *etc.*), hazardous, and nonhazardous waste, medical waste, and other not classified as municipal, industrial, medical *etc.*. Solid waste are substances or objects which appear mainly in solid state from which the holder needs or is required to be exempted and are not considered hazardous according the European Union Hazardous Waste Catalogue (Karagiannidis et al. 2008; Inglezakis and Moustakas 2015; Malamis et al. 2017). MSW include the heterogeneous solid waste mass deriving from local authorities (including municipalities and communities) as well as the homogeneous mass of agricultural, industrial and debris waste (Zorpas et al. 2013b; Inglezakis et al. 2018), namely solid waste produced by households, shops, street and other public spaces cleaning procedures, but also those produced by all kinds of businesses and which by nature can be considered similar to household solid waste. In particular, within the classification of MSW, all waste other than those in liquid form are included, without measuring a significant percentage of particulate pollutants (*i.e.* liquid waste) and gaseous pollutants (Gidarakos et al. 2006). MSW are divided into two main categories, municipal waste and special waste, and these are classified into many other sub-categories. Zorpas, et al. (2015) divide MSW into 13 main streams and

those in more than 50 sub categories, while according to [Misra and Pandey \(2005\)](#) MSW is divided into 970 types, 406 of which pose a risk to the environment and public health due to either high toxicity, or mobility, or carcinogenicity effects, or to some extent persistence in the environment, *etc.* like chlorinated solvents, waste from metal degreasing, cyanide waste, dioxin-based waste, and polychloro biphenyl waste.

MSW sustainable management, must take under consideration all the relevant economic, social and environmental constraints as well as the carrying capacities of the ecosystem, aiming towards autonomy ([Tatsi and Zouboulis 2002](#); [Skordilis 2004](#); [Seadon 2006](#); [Bovea and Powell 2006](#); [Asase et al. 2009](#); [Abeliotis 2011](#)). More specifically it is considered necessary to conduct relative qualitative and quantitative analysis of the municipal waste produced ([Fragkou et al. 2010](#)). [Zorpas et al. \(2015\)](#) suggests that using waste compositional analysis could define the origin and the scale of the waste produced. The heterogeneity of the materials and their quantities is a function of the geographic and demographic characteristics of each region, the GDP, the technology used, the seasoning, the consumption patterns, ethics, daily routines, educational level *etc.* ([Tchobanoglous et al. 2001](#); [Zorpas et al. 2015b](#)).

Sustainability is a matrix looking towards an ideal economic outcome for both human and natural environment, both in present and the indefinite future. Principal element is the harmony among raw materials and the production of goods ([WCED, 1987](#)). Hence, sustainable actions objective is to achieve high production using as fewer raw material as possible. Sustainability implies that natural resources should be exploited at a rate proportionately lower than the rate of which are recycled, otherwise the environment is degraded which at the long-term could lead to the inadequacy of the earth's ecosystem to sustain human existence (ecological crisis) ([Zorpas 2014](#)) and as result sustainability is divided into three interrelated pillars, namely the environment, the economy and the society ([Duić et al. 2015](#); [Vardopoulos 2017](#)). Furthermore, sustainability is a dynamically improving process with long-term objectives and varying goals ([Bagheri and Hjorth 2007](#)) and is linked to political thinking and participation of society in decision-making ([Bagheri and Hjorth 2007](#); [Zorpas and Saranti 2016](#)). Sustainable development is addressing economic growth, as studied and implemented, considering the environment and the society ([Lélé 1991](#); [Kostakis et al. 2018](#)). The criterion for sustainable development is the maximum possible raw materials use without however interrupting their natural production rates and their endless sufficient quantity ([Borowy 2013](#)). Possible decision, planning and activation of the mechanisms towards sustainable development require both qualitative and quantitative assessment ([Mitoula et al. 2012](#); [Vardopoulos 2018](#)). For this reason it is best advised to use an indicators system which is able to highlight the most important aspects of sustainability ([Farrell and Hart 1998](#); [Tscherning et al. 2012](#); [Inglezakis and Zorpas 2014](#); [Vardopoulos et al. 2018](#)).

Indicators are computational sets seeking at simplifying, quantifying and transmitting certain information contributing towards identifying information that are not easily perceptible ([Gamberini et al. 2013](#); [Vardopoulos et al. 2018, 2019](#)). Sustainability indicators are developed for measuring the environmental performance of actions and/or procedures implemented at an area or by an organization ([Mori and Christodoulou 2012](#); [Ravetz et al. 2018](#)). Although mainly used at national inventories (eg. national greenhouse gas emissions inventory), there is a huge interest from corporations for the calculation and reporting of their environmental performance

(Bossel 1999). An environmental and sustainability indicators system constitutes the framework for monitoring and recording the environmental condition and contributes towards the compensation of established needs and requirements for assessing and comparing the situation of an area to another, while it seeks to support competent bodies in decision making and developing action plans (Victor 1991; Zorpas et al. 2013a; Inglezakis and Zorpas 2014).

Sustainability indicators development for managing MSW depends almost entirely on the competent bodied reported quantities. However, there is a significant uncertainty about the reliability of the data inputs delivered. Some researchers try to determine the “fault” range using mathematical models (Chowdhury 2009; Kollikkathara et al. 2010; Al-Khatib et al. 2015), while others are addressing the municipal waste management issue via the economics discipline (Victor 1991; Pearce and Atkinson 1993; Olewiler 2006).

The current research proceeds comparing practices, procedures and results obtained in order to determine whether the MSW management implemented in Greek urban areas, could be considered viable and sustainable. In doing so, three major municipalities in Attica Prefecture of Greece are used as case study; Municipalities of Nea Smirni, Vyronas and Piraeus.

2. Methodology

2.1. Area Selection

According to Eurostat (2019), the per capital production of MSW in Greece was 504 kg for 2017, which is 60% highest compared with the 1995 baseline. Since the first bailout agreement early 2010, Greece has come through a nearly ten year actual economic, political and social crisis; economic adjustment programs followed austerity packages amid elections and successive change of power, Greece-wide strikes and riots and the European migrant crisis. The consequences were far from negligible and no-one currently disputes the fact that the crisis triggered particular social and consequently urban transformation; unemployment, migration, gentrification, *etc.* (Mavridis 2018) (Table 1). As a result, and since waste production, collection and sustainable management depends on the social and economic system (Koumparou 2017), it is anticipated that MSW issue in Greece has also been affected.

[Table 1]

The legal framework for waste management in Greece closely follows the European developments as well as the corresponding directives. The main legislation on waste management governing Greek authorities is Greek Law 4042/2012. In full compliance with the waste framework directive 2008/98/EC, the basic concepts and the management framework laid down in Greek Law 4042/2012 are applicable to the scope, definitions, waste hierarchy, permits, liability, *etc.*. In addition, Greek Law 2939/2001 regulates the packaging waste and other special waste types management and reuse. Further legislative measures, such as presidential decrees and ministerial decisions, complete the Greek legislative scheme with the Joint Hellenic Ministerial Decision 50910/2727/2003 on measures and conditions for the management of solid waste, being one of the most significant.

A significant number of waste management plans have been established during the last ten years by local authorities and central administration in Greece, in line with the European Union planning requirements. The Hellenic National Waste Management Plan (NWMP) and the Hellenic National Waste Prevention Program (NWPP) ([Hellenic Official Gazette A' 174/2015](#)) describe domestic waste management strategies, policies, and objectives, indicating the overall requirements and suitable steps for waste management, addressing the problem of particular waste types or even regional planning. Particularly, included in the NWMP are adequate data on location identifying requirements and the capability of potential landfill or significant waste disposal facilities, current waste collection systems and large waste disposal and recovery installations and waste prevention programs, *etc.*. In addition to the Hellenic National Hazardous Waste Management Plan (NHWM) ([Hellenic Official Gazette B' 4326 2016](#)), Regional Management Plans (RMP) have been released towards ensuring a sufficient and integrated network of waste disposal systems, as well as addressing the present waste management state. In the RMP, the landfill sites or major waste treatment site ([Hellenic Official Gazette B' 1572 2002](#)) have to be included, but unfortunately most often they are not, arising local conflicts.

The Hellenic Ministry for the Environment is accountable for the development of strategies, domestic planning, technical engineering issues, licensing, regulating and funding the waste and disposal systems in Greece (www.ypeka.gr). The collection, the transportation as well as the storage of MSW is, by default, the responsibility of the Greek Municipalities. It is the duty of each municipal's Waste Management Authorities to operate transmission facilities, process and disposal of waste. Greece lacks waste prevention practice on separate collection, re-use, recycling and recovery. Hellenic Decentralized Administrative Authorities are the competent officials in economic issues, environmental matters and permits, whereby Hellenic Regional Authorities are the competent bodies on industrial permits and health and safety provisions. The private sector has recently become more involved in urban waste treatment, primarily through the public-private partnership system, regulated by the [Greek Law 3389/2005](#).

Despite the fact that the local authorities' power is limited in terms of intervention throughout the waste management stages, as previously described, it is clear that their role is of particular importance for a number of reasons. Waste collection (Pressure), environmental protection (Impact), recycling (Response), ensuring public health (Driver) and maintaining of public spaces cleanliness (Pressure), *etc.*, fall within the competence of all the local authorities. Thus, local authorities have the opportunity to elaborate their own adapted to local needs operational and management plan.

All municipal authorities, by developing environmental strategies (Response), look forward to the sustainable development of the region. The protection (Impacts) and improvement of the environment as well as the improvement of the quality of life of the residents along with the improvement of their activities regarding the environment, constitute the fundamentals under which the local competent bodies operate. The identity and the physiognomy of each municipality (Drivers) are of particular importance in shaping the sustainable local development agenda. The specific characteristics of the municipalities act as a reference point since they shape the residents way of life and environmental identity. The importance of the urban

environment constitutes a collective principle since the environment is not only a physical space but also an organic tier that connects humans to the physical world and culture. The three municipalities of the current research were chosen for case study by population density. Municipality of Piraeus representing Attica Prefecture urban areas with population approximately 150000 inhabitants, Municipality of Nea Smirni of about 100000, and Municipality of Vyronas of about 50000 residents. In addition, it is estimated that this three Municipalities share mutual characteristics and combine certain features to a number of cities in Greece and Europe, such as the temperate Mediterranean climate, the scale and geometry of the urban layout, consumption patterns, *etc.*.

In particular, Municipality of Nea Smirni occupies an area of approximately 3500 km². According to the Hellenic Statistical Authority latest census ([Hellenic Official Gazette B' 698 2014](#)), Nea Smirni counts approximately 73500 residents, however, according to Municipal Authority calculations, the actual number of residents is estimated at around 97000. Morphologically, the municipality of Nea Smirni has significant slopes from the West to the East. Population is purely urban and the neighborhoods are almost homogenized. Currently, there is no city space left for horizontal expansion. The affinity with the Municipality of Athens, in addition to housing development inducement, is considered the main reason for the development of the services market, mainly around Syngrou Avenue, and has been the main reason for not witnessing any noisy activities market. The -services- market expands around the municipality but is focusing to the city center ([Mitoula and Georgitsoyanni 2012](#)). In recent years, Municipality of Nea Smirni has witnessed an intense construction outbreak and a considerable population increase that gradually stretched the municipal infrastructure to the limits, while a number of environmental issues have been raised ([Malindretos and Abeliotis 2011](#)). Minimization of the unstructured land, constantly burdensome traffic volume, lack of parking spaces, considerable waste quantities, *etc.*.

[Figure 1]

According to the [Municipality of Nea Smirni Regional Waste Management Plan \(2015\)](#) 7.6% w/w of the total MSW produced end up to recycling or other recovery, while the remaining 92.4% w/w is led for disposal in the Sanitary Landfill of Fili (Attica region), whereas the average quantity of MSW generated per capita is shaped at 1.01 kg/day, which is 19% lower than the national average (1,25 kg/day) ([Table 1](#)). The municipality for the collection of the MSW (including recycling) offers 2440 waste collecting containers or bins, and holds 18 waste collection heavy vehicles and a number of other smaller supporting equipped vehicles. MSW management costs approximately € 85/ inhabitant/ y. The main objectives set by the [Municipality of Nea Smirni Regional Waste Management Plan \(2015\)](#) for 2020 are presented in [Table 4](#).

[Table 2]

[Table 3]

[Table 4]

Municipality of Piraeus covers an area of 10.9 square kilometers and hosts approximately 164.000 inhabitants, a number which classifies Piraeus as the fourth

largest city in Greece. Also, Piraeus is the most important industrial center of the country, the largest commercial center of the Greek economy, and the most significant commercial and passengers port of Greece (the largest in Europe with regard to passenger traffic), connecting the main land with the almost all of the Aegean Islands. Thus given the tourist traffic, according to the [Hellenic Chamber of Hotels](#), 41 hotels are located in Piraeus, holding 1645 rooms or 2967 hotel beds. In addition, in Piraeus are located 114 public schools, 62 churches, 6 public hospitals and 5 public factories, while according to the [Piraeus Professional Chamber](#) approximately 2200 businesses of all types and size are currently operating. Solid waste production quantities are presented in [Table 5](#) according to the [Municipality of Piraeus Regional Waste Management Plan \(2015\)](#). Piraeus has a fleet of motor-driven equipment including 54 waste collection heavy vehicles, 22 several utilities heavy vehicles, and 14 other supporting equipped heavy vehicles. Within the municipality of Piraeus approximately 12000 waste collecting containers or bins are currently serving the waste collection needs. The main objectives set by the [Municipality of Piraeus Regional Waste Management Plan \(2015\)](#) for 2020 follow the objectives set by the NWMP, as presented in [Table 4](#), without further in-depth investigation or assessment of the handling capacity.

[Figure 2]

[Table 5]

The municipality of Vyronas is located at the foothill of mount Hymettus in the northeast of the Attica Prefecture. It owns a privileged position due to its proximity to the city center of Athens, a fact that justifies the urbanization of recent years. The municipality area located close to mount Hymettus is a forest, while the southwest part is urban. The total area covered by municipality of Vyronas is approximately 9500 square kilometers. According to the latest census the population counts approximately 61000 residents, without any considerable population fluctuations over the last years. However, anthropogenic pressures are intensifying due to the increase of immigrant and students (proximity to University campus). Hence, the management of the natural and anthropogenic environment along with the municipal waste has been identified as of first priority by the municipal authorities. For 2014 MSW production is estimated to 327.75 kg / person, with the total MSW management cost accounting to € 2536340. However, it should be noted that the recyclable materials collected are directly sold (Concerns secondary materials absorption industries by recycling and incorporating (recyclers) into their production process. These are mainly the metal industry (Fe, Cu, Al) and secondarily the plastics, glass, tires, oils, polyurethane industry and generally all the industry is able to utilize the secondary materials in the production process).

The municipality for the collection, reception, and recycling of the MSW holds 35 waste collection heavy vehicles including a number of some smaller supporting equipped vehicles, and offers 1751 waste collecting containers or bins, located at 103 points around the Vyronas district. The main objectives set by the [Municipality of Vyronas Regional Waste Management Plan \(2015\)](#) for 2020 follow the objectives set by the NWMP, as presented in [Table 4](#), without further in-depth investigation or assessment of the handling capacity.

[Figure 3]

[Table 6]

At this point it should be noted that all three selected municipalities, as most of the municipalities in Attica Prefecture for the collection and transportation of the MSW use the same pattern, *id est* heavy vehicles collecting waste arrive at the transfer station and empty their load to container vehicles, which will end up at the Sanitary Landfill of Fili (Attica region). No compaction of the municipal waste occurs in the containers.

2.2. DPSIR framework

The evaluation of the most significant aspects of sustainability is done by creating a series of appropriate indicators. Selection and use of indicators, which reflect and identify the connection between human activities and their environmental effects, and consequently, the appropriate strategies to respond to these effects. The most typical method for reporting the connection between environmental causes and effects is the DPSIR model (Fig. 1) (Vardopoulos et al. 2018).

[Figure 4]

The DPSIR indicators development model is based on the relative actions taken in order to assess the negative consequences deriving from human economic activity, and is associated with the quantitative results of the MSW management procedures. Thus, using the appropriate indicators, the human-and-environment cause-and-effect relationship and interaction is captured (Jacob and Volkery 2004). Thus in order to highlight the most important aspects of sustainability, methodologically, an indicators system is applied. Sustainability indicators for the scope of the current research are developed, using the latest official data available for three major municipalities in Attica Prefecture, Greece.

The sustainability indicators are developed under the following principles (Jacob and Volkery 2004):

- The social and economic development (driving force) is considered the major source of pressure on the environment.
- Driving forces act pressure on the environment.
- Therefore, the state of the environment is altered thus the ability to support demand is differentiated.
- Alterations on the environmental state will most likely have impact on human health, ecosystems, *etc.*, which may be reflected by the volume of those environmental state alterations.
- Thereby, impact leads to necessary mitigation measures (response), which accordingly with their kind and nature act directly on the driving forces, the pressure sources the environment and its state.

The developed sustainability indicators were:

- i) the Municipal Solid Waste Production (MSW-P) indicator representing the ratio of the amount of MSW produced to the municipal population at a given time. This

- indicator provides a measure of the average waste quantity, a figure that is quite usable and comparable,
- ii) the Municipal Solid Waste Composition (MSW-C) indicator recording the ratio of the most known materials included in the reported amount of MSW (Table 3) to the total amount of MSW produced at a given time. The indicator provides information on the economic and ecological utility of the waste as well as the disposal methods provided, and
 - iii) the Municipal Solid Waste Recycling (MSW-R) indicator measuring the recycled municipal solid waste compared with the total amount of MSW produced at a given time.

By putting the focus on quantifiable parameters, the developed sustainability indicators identify differences among similar activities and efficiency-reduced points, providing insights for optimizing MSW management. The developed sustainability indicators address certain aspects for the assessment of the MSW management efficiency and effectiveness, and have been drawn up by the authors following a significant number of years in research on the matter subject and after several conservations and debates with different stakeholders in the field. However, the efficiency and effectiveness of the MSW management appears to be affected by a number of crucial non-quantifiable (at least necessarily) parameters, namely cultural, social, economic, and political conditions. Hence, although it is clear for the authors that the developed sustainability indicators do not cover the entire spectrum for the assessment of the MSW management efficiency and effectiveness, they have chosen to further proceed with the current research, aiming towards paving the way for a future deeper assessment. In addition, the information and data accessible to the study group did not permit for a more advanced analysis during the course of this study.

For the current methodology setup commercially available data were collected from; (a) Eurostat (www.ec.europa.eu/eurostat), the Director General of the European Commission responsible to provide statistical information data, (b) The Hellenic Statistical Authority (ELSTAT) (www.statistics.gr) the on regular basis updated official national statistical provider in Greece, (c) The Hellenic Ministry of Environment and Energy (www.ypeka.gr) the Hellenic government department responsible for industrial, environmental and energy policy, (d) the [Municipality of Nea Smirni Regional Waste Management Plan \(2015\)](#), (e) the [Municipality of Piraeus Regional Waste Management Plan \(2015\)](#) (f) the [Municipality of Vyronas Regional Waste Management Plan \(2015\)](#).

3. Results and Discussion

MSW management by sustainability indicators assessment, from an environmental point of view, is a common structured approach for the thorough examination and comparison of the procedures and activities followed by various municipalities (Zotos et al. 2009). The DPSIR model based sustainability indicators developed stand on the relative procedures and activities followed by various municipalities, as actions taken towards addressing social activities. Table 7 lists the developed sustainability indicators and their function in the DPSIR causal framework.

[Table 7]

Table 8, providing a measure of the average waste quantity, presents the ratio of amount of MSW produced to the municipal population of the three municipalities under study during 2010-2015 (based on the data of the 2011 Hellenic National Census). Using data listed in Table 8 the MSW-P sustainability indicator is developed as illustrated in Fig. 5.

[Table 8]

[Figure 5]

The annual amount of MSW attributable to each resident presents a sharp fall in 2011, which stabilized around 2013. This was somewhat anticipated reflecting the first signs of the actual economic, political and social crisis occurred in Greece. Ranging from 178 kg MSW per capita in Romania to 789 kg MSW per capita in Denmark, the corresponding value for Greece in 2015 was somewhere in the European in-between, *id est* 488 kg MSW per capita as recently reported by Eurostat (2019b). Thus, the values reported in Table 8 and illustrated in Fig. 5 concerning the three Greek municipalities under study are placed below the Greek average, while the best performance is over time held by Vyronas. The indicator clearly reflects a consumer patterns change tendency (Theodoropoulou and Zavali 2018), and perhaps reflects on population growth trends. Of particular importance is the fact that the indicator trend is convergent with the socio-economic dimensions presented in Table 1.

The MSW-C sustainability indicator, recording the ratio of the most known materials included in the reported amount of MSW (Table 3) across the three municipalities of the Attica Prefecture is presented in Table 9 and Fig. 6 accordingly.

[Table 9]

[Figure 6]

Moreover, in an attempt to capture the recycling status among the under study municipalities of the Attica Prefecture, the MSW-R sustainability indicator is developed measuring the total recycled MSW compared with the total amount of MSW as presented in Table 10 and illustrated in Fig. 7 accordingly.

[Table 10]

[Figure 7]

The above analysis suggests that MSW management has evolved over the last two decades in certain municipalities in Greece. Properly treating MSW can provide social and economic benefits by dealing waste as a resource (suitable waste management can provide vital resources), reducing environmental pressures, create new jobs and boost competitiveness, in the course towards circular economy aiming at achieving a desirable urban sustainable development. However, although progress has evidently been made, the sustainability indicators developed suggest that MSW management is far from been considered sustainable, while progress -statically wise- is depended to the economic differences among districts (usually most affluent produce more MSW per capita), and the recent economic crisis. Despite the fact that urban waste account

for only about 10% of all waste, waste composition patterns are directly related to the consumption patterns. The current prevailing EU waste policy rationale is the waste hierarchy which gives priority to waste prevention, followed by reuse, recycling, other forms of recovery and, finally disposal or landfill as the less desirable option (Zorpas et al. 2018). Although the main driving forces behind sustainable MSW management are the European policies and guidelines, policymaking at national, regional and local level is of great importance (Karagiannidis et al. 2004).

This research in particular indicates that there is currently room for improvement in the MSW management plans implemented by the three municipalities, and consequently in other municipalities in Greece, thus it cannot be considered to be viable and sustainable. Through examination and comparison of the three local municipal waste plans it is evident that the Greek municipalities operate independently. Moreover, the plans are mostly developed with estimation methods - subject to a large margin of errors-, and they tend to present similar projections, while it is noted that they are quite similar at both their estimations and future projections. Additionally, although these plans have been drawn up by scientific groups (either in-house or outsourced) it is noted that the huge ever-growing body of scholarly literature dealing with MSW, which is found to be consisted with the findings of the current research, and which would greatly contribute towards achieving the main sustainability objective, is flagrantly ignored. More particularly, Abeliotis et al. (2009), studying Greece, developed a novel decision support system for MSW, while Zotos et al. (2009) developed a systemic approach for MSW summarizing the state-of-the-art available tools while compiling a set of guidelines for developing waste management master plans at the municipal level. Economopoulos in 2010 suggested a methodology for developing strategic municipal solid waste management plans. Chalkias and Lasaridi already since 2011 stressed the benefits from GIS-based modelling for MSW management, while Economopoulou et al. (2013), discussed about a system capable of formulating alternative MSW management plans meeting certain constraints set by local communities and authorities. In 2015 Lasaridi et al. presented the design, development and main features of a web-based tool capable of enabling local authorities to select and implement the optimum MSW strategies considering their local conditions and to prepare their local municipal waste plans. Later, Panaretou et al. (2017) presented an integrated methodology on the development, implementation and evaluation of the MSW scheme. Lately, Poulos et al. (2018) recorded the inconsistencies and deficiencies in the MSW management practices in the municipality of Athens, Attica, pointing out certain major issues affecting the overall efficiency and effectiveness of the strategy as a whole such as the working hours of the landfill site, the stealing of the recyclable waste from the available bins (for black-market sales), traffic jam, the lack of cooperation by the inhabitants and among authorities, the economic crisis and the lack of political will. Scientifically proven and tested perspectives, analyses and solutions that are neither encountered nor adopted across the three municipalities' local waste plans, which would provide after all adequate solutions in specific aspects of the MSW management issue.

As follows the prospects for achieving the 2020 objectives although mixed and somewhat complicated are particularly bleak. However, most Greek cities will have to step up their efforts to reach the target. Although bottlenecks preventing a more integrated approach are perfectly understandable (political orientations, budgets, etc),

a cooperative, measurable, applicable and effective MSW system shall be applied in full compliance with the requirements set by the EU, reflecting contemporary scientific standards.

Thus, in view of the above, efficiently visualizing the complex aspects surrounding waste management in the inner-city areas, offering a solid ground for rethinking the entire waste process and perhaps policy, further actions and strategies are suggested in order to achieve the goals of sustainable MSW management. For start the promotion of the most-clean and environmentally friendly processes such as prevention, reuse and zero waste recycling. Subsequently separation of the biodegradable waste in order to make them available for compost and energy production. Moreover, development of innovative, cost-effective and environmentally friendly solid waste management methods and tools, through transferring the know-how and experience among Greek cities. Next, alteration of the pricing policy by introducing a 'pay as you pollute' system. And finally, public awareness raising and awakening of the ecological consciousness through environmental education.

The most important limitation in this particular study lies in data. The three municipalities' incomplete collection and availability of statistical data for the longitudinal assessment of appropriate sustainability indicators makes it difficult to assess the situation in the long term and to provide a comprehensive solution to the complex and multidimensional problem of the municipal waste management.

Future work should focus on the assessment of further Attica Prefecture municipalities in order for a complete argument to be drawn. Subsequently, future work is required to raise the number of sustainability indicators seeking evidence of interconnection among society, culture, environments and economy. Furthermore, and since indicators adequacy is not addressed, future research in order to avoid possible unnecessary duplication of facts and improve the accuracy of the study, should first use an interview analysis system to better understand the waste management system pathogenesis and particularities of each municipality.

4. Conclusion

This study provides an urban sustainability assessment through indices of the MSW management. In particular, following the DPSIR model, three indicators were developed for three municipalities of the Attica Prefecture, namely Piraeus, Vyronas and Nea Smirni in order to assess the urban sustainability perspectives by means of addressing in an appropriate way offering adequate response to the matter of the waste -global crisis- with the urgency and seriousness that it deserves.

The sustainable indicators developed were i) the Municipal Solid Waste Production Indicator representing the ratio of the amount of MSW produced to the municipal population at a given time, providing a measure of the average waste quantity, ii) the Municipal Solid Waste Composition Indicator reporting the weight of the most known materials included in the total amount of MSW, providing information on the economic and ecological utility of the waste as well as the disposal methods provided, and iii) the Municipal Solid Waste Recycling Indicator measuring the recycled MSW compared with the total amount of MSW.

The results indicated that MSW in Greek cities have reduced over the last years, also suggesting a steady downward trend, which could be considered consistent with that of that of the per capita incomes in Greece due to the extended economic austerity. Recycling has also become effective in the last decade in the municipalities of Attica Prefecture, which is to be found well below the targets set by the EU and enacted in [Greek Law 4042/2012.](#), and which could also partially explain the decline in generated waste. The findings from this study also support that the impact of the economic crisis is notably negatively expressed in the sustainability indicators, evidently apart from the significant reduction in the amount of waste, which is of course, a critical parameter for the urban sustainable development. However, it should not be directly related to recycling increase, or better waste management, but better to income loss and an unemployment increase effecting consumer habits. After all, sustainability is directly connected with municipal policies in waste treatment and tends towards the so called circular economy ([Loizia et al. 2019](#)). The main MSW management method is disposal in the Sanitary Landfill of Fili (Attica region), while recyclable materials are subject to undertakings entrusted by the municipal authorities with the operation of recycling services, expect the case of Vyronas as previously indicated. The MSW composition does not differ considerably from municipality to municipality, but it certainly changes with time. However, MSW composition data as subject to estimations calculated by reference to the national composition. Comparing the three local municipal waste plans, which by definition indicate, that the Greek municipalities operated independently, it is noted that they are -strangely enough- quite similar, they are mostly developed with estimation methods - subject to a large margin of errors-, and they tend to present similar projections. The regional objectives set for 2020 follow the objectives set by the Hellenic National Waste Management Plan, without further in-depth investigation or assessment of the handling capacity. Exception is the case of Nea Smirni, where a more realistic approach is presented in accordance with the pathogens and management capacity of the Municipality. It should be stressed that because these Regional Waste Management Plans lack of a mandatory character, they do not strive for any kind of efficient, effective and sustainable waste management, and should merely be viewed upon as an actual guide or plan but rather as (perhaps political oriented) wish list in the run-up to the forthcoming European regulation(s). In addition, a centralized national waste data system evidently does not yet exist, clearly making the collection of reliable figures and information a challenging task, thus setting the solid waste management objectives, assessment and results -conveniently- into question.

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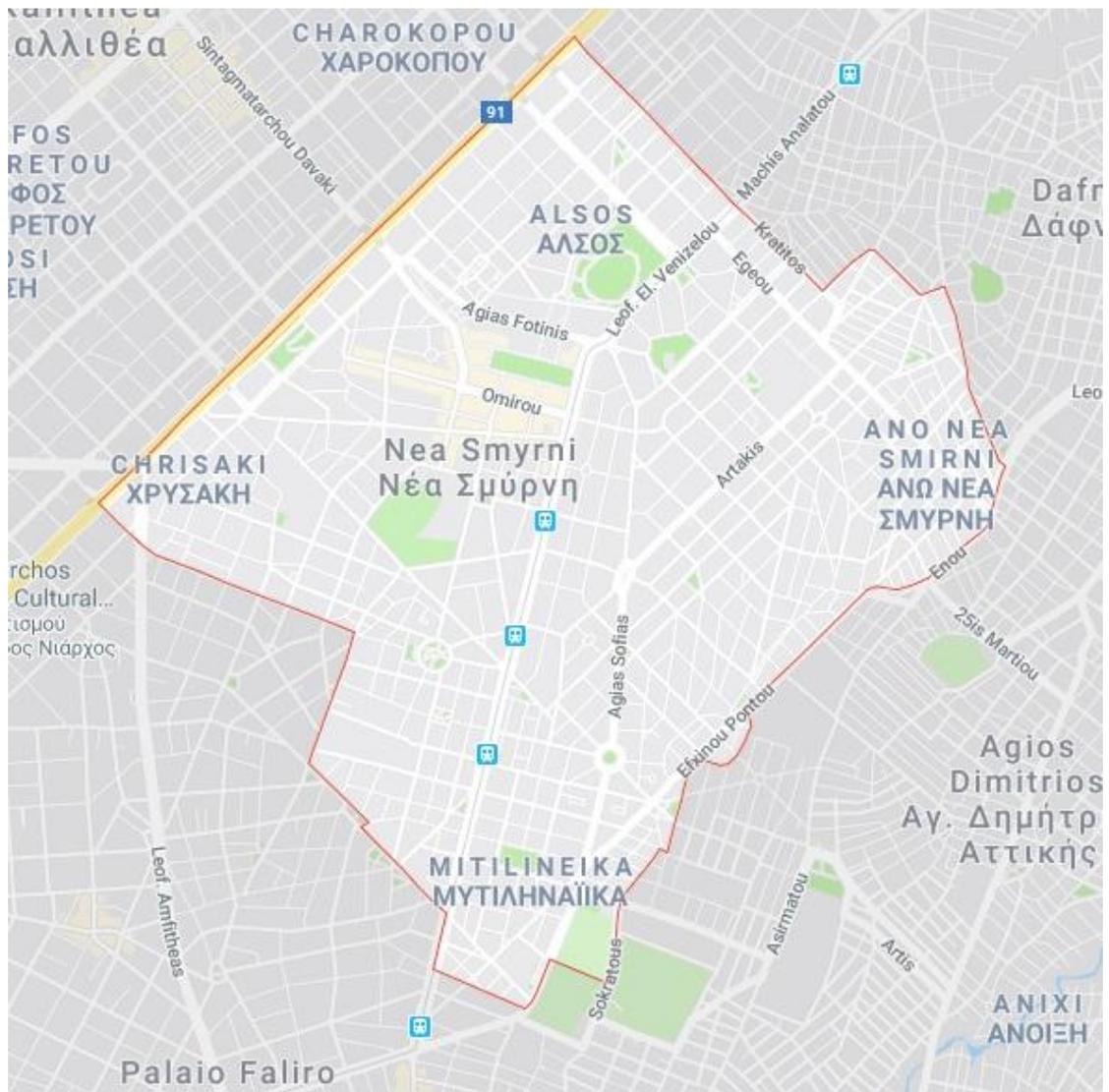


Figure 1 Strep map by Google displaying area covered by Nea Smirni

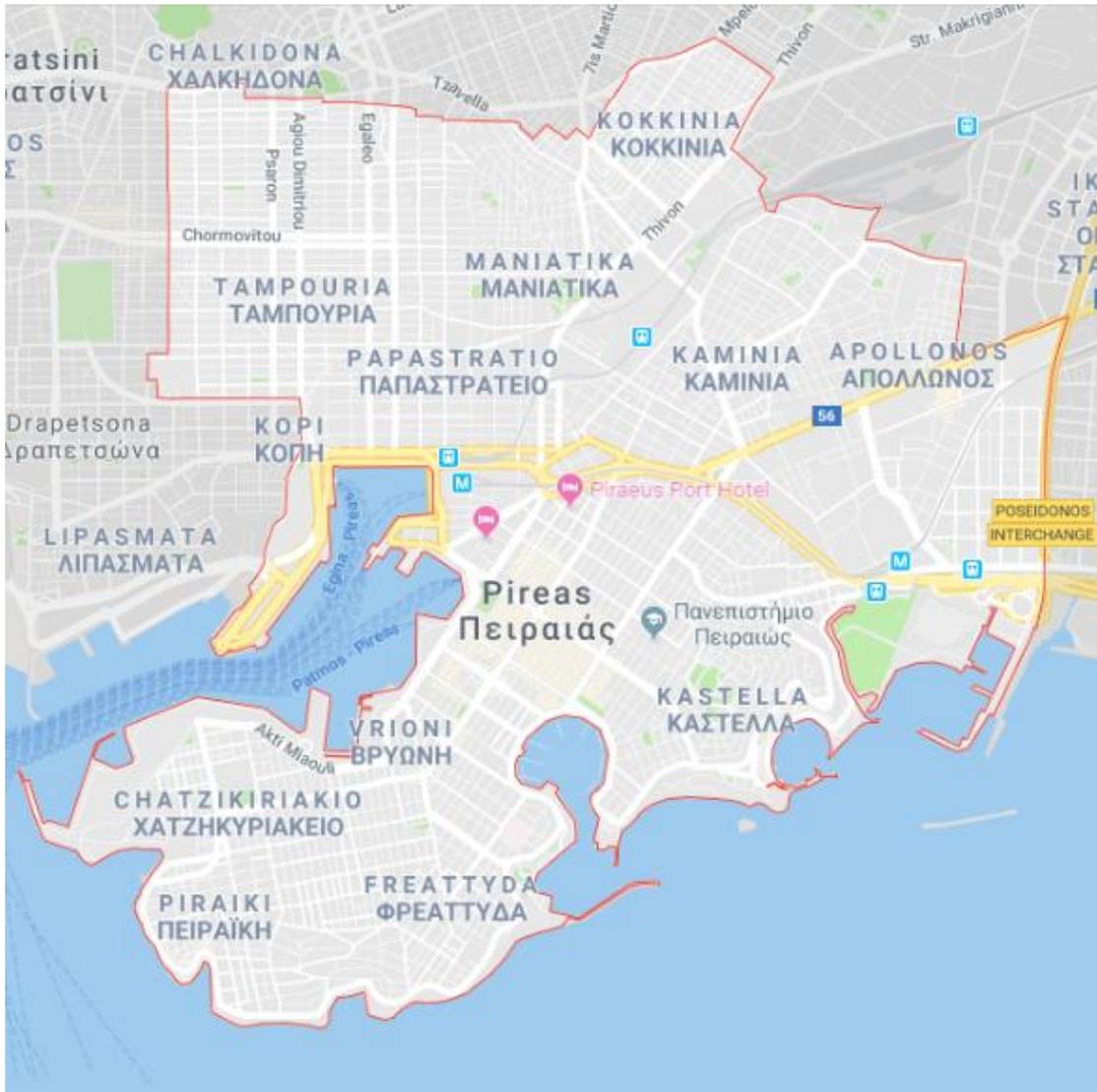


Figure 2 Street map by Google displaying area covered by Piraeus

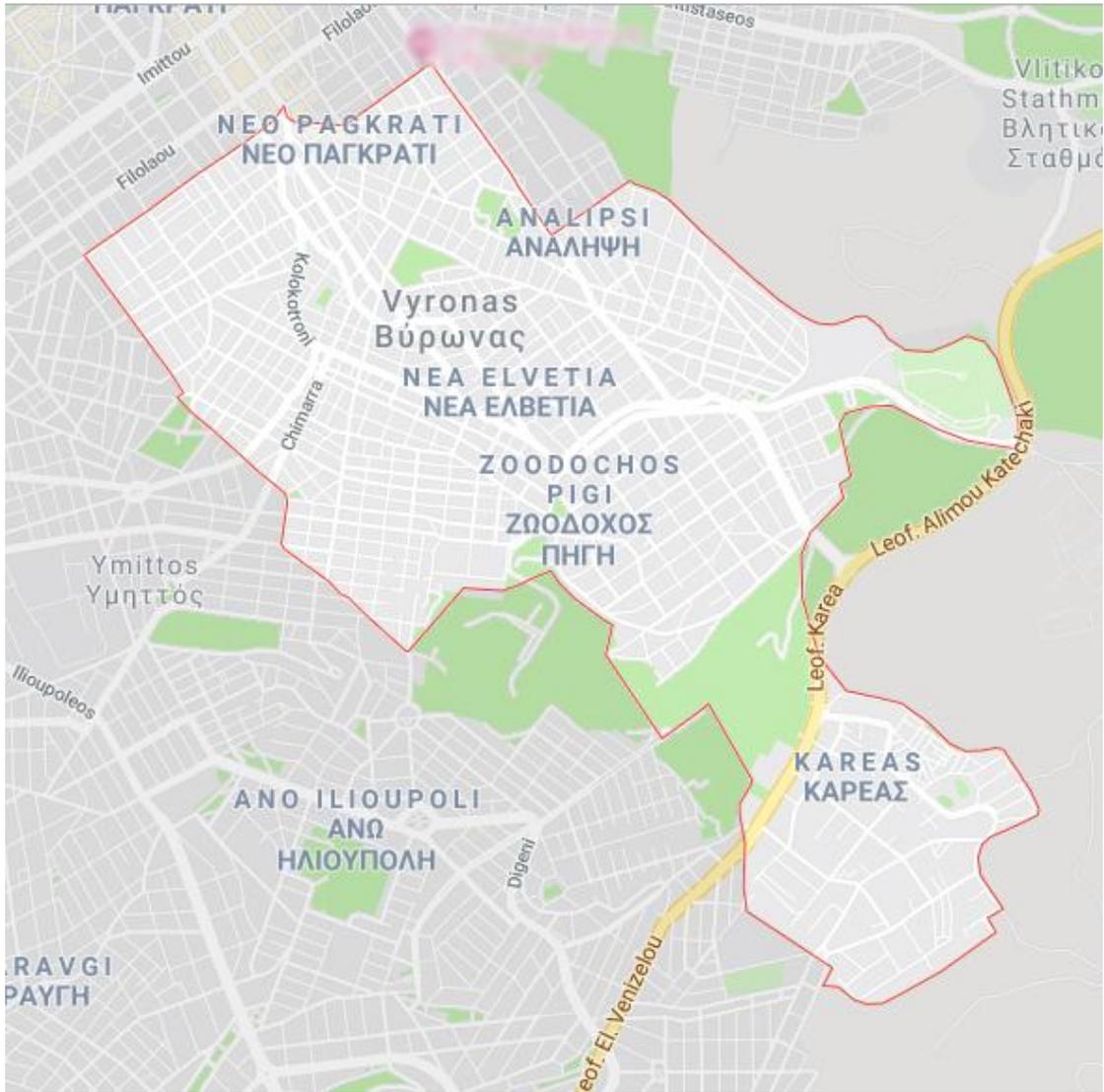


Figure 3 Strep map by Google displaying area covered by Vyronas

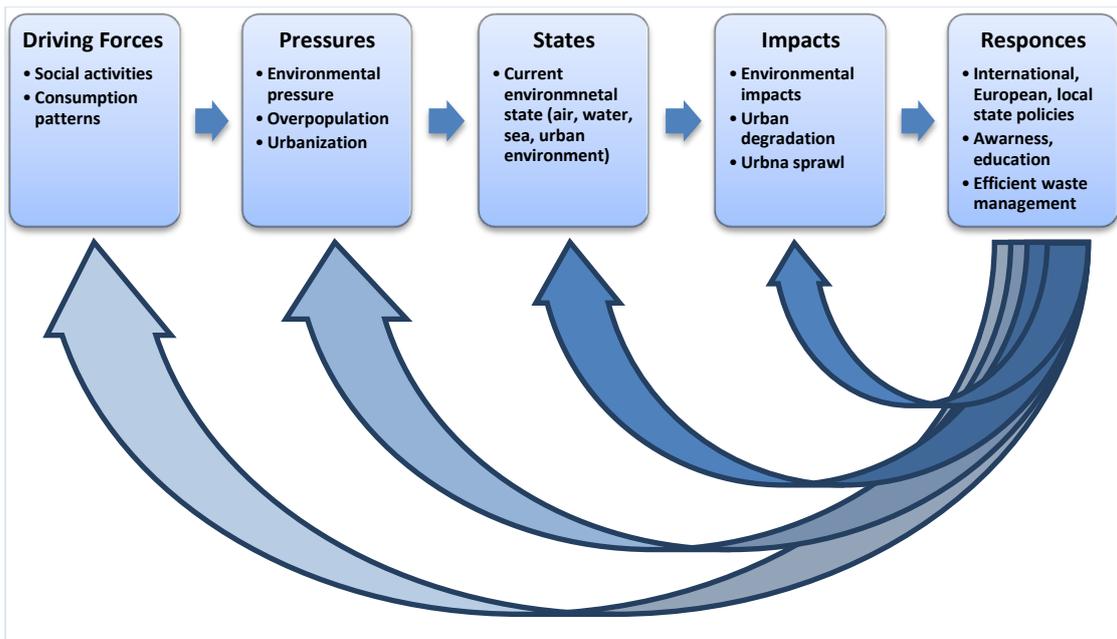


Figure 4 The DPSIR Modelling Framework
(Source: PBL Netherlands Environmental Assessment Agency)

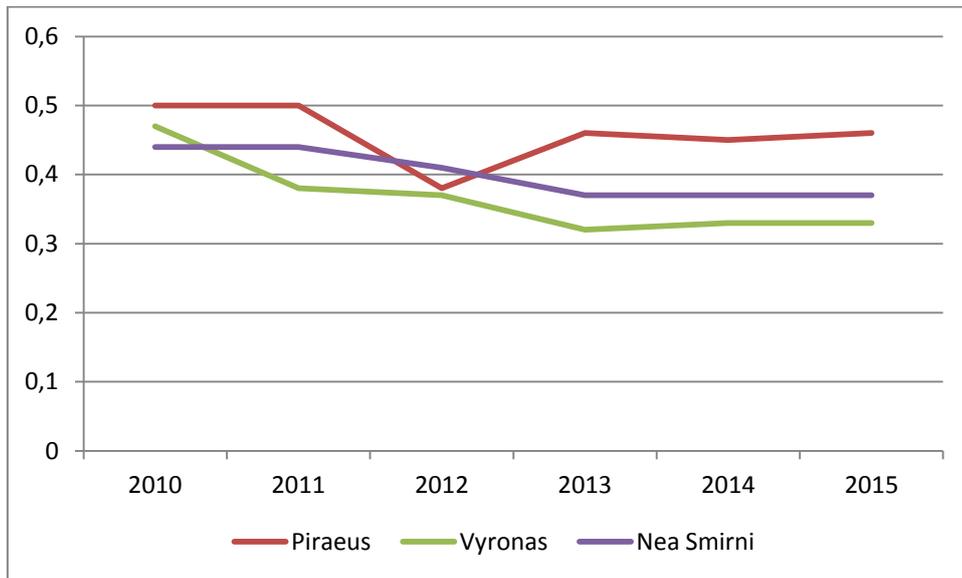


Figure 5 MSW-P indicator

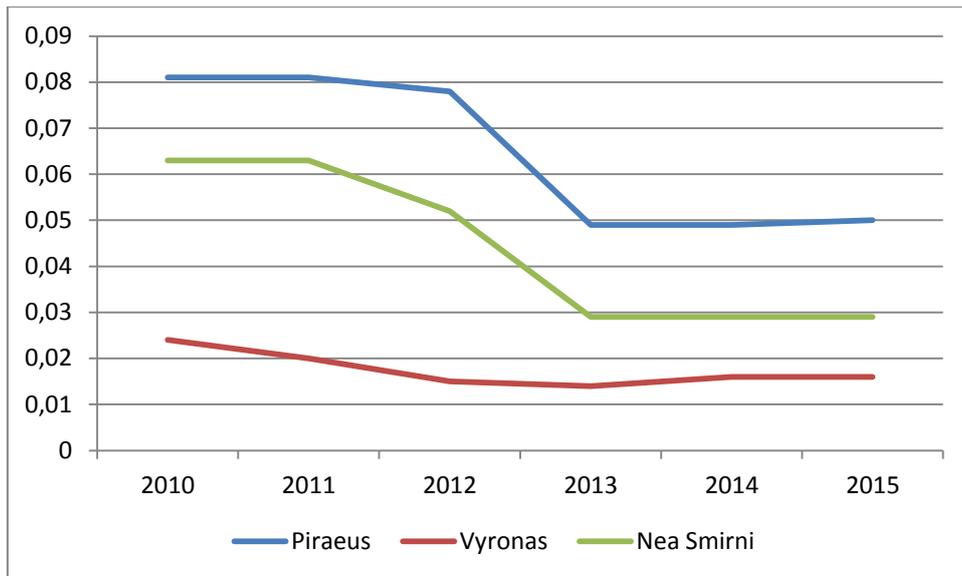


Figure 6 MSW-C indicator

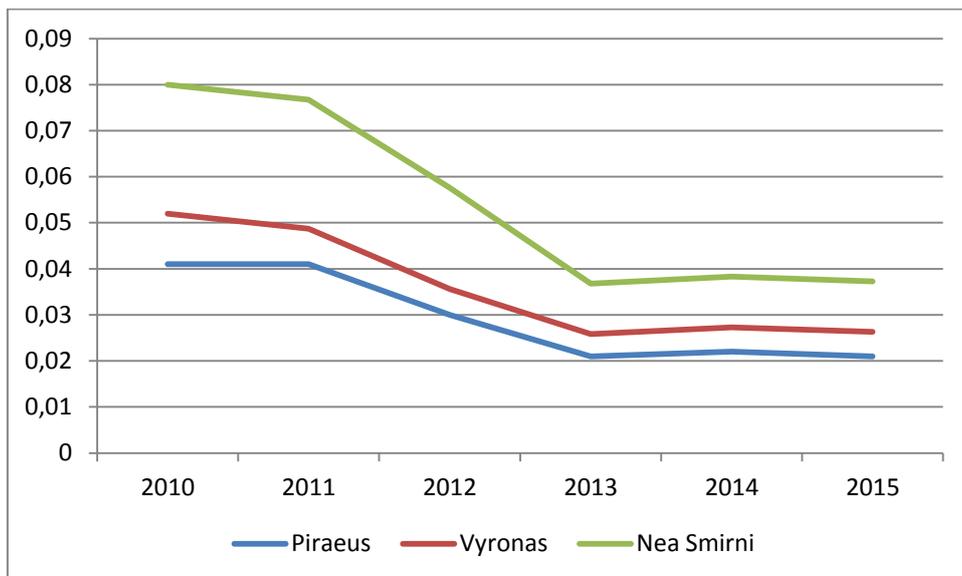


Figure 7 MSW-R indicator

Table 1 Indicators depicting the social effects of the Hellenic financial crisis

Year	2010	2011	2012	2013	2014	2015	2016
inc ¹	16363	14661	13996	13386	13515	13475	
Emp ²	4705483	4381819	4105223	3997708	4034842	4064038	
Un % ³	12.7	17.9	24.5	27.5	26.5	24.9	23.6
UnA % ⁴	12.6	18.0	25.8	28.7	27.3	25.2	23.0
Pov % ⁵	27.7	31	34.6	35.7	36	35.7	35.6

1. Net national disposable income
 2. Total employment in number of persons
 3. Total unemployment percentage rate of active population
 4. Total unemployment percentage rate of active population in Attica Region
 5. Percentage of people at risk of poverty or social exclusion
 Source: Eurostat, Hellenic Statistical Authority

Table 2 Municipality of Nea Smirni solid waste generated amounts

Years	MSW (tn)	Per Capita (kg/day)	Separate Collection Rate (%)	MSW rate of change
2011	32234,32	1.21	10,2	
2012	29917,26	1.12	9.2	-7.2%
2013	26973,29	1.01	7.6	-9.8%
2014	26976,32	1.01	7.6	

Source: Municipality of Nea Smirni Regional Waste Management Plan (2015)

Table 3 Municipality of Nea Smirni generated solid waste qualitative composition

	Nea Smirni		Piraeus	Vyronas	
	Generated MSW (tn/2015)	Composition (%)	Composition (%)	Composition (%)	Quantity (tn/2014)
Organic Fraction	11870	44	44.3	43.6	8760.97
Paper & Cardboard	39535	22	22.2	28.1	5646.40
Plastic	3777	12	13.9	13	2612.21
Metal	1079	4	3.9	3.3	663.10
Glass	1079	4	4.3	3.4	683.19
Wood	1349	5	4.6	-	-
Other (WEEE, Batteries, etc.)	1888	7	6.8	8.6	1728.08
Total	26976	100	100	100	20093.96

Source: Municipality of Nea Smirni Regional Waste Management Plan (2015), Municipality of Piraeus Regional Waste Management Plan (2015), Municipality of Vyronas Regional Waste Management Plan (2015)

Table 4 Municipality of Nea Smirni Regional Waste Management Plan main objectives set for 2020 and 2025 compared with the National Objectives

	Regional (2020)	National (2020)	Regional (2025)
Separate collection of waste	45%	50%	57%
Separate collection of 4 recyclable materials (glass, paper, metal, plastic)	53%	65%	68%
Separate collection of bio-waste	40%	40%	44%

Source: Municipality of Nea Smirni Regional Waste Management Plan (2015)

Table 5 Municipality of Piraeus solid waste generated amounts

	2011	2012	2013	2014	2015
MSW (tn)	74928.16	57654.311	71389.255	70559.88	-
Recyclable & packaging materials (tn)	6672.79	4896.09	3737.31	3657	-
Total (tn)	81600.95	62550.4	75126.57	74216.88	75757

Source: Municipality of Piraeus Regional Waste Management Plan (2015)

Table 6 Municipality of Vyronas solid waste generated amounts

	2010	2011	2012	2013	2014
Total (tn)	2855.83	23509.57	22388.33	19662.77	20093.96
Recycled					
Paper & Cardboard (tn)	465.58	314.55	189.75	153.82	205.46
Plastic (tn)	126.58	91.12	117.15	106.18	113.38
Metal (tn)	10.73	8.31	8.31	6.04	0
Glass (tn)	64.52	57.10	29.26	25.16	3.2

Source: Municipality of Vyronas Regional Waste Management Plan (2015)

Table 7 The sustainability indicators developed and their function in the DPSIR cause framework

Indicator	DPSIR
Municipal Solid Waste Production (MSW-P) indicator	Driving Force
Municipal Solid Waste Composition (MSW-C) indicator	State
Municipal Solid Waste Recycling (MSW-R) indicator	Response

Table 8 The ratio of the amount of MSW produced to the municipal population

Year	Piraeus	Vyronas	Nea Smirni
2010	-	0.47	-
2011	0.5	0.38	0.44
2012	0.38	0.37	0.41
2013	0.46	0.32	0.37
2014	0.45	0.33	0.37
2015	0.46	-	-

Source: Hellenic Statistical Authority

Table 9 The weight of the most known materials included in the reported amount of MSW

Year	Piraeus	Vyronas	Nea Smirni
2010	-	0.024	-
2011	0.081	0.02	0.063
2012	0.078	0.015	0.052
2013	0.049	0.014	0.029
2014	0.049	0.016	0.029
2015	0.05	-	-

Source: Hellenic Statistical Authority

The most known materials included in the reported amount of MSW are;(1)Organic fraction, (2) Paper & Cardboard, (3) Plastic, (4) Metal, (5) Glass, (6) Wood

Table 10 The recycled MSW compared with the total amount of MSW

Year	Piraeus	Vyronas	Nea Smirni
2010	-	0.011	-
2011	0.041	0.0077	0.028
2012	0.03	0.0056	0.022
2013	0.021	0.0048	0.11
2014	0.022	0.0053	0.011
2015	0.021	-	-

Source: Hellenic Statistical Authority