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SOM-theme B: Innovation and interaction

Abstract

Long-term estimates make clear that the amount of solid waste to be processed at landfills in the Netherlands will sharply decline in coming years. Major reasons can be found in the availability of improved technologies for waste recycling and government regulations aiming at waste reduction. Consequently, market size for companies operating landfills shrinks. Among the companies facing the problem is the Dutch company Essent. Given the expected market conditions, it looks for alternative business opportunities. Landfill mining, i.e., the recycling of existing landfills, is considered one of them. Proceeds of landfill mining are related to, for example, recycled materials available for re-use, regained land, and possibilities for a more efficient operation of a landfill. The market for landfill mining is of a considerable size – there are about 3800 landfills located in the Netherlands. Given market size Essent faces the dilemma of how to explore this market, i.e., select the most profitable landfills in a fast and efficient way. No existing methods or tools could be found to do so. Therefore, to answer to the problem posed, we propose a step-wise research method for market exploration. The basic idea behind the method is to provide an adequate, cost-saving and timely answer by relying on a series of quick scans. The method has been tested for its practical use in a pilot study. The pilot study addressed 147 landfills located in the Dutch Province of Noord-Brabant. The study made clear how method application resulted in the selection of a limited number of high potential landfills in a few weeks, involving minimal research costs.

1 Introduction

In recent years the amount of solid waste (SW) to be processed at landfills in the Netherlands has sharply declined. While landfills were used to store 13,000 ktonnes of SW in 1993, figures for 2001 show a reduction to 6,500 ktonnes. Trend figures indicate a further decrease to 2,000 ktonnes in 2010 (AOO 2002). Main drivers of this development are government regulations and tax policies that aim at waste reduction, together with new technologies that increase possibilities of re-use or recycling of products and materials. As a net consequence market volume for companies operating landfills shrinks.

Among the companies facing the problem is Essent. The company operates eleven landfills in the Netherlands. Together 2080 ktonnes of SW was processed at these landfills in 2001. This is equivalent to a market share of approximately 32% (AOO 2002). Given the perspectives on market development Essent is initiating new services to guarantee its long-term survival. One of these services concerns landfill mining. Landfill mining, also addressed as landfill reclamation, is a process of excavating a landfill using conventional surface mining technology to recover e.g. metals, glass, plastics, soils, and the land resource itself. In addition to reclaiming valuable resources, the recovered site can then be either upgraded into a state-of-the-art landfill, closed, or redeveloped for some other suitable purpose (Morelli 1990). As for the required resources and technology, landfill mining is a natural extension to the current activities of Essent.

The market for landfill mining in the Netherlands seems to be of considerable size – next to 30 operational sites, there are about 3800 closed landfills (Perrée 2001). Rough estimates indicate a countrywide profit potential for landfill mining of about € 150-200 mln (De Visser 2002). However, the landfills are quite diverse with respect to location, size, and contents. Hence costs and benefits of their mining may be quite different. It is likely that in many cases benefits will not outweigh the costs. The dilemma faced by Essent is how to find out the best business opportunities, i.e., landfills for which estimated profit would be the highest, in a fast and efficient way.

Detailed research of a large number of landfills was not considered a valid option. This is mainly due to the high costs involved. For example, the required laboratory analysis of landfill contents is estimated at approximately € 2,000 per acre (acre = 0,4047 ha). Also data collection costs for getting familiar with local regulations, economic development programs etc. may be significant. Furthermore, the limitations set to company resources would make it impossible to explore the market within a reasonable amount of time. Therefore, Essent looked for a less costly and time consuming research methodology.

In this article we present a *research method* for exploring and scanning the market for landfill mining as an answer to the question posed by Essent. The core of the method consists of two elements:

A *categorization* of costs and benefits associated with landfill mining projects.
A *step-wise approach* for establishing a set of profitable land fill mining projects

The categorization is used as a starting point for identifying costs and benefits relevant for the set of mining projects under consideration. We assume this set to be restricted by a choice for a geographical region. Such a choice may have important implications for the relative weight of specific types of costs and benefits. For example, due to factors like the density of population or the availability of certain types of industry the proceeds of regained land or recyclables will differ significantly. Also costs of mining operations may be quite different due to e.g. geological circumstances, availability of qualified facilities and personnel etc. A generic description of costs and benefits in terms of a categorization guarantees *flexibility* of the method in this respect.

The first step in method application concerns the determination of an initial set of landfills to be considered for exploration. Next to geographical boundaries, see above, this set may be further restricted by criteria related to e.g. the contents of landfills. Subsequently, in a series of four steps the potentially most profitable landfills are selected. Each next step assumes a more precise insight in costs and benefits of projects considered, given the use of more elaborate research means. On the basis of this insight, projects for which it is clear that they do not meet profit standards are omitted. The reduced set is to be considered for further evaluation in the next step.

The basic idea behind the step-wise approach is to provide an adequate and timely answer to the research question while minimizing research costs. This idea is implemented by relying on quick scans in the first steps. Ideally, such a quick scan has a high discriminative power, while underlying data can be acquired with relative ease. The final step concerns the detailed research as mentioned above.

To evaluate the practical use of the method a pilot study has been carried out for 147 landfills in the south of the Netherlands. The pilot was quite successful as the number of candidate landfills could be reduced with minimum research efforts to 2. The associated cost savings amounted to approximately € 1,8 mln.

The remainder of the paper is organized as follows: in the next section we will review related literature and outline contributions of this paper. In Section 3 we describe the new research method in terms of the underlying framework of costs and benefits of landfill mining, its step-wise approach and management involvement. Subsequently, in Section 4, we discuss the implementation of the research methodology in terms of a pilot study. The study concerned 150 landfills located in the south of The Netherlands. Finally, conclusions are summarized in Section 5.

2 Literature review

In this section we relate our research to literature. Starting from mining projects reported in the literature, we consider motivations for mining a landfill and the way the decision on whether to mine a landfill has been made. More in particular we will address four mining projects in the Netherlands. Next, we discuss tools that may support decision making on mining landfills. We conclude by stating our research contributions.

Landfill mining projects: motivations and decision making

In literature a few overview articles are available on landfill mining projects. Savage et al. (1993) mention how the concept of landfill mining was introduced already in 1953, when a landfill operated by the city of Tel Aviv, Israel, was mined. However, it remained the sole application reported until the late 1980s. From then on several mining projects have been mentioned, see e.g. Nelson (1994, 1995) and EPA (1997). An important reason for this renewed attention is the shift towards resource recovery (Savage et al. 1993). Other motivations for mining are a lack of landfill space, pollution liability, costs of implementing government regulations, and benefits of mining in terms of e.g. landfill cover material and energy production, cf. Nelson (1994, 1995) and EPA (1997). Case descriptions indicate that many projects have been successful in terms of costs and benefits. What is striking about all of these cases is the fact that almost all of them appear to concern stand-alone projects. In many cases the initiative for mining comes from a regional authority and addresses a specific landfill. Another point of interest concerns the decision process – whether to mine or not. In some cases this was no issue, for example because of the real danger of pollution or because of government regulations. In remaining cases it is largely unclear on what basis the decision for mining has been made.

In the Netherlands only few landfill mining projects have been carried out so far. We found reports on four mining projects in literature. They concerned landfills near the cities of Arnhem (De Groot 2001), Born (De Visser 2002), Apeldoorn (VAR 2000), Heiloo (De Visser 2001). In the first two cases mentioned the trigger for landfill mining was the development of an industrial area at the location of the landfill. In a third case the main driver was the avoidance of pollution of the environment surrounding the landfill. The last case concerned a landfill mining project that aimed at creating new landfill capacity. In the first three cases the local government played an important role in initiating and funding the projects.

It is interesting to see that the projects mentioned above all assume a major role for the local authorities in initiating mining projects. As far as the companies realizing the mining operations are concerned, they often seem to act rather passively in initiating projects, as if they are in a "sellers market". In this article, however, we consider a company, Essent, which starts from a pro-active market approach. This requires the active exploration, and scanning of market opportunities. The research method proposed in this article is meant as a means for supporting these activities.

Decision making

The literature shows several examples of tools that are helpful for comparing alternative projects for which holds that the (potential) costs and benefits cannot be measured at one dimension. For example, in a cost-benefit analysis (CBA) "all potential gains and losses from a proposal are identified, converted into monetary units, and compared on the basis of decision rules to determine if the proposal is desirable from society's standpoint." (Nas 1996). Of course, the problem at hand is no societal issue, but a problem faced by a company, Essent. The methodology of cost-benefit analysis can be an interesting tool at designing a quick scan for the selection of promising landfills. According to the method of cost-benefit analysis the relevant costs and benefits of a project have to be identified and measured. After this the projects are compared and the most promising project(s) selected. The systematic approach of multi criteria analysis (MCA) is another tool to help decision-makers in specifying and evaluating criteria to select the best solution (see for example Hokkanen and Salminen 1997; Cheng et al. 2002). Where CBA tries to relate project characteristics to a single *financial* dimension, MCA assumes the rating of project characteristics according to multiple dimensions. Consequently, the best project in case of CBA is found is a straightforward manner, while MCA requires weighting to determine a best candidate. For both CBA and MCA, the identification of the relevant costs and benefits is crucial.

In our method we assume the use of both multi criteria analysis and cost benefit analysis. Cost benefit analysis is implemented as quick-and-dirty screening tools in the early steps of our method, based on straightforward indicators for promising landfills. The choice for CBA is motivated by the priority given by the company to the commercial success of the project. Alternative criteria, either originating from the company or from third parties, are assumed to be considered in the later steps of the research method. This implies the use of MCA. Typically, the final decision on landfill mining will involve other stakeholders next to Essent like e.g. local authorities, environmental pressure groups, and citizens living in the proximity of the respective landfill. Usually, these stakeholders adopt non-financial criteria in their judgment of project success. Another reason for postponing the application of MCA may lie in the required resources for doing research - the diversity and quality of the required expertise may give rise to significant costs.

Research contributions

In this article we propose a research method for assessing the market opportunities of landfill mining projects. As such it answers to a new development according to which commercial companies would like to play a more pro-active role in market exploitation. The research method concerns a step-wise manner for evaluating costs and benefits of candidate landfills within a certain region. Underlying criteria in the development of the method are the minimization of research efforts in terms of costs and time, and flexibility with respect to its use in case of alternative regional circumstances.

3 Research methodology

3.1 Introduction

This section introduces a research method for exploring markets for landfill mining projects. We assume a market to be defined by a (possibly large) set of landfills located in a certain geographical region. Application of the method should result in a reduced set of mining projects for which estimated profits meet the standards of the mining company. Typically, the size and contents of the latter set is related to the availability of landfills meeting company standards, and the resources and financial risks involved in their mining. The determination of this set requires an *assessment* of the profit opportunities of all landfill projects involved. However, to make a final decision on the mining of a landfill a thorough investigation is required, involving for example, the analysis of samples of the contents of landfills, geologic and geographic information, and local legislation and development plans. This assumes the elaborate use of dedicated research means. The dilemma faced by the mining company is that its standards and restrictions on the use of budget, time, and resources, make it infeasible to perform a thorough investigation for all alternative projects. This brings us to two essential qualities of the proposed research method: *speed* and *efficiency*. Speed is related to the time required for obtaining an answer using the method, that is to say, the set of high-potential landfills. Efficiency is determined by the costs of research means involved in the method application. Both speed and efficiency require a careful selection of research means – preferably, non-profitable and less profitable projects should be found and excluded with minimum efforts. As a third quality of the method we mention *flexibility*, i.e., adaptability to specific market characteristics. For example, type and significance of costs and benefits may differ per region, or even per landfill owner.

The remainder of this section will address the main elements of our research method. First, we provide a general categorization of costs and benefits of landfill mining (subsection 3.2). This categorization is meant as a generic basis for defining main costs and benefits associated with a specific set of landfills. Next, in subsection

3.3, a step-wise approach for assessing the profitability of candidate mining projects is introduced. In Subsection 3.4 we discuss method flexibility in terms of alternate market characteristics. Finally, we will consider the use of the method by identifying the parties involved in its application and their associated roles.

3.2 Costs and benefits – a categorization

To assess profitably of mining projects insight in their costs and benefits is required. As a starting point we use the overview supplied by the United States Environmental Protection Agency (EPA 1997). Their overview is validated by many mining projects. *Benefits* fall into two main categories: the benefits related to more efficient operation of landfills, and the benefits resulting from recyclables and regained land. On the other hand *costs* are distinguished in capita costs and operational costs. Some remarks on the overview are:

- Costs and benefits from reclamation projects are facility-specific, any or all may appear in a specific mining project.
- Subsidies from (local) authorities or third parties are not mentioned as a potential benefit. Also efforts involved in researching costs and benefits of mining projects are not made explicit in the overview.
- A pro-active market approach towards landfill mining may also imply the purchase of landfills.
- The overview implies a strict division in capita costs and operational costs. In some cases this is not too clear. For example, worker training in safety procedures may concern a one-time exercise, however, it may also refer to an activity that is carried out on a regular basis – to guarantee a certain routine in conforming to standards.

Table 1: Benefits and costs of the reclamation of a landfill

Benefits	**Costs**
Increased disposal capacity Avoided or reduced costs of: – Landfill closure – Post-closure care and monitoring – Purchase of additional capacity or sophisticated systems – Liability for remediation of surrounding areas Revenues from: – Recyclable and reusable materials – Combustible waste sold as fuel – Reclaimed soil used as cover materials, sold as construction fill, or sold for other uses Land value of sites reclaimed for other uses	Expenses incurred in project planning Capita costs: – Site preparation – Rental or purchase of reclamation equipment – Rental or purchase of personnel safety equipment – Construction or expansion of materials handling facilities – Rental or purchase of hauling equipment Operational costs: – Labor – Equipment fuel and maintenance – Land filling non-reclaimed waste or noncombustible fly and bottom ash if waste material is sent off site for final disposal – Administrative and regulatory compliance expenses – Worker training in safety procedures – Hauling costs

3.3 A stepwise approach for market exploration

In general, a mining project involves a significant financial investment and is not free of risks. Therefore, the respective mining companies will demand an accurate insight in its profit potential before making the final decision on initiating the project. This insight has to be obtained as the net result of a rather elaborate investigation preceding the actual mining activities. We will refer to such an investigation as a “full investigation”. It involves a multitude of research efforts like the analysis of samples of the contents of landfills, and the acquirement and interpretation of local regulations and development plans. For a single project such efforts may be acceptable. However, for a large set of projects this is no feasible alternative, given the required time and the amount of costs and resources involved. In this subsection we try to solve this dilemma by (strongly) reducing the number of landfills to be considered for a full investigation through the use of simpler research means. We implement this idea by distinguishing five steps in researching profitability of mining projects (see Figure 1). Each next step assumes the use of more elaborate research means in terms of time, costs and the required resources. The final step equals the full investigation. Basically, the choice of research means for each step assumes a trade-off between the required efforts and their discriminative power. After each step the set of projects to be considered for further evaluation is reduced by omitting those projects for which estimates clearly indicate insufficient profitability. As such, the instrument is a funnel model: every step in the model starts with a number of potential interesting landfills, and reduces this set to a subset of even more promising landfills. This reduction assumes management involvement and agreement. As such we mark it as a decision moment. We come back to their meaning in Subsection 3.5.

Let us now characterize each of the steps in our method. As such it provides a generic approach for setting up the market exploration. In Section 4 we will show how it may be applied in practice.

Step 0 of the method concerns the market definition, i.e., the creation of an initial set (start set) of landfills to be explored. This definition may be influenced by factors like the region the company is already active in, its (technical) knowledge and expertise, its resources, and its business contacts. Profitability is not a primary issue in making up the start set. For example, a start set could contain all closed landfills in a certain area, or all closed landfills belonging to the same owner, such as the (local) government, or the mining company itself.

The first selection step mainly implies desk research that makes good use of data sources that are readily available. It assumes rough, diagnostic indicators to be used for a first reduction of the start set. Typical sources of data to be used are for example the Internet, regional authorities (public data) or research institutes. The indicators relate to a first analysis of the main costs and benefits relevant for the landfills under consideration, cf. Subsection 3.2. As such indicators serve as proxies for relevant types of costs and benefits. For example, in highly populated areas the proceeds of regained land may be a significant benefit to consider. If this is the case it may be important to know whether a landfill is located in an area that is appointed for further development in terms of e.g. new houses, factories, offices etc. Consequently, the location of a landfill relative to such areas may serve as an indicator. Another benefit may follow from the recyclables. We found that the presence of recyclables in a landfill may show a strong relationship with the age of the landfill. Some types of recyclables are only present if the landfill is of a certain age. In this way a first impression may be obtained of the possible proceeds of recyclables. This is due to legislation and technological improvement in the recycling process. Also the presence of hazardous materials may sometimes present a simple indicator for the amount of costs to be expected. Typically, the indicators in this step should allow for simple and speedy data collection. Preferably they act as a straightforward qualifiers or disqualifiers for a project.

Step 2 assumes the use of quantitative indicators. Again, mainly desk research is assumed. The landfills remaining after the first reduction of step 1 will be compared by means of a so-called cost-benefit analysis (see section 2). This assumes a trade-off of main categories of costs and benefits. Given the uncertainty related to certain costs and benefits several scenarios may be considered in terms of alternative values within a certain pre-specified range. In this way some idea may be obtained of the robustness

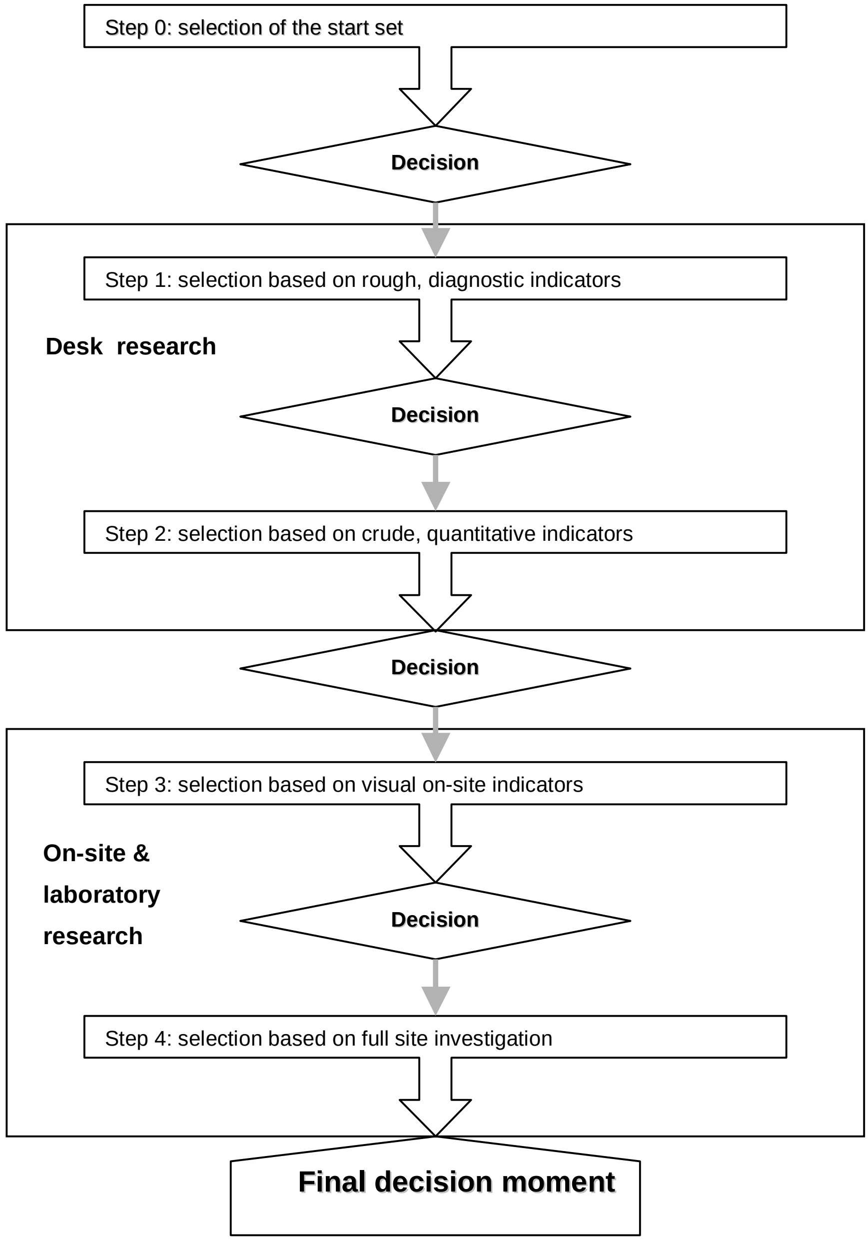

Figure 1 A step-wise approach for researching profitability of landfill mining projects

and risk associated with the outcomes. An important source in determining and valuating indicators may be historical data on previous mining projects and landfill operations. Typically, such information is already in company possession.

The next selection step, step 3, assumes on-site research and laboratory research, next to desk research. In this step all remaining landfills are visited by a multidisciplinary team of experts. By means of visual checks (possible by means of studying pictures instead of on-site observation), this team should focus on the feasibility of the mining project from several perspectives. Basically they should give their judgment on the question whether the mining operation itself is possible, and whether the foreseen future use of the mined area is a valid option. This requires sound judgment from a technical, social and legal perspective. Multi-criteria decision making is a suitable technique here for deciding on the projects to be omitted for further evaluation. Please note, that the focus in this step is more towards an initial judgment (quick scan) of experts. More detailed research should be a part of the full investigation (step 4).

The final step assumes the use of all research means required for making a final decision on mining a landfill. Next to a careful analysis of landfill contents, and its geological and geographic setting, this involves the collection of detailed data on for example, local legislation, politics, development plans, and possibilities for acquiring subsidies. However, instead of having to do this costly research for all landfills, this only has to be done for a small, highly potential subset.

3.4 Flexibility of the method

To allow the instrument to be useful from a practical perspective, it should be suitable for alternative markets (so for different start sets). But besides this, it should be a flexible model, as other regions, the moment of its application, and data availability influence the choice of indicators. For example, in the highly-populated Netherlands, vacant land is scarce and therefore very expensive. In scarcely populated areas, the profit of vacant land is much lower. Furthermore, technological innovation or new demands may make materials that cannot be re-cycled or re-used nowadays, interesting products. Given this demand on flexibility our method has been defined in generic terms, prescribing and characterizing essential steps in the exploration process, but leaving the details in terms of suitable indicators open.

3.5 Use of the method

The previous sections described the research method as a five-step model. Let us now consider the sequencing of steps and the parties involved in method application. While our approach specifies a sequence in executing the market exploration, we acknowledge the possibility of iteration. This may happen e.g. because new information came in, or improved indicators are suggested.

The market exploration given the application of our method is to be considered as a project itself and assumes three main activities:

- Planning
- Doing research
- Decision-making

Planning refers to the overall management of the research project. It involves management of the required resources, in terms of researchers, and their means, and the safe-guarding project progress.

Research activities will be executed by multiple researchers, as different types of expertise are required for making sound judgments on the many facets of a mining project. Also certain research steps may require multiple equally skilled researchers in order to guarantee timely answers.

Each step in our method is concluded by a decision moment. This involves the management of the mining company. They have to make a final decision on the set of landfills to be considered for further evaluation. This decision may be in line with research outcomes, but may also deviate. A reason for such deviations lies in new information brought in. This may lead both to a reduction or an increase of the set of candidate landfills. Also management may decide to run through the research step again with other or adapted indicators.

In the later steps, especially step 4 of our method, also parties other than identified above become involved. For instance, the mining company needs permission of both the landfill owner and the local authority for collecting on-site samples. To allow a smooth application of the model, it should be analyzed beforehand which parties will be involved. Furthermore, if a certain landfill is selected as the best business opportunity, that is as the landfill for which estimated profit is highest, other stakeholders, like representatives of people living in the neighborhood, the municipality, and ecology groups will come into play.

4 Implementing the methodology

4.1 The pilot

To assess the research method for its practical use a pilot study was defined. The pilot study concerns a set of landfills in the region around the cities Eindhoven and Helmond in the Dutch Province of Noord-Brabant (see Figure 2). The aims of the pilot study were to:

- Illustrate the application of the method
- Test the method for its principal qualities: cost, speed and flexibility.

The first aim is related to the company's wish for having a showcase that makes clear how market exploration can be done using the new method. Where the first aim mainly highlights the procedural aspects of the method, the second aim is directed towards its contributions in terms of an efficient and effective market exploration.

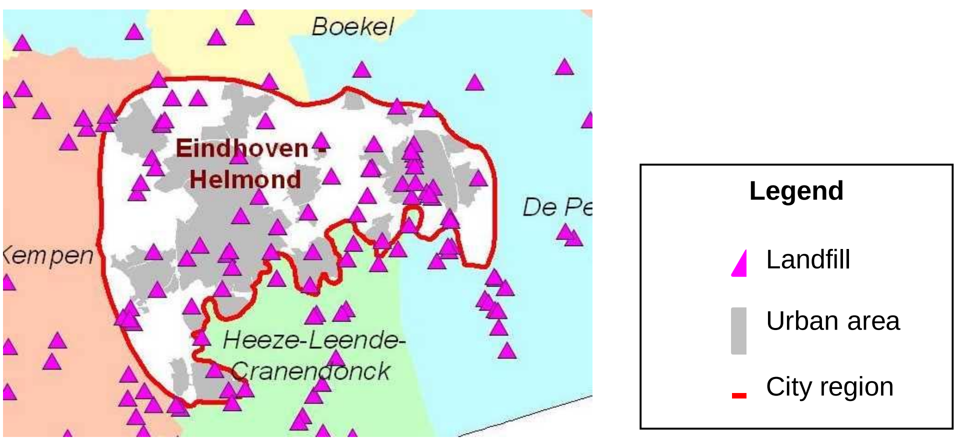

Figure 2 Pilot study: region around the cities Eindhoven and Helmond (Bureau of Monitoring & Information, Province of Noord-Brabant)

The pilot study was realized as a project, for which a project co-coordinator was appointed. Part of the research activities (especially steps 1 and 2 of the method) were also allocated to him. The research activities assumed consultation of several experts in- and outside the company. For step 3 a research team was being formed in order to answer to the multidisciplinary approach assumed in this step.

In the next subsections we will first discuss method application for the pilot study (first aim). Next, we consider it significance for market exploration (second aim).

4.2 Method application

As a starting point in our discussion on method application for the pilot study table 2 is used. It summarizes the main characteristics of the market exploration as they result from method application. Our focus will be on steps 0-3, as here lies our main research contribution.

Step 0: Selection of the start set

As already mentioned above, the market to be explored concerned a set of landfills located in a region around Eindhoven and Helmond in the Dutch Province of Noord Brabant. This set was made up of 147 landfills. The choice for this particular region was motivated by a number of reasons:

- Essent is familiar with the region as it processes a significant amount of solid waste originating from this region
- High benefits of regained land are expected, as land is scarce while demand for it is high
- Good possibilities for re-using recycled materials resulting for mining operations in road building projects within the region
- Provincial authorities show an open mind for landfill mining opportunities

Given the above reasons the region was considered a well-qualified candidate for a pilot study. Not only would it suit the purposes of the pilot study, it also harbored the potential for Essent in making the first real steps towards market exploration.

Step 1: Rough diagnostic indicators

The first selection step in our method assumes the application of rough, diagnostic indicators for reducing the size of the initial set of landfills. In the pilot study, we used three of this kind of indicators. The indicators were chosen based on the expectation that both benefits of regained land and costs of redumping waste may be significant, and the publicly available data on the respective landfills (Province of Noord-Brabant 2001). This data bank supplied information concerning location, contents, and size of the landfills under study. Next to these data the researchers used documents on town and country planning. This information is supplied by the Province of Noord-Brabant and is available on Internet. Among others, it highlights areas that will be allocated to industries of for housing people. Let us consider the indicators chosen.

The first indicator builds on the notion that mining landfills located in urban areas is more likely to be profitable than mining of landfills located in rural areas. This follows from the fact that prices of regained land tend to be significantly higher in urban areas given its use for industrial purposes or for housing. To make the distinction between rural and urban regions, plans for regional development were consulted, see above. Landfills located in rural areas – outside the city region - were removed from the set (compare Figure 2). After applying this first very rough and very cheap indicator, only 76 landfills remained.

The second indicator again focuses at expected benefits from regained land. However, its precision is greater as it includes the distance of landfills from build-up areas - landfills located closer than 500 meters from a build-up area were removed from the set. This indicator lead to a further reduction of 41 landfills.

Table 2: Method application - selection model for Essent pilot

Step	Type of research	Indicators used	Time spent	Research costs	# landfills
0	Desk research	• Familiarity with region • Land prices • Proceeds of recyclables • Supportive authority (province)	16 hrs	€ 1600	147
1	Desk research	• Location of landfill: rural/urban region • Location of landfill: distance towards the built-up area • Recyclables: amount of building and demolishing waste	3 hrs. 2 hrs. 1 hr.	€ 300 € 200 € 100	147 → 76 76 → 41 41 → 9
2	Desk research	Cost /benefit analysis based on: • Research costs • Mining costs • Costs of non-recyclable waste • Revenues recyclables • Revenues regained land	16 hrs.	€ 1600	9 → 4
3	On-site Laboratory	• On-site checks	2 days, 2 people 32 hrs.	€ 3200	4 → 2
4	Beyond the scope of this pilot.				

Whereas the two aforementioned indicators focus at the benefits of regained land, the third indicator is based on the potential costs and benefits related to landfill contents. In case the percentage of recyclable and re-usable materials (in this case building and demolishing waste) in the landfill was less than 69% (average percentage of building and demolishing waste in a landfill situated in the considered region), the landfill was removed from the set. This is because under these circumstances it is expected that the costs of redumping waste will outweigh the proceeds of regained land. Again, the information needed stems from the data bank. After applying this third indicator, only nine candidate landfills were left.

Above we discussed three indicators. We applied these indicators successively given the amount of research costs associated with their use. It should be remarked that given the nature and set up of the research and the efforts involved one may consider the possibility of a simultaneous approach - characterizing all landfill on all indicators at the same time. This may result in about the same or even less costs.

Step 2: Crude quantitative indicators

Step 2 consisted of a cost-benefit analysis, performed on the nine landfills that still remained. The costs factors considered were research costs, mining costs, and costs of re-dumping of non-recyclable waste. Assumed benefits were the profit of regained land and recyclables. The parameter settings of costs and benefits were determined by two experts within Essent. As precise estimates of costs and benefits cannot be made they were evaluated for three scenarios: a best-case, a worst-case, and a realistic-case scenario. Where the best-case assumes a high level of benefits and a low level of costs, the worst-case scenario starts from the idea that benefits are relatively low and cost levels are high.The realistic scenario holds an intermediate position, cf. Table 3. Under the parameters of the realistic-case scenario, four of the nine remaining landfills were expected to be profitable in case of mining. According to the worst-case scenarios only two projects would result in a profit, whereas under the best-case scenario five projects indicate a profit. As a result of a discussion with the management of Essent it was decided to follow the realistic scenario. Consequently, four landfills are considered for further evaluation in step 3.

Table 3: Step 2 – Scenario analysis for a landfill (fictitious data)

	Worst-case	**Realistic case**	**Best-case**
Costs			
-Research	20,000	15,000	10,000
-Mining	1,000,000	800,000	600,000
-Re-dumping	300,000	200,000	100,000
Benefits			
-Regained land	1,000,000	1,250,000	1,500,000
-Recyclables	50,000	80,000	100,000
Profit	-270,000	315,000	890,000

Step 3: Visual on-site indicators

Step 3 was conducted on the four landfills that remained after the cost-benefit analysis under the realistic scenario. This part of the research was performed by a multidisciplinary team of experts. All experts were employees of Essent. They considered mining opportunities using visual data on the landfills. More in particular they focused at aspects like:

- Proximity of houses, factories
- Current use
- Possible pollution
- Geological and geographical characteristics of the site that may hinder mining activities

Note how these aspects may involve additional costs or benefits for the mining process. Together with the data already collected in step 2, they make up a more complete picture from a financial perspective. In the end, two landfills were selected as the most promising ones.

At this moment, Essent is seriously considering mining the selected two landfills. As one of the first steps in the full investigation required for making the final decision, it started negotiations with landowners and property developers.

Finally, some remarks on the implementation of the steps in our approach as they are shown in the pilot study. The indicators as described here, are the net results of discussion with managers after each subsequent step. In some cases those discussions resulted in redefinitions or refinements of indicators. As such, the decision moments played an essential role in method application.

4.3 Qualities of the method - speed, efficiency and flexibility

Table 2 makes clear how both the time spent (per landfill considered) and the research costs (also per landfill considered) increase for every subsequent step in our approach. This means that cheap and fast indicators are used in the beginning, when a large number of landfills has to be investigated, whereas more expensive and more time consuming indicators are used in the latter steps, when only a few candidate landfills remain.

The selection of two promising candidates took approximately 1,5 weeks, while total costs amounted to €7000 (rate: € 100/ hr.). The full investigation of these two landfills will approximately take another 10 weeks and involve costs of about €20.000. Let us compare these figures with a scenario where all 147 landfills were fully investigated. This would have taken an estimated two years - among others depending on the availability and capabilities of the research bureau within Essent). Associated costs are estimated at €1,820,000.00[1]. Clearly, the method application has significantly contributed to fast and efficient market exploration.

[1] Research costs of a full investigation is estimated at € 2,000 /acre. The mean surface area of the 147 landfills considered is 6.2 acre. Given this figures a full investigation of all 147 landfills would involve research costs of 147* 6.2 * 2000 = € 1,82 mln.

Some interesting findings of the pilot study relate to the flexibility of the method. Two observations we would like to mention:

- Candidate mining projects that are expected not to be profitable at the moment of method application may be so at a later moment.
- The need for scenario-analysis in the application of some indicators

The first issue relates to the fact that outcomes of selection models are dependent on the time scale chosen for initiating mining projects, and the parameters that set the context for evaluating candidate landfills. Typically, parameters like e.g. local regulations, mining technology, and economic growth may strongly influence costs and benefits of landfill mining. Ideally, the need for reconsidering a set of landfills would lead to an incremental use of the method. Such an approach assumes a new selection model for market exploration being built, using the set of previously defined indicators as a starting point. This points out the need for a careful documentation of selection models. Also, it may be worthwhile to explicitly mark and monitor those landfills that currently do not meet standards on profit, but may do so in the foreseeable future.

While some indicators allow for omitting candidate landfills in a straightforward manner, as it is a-priori true that they will not meet standards on profit, other indicators may not be that straightforward. For example, in step 2 in method application for our pilot study we distinguished between three scenarios, as cost and benefits could not be estimated within small bounds.

Where flexibility in the first situation relates to the method's capability of dealing with (partially) new data, the second situation points at the practical need for being able to cope with alternative data sets. The examples show how model re-use and scenario-analysis are tools, which may be used to realize such flexibility.

5 Conclusions and directions for future research

In this article we propose a method for exploring the market for profitable landfill mining projects. The need for this tool follows from a more pro-active market approach taken by mining companies. Such an approach assumes an active role of the mining companies in selecting potentially profitable landfills for possible mining. Typically, the number of landfills to choose from will be significant - it may concern dozens or even hundreds of landfills. Given these numbers, the “classic solution” to the problem in which every candidate landfill is subjected to detailed research, will not work because of the time and costs involved. Therefore, we formulated an alternative method. Its main elements are a categorization of costs and benefits associated with landfill mining and a generic step-wise approach for selecting profitable mining projects. The first element helps in getting a quick start in recognizing relevant costs and benefits. The step-wise approach is reflecting the need for adequate choice of research means in terms of the time and costs involved in their use. In total four steps are foreseen. While the final step foresees in the detailed research mentioned above, the first three steps strive for an efficient reduction of the set of landfills under consideration using quick scans.

The method has been successfully tested in a pilot study concerning 147 landfills located in the Province of Noord-Brabant in the Netherlands. At a cost of about €7000 the initial set was reduced to 2 landfills within less than two weeks.

Next to its direct meaning for market exploration, the development and application of the tool had several implications that are relevant from a management perspective. The method assists in structuring the decision making process – it suggests the use of a phased approach embedded in a project organization having a clear course and goal. Consequently, the decision for mining a landfill can be seen as the net result of a well-defined project. This increases confidence and commitment for this “new” line of business.

Several interesting directions for further research remain. We mention the application of the method for similar markets. For example, gas works may provide another interesting opportunity for mining. In the Netherlands quite a few of these can be found, often in the middle of cities. Another interesting route may be the extension of step 2 of our method, which concerns the use of crude quantitative indicators for selecting landfills. Currently, we are working on more refined models in this respect building on historical data.

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