Case Study

Complex Risks from Old Urban Waste Landfills: Sustainability Perspective from Iasi, Romania

Ioan Manuel Ciumasu[1]; Mihai Costica[2]; Naela Costica[3]; Mariana Neamtu[4]; Alin Constantin Dirtu[5]; Luiz Felippe de Alencastro[6]; Liana Buzdugan[7]; Ramona Andriesa[8]; Luminta Iconomu[9]; Anisoara Stratu[10]; Ovidiu Alin Popovici[11]; Cristian Vasilica Secu[12]; Codrin Paveliuc-Olariu[13]; Simona Dunca[14]; Radu-Ionut Dimitriu[15]; Marius Stefan[16]; Adrian Lupu[17]; Alina Stingaciu-Basu[18]; Adrian Netedu[19]; Ovidiu Gavrilovici[20]; Mihai Talmaciu[21]; and Mioara Borza[22]

Abstract: Landfills continue to represent the most frequent managerial practice for municipal solid wastes and an increasing and complex problem globally. In certain countries, a transition to an open society and free market is superimposed on the transition to sustainability, resulting in even higher complexity of management. This paper proposes an approach for problem-structuring of landfills in complex transitions: sustainability or unsustainability of a management approach is determined by a set of sustainability filters that are defined by sets of indicators and prioritized according the systemic concept of sustainability, which says that economy is embedded in society, which is embedded in nature. The writers exercise this approach with an old landfill in Iasi, Romania, and conclude for unsustainability, because the ecological sustainability filter is not successfully passed. Social and economic sustainability filters are also discussed in relation with the ecological sustainability indicators. The described approach allows a coherent, transdisciplinary synthesis of knowledge scattered across various disciplines, a pervasive problem in landfill management. The case study helps distinguish between generally true and context-dependent aspects. **DOI: 10.1061/(ASCE)HZ.2153-5515.0000090.** *© 2012 American Society of Civil Engineers.*

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[1]Research Associate, Scientific Coordinator, Centre for Sustainable Exploitation of Ecosystems (CESEE), Faculty of Biology, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania; and Visiting Professor, 'Econoving' International Centre in Generating Eco-Innovation, Pôle de Recherche et d'Enseignment Superieur UniverSud Paris, Univ. of Versailles Saint-Quentin-en-Yvelines, 5-7 Boulevard d'Alembert, Bâtiment d'Alembert, 78047 Guyancourt, France (corresponding author). E-mail: ioan.ciumasu@uvsq.fr

[2]Lecturer, Faculty of Biology, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[3]Associate Professor, Faculty of Biology, and Coordinator of the European Centre for Training of Trainers in Environmental Education, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[4]Assistant Professor, Dept. of Environmental Engineering and Management, Technical Univ. of Iasi, Bd. D. Mangeron 71A, 700050 Iasi, Romania.

[5]Lecturer, Faculty of Chemistry, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700506 Iasi, Romania.

[6]Senior Scientist and Associate Professor, Ecole Polytechnique Fédérale de Lausanne (EPFL), Institut des sciences et technologies de l'environnement (ISTE), EPFL/ENAC/ISTE/CEL, Station 2, 1015 Lausanne, Switzerland.

[7]M.Sc. Student, Faculty of Biology and Junior Scientist, the 'Anastasie Fatu' Botanical Garden of Iasi, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[8]M.Sc. Student, Faculty of Biology, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[9]Scientist, Environmental Protection Agency (APM) – Iasi, Str. Th. Vascauteanu nr. 10, 700462 Iasi, Romania.

[10]Lecturer, Faculty of Biology, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[11]Assistant Professor, Faculty of Biology, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[12]Associate Professor, Faculty of Geography and Geology, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[13]Ph.D. Student, 'Ion Ionescu de la Brad' Univ. of Agricultural Sciences and Veterinary Medicine, Aleea Mihail Sadoveanu nr 3, 700490 Iasi, Romania.

[14]Associate Professor, Faculty of Biology, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[15]Lecturer, Faculty of Biology, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[16]Lecturer, Faculty of Philosophy and Social-Political Sciences, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700506 Iasi, Romania.

[17]Ph.D. Student, Faculty of Philosophy and Social-Political Sciences, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700506 Iasi, Romania.

[18]Associate Professor, Faculty of Philosophy and Social-Political Sciences, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700506 Iasi, Romania.

[19]Lecturer, Faculty of Geography and Geology, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[20]Associate Professor, Faculty of Psychology and Education Sciences, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700506 Iasi, Romania.

[21]Associate Professor, Faculty of Economy and Business Administration – FEEA, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

[22]Associate Professor, Faculty of Economy and Business Administration – FEEA, 'Alexandru Ioan Cuza' Univ. of Iasi, Bd. Carol I nr 22, 700505 Iasi, Romania.

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Introduction

The relation between humanity and nature can be understood at various scales and through a multitude of lenses—as offered by arts and philosophy, history and social sciences, natural sciences and technology, or economics. An historic attitude predominated until very recently, and still persists, that nature is simply a source of either happiness or unhappiness for people. Not many people used to bother about the converse relationship—what returns from us to nature. In a way, such awareness was largely unnecessary as long as the impact of humanity was too small and simply absorbed by the natural processes. Humans could afford the luxury of only thinking about fulfilling our needs by taking from nature. Neoclassical economics—sustained by the successes of free market and technologies—stood as the appropriate path by which ambitious enough individuals could attain everything they wanted.

That era of innocence is clearly over, as we have known for a quarter century, but signals have been coming for the last half century. We do harm to nature, and this harm returns against us through nature. The consequences of our deeds on nature belong to two main categories: overconsumption of resources and wastes. By applying the laws of thermodynamics to economics, Nicholas Georgescu-Roegen (1971) already argued four decades ago that it is conceptually wrong to assume that natural resources and their self-regeneration power are infinite when the planet we inhabit is finite. Even technological progress does not necessarily solve the problem. In fact, it may worsen it—technological genius and efficiency cannot replace the wisdom needed for its use. Other factors must be taken into account, such as regulations and other social processes. For example, higher energy efficiency will not lead to less energy use but to cheaper prices for energy, hence to more intensive use of resources—a phenomenon known as the rebound effect (e.g., Herring and Roy 2007). During the 1960s and 1970s, such signals were simply dismissed by a social reflex: such ideas were seen as basically communist. The fact that Georgescu-Roegen himself arrived in the United States after escaping Romania, a communist country at that time, was perhaps taken by most economists as a convenient surrogate proof. The fundamental problem with that kind of argument was that the economies in the former socialist block were even less concerned about environmental issues (Turnock 2007). Several decades later, such warnings started to be well understood and generated new fields of research—bioeconomics and ecological economics took off during the 1980s (Ropke 2004, 2005). Nevertheless, in the meantime, the public began to be concerned with the destruction of surrounding nature, so that the idea of nature (an ambiguous concept, whose relation to humanity is notoriously ambivalent) started be replaced with that of environment, and the Environmental Protection Agency was established in the United States (Marx 2008).

Finally, the idea that any economic development needs to be sustainable has been recognized with the publication of the "Our common future" report (WCED 1987) of the United Nations. According to the current understanding in sustainability sciences, nature, society, and economy are connected in a systemic way by nested inclusion. Thus, any economic system is a subsystem of a social system, which is itself a subsystem of natural system (Giddings et al. 2002). This fundamental relation applies to both local and global issues and constitutes the original point of the present analysis on the management of wastes.

Solid wastes are usually dumped into landfills and are usually regarded as mainly a local management issue. However, local solid waste problems accumulate and become a global problem, e.g., the massive accumulation of plastic wastes originating on land (plastics represent 10% of the total solid wastes) at the surface of the North Pacific Central Gyre. Studies reported that the mass of plastic debris was six times higher than the mass of zooplankton and posed grave long-term problems to the entire biosphere (Moore et al. 2001; Barnes et al. 2009; see also Casey 2010). Although, from a technical or project managerial perspective, the issue of landfills may not be easily related to the floating wastes in the Pacific, the two are direct consequences of the historical deficit of humanity in dealing with solid wastes. The accumulation of wastes in the Pacific is at global scale what a landfill is at local scales. Although this parallel is striking, it is also a signal that the unsustainable management of solid wastes has already become ubiquitous and too large a burden for the Earth, one that can hardly be ignored anymore. Inasmuch as this problem increased in pace with the rapid urbanization of the planet, this problem is largely one of municipal solid wastes (MSW). In this sense, solving the local problem of landfills really involves global stakes.

During the last decade of the 20th century, MSW ceased to be regarded as a merely technical problem, and has begun to be seen as a wider, serious management problem (Fehr 2003). When long-time ignored, the waste problems can easily become intractable. Given the complexity of their sources and of their effects, dealing with wastes requires a multidisciplinary and problem solving-oriented, transdisciplinary approach, in which each method and discipline is seen as contributory to a whole, and where feedbacks exist between science and technology (on the one hand) and stakeholders in metropolitan areas (on the other hand) (e.g., Pickett 2001; Dijkema et al. 2000).

The central question of sustainability studies is how to do the transition to sustainability. This question is usually being posed at general, ethical, and epistemological level, but also at applied levels such as sustainability-compatible technologies as means of production and management.

The aim and scope of this paper is to identify meaningful answers to this question, as applied to MSW. These are domestic wastes but may also come from other sources, notably industrial. In the case of waste management, the difficulty is double-fold: (1) the variety of sources and (2) the variety of the potential harmful effects for nature and humans. From MSW to the global problem of atmospheric pollutants, wastes are a socioeconomic product and a complex problem. The direct effects of pollutants in the atmosphere, lithosphere, hydrosphere, and biosphere are intertwined, and their interaction produces unique emergent effects (e.g., Ciumasu and Costica 2010; Yan et al. 2010).

Recent efforts to tackle the MSW problem focused on the necessity of structuring the problem so as to achieve the transition from unsustainable to sustainability-compatible practices in MSW management (Kemp et al. 2007; Scholz et al. 2009).

In the remainder of this paper, the writers refer to such experiences and attempt to define what transition management should look like, with particular discussions on Central Europe—a region understood as made up by the former socialist countries that are now members of the European Union. In a following section, the writers discuss a case study from Iasi, a 0.4 milion city in Romania, which is typical for the transition to sustainability but also reflecting the transition from command economies and centralized societies to free markets and open societies.

Furthermore, we use a sustainability scenario-typology (Ciumasu et al. 2008) to take problem-structuring for waste management a step further: a sustainability filters approach is being proposed for integrating disciplinary views among themselves and with the nested inclusion concept of sustainability.

J. Hazard. Toxic Radioact. Waste 2012.16:158-168.

Problem-Structuring

Unlike the neo-classical theory of economics, ecological economics is a transdisciplinary approach that takes into account the nonlinear behavior of the natural systems, i.e., the reality that ecosystems supporting socioeconomic activity are described to a large extent by thresholds. This supposes taking into account feedback effects and self-organization and uncertainties, which further means recognizing the natural limits of the socioeconomic activities. Most notably, in the case of environmental modifications, the existence of ecological thresholds means that a substantial change induced by humans onto the environment may cause a switch between alternative equilibria of the natural systems (e.g., Muradian 2001), i.e., loss of the current capacity of ecosystems to provide the benefits to which the local community is accustomed (and usually and erroneously take for granted).

This is why the field of ecological economics and sustainability studies acknowledges the systemic view of the relation between nature/environment, human society, and economy: a nested inclusion relationship where any economic system is a subsystem of a social system, which is itself a subsystem of natural system (Giddings et al. 2002). This paradigm can be rendered operational for sustainability assessments of a particular management approach by defining a set of sustainability filters and a rule of prioritization (Ciumasu et al. 2008) (Table 1). In essence, the existence of any social system is dependent on the existence of the natural system (its carrying capacity) in which it is embedded; similarly, the existence of any economic system is dependent on the existence of the social system in which it is embedded. If the natural system collapses (it loses it carrying capacity), then the social system (dependent on it) collapses; if the social system collapses, then the economic system (dependent on it) collapses. This order of dependence between natural, social, and economic systems translates into the process of decision making (e.g., scenarios of development of a local region or options for addressing a problem) as a rule for priority setting and managerial precedence of parameters belonging to various domains. This rule can be represented as follows: Ecological System > Social System > Economic System, where > indicates the sense of inclusion between systems (the system to the left of the sign includes the system to the right, with the ecological system including all the others). In terms of sustainability filters, the rule becomes: Ecological Sustainability Filter > Social Sustainability Filter > Economic Sustainability Filter, where > indicates the sense of managerial precedence of a sustainability filter (the filter on the left of the sign has precedence over the filter on the right of the sign).

Thus, to verify sustainability, a certain chain of decisions is bound to represent a sustainable scenario (from a managerial perspective): the results of the decision must first meet the requirements of an ecological sustainability filter, i.e., successfully meet the list of requirements (parameters) listed within the filter; then, if this is successfully met, a social sustainability filter must be confronted; and finally, if those social requirements are also met, then the economic sustainability filter must be confronted. From an applied managerial point of view, if the requirements for the ecological sustainability filters are not met, then there is no point to check the subsequent filters (the social one and economic one) because they simply cannot exist if ecological sustainability does not exist. Alternatively, in a case where the ecological sustainability filter is successfully passed but the social sustainability filter is failed, there can be no economic sustainability, hence no point to check the economic sustainability filter. However, even when analysis of subsequent filters is rendered unnecessary, foresight exercises may still be useful to assist management with heuristic analytical anticipations of the issues related to the sustainability filters that failed. But those foresight exercises must include a set of uncertainties related to the failed filters.

Table 1. Types of Scenarios Made Possible (1) by the Existence of the Three Sustainability Filters and (2) by the Nested Inclusion Relationship

Scenario type no.	Sustainability filters			Sustainability status (yes/no)
	Ecological	Social	Economic	
I	Fail	—	—	No
II	Succeed	Fail	—	No
III	Succeed	Succeed	Fail	No
IV	Succeed	Succeed	Succeed	Yes

Table 1 is a synthetic way to show that each of the three types of system (ecological, social, economic) in the nested inclusion relationship described above can be formalized as an autonomous filter for knowledge-based decision making. Each filter collects knowledge from its respective domain (notably research studies) to indicate coherently and explicitly which knowledge is available and what each piece of knowledge means for a situation of management of complex situations where you have to deal with such diverse domains as environmental, social, and economic. In this sense, Table 1 shows types of decision making scenarios: for example, scenario type number III indicates a situation where environmental and social constraints of the development of an area (or solving a local problem, such as dealing with an old landfill or the issue of a heavily polluted river) are being respected (no serious pollution or other forms of environmental degradation and no serious social problems such as lack of access to education, etc.; i.e., the ecologic and the social sustainability filters are being passed successfully by a development plan of the local community), but the economic sustainability filter is not passed successfully, meaning that that particular plan of development is not feasible from an economic perspective. In other situations, the failure may not be associated with the economic domain, but with social (type II in Table 1), or with the ecologic sustainability filter (type I in Table 1), or with both (not discussed, for simplicity reasons). All these situations correspond to a situation of unsustainable scenario of development. Obviously, each scenario type can correspond in reality to various stories of economic-social-ecologic profiles and details. Table 1 indicates a common frame to understand where each such local contexts/problems can be placed, understood, and addressed. Only when all three types of constraints (formalized as respective sustainability filters) have been passed with success S then we have a scenario of sustainable development (type IV). Blanks in Table 1 indicate that, in practice, there is no point even considering the situation of failure or success (in meeting sustainability requirements) in a filter that is subsequent to a filter that has been already been decided as failing. The reason is given by the nested inclusion relationship previously described: if a system fails, its subsystems are bound to fail by definition.

Given the transdisciplinary imperative to integrate scientific knowledge from various disciplines and scholar traditions, knowledge can be integrated into a set of scenarios. From a governance perspective, and given the complexity of transition that is anticipated to occur from unsustainable to sustainable MSW management, the sustainability filters-based scenarios scheme can be made contiguous to the social process of problem-structuring for complex transition (SCT) to sustainability developed by Scholz et al. (2009). Table 2 proposes a description of how this connection can be described.

J. Hazard. Toxic Radioact. Waste 2012.16:158-168.

Table 2. Correspondence between the Filter-Based Sustainability Approach and the SCT Procedure

SCT procedure according to Scholz et al. 2009		Corresponding technical filter-based scenario decision-making operation according to Ciumasu et al. 2008
Phase	Step	Operation
a. Preparation	$a - 1$ Analytically decompose sociotechnical system in facets	Separation in three types of sustainability filters
	$a - 2$ Determine interests within sociotechnical system	Adjust definition of filters according to the relevance to potential uses of the scientific analysis (largely already implied in the nested inclusion relationship)
	$a - 3$ Identify possible/select definitive participants	Identify the stakeholders for each filter
b. Elicitation	$b - 1$ Individually define impact factors (divergence)	Long list of environmental/social/economic indices of all kinds (disciplinary methods, studies, and data)
	$b - 2$ Interactively group and abstract impact factors (sense-making and convergence)	Pooling indices in separate filters (codefiners of a sustainability filter)
	$b - 3$ Individually prioritize impact factors (convergence)	Order of the importance of the filters follows the nested inclusion relationship: first filter that any scenario of management must confront is the ecological filter; then the social filter, then the economic filter.
	$b - 4$ Aggregate individual prioritizations (convergence)	Scenarios (sustainable or unsustainable, types)
c. Postelicitation	$c - 1$ Adjust and standardize facet's results	Scenarios (sustainable or unsustainable, types)
	$c - 2$ Structure results according to levels of mastering the system (synthesis)	Mapping potential scenarios and their main feature (sustainable or not) and technical details (which filters have been successfully gone through) and the meaning according to the updated description of each filter.

The Case Study—Brief Synthesis and Illustration

Description of the Tomesti Landfill

The MSW landfill from Tomesti (47”8’33.68”N, 27”40’47.61”E), 35 m altitude, is located in a sedimentary plain, on the banks of Bahlui River, less than 2 km from the outskirts (and 7 km from the city center) of the city of Iasi (Fig. 1). With a population of approximately 0.4 million inhabitants in the metropolitan area, Iasi is the second largest city of Romania. The city produces approximately 0.9 kg of MSW per capita per day, and the figure is increasing with an average annual rate of 2.5%. In the surrounding rural areas, the figure is 0.4 kg per day.

The landfill in Tomesti functioned between 1968 and 2009, having a projected surface of 30 ha and a volume of 4.5 million m^3 (PRGD 2006). Since 2009, the deposit is closed, and MSW are being taken over by a new, 50-ha wide, ecologically safe regional MSW deposit in the nearby village of Tutora, with a projected total capacity of 8.6 million m^3 of nondangerous wastes (undifferentiated, biodegradable, plastics) meant to serve for 0.4 million inhabitants for 20 years. The new deposit also has a sorting system, for the step of recycling, with a capacity of 10,500 tons per year (5 tons per hour), and a compost plant for biowaste, with a capacity of 10,000 tons per year. It applies a membrane technology to transform organic content into gas (directed for domestic consumption) and treatment of the leachate before releasing the residual water into the Bahlui River. Part of the treated water is recycled into the system. However, the possibility of temporary reopening of the Tomesti landfill still exists, should excess MSW appear before the Tutora plant develops full capacity.

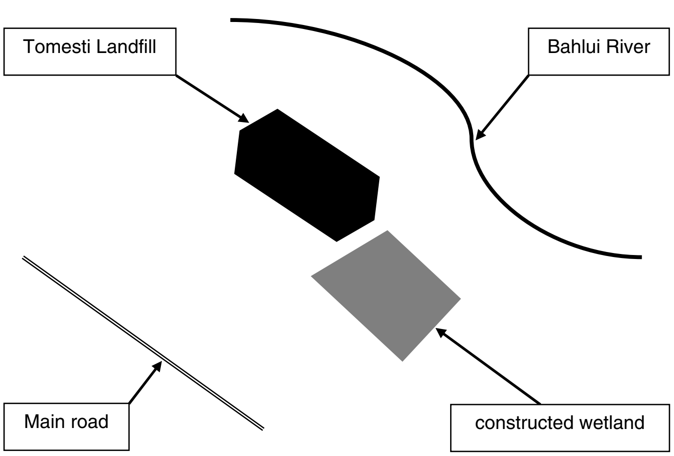

Fig. 1. Tomesti landfill and the surroundings

However, the current approach to MSW seems to be mainly technical and legislative, with sustainability being involved only indirectly. In the Local Agenda 21–Local Plan for Sustainable Development of Iasi Municipality (LA21–Iasi 2002), Chapter 2.3–Health mentions the complaints of the citizens of Tomesti about the landfill as a problem of “disagreeable smells, insects, and rodents,” which is rather minimal and unscientific. Chapter 5—Sustainable Waste management states a series of three objectives: “build a regional landfill for municipal wastes coming from the city and the surrounding areas, complying with European Union’s standards for environmental protection”, “create a selective collection waste network for recycling (paper, glass, plastic, metal),” and “build an incinerator for the final disposal of toxic and hazardous waste (expired pesticides, wastes resulting from galvanic covering, etc.).” Basically, at the time of writing the local agenda document (2000–2002), the concept of sustainable development was understood by the writers of the document in a rather reactive way, of simply complying with the requirements of the European Union on environmental-related matters. It sounded more like a mere concession made to the European Union and less like a substantial and assumed acknowledgment of the issue.

According to the Iasi county’s Long-Term Investment Plan (2008–2038) for the Integrative Management of Wastes (PITL-2008-2038-MIDI 2009), Romania must simply fulfill its obligations from Treaty of Accession to the European Union and more specifically the requirements of the Framework Directive 75/442/EEC regarding the Framework Directive 91/689/EEC regarding hazardous as integrated in the revised Waste Framework Directive 2008/98/EC (RWFD 2008).

The context of Romania is typical for wider Central Europe, i.e., countries that undergo a process of socioeconomic convergence with Western Europe. The current socioeconomic context in the region can be described as a situation of overlapping transitions: (1) the transition from planned economy and closed societies toward market economy and open society, and (2) the transition from unsustainable development to sustainability. This overlap means that standards, references, and mechanisms are being changed in a very short time (at history's scale), and very often different (even opposing) values systems and managerial practices in various sectors of the society may coexist for certain periods of times. To this situation the consequences of the recent financial and economic crisis was added, which has occasionally cut short certain change processes. For those reasons, the public management of the issues of main public concern is typically more complex than is the case in either Western Europe or in other developing countries (Ciumasu 2009; see also Turnock 2007; Mitra et al. 2010).

In the case of MSW in Iasi, current priorities and parameters are mostly detailed in the Local Environmental Action Plan of the Iasi County—2009–2013, by the local branch of the Environmental Protection Agency (PLAMJI 2009). In Chapter 2.2.2.4.5 Wastes, there is a set of general principles to be taken into account, in relation with the imperative of sustainable development, most notably: protection of the primary resources, prevention, polluter pays, subsidiarity principle, proximity and autonomy, and integration. According to this document, the Agency uses the European catalog of wastes since 1995. When it comes to options, the main idea is again—it appears—to comply with the European Union demands. It is not clear how MSW issues can be resolved without proactively taking into account, in a coordinated manner, the dependency of the potential solutions on the local context. In the remainder of the paper, the writers present a way to approach the issue that is both proactive and complies with the general lines of the European Union's strategy.

Illustration of the Sustainability Filters

In a scenario exercise for the Tomesti landfill, a series of technical indicators of risks have been selected (Table 3), on the basis of extant studies, for the definition of the ecological, social, and economic sustainability filters. All indicators basically represent thresholds: a managerial decision either fails or succeeds to meet an indicator requirement (expert evaluation). A failing to meet one or more indicators of a sustainability filter results in failing to comply with that particular sustainability filter. Failing at least one sustainability filter results in failing sustainability with the given management.

Ecological Sustainability Filter

The list of indicators defining the filter of ecological sustainability is updatable, and should feed on earlier researches and reviews upon the use of ecological indicators (e.g., Niemi and McDonald 2004) and health indicators (Galea and Vlahov 2005).

Regarding the EcSF–1 indicator, the dominant wind direction is from west-northwest to east-southeast, with a typical speed of 2–4 $m \cdot s^{-1}$ along the Bahlui River valley between hills, which determines odor pollution of the two nearby localities to the east—Tomesti and Holboca. The local habitat conditions favoring the formation of mist and the occasional open fires inside the area of the deposit contribute to aggravating the MSW deposit-generated air pollution and its effects. The nearby agricultural area is also polluted at times with materials carried out by winds from the MSW deposit and over the buffer area surrounding the deposit. Other air pollutant typical for landfills is the landfill gas (LFG), which is composed mostly by methane and carbon dioxide and other volatile organic compounds (VOCs). Landfill methane, a strong greenhouse gas, is partly degraded by bacteria and partly reaches the atmosphere. In modern MSW treatment plants (like the one in Tutora), methane is collected and used as an energy source.

With respect to EcSF–2, Dragan et al. (2006) carried out measurements of the contamination levels of soils at Tomesti MSW deposit with persistent organic pollutants (POPs), with some samples exceeding the Romanian value of 250 $ng \cdot g^{-1}$ for polychlorinated biphenyls (PCBs), being also the highest values measured in the entire Eastern Romania (8 counties). High levels were also measured for dichlorodiphenyl trichloroethane family (DDTs), topped only by another heavily populated and industrial urban area—Bacau. Contamination of the river sediments also indicated higher contamination levels in this area. Neamtu et al. (2009) carried out similar measurements of POPs in sediments along the Bahlui River flowing nearby and found contamination levels in about the same range of concentration; they also found that contamination with POPs was stronger downhill from the landfill.

The composition of the contaminants in both studies (ratio between DDTs and DDEs of approximately 1.3–2.5 in the two studies) suggested intensive contamination in the past. These substances are not used anymore, but their higher persistent character points out to a lingering chemical pollution of the soils and toxic effects in this area, the agricultural soils included.

With respect to EcSF–3, a main issue for all waste and management is the convergent ecotoxicological effects of various pollutants that are old or new-on-the-market substances (Yan et al. 2010) and go in the leachate. Neamtu et al. (2009) also carried out ecotoxicological investigations on surface waters and their results have shown both indirect and direct effect of the MSW deposit on the quality of the Bahlui River. Standardized bioassays with algae and invertebrates adapted for whole effluent toxicity indicated a clear degradation of the river water quality downhill from the old MSW deposit and the major sources of urban point pollution of the Iasi Metropolitan Area [Zona Metropolitana Iasi (ZMI)]. The leachate from the MSW deposit was highly toxic: 16% (volume) of the leachates was enough to produce a 50% inhibition of growth the green alga (*Pseudokirchneriella subcapitata*), whereas 55% caused complete inhibition. The mortality percentages of an invertebrate species (*Daphnia magna*) were 28% and 40%, respectively. This basically shows that typical primary producer species and consumer species cannot be maintained in such leachate. Although later diluted out in the Bahlui River, the toxic leachate still contributes to lowering the quality of the river water by adding up to other sources of pollution and toxicity of the river, like municipal wastewaters (Iconomu and Redinciuc 2004). The leachate from the landfill is also a source of risk and intense local pollution of the soils and of the groundwaters.

Regarding EcSF–4, the aquifer in the area is not very deep (often only at 1–1.5 m near the river), which implies a high risk of contamination plumes at high-precipitation periods of the year. It is not clear if the aquifer is already polluted, but the current situation (unprotected-ground deposit) makes it very likely. Future studies will need to elucidate this aspect, including the accumulation of pollutants in the soils and the effects upon the groundwaters and biological decontamination methods (Brad et al. 2008).

Corresponding to EcSF–5–7, the measurement of ecological indices (Neamtu et al. 2009) with planktonic algae and benthic invertebrates confirmed this degradation of river water downhill.

On EcSF–8–11, preliminary results of a current study on the effect of the presence of the MSW upon terrestrial ecosystems indicate a change in the abundance and structure of insect communities. Overall abundance of insects increases with decreasing

Table 3. General Preliminary Exercise for Evaluating the Sustainability of the Past-to-Current Management of the MSW Deposit in Iasi-Tomesti

Sustainability Filter		Indicators of risks (a selection, with assigned codes)	Sustainability status (succeed/fail)	
			Indicator	Filter
Ecological (EcSF)	EcSF–1	Atmospheric pollution below admitted thresholds	Fail	Fail
	EcSF–2	Soil pollution (POPs, heavy metals) below admitted thresholds	Fail	
	EcSF–3	Surface waters / sediments pollution (POPs, heavy metals) below admitted thresholds	Fail	
	EcSF–4	Ground waters pollution (POPs, heavy metals) below admitted thresholds	Fail	
	EcSF–5	Nonlethal toxic effects upon primary producer species, e.g., *Pseudokirchneriella subcapitata*	Fail	
	EcSF–6	Nonlethal toxic effects upon consumer species, e.g., *Daphnia magna*	Fail	
	EcSF–7	Cumulative effect upon river waters within the "good waters" range (green on the color code)	Fail	
	EcSF–8	Maintenance of local ecosystem structure (biodiversity indices)	Fail	
	EcSF–9	Impact upon terrestrial primary producers (soil algae, etc)	Fail	
	EcSF–10	Impact upon terrestrial consumers (insects)	Fail	
	EcSF–11	Maintenance of the productivity (carrying capacity) of ecosystems – agricultural potential	Fail	
	EcSF–12	Accumulation of persistent organic pollutants (POPs, heavy metals) in human fluids (blood, maternal milk): below accepted threshold	Fail	
	EcSF–13	Accumulation of persistent organic pollutants (POPs, heavy metals) in human tissues (hair): below accepted threshold	Fail	
	EcSF–14	Prevention of floods, soil erosion, and landslides	?	
	EcSF–15	Maintenance of the productivity (carrying capacity) of ecosystems – other natural goods and services of local ecosystems	Fail	
	EcSF–16	Health effects of chemical contaminants upon the human population within the general morbidity and mortality limits	Fail	
	EcSF–17	Health effects of biological contaminants (pathogens) upon the human population within the general morbidity and mortality limits	Fail	
	EcSF–18	Demonstrated potential for ecological reconstruction	?	
Social (SoSF)	SoSF–1	Minimal green space surface per citizen	?	Fail
	SoSF–2	Access to public health care	?	
	SoSF–3	Access to public safety	?	
	SoSF–4	Social inclusion (social categories) – opportunities and access to information, codecision (proposal, deliberation, voting)	?	
	SoSF–5	Demographics and development of human and intellectual capital	Succeed	
	SoSF–6	Freedoms and rights of religious beliefs and minority rights	Succeed	
	SoSF–7	Family values, women, and children rights	Succeed	
	SoSF–8	Local and national values as social trust as social capital	?	
	SoSF–9	Formal and nonformal ecological education (ecological literacy) and education for sustainable development of youth / adults	?	
	SoSF–10	Access of citizens to public transport and public distance communication (roads, railways, post, telecommunications, etc)	Succeed	
	SoSF–11	Access of citizens to public systems of selective collection of wastes	Fail	
	SoSF–12	Involvement of the science and local scientists	?	
	SoSF–13	Effective local governance – knowledgeable consultations with all the stake holders, beyond the local governing	Fail	
	SoSF–14	Change management instruments, foresight public exercises	?	
Economic (EnSF)	EnSF–1	Nutrition and food security	?	Fail
	EnSF–2	Access to private financial resources (minimal income, support)	?	
	EnSF–3	Access to public financial resources (support)	?	
	EnSF–4	Access to energy resources	?	
	EnSF–5	Effective combating economic exclusion (poverty)	?	
	EnSF–6	Recycling	Fail	

J. Hazard. Toxic Radioact. Waste 2012.16:158-168.

distance from the landfill (samples along a transect spanning between 100 and 600 m from the margin of the deposit / 200 and 700 m from the geometrical center of the landfill), especially the orders Collembola (springtales) and Diptera (flies). Species from the first typically feed on dead vegetal matter; the second usually feed on dead animal matter. Although the two orders are the most abundant among the collected insects, making together approximately one of three of the total number of individuals during the summer (and more during the colder seasons), the changes in the abundance of the two orders is bound to have important biological and ecological implications. For example, the abundance of individuals from order Thysanoptera (thrips) also increases with shorter distances from the landfill, which makes sense because most thrips feed on vegetal tissues or on other insects (predators). Preliminary investigations on soil algae also indicate an impact of the landfill on species composition, with abundant presence of species indicators of organic pollutants, such as Euglenophytes, of species resistant to pollutants, such as various species of Chlorophytes, and the quasi-absence of Xanthophytes from the vicinity of the landfill.

Typically, the composition of algal communities in relation to MSW is determined by a complex interplay between facilitating factors such as increased loads of nutrients and inhibitory factors such as heavy metals. Phillamentous or monocellular species with a mucilaginous sheath around them predominate, most notably euritope (i.e., wide ecological range) species like the blue-green algae from genera Phormidium and Nostoc, but also green algae (Chlorococcales) such as genus Chlamydomonas. This sheath is made up of exopolysaccharides, a most stabilizing matter for microaggregates in soil, and is probably conferring them an advantage in a highly polluted environment. Lombardi et al. (2002) have shown that the sheath of Chlorococcales species that are sensitive to heavy metals secrete a mucilaginous capsule that retains copper ions, and so allows the species to survive in metal-polluted environments that would otherwise be highly toxic to them. Sharma et al. (2008) have shown that the exopolysaccharides sheath of Nostoc and other blue-green algal strains are able to sequester Chromium from the environment, which make it suitable for site decontamination.

Wang et al. (1998) have shown that species from the genus Phormidium are suitable for heavy metal decontamination because of a two-stage uptake of heavy metal by the species: an initial biosorption of metal ions followed by slower ion sequestration by physiological processes. Such proprieties of the algae can be used in principle for removing heavy metals from polluted environments, in future remediation strategies, by using the equilibrium between toxicity (vulnerability) and toxicity resistance of species (e.g., Mehta and Gaur 2005). This is an important aspect because pollution of soils with heavy metals is a serious concern inasmuch as the heavy metal pollution in the Tomesti landfill area is actually superimposed on a wider area of Iasi metropolitan area where the concentrations of heavy metals in soils have been mapped in relation with the local industries and need special attention from the local authorities (Secu et al. 2008).

Furthermore, aquatic and terrestrial species and ecosystems can be affected by chronic pollution at a site via the effects such as (1) bioaccumulation of pollutants in organisms via the biophysical processes and the metabolism of given organisms and (2) biomagnification of the amounts of bioaccumulated pollutants in species and ecological guilds down the trophic chain. Living organisms (bacteria, plants, and animals) "suck and store" pollutants, and the effect is magnified by the fact that the species down the trophic chain that consume those heavily polluted organisms will retain their pollutants in their body. In the end, as per EcSF–12–13, these effects lead to persistent pollutants, notably PCB, HCHs, and DDTs, being accumulating in consumer species like fishes and ultimately in humans (Van der Oost et al. 2003; Kelly et al. 2007). A similar pair of effects is well known for the heavy metals contaminating waters and soils (e.g., Goodyear and McNeill 1999; Van Vliet et al. 2006). This effect constitutes a menace for both (1) ecosystem health and their capacity to support human communities with ecosystem goods and services and (2) human health.

It is very difficult to anticipate where POPs or heavy metals (from the unprotected landfill or from its leachate) would end up, unless detailed chemical, ecotoxicological, and biological studies are being carried out at all trophic levels in all ecosystems in the area. Therefore it is difficult to clearly warn against particular types of risks deriving from such a source of pollution.

In a wider picture, corresponding to EcSF–14–15, the important modification introduced in the local landscape by this type of landfill increases the risks of general hazards—soil erosions, occasional floods, and landslides. Climate changes are expected to exacerbate such risks; the local tendency is a shift toward a slightly dryer climate, which is bound to favor meadows over forests and the formation / expansion of salty soils (locally known as "saraturi"). Climate changes also will exacerbated all morbidity risks and intertwine different types of risks.

Regarding EcSF–16–17, the increased populations of Diptera determined by the landfill augment the hygiene and epidemiological risks. Typically, Diptera families that are seen as nuisance related to landfills are different—mostly Muscidae (which also includes the common house fly), Calliphoridae, and Sarchphagidae (flesh flies)—than those in the surrounding natural area, which are mostly vegetation feeding or parasitic (Howard 2001). On Diptera (Muscidae) samples from the same region (Central Europe), the Szadolki landfill and a farm in the area nearby, near Gdansk, Poland, Szostakowska et al. (2004) demonstrated the presence of a real risk of animal / human cryptosporidiosis and giardiasis maintained and spread by Diptera: captured flies living on the landfill tested positive for *Cryptosporidium parvum* and *Giardia lamblia*. This is important information for our case study, because Diptera species can fly as far as 30 km and localities like Tomesti and Holboca are only within 1–2 kms, and the city of Iasi within 3–10 km.

In another landfill in Poland (Czestokowa), Graczyk et al. (2007) tested landfill leachate and sludge positive for *Enterocystozoon bieneusi*; and the sludge was also positive for *Encephalitozoon intestinalis*. Those viable, human-virulent microsporidian spores could be destroyed by quicklime stabilization and sonication. We do not know yet about such situations in our Tomesti landfill in Romania. But the risk is real because the two Central European countries have very similar biogeograhical and socioeconomic conditions. Past studies on microbiota in the soils near the Iasi landfill (e.g., Dunca et al. 2006) did not reveal serious dangerous species for humans or animals. Future studies are needed to investigate the entire array of pathogens that may present risks.

Another important aspect is that landfill risks are self-maintained: the worse the situation is, the higher the risk that actions of ecological reconstruction will fail. Therefore, scientists along with all stakeholders must demonstrate the viability of various methods of ecological reconstruction (EcSF–18) and their potential to restore the local benefits that ecosystems provide in urban areas. Some recent studies on phytoremediation revealed that the plant species growing in the area belong to ecotypes that are physiologically resistant to heavy metals and that display important biological effects of pollution. For example, plant species such as *Amaranthus retroflexus* or *Atriplex tatarica* accumulated heavy metals (Pb) in their roots (Murariu et al. 2007). On the basis of all the results obtained locally and the reach of international literature on the subject, various remediation options can be discussed. Currently, it is too early to conclude whether phytoremediation is a viable option for the Tomesti landfill and under which conditions.

Social Sustainability Filter

Urban ecosystems provide important ecosystem goods and services (Bolund and Hunhammar 1999), either biophysical or general welfare, including sewage (waste) treatment, but also the green spaces as areas of both interaction with nature and places of social interaction, education, and relaxation (Picket et al. 2001; Galea and Vlahov 2005). On indicators SoSF–1–3, any urban policy for waste minimization and management must therefore take into account the preservation of urban ecosystems, most notably urban green spaces, in relation to the public welfare, but also in relation to rural natural environments with its natural and cultural heritage.

Until the end of 2013, Romanian cities must ensure a minimum of 26 m^2 of green spaces provision per capita of inhabitant (to comply with the European Union' regulation). The city of Iasi has a dynamic management of the territory, attributable to its fast development, with an estimated 26.8 m^2 in 2002, but it is not clear if the surface has now increased or decreased. Also, given the concept announced by the recent city strategy for horizontal urban development in relation to the other localities in the metropolitan area, the area occupied by the landfill and that is now outside the city itself will become intra-urban area. Therefore its management must be part of the general management of green spaces and all other land uses. The history of the city provides a most telling example: the Botanical Garden of Iasi, established in 1856, has moved since 1963 into a new location, which was at that time a peri-urban place for dumping municipal solid waste and is now a main attraction inside the city. It is therefore necessary, in subsequent analyses of the management options for the Tomesti landfill, to anticipate development paths and avoid potential obstacles. Decision-making steering authorities and public voices should make sure that all local communities in the metropolitan area are included in the process of decision (SoSF–4). Attempts to impose decisions onto a local community will sap the sustainability of any solution.

To create the conditions for effective governance (SoSF–5–8), the city and the metropolitan area as a whole must be seen by its inhabitants as a place to attract talent, a place of shared values and freedoms for all generations, genders, cultural, and religious minorities. The results will be social trust, which in terms of effective management means social capital. Demographic data used by a recent environmental report on a 2009–2015 development plan for ZMI (RM-PIDCPI 2009) indicate that, during the socioeconomic transition period between 1992 and 2007, ZMI underwent two main changes: (1) a decline of the total population at a rate of 3.5% per decade to 390,000 in 2007 and (2) a decrease of the rural/urban ratio. Urban population of ZMI dropped from 83.2 to 77.9%. Although rural population increased steadily by 1.6% per year, urban population decreased by 0.8% per year. Tomesti is placed in between these two tendencies, with an increase of 0.6% per year. Although all rural areas appear to have benefited demographically an urban-rural migration, Tomesti is not among the most attractive rural localities around the city of Iasi. A very similar situation (up 0.8% per year) is Holboca, the next closest locality to the landfill. These support the assumption that this unprotected landfill may have a discouraging effect on demographics on the neighboring areas.

As shown by Sauer et al. (2008) with a survey in a central European country (Czech Republic), economics is less a driver for an efficient system of waste reduction by recycling than the general context of households and social aspects. Economics in transition countries, however, may determine the structure of the families and households, the roles of each generation, and the place of women and children in the society (Bardasi and Monfardini 2009). In this sense, a powerful social indicator of the general state of the society is the issue of social inclusion, family, children care, and education (Gavrilovici 2009). Formal and informal education for sustainable development (SoSF–9) is a prerequisite for citizen and household attitudes toward waste generation, recycling, and waste treatment. Given the current local situation in Tomesti, there are important insufficiencies on that matter.

As shown by recent studies, residential areas can also be evaluated in terms of functionality and sustainability (SoSF–10), within the wider context of the cities in former socialist countries now members of the European Union (e.g., Viteikiene and Zavadskas 2007). A particular aspect of the functionality of the local public services is the access to facilities for selective collection of wastes (SoSF–11). Civic attitudes (social capital) are often underutilized for resolving a great deal of the waste problem. In a social survey during 2008 only 24.5% of the respondents have noticed elements of a system selective collection of the solid waste in their city neighborhood. This roughly corresponds to the situation of where in 2009, out of 597 points of waste collection, only 110 (one-fifth) allowed selective waste collection. In general, the attitude of the citizens was favorable to the system itself, suggesting that a fully endowed system would have a positive result. On the relation between science, citizens, and authorities (SoSF–12) the same survey revealed an important lack of information about wastes and waste management, despite a willingness to contribute to the local sense of clean environment.

Regarding a general integration of scientific, civic, and public authorities into functional governance (SoSF–13), certain exercises existed, such as with the public consultations that have been carried out on the occasion of the development of the cities strategy for development. Local universities carried out actions on themes such as "university in society" and "ecological education," "EcoFun," "green schools" but impacts are still insufficient on local MSW management.

Upgrading of the social and technical systems is difficult during transition times; therefore new instruments must be developed, tested, and updated for change management (SoSF–14). Dijkema et al. (2000) identified public awareness and attitude as the main parameters determining the future context of MDW / landfill management, before technological development, resource scarcity, and final waste abatement of waste processing residues. Effective governance must build on a foresight exercise—a predefined process by which local stakeholders construct a vision of what their community is. The vision of common values builds a sense of shared identity and interests integrating local stakeholders' to get involved in joint efforts—municipal projects—and acquire literacy of the subject along the process (Jenssen 2009).

Economic Sustainability Filter

In Central Europe, the main economic aspect related to sustainable development in general, and MSW management in particular, is that sustainable development tends to be a priority only as long as the emphasis falls on the development part. This is unlike the more economically affluent Western Europe, where sustainability discussions usually go about environmental protection. All indicators that detail the economic sustainability filter are related to opportunities for economic development. When technical solutions are being applied, transaction costs are determinant. As Thomas (1999) pointed out in an earlier survey on waste management in Romania, the main obstacle in MSW management appeared to be not technical nor managerial but the lack of money to do it.

J. Hazard. Toxic Radioact. Waste 2012.16:158-168.

A correct MSW management requires a minimum cost, which must be supported by local revenues. Therefore a certain amount/level of economic development is necessary. In this sense, all economic discussions regarding economic indicators come down to one idea: proving that a proposed solution is generating economic activity and revenues.

For example, a most effective path for promoting environmentally safe managerial solutions for the Tomesti landfill will be to propose landfill management solutions that will have the demonstrable capacity to increase agricultural activity and derived revenues in the neighboring traditionally agricultural area. International literature actually suggests that agricultural grasslands are the most common land use after landfill ecological reconstruction (Simmons 1999).

Similar solutions must be developed in terms of utilizing the local potential for green business, such as composting and gas production and other types of developing a business related to MSW. In the same sense, the current studies and attitudes suggest that ecological restoration for increasing biodiversity will not have an important success unless related to chemical decontamination, removal of health risks, and favoring the use of the current tourist facilities in Tomesti related to the natural environment and the vicinity with the historic city of Iasi.

Integrative Discussion

The problem of municipal landfills has grown by accumulation of various different problems related to various types of environmental degradation, with other social and economic issues added on. This makes landfill managements much more complex than is usually acknowledged. Currently, a comprehensive environmental and health hazard assessment procedure at solid wastes disposal sites, covering all risk aspects for landfill-related soil, leachate, and gas, does not exist in the international literature (Butt et al. 2008; Renou et al. 2008). The filters-based scenario approach proposed by the writers in this paper, in relation to the recent progresses in problem structuring for complex transitions, is one potential way to proceed.

The indicators used to define sustainability filters are open to updates: any time new relevant information is available, it can feed in a filter, either as an update of an extent indicator or as a separate one.

The exercise for the Tomesti landfill case study shows that the current management practice does not pass successfully through the ecological sustainability filter, which means, according to the nested inclusion relationship, that the situation is already readable as unsustainable before taking into account the social and the economic issues.

However, a minimum discussion on the social and economic filters can be useful from a foresight exercise logic: anticipate what the next issues will be after environmental sustainability will be achieved. There are two main aspects to consider.

The first issue to take into account is related to costs. Thus, landfills remain the most applied MSW disposal method around the world, but it becomes a less cheap option because of increasingly stringent legislation in developed countries; consequently MSW started to be increasingly diverted from landfills to the managerial options (e.g., Fehr 2003; LFD 1999; Giusti 2009), which require that landfills can only be used for inert materials, encouraging the use of MSW with high organic content to be used for the production of gas. Incineration and recycling represented 18 and 25%, respectively, in 2000 in Western Europe and increasing, whereas the percentages for Central and Eastern Europe were 6 and 9% but lack of data does not allow for identifying a clear tendency (Giusti 2009). Data from a pilot study (Koneczny and Pennington 2007) in a series of cities in Central Europe indicated that the preferred solution for diversion from landfills is a mix of recycling (10–20%), composting (15–45%), and refuse derived-fuel (40–80%). The optimum combination of options would be region specific. Incineration also represented an important option, especially with energy recuperation. The Iasi-Tomesti site was part of that regional study, with the following percentages being calculated for various potential management alternatives (scenarios): 74% recycling + composting, 51% recycling + incineration, 81% intensive recycling, 77% intensive composting, 43% intensive incineration, 38% recycling + composting.

The second essential economic issue is that getting richer does not automatically mean a better management of wastes. By using an environmental performance index for cities, which included among others the treatment of urban wastes, Liu (2009) showed that the relation between economic and environmental performances of the Chinese cities does not follow a Kuznets Curve pattern, i.e., the production of MSW does not decrease after an economic threshold is passed.

Concluding Remarks—Future Perspectives

With regard to the local and the national sustainable development strategy, the major change that needs to be done is the adoption of a predominantly proactive attitude. In a sense, this will mean getting out of the EU-accession mentality and acquire an EU-membership mentality. This will require wider international collaboration and coworking between local authorities, universities, and business to overcome institutional automorphism at the city level (e.g., Czerniawska 2002; Schwartz 2009).

To anticipate obstacles and traps, innovative prospective methods should be envisaged for comparative analyses. For example, Lang et al. (2007a, b) used a quantitative method to evaluate sustainability potential analysis (SPA) of landfills based on a set of sustainability criteria and hazard scores. Furthermore, MSW management is very complex and requires a process of learning from the experiences of other countries so as to identify both common features and context dependencies (e.g., Koneczny and Pennington 2007).

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