Making of
Decision Support Tool 1

December 2018

Disclaimer

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1. Overview of involved workpackages

This document is related to the activities of the Interreg North-West Europe project RAWFILL. The target of RAWFILL is ameliorating the reuse of waste currently stored in landfills[1]. To achieve this, a multicriteria tool will be developed to support decisions of companies, governments, etc. The project is divided into several work packages, of which two are related to this document.

The rationale behind this research program is the large quantity of landfills to be managed. Estimations pointed out that the EU has about 350.000 to 500.000 landfills (Hogland et.al., 2010). Based on additional data in some (regions of) member states, a correlation between the number of municipalities and the mapped landfills was made. The extrapolation to the EU-level revealed an even higher number of potential landfill site: up to 1 million (E. Wille, 2015[2]). Most of them are no longer operational but the former exploitation and closure procedures were not always in line with the standards of sanitary landfills as described in the EU Landfill directive 1999/31/EC.

In order to set up sustainable and comprehensive management plans, data collection and data processing should be well established to make good decision making possible. Based on the detected (rather limited) practices worldwide, the objectives of RAWFILL were transformed in the several workpackages but also the large scale and easy applicability of the deliverables should be emphasized.

1.1. Workpackage T1

Citing the application form of the RAWFILL project:

"WP T1 develops a standard and comprehensive LF Inventory Framework (EIF) taking into account LFs resources. EIF will be used to describe LFs not only in terms of environmental & risk issues, but will focus on available dormant materials, so that it will be possible to economically evaluate later the resource-recovery potential of each LFs. EIF is the basis for DST LFs ranking and so a prerequisite to assess feasibility, business plan & business case for LFM projects."

[1] This aspect of valorization was not only discussed with the RAWFILL-members but also with the partners of Interreg Europe COCOON. Limiting the valorization to the reuse of the landfilled waste was not considered as a good practice. In line with these discussions, the scope was broadened to the following aspects: Waste to Material, Waste to Energy, Waste to Land, Preservation of the Environment and the groundwater supplies in particular.

[2] Estimations made in preparation of Eurelco workshop in EU-Parliament 20th October 2015.

1.1.1. Target of the EIF structure

The EIF[3], abbreviation of Enhanced Inventory Framework, is one target of the RAWFILL project. Its primary goal is combining innovative landfill geophysics methods with the DST prioritization tool.

1.2. Workpackage T2

Citing the application form of the RAWFILL project:

"The objective is that relevant stakeholders in NWE region use a standard information & decision framework for selecting optimal LFM projects. WP T2 provides public & private LF owners/managers, operators and potential investors in charge of LFMprojects with a standard Decision Support Tool (DST) to screen LFs and to select the most promising sites for resource-recovery projects according to RAWFILL methodology. In order to create consensus on the methodology, AdvB is shaped, involving a broader group of stakeholders providing feedback."

1.3. Integrated approach

The general concept of landfill management is based on the multi-barrier safety measures – the so-called IBC approach (Dutch for Isolatie, Beheersen en Controleren; Containment, Maintenance and Monitoring). These concepts do not aim at the recycling of the landfilled waste and the landfill area. The new approach is to treat the (former) landfill sites as dynamic reserves. This approach fundamentally differs from traditional visions on waste management and the remediation of landfill sites.

The main objective is the maximum reintroduction of the landfill sites into the materials cycle and as land in order to contribute to a sustainable resource management. Three important elements can be distinguished in this process: the content of the landfill, its surface area and its surroundings. The properties of the interaction between these three elements direct the sustainable resource management in time and space. The added value is the integrated approach which can be described as Dynamic Landfill Management (DLM[4]). RAWFill will develop a Road map in order to link and connect the several workpackages (Inventory, Data collection and surveying methods, Decision Support, Landfill Miner Guide, Communication,…).

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[3] Due to the specific application on landfills the EIF was changed in ELIF, i.e. Enhanced Landfill Inventory Framework.

[4] DLM is a cross-cutting approach to bring landfills in harmony with their environment by preventing or reducing negative effects as far as possible and with respect to the European policies and legislations in the broadest sense (Waste and Resource Management, Climate change, Flooding, Soil sealing, No net land take, Biodiversity). This concept 'Land(fills) as a resource' is fully in line with EU-needs to restore degraded land and encourage land recycling, in particular by supporting the regeneration of brownfields such as landfill sites.

2. Original objective of Flaminco

2.1. Policy background

Over the last decade, 70% of Flemish household waste is collected separately, reused and/or recycled. Less than 2% of MSW ends up at landfills. For industrial waste a similar trend can be observed. These successful results have led to a situation where only 28 licensed landfills remain operational in Flanders in 2015. On the other hand, there are 2.033 former landfill sites (OVAM inventory, 2015). Most of these were closed before 1977 (mergers of municipalities) or 1984 (end of transition measures to more severe regulations). Even though the size of each landfill site is usually limited to less than 1 hectare, the total landfill area is estimated at 88 km², i.e. the surface area of a major Flemish town. These are often underused sites, and this in a densely populated region with high pressure for land. Therefore, there is a need for a general vision on the redevelopment possibilities of landfill sites which are currently rather static storage places for problem materials, sometimes part of an aftercare phase.

In 2006, the Flemish government and the Flemish Public Waste Agency (OVAM) started a transition process on Sustainable Materials Management. This new policy emphasizes on the opportunities of urban mining but also landfills were considered as a valuable stock of resources (concept of Enhanced Landfill Mining (ELFM)). In 2011, a vision on Enhanced Landfill Mining (ELFM) was approved by the OVAM board of directors and resulted in an operational program over the period 2011 – 2015. The main idea of this concept is the approach of gathering materials (in its most broad definition) of a recent or an old landfill site or dumping site and reuse it for some purpose by introducing it again in the material chain. The approach makes it possible to gain important resources: materials, energy resources, drinking water and free space. A secondary benefit is that the approach is also suitable for purposes on soil remediation.

Recent research conducted by OVAM has shown that (former) landfill sites represent more than just a potential source of pollution and neglected land. The recovery of the waste stored and the underused land are no longer unrealistic scenarios. The total surface[5] area of more than 80 km² indicates the importance of this potential space. Thanks to the technological developments and in view of the strong need for a healthy environment and materials, landfill sites could offer solutions instead of constituting a threat. There is added value for several policy areas and policy levels.

In its "Vision 2050" the Flemish government (2015) considers the further transition towards a circular economy to be essential and affirmed the opportunities of ELFM. In 2015 the Minister of Environmental Affairs introduced the concept of Sustainable

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[5] According to VITOs GIS-survey on the OVAM-databases (2018), the total area of landfills was brought on 163 Km², represented by 3.380 sites.

Resource Management of Landfills[6]. This concept would not only enable the recovery of valuable materials, but also the reclamation of land and protection of the environment. Due to the large number and variety of landfills, a decision support tool (DST) was needed to transform the data into valuable information, useful for prioritization purposes. The Flaminco[7]-tool(as developed by OVAM, delivers a ranking of landfills based on the resource potential and environmental risks. It is a first step towards a long-term stock management of landfills within a circular economy.

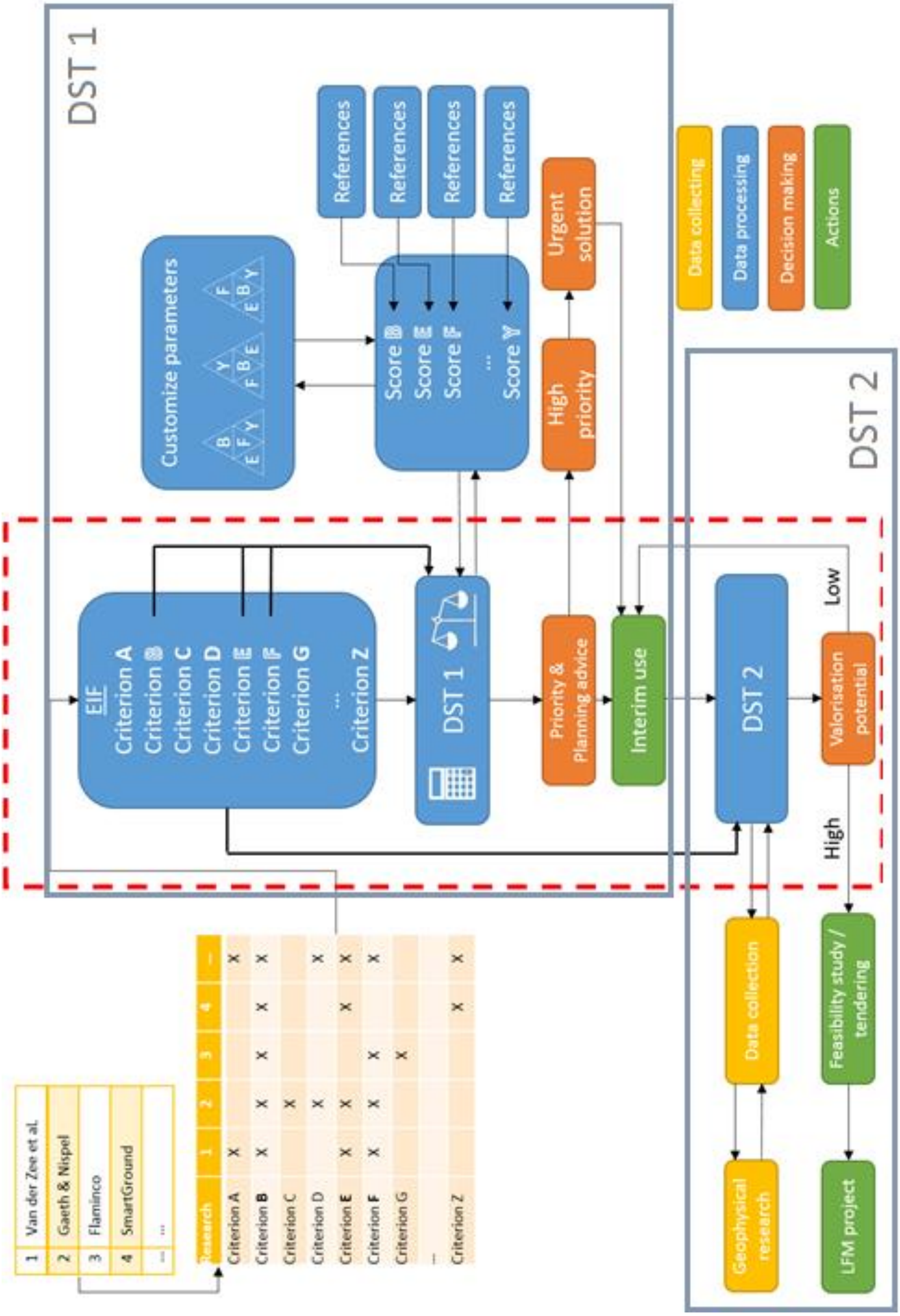
2.2. History of Flaminco

When the Public Waste Agency of Flanders (OVAM) was established in 1981, it started to collect information about pollution on land plots, mostly landfills. After 30 years of collecting data, several databases contained information about 2.000 landfill sites spread across Flanders. The information of these databases was very verstatile and not always equally qualitative. In order to improve the data collection, OVAM developed a three step approach towards ELFM: mapping (inventory of the number of landfill sites on level of the Flemish Region, with indication of specific characteristics of the area), surveying/exploring individual landfill sites (identification of the specific landfill body, identification of the composition of the landfilled waste, identification of the geo-physical and -chemical characteristics of specific surroundings of the landfill site) and mining of a specific landfill site (digging up of the waste, (pre-)treatment of the waste to make it suitable for material reuse or valorisation).

The concept of landfill mining wasn't brand new for the Agency. Already at the very beginning, measures were taken to ensure an optimal reuse. This was achieved by the way landfills were built and the composition of the material that was stored i.e. OVAM tried to create as many mono-landfills as possible (Van den Bossche, Bal, Behets, Umans & Wille, 2013). However, in order to be able to perform a consistent policy on historical and active landfill sites, the Agency was in need of a quick way to analyse all the data that it had. For this purpose, Flaminco was introduced.

Flaminco is a decision support tool, just as DST 1 will be. The tool will help policy makers to pick out the best suitable landfills for a profitable landfill mining project by ranking all available landfills from most promising to least promising. DST 1 will follow the same methodology but will be designed based on new insights and practical experience. The tool produces planning proposals for landfills in various time-related stages. The final goal can be - but not necessarily is - a landfill mining project in the future. According to the current ELFM²-policy, sustainable valorization of the landfills is the main objective.

[6] In line with the ELFM-definition, OVAM choosed ELFM² as the English translation (Enhanced Landfill Management & Mining).
[7] Acronym Flaminco stands for Flanders landfill mining challenges and opportunities.


DST 1
References
References
References
References
Customize parameters
Score B
Score E
Score F
...
Score Y
Urgent solution
High priority
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Criterion A
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DST 2
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High
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Data collection
Geophysical research
Feasibility study / tendering
LFM project
Data collecting
Data processing
Decision making
Actions
1 Van der Zee et al.
2 Gaeth & Nispel
3 Flaminco
4 SmartGround
... ...
Research

2.3. Applied criteria

Flaminco made use of six basic criteria: type of landfill, age, volume, use, accessibility and direct environment.

2.3.1. Type of landfill

This is basically the main sort of waste that was deposited on the landfill. Waste can have many forms, and can go from very common types like municipal solid waste and industrial waste, to very specific types (wheter or not mono-landfills) like gypsum, asbest, sludge, etc. Mono

Mono-landfills have a higher score in Flaminco, since their potential for a succesfull landfill mining project is higher. This is caused, among other things, by an avoided cost of sorting and separation the waste, an inevitable step in for instance municipal solid waste landfills.

2.3.2. Age

The criteria age is linked to the criteria type of landfill and has a role when environmental related decision have to be taken. In general two types can be distinguished: the landfills prior to the Flemish Environmental Act (VLAREM) of 1985 and those after VLAREM. For municipal solid waste, age is also an indication for the content that can be expected.

2.3.3. Volume

The ratio between a successful LFM project and the volume of the landfill that is under investigation depends on the necessary investments that need to be taken to run the exploitation.
Flaminco states that in general, the bigger a landfill is, the more interesting it becomes to include it in a project.

2.3.4. Use

Use in this context is meant as the spatial designation of the land plot. This can be residential, industrial, recreational, green area depending on how a region's spatial planning defines the territory.
Spatial data are usefull to find out were potential allotments can be constructed. This strongly influences the land price and can be of decisive importance for the project.

2.3.5. Accessibility

The accessibility defines how easy the landfill can be reached or how easy material can be supplied or removed from site. FLAMINCO uses the access to roads suitable for vehicles, railroads and waterways.
The distance was calculated in a bird's-eye view using a GIS application, consequently from the landfill location to the nearest road, nearest station or nearest docking facility.

2.3.6. Direct environment
The main question of the criterion direct environment is whether another landfill site is close to the landfill site to be evaluated. In case such a situation is present, the aim is to cluster these landfills. It was decided to link the same types of landfill sites with each other. In this way inventory management can be done.

2.4. Experienced problems
Although the structure of the Flaminco tool seems very logic when put in the context of a landfill, it turned out that the output of the tool did not match the reality. Five years have passed since its introduction and it turned out that the top fifty landfills, according to Flaminco, not a single one was considered to be interesting enough to do a landfill minig project on. On the other hand, landfills with rankings numbers exceeding four our five hundred did undergo a landfill mining project. The target is to investigate why or why not these landfills were selected for such projects.

3. Definition of LFM criteria and environmental prioritisation

Sub-task 1 mainly consists in a theoretical exercise with the following objectives:
overview of criteria which can be used to select landfill sites in Flanders that are eligible for Landfill Mining (objective 1);
development of a methodology to determine the environmental priority of landfill sites (objective 2).

3.1. Introduction

This chapter describes the basis for the calculation tool which has been developed to determine the environmental priority for Landfill Mining (LFM). This calculation tool is attached in Appendix 1. Based on the defined set of criteria, a methodology has been developed to determine the environmental priority of a landfill site to carry out LFM. This set of criteria is linked to the various objectives (4 in total), which enables us to determine the potential of a landfill site.

3.1.1. Objectives

To determine the potential of LFM, the following three objectives are taken into account:
- Objective 1: Waste to Energy (WtE);
- Objective 2: Waste to Materials - Materials management (WtM);
- Objective 3: Waste to Land - Space (WtL);

Even though LFM is a new concept, various studies have been carried out for objectives 1 and 2 (WtE and WtM). These studies are mainly based on the concepts of LCA, C2C and Lansink's Ladder. Unlike for objectives 1 and 2 (WtE and WtM), until now little attention has been given to objectives 3 and 4 (WtL) from an LFM perspective.
The following definitions have been established for the various objectives:

- Waste to Energy (WtE): the production of energy in the form of electricity or heat from landfill gas resulting from the decomposition of organic material or from the dump material, where the waste is converted into fuel through heating.
- Waste to Land (WtL): the creation of space at the location of the landfill site and the assigning of a new land use to the landfill site.
- Waste to Material (WtM): the valorisation of the waste streams that are released from a landfill and the reuse of the waste streams as materials.

3.1.2. Overview of criteria

To determine the potential of LFM a total of six criteria are used:
- Criterion 1: type;
- Criterion 2: age;

- Criterion 3: volume;
- Criterion 4: use;
- Criterion 5: accessibility;
- Criterion 6: surroundings.

In Chapter 3.1.3 'Matrix of objectives - criteria' the criteria are briefly described, providing a general overview, the interpretation of the criterion and the sources for the input of the data.

3.1.3. Matrix of objectives – criteria

By linking the different criteria to the objectives, an environmental prioritisation of landfill sites for LFM is obtained for each objective.

In Table 3 an overview is given of the criteria that are used to determine the environmental priority for each objective. This matrix has been made based on expert judgement, experience in practice and consultation with OVAM. This matrix shows that the landfill type (criterion 1) is the most decisive criterion for the different objectives. In Chapters 3.2.1 through 3.2.6 these objectives are elaborated on further, starting with a definition and a detailed description of the criteria for each objective.

	Type	**Age**	**Volume**	**Use**	**Accessibility**	**Surroundings**
WtE – energy	X	X	X	X	X	-
WtM - materials	-	X	X	X	X	X
WtL – space	-	X	-	X	-	X
Resource management - **Temporary storage**	-	X	-	-	X	X
X: criterion is used to determine the potential of a landfill site for the concerned objective -: criterion is not used to determine the potential of a landfill site for the concerned objective						

3.1.4. Result

By means of the calculation tool the environmental priority is determined for each assessed landfill site for each objective. This results in a prioritisation of all assessed landfill sites for each objective.

3.1.5. Document structure

After a brief explanation of the different criteria and the weighting factors used to determine the environmental priority for Landfill Mining, in the next chapters the various objectives will be described at length, including the concrete interpretation and the basis of these criteria. In Chapter 3.8 a technical explanation of the calculation tool is provided. Finally, in Appendix 3 an overview is given of the sources and references that have been used for this study.

3.2. General overview of criteria and weighting factors

In this Chapter a brief explanation and basis is provided for the criteria and weighting factors used to determine the potential for LFM based on the aforementioned objectives. This Chapter includes a link to the calculation tool as included in Appendix 4 of this report. In Chapter 3.8 a brief explanation of the calculation tool is provided, using these criteria and weighting factors. The calculation tool itself contains instructions for use with notes for each sheet and step.

3.2.1. Criterion 1: Landfill type

3.2.1.1. General

The landfill sites are subdivided into the following landfill types:

- Household waste;
- Industrial waste;
- Mono-landfills:
    - dredging spoil;
    - water purification sludge;
    - inert waste;
    - gypsum;
    - fly ash;
    - asbestos;
    - metal slag;
    - mining (high-grade metals);
- Mixed landfills;
- Other (undefined landfill sites).

3.2.1.2. Input sources

The subdivision into landfill types is based on the structure of the OVAM database of old landfill sites 'elfm oude stortplaatsen_OVAM'. In the current 'elfm oude stortplaatsen OVAM' database no data are included about mono-landfills for mining waste and metal slag. As these mono- landfills certainly have potential for LFM, it is proposed to include these types into the database. The 'elfm oude stortplaatsen_ovam' database also contains landfill sites which fall into several categories, e.g. ‘household waste’ and ‘industrial waste’. For these sites a separate ‘mixed’ category is included (see also the ‘Matrix database’ sheet in the calculation tool).

Based on the OVAM database different landfill sites are classified into different types (e.g. landfill site X is classified under household, industrial and inert waste). For the prioritisation it is assumed that each waste type present at a certain landfill site is present in the same proportion (e.g. for landfill site X: 1/3 household, 1/3 industrial and 1/3 inert) (see also the 'Calculations 1' sheet in the calculation tool). This proportion can be changed after a site-specific investigation. There is a possibility to adjust it in the calculation tool.

Finally, it must be remarked that radioactive waste has not been included, because due to its properties radioactive waste does not have any potential for LFM (either now or in the future).

3.2.1.3. Uncertainty factors

The criterion 'type' must be linked to the uncertainty factors 'uniformity/heterogeneity' and 'layering'. However, the layered nature of a landfill site is related to its uniformity. Therefore, only the uncertainty factor 'uniformity' is used. In the OVAM database and the PCS files currently no location-specific data are available about the uniformity of the landfill sites. Hence, in the determination of the environmental priority the uncertainty factor 'uniformity' is taken into account for each landfill type as included in Table 4. The uniformity of a landfill site is primarily deduced based on the reliability of the historical data and its greatest impact is on the landfill types household waste, industrial waste, mixed waste and other types. Mono-landfills can be heterogeneous, but for simplicity's sake these landfills are considered to have a homogeneous composition.

If more information about a landfill site is known, location-specific data can be entered afterwards in the location-specific database (see 'Additional input' sheet in the calculation tool). If a value for uniformity is entered into this location-specific database, this value will be used in the calculation instead of the values shown in Table 4. In the 'Input' sheet it can be checked what data are used for the calculations.

Landfill type	**Uniformity**	**Basis for uniformity factor**
Household waste	50	Composition unknown, field work required
Industrial waste	50	Composition unknown, field work required
Dredging materials	100	Supposed to be homogeneous
Waste water sludge	100	Supposed to be homogeneous
Inert waste	100	Supposed to be homogeneous
Gypsum	100	Supposed to be homogeneous
Fly ash	100	Supposed to be homogeneous
Asbestos	100	Supposed to be homogeneous
Metal slag	100	Supposed to be homogeneous
Mining waste (high grade metals)	100	Supposed to be homogeneous
Mixed	25	Composition unknown, field work required
Other	25	Composition unknown, field work required

The uniformity of mono-landfills is estimated to be high, but this percentage can be refined in the location-specific database after further analysis of each case. Especially with a view to an effective mining operation the inclusion of detailed data is necessary. The factors 'production process' and 'filling method' will play a crucial role. Any changes to the production process will lead to possible variations in concentrations, changed mineralogical or physico-chemical properties and finally different waste streams. Heterogeneity is possible as well in case of hydraulic supply depending on the position of the outlet sluices.

Finally, the uniformity of a landfill site is determined by its age. It can be expected that more recent landfill sites are subdivided into 'uniform' landfill sections. Older landfills, on the other hand, will be very heterogeneous. Nevertheless, for the calculation tool and the determination of environmental priority no link is established between age and landfill type. Based on the available data (e.g. this is not included in the PCS files) this cannot be calculated, as a result of which the uncertainty factor is too high.

3.2.2. Criterion 2: Age of the landfill site

3.2.2.1. General

When the 'age' criterion is taken into account in the determination of the potential, this criterion will depend on the landfill type (criterion 1). The impact of this criterion on the environmental priority will also differ according to the landfill type. For instance, information about the age will be more decisive for environmental prioritisation for a household waste landfill than for a specific mono-landfill.

Generally speaking, the following principles were used for the 'age' criterion:
first of all, for each landfill type based on the 'elfm oude stortplaatsen OVAM' database the oldest landfill site was chosen as a lower limit;

- former landfill sites where landfilling was not subject to the VLAREM licence (before 1985);
- landfill sites where landfilling is subject to the VLAREM licence (after 1985).

3.2.2.2. Input sources

The OVAM database 'elfm oude stortplaatsen_OVAM' shows the age of the landfill site. However, for many sites in this database the age is missing or unknown (indicated by '?'). The information taken from the PCS files gives a clearer view on the age of the sites (see also 'Matrix database' sheet in the calculation tool).

When using the calculation tool and making the calculations with a view to environmental prioritisation for LFM, the oldest age available is taken into account.

3.2.3. Criterion 3: Volume of the landfill site

3.2.3.1. General

The determination of the potential for LFM in relation to the volume strongly depends on the total amount of investment necessary to set up an LFM project. In case of small investments the volume will not be very important. As a general rule, it can be said that the larger the volume, the more interesting LFM becomes. Therefore, it is better for the initial investments to be spread out with a lower unit rate per m³ of waste.

Furthermore, for all four objectives the volume will depend on the landfill type (see criterion 1) and the economic value of the different waste streams at the moment LFM is carried out. For instance, a small volume (e.g. < 100,000 m³) of high-grade metal slag may have a higher potential for LFM (Objective 2: Waste to Material) than a larger volume (e.g. > 1 million m³) of dredging spoil. Based on the available data for Flanders, volumes varying between the order of 100,000 (small) and the order of 1 million m³ and more (large) have been chosen. A volume larger than

100,000 m³ and smaller than 1 million m³ is considered to be medium (see also the 'LFMinst' sheet in the calculation tool).

3.2.3.2. Input sources

In the PCS files the surface areas of the landfill sites are mentioned. These data are further supported by means of GIS data. In this process, it is assumed that the surface area equals the total surface area of the plot (or several plots) on which the landfill site is located. This results in uncertainty, and in some cases an overestimation of the surface area.
In order to calculate the final volumes, these surface areas are linked to the height. For information about the height, the PCS files are used. These mention the height for some landfill sites. Where the height is not mentioned, '0' is entered into the cells concerned and the following assumptions are made (see also 'Matrix database' sheet in the calculation tool):

- for clay pits and quarries: arbitrary height of 7 m;
- for the remaining landfill sites (natural relief): arbitrary height of 3 m.

These assumptions have been made based on expert judgement and experience in practice.

3.2.4. Use of the landfill site

3.2.4.1. General

The 'use' criterion is determined by various characteristics of the landfill site which influence the environmental prioritisation for LFM. The following characteristics are taken into account:

- current use in accordance with the regional land use plan, land use implementation plans ('RUP's and 'GRUP's);
- presence of buildings.

3.2.4.2. Use

For the use the same general code has been used as in the regional land use plan (codes 0100 to 1700). Given the importance of reserve areas or potential development areas (code xx80) for LFM, these areas have also been included separately in the environmental prioritisation (see also ‘Matrix database’ sheet in the calculation tool).

The intermediate use and the future use are also taken into account. If no data are known yet, these are assumed to be the same as the current use.

Finally, for a certain regional land use plan the corresponding land use type I, II, III, IV or V from the VLAREBO legislation is also mentioned.

3.2.4.3. Presence of buildings

Another aspect of land use is whether the location has already been developed or not, either for residential or for industrial use.

The presence of existing buildings at a landfill site is not favourable for redevelopment, but this does not mean that this is a limiting factor. If we assume that the development took place soon after the creation of the landfill site, this development may need to be modernised. The redevelopment of these landfill sites to high-quality public spaces or buildings is perfectly possible.

It must be noted that the possibility that an entire residential neighbourhood will be renovated at the same time is fairly small. On the other hand, an old industrial site for which a project developer has plans is interesting.

3.2.4.4. Input sources: Use

For the current use the regional land use plan is used, with the corresponding code. These data were already included in the OVAM database 'elfm oude stortplaatsen_OVAM'. For the intermediary and future use completing this information is more complicated. To do so, the land use plans will need to be requested from the municipal or city authorities, or a request will need to be sent to these authorities to enter these data into the location-specific database.

3.2.4.5. *Input sources: presence of buildings*

The presence of buildings is not mentioned in the OVAM database 'elfm oude stortplaatsen_OVAM'. However, input can be obtained from the PCS files, Google Earth and the OVAM GIS layer where buildings are shown. It must be noted that this is a variable factor, especially when looking at the future, e.g. the year 2100.

3.2.5. Criterion 5: Accessibility of the landfill site

3.2.5.1. *General*

The accessibility of a landfill site is determined by the following three characteristics:
- accessibility via a public road;
- accessibility via the railway;
- accessibility via waterways.

3.2.5.2. *Public road*

In order for a landfill site to be accessible via a public road, this public road must be passable. The available data (GIS) show that some landfill sites are not or hardly accessible, while others are easily accessible. If a landfill site is not accessible (e.g. in a forest area or a remote nature area) it may be interesting to invest in the construction of a new road. The latter was not taken into account in the environmental prioritisation.

The GIS data show that the accessibility by public road ranges from 0 m (landfill site is located on a public road) to a few hundred metres. The relationship between the distance from a landfill site to a passable public road and the weighting factor assigned to this in the determination of the environmental priority can be shown by means of a natural logarithmic function (see also 'LFMinst' sheet in the calculation tool).

3.2.5.3. *Rail*

To determine the accessibility of a landfill site by rail, for simplicity's sake it was decided to calculate the distance to a railway line via GIS, i.e. not specifically to a station for passenger transport or a station for freight transport. It is currently being studied whether the distance to stations can be deduced based on SNCB information.

The GIS data show that the accessibility by rail ranges from less than 50 m (landfill site located near a railway line) to more than 20 km. The relationship between the distance from a landfill site to the nearest railway line and the weighting factor assigned to this in the determination of the environmental priority can be shown by means of various functions (see also 'LFMinst' sheet in the calculation tool).

3.2.5.4. Waterways

To determine the accessibility of a landfill site via a waterway, it was decided to use GIS to calculate the distance to a navigable waterway, which was defined as a waterway open to river traffic.

The GIS data show that the accessibility via a waterway ranges from 0 m (landfill site is located on a waterway) to a few hundred metres. The relationship between the distance from a landfill site to the nearest navigable waterway and the weighting factor assigned to this in the determination of the environmental priority can be shown by means of various functions (see also 'LFMinst' sheet in the calculation tool).

3.2.5.5. Input sources

All input data for accessibility via public roads, railway lines and waterways are obtained through the available GIS files. These GIS data are reflected in the 'Matrix database' sheet in the calculation tool.

3.2.6. Criterion 6: Surroundings of the landfill site

3.2.6.1. General

For the 'surroundings' criterion the main factor that is checked is whether there is another landfill site near the landfill site under assessment, with the aim to cluster landfill sites. To this end, it has been decided to link the same types of landfill sites to each other. This way, resource management is possible.

To determine the presence of landfill sites near a specific landfill site the distance is calculated via GIS. Currently this GIS data layer is being prepared by OVAM. The GIS data received until now show that the distance ranges from less than 50 m (landfill site is located near another landfill site of the same type) to more than 10 km.

3.2.6.2. Input sources

To link a specific landfill site to landfill sites located nearby, the input data are obtained via the GIS files that are already available. These GIS data are reflected in the 'Matrix database' sheet in the calculation tool. Currently OVAM is preparing a GIS data layer with the location of all landfill sites.

3.3. Weighing factors

Based on the aforementioned criteria and objectives, two types of weights are used to determine the potential for LFM and carry out the environmental prioritisation of the landfill sites:

- weight per criterion for the determination of the potential;
- weight based on the characteristics of the landfill site under assessment.

The calculation tool was designed in such a way that the weighting factors can be adjusted at any time so that they are always up to date. Therefore, it is important to be able to adjust the weighting factors in case of changes in the economic situation, developments in available technologies, etc.

3.3.1. Weight per criterion for the determination of the potential

As included in Table 3-1, various criteria determine the intended objective. However, certain criteria will be more decisive for the intended objective than others. For instance, for the WtE objective the 'landfill type' criterion will be more important (factor 3) than the age of the landfill site (factor 2).

For the current situation an overview of these weights is given in Table 5. The maximum value of the weight is equated to the number of criteria used for that specific objective. The weights in the calculation tool were chosen based on the information described in Chapters 3.4 through 3.7, expert judgement and consultation with OVAM.

For a detailed description of the weights we refer to the 'LFMinst' sheet in the calculation tool.

	Type	**Age**	**Volume**	**Use**	**Accessibility**	**Surroundings**
Wte - Energy	3	3	2	1	1	1
WtM – Materials	4	2	3	1	1	2
WtL – Land	3	-	3	3	-	1
Resource management – temporary storage	3	-	-	-	1	3
1, 2, 3, 4: criterion is used, with a certain weight assigned to it, to determine the potential of a landfill site for the concerned objective -: criterion is not used to determine the potential of a landfill site for the concerned objective.						

3.3.1.1. Weights based on the characteristics of the landfill site under assessment

For the environmental prioritisation of a certain landfill site, a weight in percentages is assigned for each characteristic of the landfill site. The weights in the calculation tool were chosen based on the information described in Chapters 3.4 through 3.7.

For the following criteria weights are linked based on the characteristics of the landfill site under assessment:

- landfill type;
- age;
- volume;
- use;
- accessibility;
- surroundings.

3.3.1.2. *The weight of the landfill type depends on the objective*

Depending on the intended objective, a different weight is assigned to the landfill type. For instance, a gypsum landfill will score low for a WtE objective, whereas the same gypsum landfill does have potential for material reuse (WtM objective). In Table 6 an overview is given of the weights used for a landfill type for each intended objective.

Landfill type	**WtE**	**WtM**	**WtL**	**RM**
Household waste	100%	100%	100%	100%
Industrial waste	100%	100%	100%	100%
Mining (high-grade metals	25%	100%	100%	100%
Waste water sludge	25%	100%	100%	100%
Metal slag	0%	100%	100%	100%
Gypsum	0%	100%	100%	100%
Fly ash	25%	100%	100%	100%
Dredging materials	25%	100%	100%	100%
Inert waste	100%	100%	100%	100%
Asbestos	0%	25%	25%	25%
Mixed	100%	100%	100%	100%
Other	50%	50%	100%	100%

3.3.1.3. *Weight of age for each landfill type*

The age criterion strongly depends on the type of landfill.

- Only few household, industrial, mixed and other landfill sites created before 1950 are selected for LFM due to the relatively low economic value for LFM and the low expected energy recovery for old landfills. Therefore, a weight of 25% is assigned to these. To determine the lower limit, the oldest landfill site included in the PCS files was identified for each landfill type;
- Generally speaking, landfills created before 1985 have a relatively high economic value for LFM, which is why all landfill types are assigned a weight of 100% for this age.
- Landfills created after 1985 are selected for LFM to a lesser degree (weight of 75%). Only for dredging disposal sites and landfills containing inert waste is the potential

for LFM of a landfill site created after 1985 equal to the potential of a landfill site created before 1985 (both 100%). This is because in 1985 the waste regulations came into effect in Flanders, falling under the competence of OVAM.

It should be noted that the chosen weights are not absolute weights, but relative weights to compare landfill types to each other.

In the table below, the different weights and lower and upper limits for each landfill type are shown.

Landfill type	**Age**		**Weight**
	Lower limit	**Upper limit**	
Household waste	1930	1950	25%
	1950	1985	100%
	1985	2100	75%
Industrial waste	1910	1950	25%
	1950	1985	100%
	1985	2100	75%
Minig (high-grade metals)	1930	1985	100%
	1985	2100	75%
Waste water sludge	1950	1985	100%
	1985	2100	75%
Metal slag	1930	1985	100%
	1985	2100	75%
Gypsum	1950	1985	100%
	1985	2100	75%
Fly ash	1950	1985	100%
	1985	2100	75%
Dredging materials	1940	1985	100%
	1985	2100	100%
Inert waste	1950	1985	100%
	1985	2100	100%
Asbestos	1930	1985	100%
	1985	2100	75%
Mixed	1930	1950	25%
	1950	1985	100%
	1985	2100	75%
Other	1900	1950	25%
	1950	1985	100%
	1985	2100	75%

To determine the lower limit, the oldest landfill site included in the PCS files and the OVAM database was identified for each landfill type.

3.3.1.4. Weight for each landfill type

As a general rule, one can say that the larger the volume of dump material of a certain landfill type, the more interesting this landfill site will be for LFM. A weight of 100% is assigned to household, industrial, mixed and other landfill sites with a volume greater than 500,000 m³. A weight of 75% or 25% is assigned, respectively, to volumes lower than 500,000 m³ and lower than 100,000 m³ for these landfill types. Despite containing a low volume of dump material, these landfill types are still interesting (to a limited extent) when it comes to applying LFM.

The potential for LFM of a landfill site with metal slag will increase linearly with the volume of dump material from less than 100,000 m³ (0%) to more than 1,000,000 m³ (100%), as shown in Table 3-6. The remaining landfill types are assigned a weight of 100% if the volume of dump material is greater than 100,000 m³, and are not taken into account in the calculation to determine the potential (weight of 0%) if the volume of dump material is smaller than 100,000 m³. For volumes of dump material smaller than 100,000 m³ the investments required for the application of LFM will not be profitable enough for these landfill types.

The volumes were chosen based on the article 'Exploring the socio-economics of Enhanced Landfill Mining' (Van Passel et al., 2010) and the volume range present in the OVAM database. It should be noted that the chosen weights are not absolute weights, but relative weights to compare landfill types to each other.

Landfill type	**Volume limit (m³)**		**Weight**
	Lower limit	**Upper limit**	
Household waste	-	100.000	25%
	100.000	150.000	75%
	500.000	-	100%
Industrial waste	-	100.000	25%
	100.000	500.000	75%
	500.000	-	100%
Mining (high-grade metals)	-	100.000	0%
	100.000	-	100%
Waste water sludge	-	100.000	0%
	100.000	-	100%
Metal slag	-	100.000	0%
	100.000	200.000	10%
	200.000	300.000	20%
	300.000	400.000	30%
	400.000	500.000	40%
	500.000	600.000	50%
	600.000	700.000	60%
	700.000	800.000	70%
	800.000	900.000	80%
	900.000	1.000.000	90%
	1.000.000	-	100%
Gypsum	-	100.000	0%

	100.000	-	100%
Fly ash	-	100.000	0%
	100.000	-	100%
Asbestos	-	100.000	0%
	100.000	-	100%
Mixed	-	100.000	25%
	100.000	500.000	75%
	500.000	-	100%
Other	-	100.000	25%
	100.000	500.000	75%
	500.000	-	100%

3.3.1.5. Weight of use

The presence of buildings at a landfill site is not favourable for the application of LFM, but it is not a limiting factor. Therefore, a weight of 50% is assigned if buildings are present at the landfill site. If the landfill site has not been developed, a weight of 100% is assigned.

Aside from buildings, the current and future use of the landfill sites must also be taken into account in the calculation to determine the potential for LFM. The redevelopment of landfill sites into buffer zones, green areas, forest areas, agricultural areas, mining areas, landfills, rural areas and development areas has a high priority and is therefore assigned a weight factor of 100%. Recreational areas and park areas have a moderate potential for LFM and are assigned a weight of 50-60%. The remaining land use types are not included in the calculation to determine the potential and are hence assigned a weight of 0%. The weights that have been.

assigned to the various current, intermediate and future land use types according to the regional land use plan are shown in Table 9. It must be noted that the chosen weights are not absolute weights, but relative weights to compare the landfill types to each other.

Where old industrial areas are concerned, brownfields are interesting and have a higher possibility of redevelopment. At the time of writing of this report, OVAM is working to map the brownfields in Flanders. As soon as these data are available, they can be integrated into the calculation tool. Space has been made available for this.

Land use type	**Volume limit (m³)**			**Potential for ELFM**
	Current	**Intermediate**	**Future**	
0100 – Residential	0%	0%	0%	No to low
0200 - Community	0%	0%	0%	No to low
0300 – Service areas	0%	0%	0%	No to low
0400 – Recreational area	50%	50%	50%	Low to moderate
0500 – Park areas	50%	60%	60%	Low to moderate
0600 – Buffer zones	100%	100%	100%	High potential
0700 – Green areas	100%	100%	100%	High potential

0800 – Forest area	100%	100%	100%	High potential
0900 – Agricultural	100%	100%	100%	High potential
1000 – Industrial	0%	0%	0%	No to low
1100 – Industrial areas (brownfields)	100%	100%	100%	High potential
1200 – Mining areas	100%	100%	100%	High potential
1300 – Landfill	100%	100%	100%	High potential
1400 – Military areas	0%	0%	0%	No to low
1500 – Infrastructure	0%	0%	0%	No to low
1600 – Other	0%	0%	0%	No to low
1700 – Rural areas	100%	100%	100%	High potential
XX80 – Development areas	100%	100%	100%	High potential

3.3.1.6. Weight of accessibility

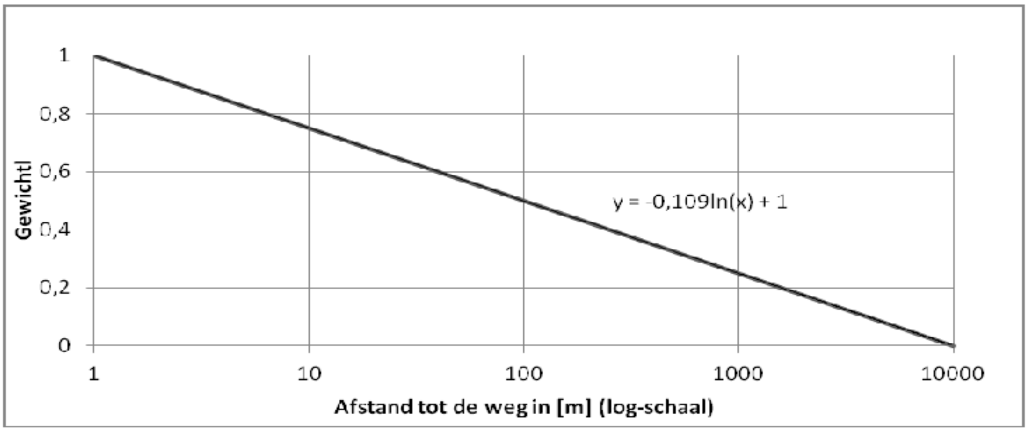
As a general rule, it can be said that the further a landfill site is located from a passable public road, a railway or a navigable waterway, the less interesting that landfill site will be for the application of LFM.

The total accessibility is determined in the calculation tool by adding up all three options (public road, railway or navigable waterway), with the possibility to assign a weight for each distance. Currently a weight of 60% is assigned in the calculation tool for a public road and 20% each for a railway and for a waterway (total 100%). These weights can be adjusted.

The relationship between the distance from a landfill site to a passable public road and the weighting factor assigned to this can be shown by means of a natural logarithmic function:

$$y=-0{,}1086\ln(x)+1$$

where x is the distance between the landfill site and the public road, and y the corresponding weighting factor. In the figure below this relationship is shown graphically.



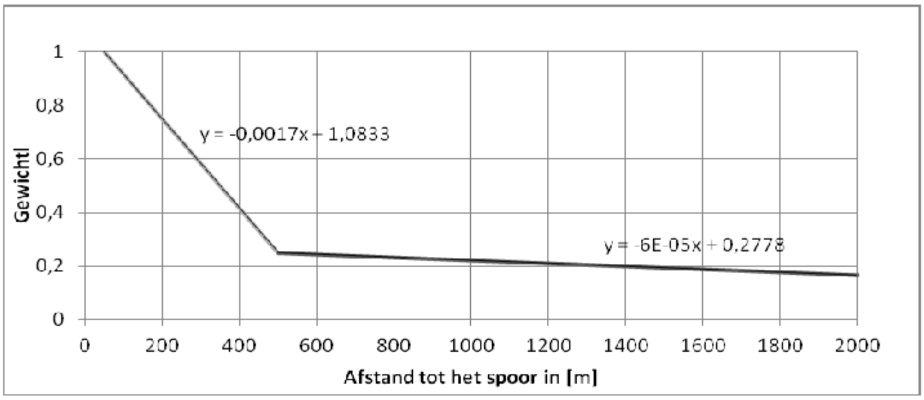
Both the relationship between the distance from a landfill site to the nearest railway and the weighting factor assigned to this, and the relationship between the distance from a landfill site to the nearest navigable waterway and the weighting factor assigned to this, can be shown by means of the following functions:

$$y = 1 \text{ if } x < 50m;$$

$$y = -0{,}0017x + 1{,}0833 \text{ if } 50m < x < 500m;$$

$$y = -6e^{-0{,}5x} + 0{,}2778 \text{ if } 500m < x;$$

where x is the distance between the landfill site and the nearest railway or navigable waterway, and y is the corresponding weighting factor. In Figure 10 below this relationship is shown graphically.



3.3.1.7. Weight of the surroundings

Another landfill site of the same type in the vicinity can offer interesting possibilities for LFM because a greater volume is generated if LFM is applied at both landfill sites simultaneously, or because one landfill site could be used to deposit waste from the other landfill site. The relationship between the distance from a landfill site to another landfill site and the weighting factor assigned to this can be shown by means of the following functions:

$$y = 1 \text{ if } x < 50m;$$

$$y = -0{,}0006x + 1{,}0278 \text{ if } 50m < x < 500m;$$

$$y = -0{,}0013x + 1{,}4 \text{ if } 500m < x < 1.000m;$$

$$y = -1e^{-0{,}5x} + 0{,}1111 \text{ if } 1.000m < x < 10.000m.$$

4. Turning Flaminco into DST 1

4.1. Introduction

A landfill is a complex combination of internal processes and characteristics which on their turn influence the natural processes and characteristics of its direct surroundings. With this in mind, one could ask itself whether the concept of a landfill as a static object In an ever increasing dynamic environment is still a good practice.

Some factors greatly influence the dynamics are for instance climate change, land pressure, pollution, etc.

At first sight, a number of basic criteria need to be found such as surface area, volume, thickness, the degree of embankment/excavation and the terrain conditions. Each criterion is divded into a number of categories that will enable the tool to generate a planning proposal.

These criteria can be subdivided into two main groups: either they apply to the deposited waste, or on the immediate environment around the landfill. The criteria applicable to the waste itself will be filtered out of the EIF of workpackage T1.

In case some data are missing to make use of the DST 1 tool, one should consider doing a walkover on the landfill that is examined. This is by far the fastest and cheapest way to collect some basic facts from the landfill. Secondly, certain aspects of the geophysical measuring methods of workpackage I1 can be used to reach the same target, nl. The collectinon of the most basic facts about the site. The very last choice, used in the unlikely case the two previous methods can not be executed, is using orientating or descriptive soil investigations to collect the necessary data.

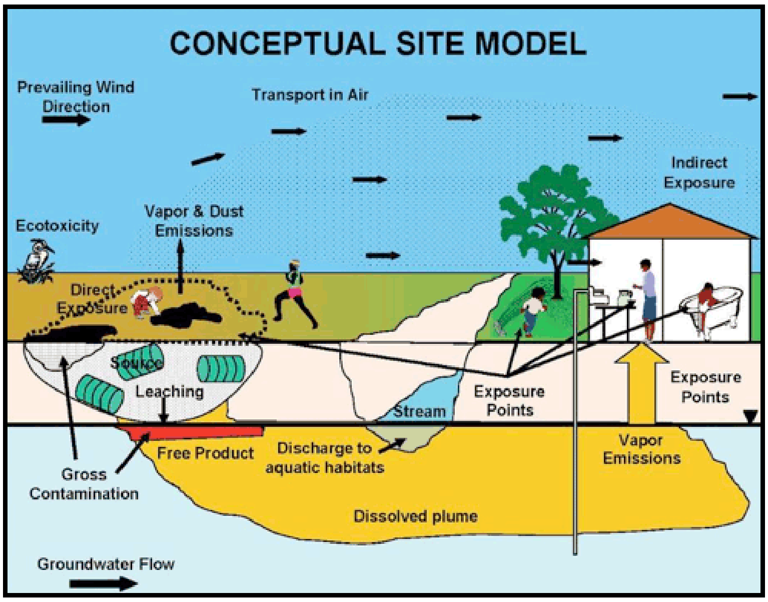
Why is this collecting of data so important is linked to the challenges of society of our time: there's on one hand land pressure, climate change, pollution, etc. How will landfill mining and management change with these future challenges in mind? The DST1 tool will point in the right direction by giving advises and a planning proposal based on four criteria: surface area, volume and thickness, slope angle and terrain conditions.

4.2. Conceptual Site Model

In the development process of a Decision Support Tool for Landfill Valorization, the use of a conceptual site model (CSM) contributes to a good visualization of the problem and points out additional elements of concern. According to EUGRIS[8] (s.a.), the CSM is one of

[8] EUGRIS project was supported by the European Commission under the Fifth Framework Programme.

the primary planning tools that can be used to support the decision making process managing contaminated land and groundwater on a large scale. The CSM organizes available information about a site in a clear and transparent structure and facilitate the identification of data and information gaps. Once the CSM is established, additionally needed data can be gathered and integrated in the CSM, followed by a revision of the CSM and a refinement of decision goals, if required. Thus, the CSM matures and enables an improved understanding of the site characteristics, such as contamination status, receptor profiles, etc., and the re-adjustment of decision criteria.



An analysis of currently applied CSM in the EU and the USA pointed out that the basic constraints of the CSMs are related to the traditional risk assessment of contaminated sites. This practice is described as a source-pathway-receptor model wherein the characteristics of the source are often limited to the mobile parameters which could impact the vulnerable receptors. In case of landfills, these parameters are the landfill gases and the leachate. Run off of solid particles (waste) is seldom considered as an important contributor. This approach is however to limited in view of the RAWFILL-objectives which aims at the potential valorization of the landfill.

Another disadvantage of the traditional CSMs are the used dimensions. In many cases the spatial dimensions are related to the impactzone and this is function of the fate and transport of the contaminants. This can range from meters to kilometers; only the contribution to greenhouse gases is seen on a global scale. Mostly, the spatial range is limited to a magnitude of tens of meters. In view of valorization potential an extended spatial area is required.

The spatial impact is not the only dimension of concern. Economic and social dimension should also be taken into consideration and last but not least the time dimension. The RAWFILL CSM should be a multidimensional system in order to the DST in a sufficient way. Making progress on society’s problems such as long term landfill management requires governments to make better use of data, involve citizens, invest in employees, and collaborate with other sectors[9].

[9] After McKinsey.

The requirement of an easy applicable DST-tool indicated that a single multidimensional CSM would be too complicated to use for non-experts. In order to deliver an easy accessibility for local governments and users, a phased approach was developed. The DST 1 will be based on a simplified CSM that focuses on easy accessible and collection of data on the landfill and its environment. This should allow a straight forward planning in the short time, detecting opportunities and threats. If no actions are required in the short time, an interim planning and use will be provided. This will be based on the Matrix as developed for Brownfields in the Hombre-project.

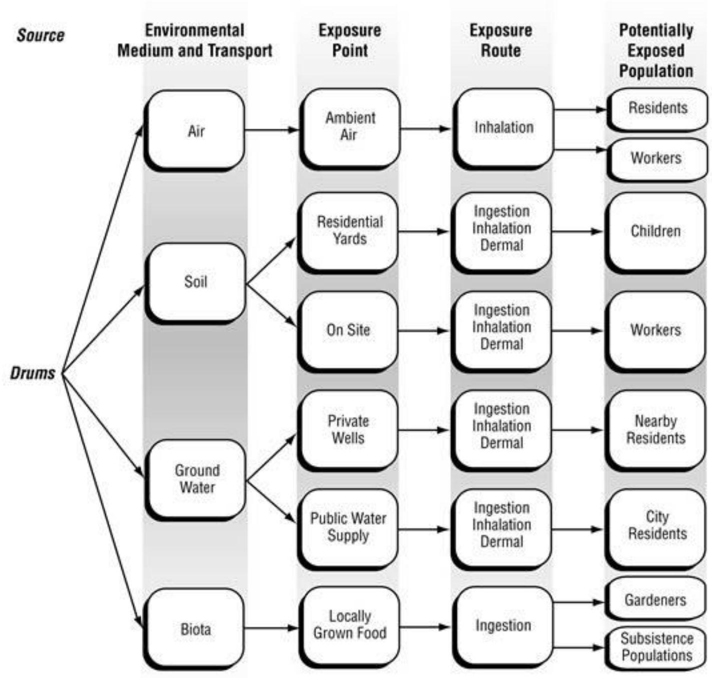


Figure 6-3. Site Conceptual Model—Exposure Pathway Evaluation

4.3. Surface area

The surface area of a landfill corresponds to the cadastral land plot, or in case it is known de actual extent of the deposited waste on that land plot. The size of the landfill takes into account how efficient the site can be exploited. This is both in an agricultural and economical sense.

4.3.1. Defining the categories

The choice of a limit to determine the smallest category of land plot size is not easy. For activities concerning nature development, recreation this is of inferior importance. There's no need to produce anything so the surface area that is used is irrelevant. Also in residential areas, the price of the land per surface unit will be a more crucial factor compared to its total size. However, for agricultural purposes this is a bt different. It is true that a bigger acreage will create higher profits, because the land will be cultivated more efficiently. This is one of the reasons why many fields were merged throughout time. Secondly, not every crop generates an equal profit; and not every crop has the same value in every country.

The latter presumes that crops are the main agricultural activity and this poses a third challenge since it is not necessarily true. A small case study for Belgium revealed that 58% of the total land available for agricultural activities is used as fodder. Two thirds of these are used as meadows and are very difficult to express in terms of money, since the only thing they will produce is grass and hay (Departement Landbouw & Visserij, 2015). So, how can this be approached in an objective way?

To be ale to work independently from ever changing market prices and differences between regions and countries, we suggest to use the definition of animal unit (AU). The Natural Resources Conversation Service (2003) of the United States defines the animal unit as: *"An animal unit (AU) is generally one mature cow of approximately 1,000 pounds and a calf as old as 6 months, or their equivalent."* For other animals, other AU apply: a horse 1,25; a sheep 0,20; etc...

Surface area (ha)	Planning proposal
0 – 0,2	Advise A
0,2 – 0,5	Margin for user
(0,2) 0,5 – 3	Advise B
3 or 10	Margin for user
3 / 10 - ...	Advise C

Each country has its own legislation on how many AU there can be on a certain area, in Europe this is expressed as AU per hectare. In Belgium, a professional farm can have 5 AU/ha (Vlaams Parlement, 2017), one per 0,2 ha, unless it is located in an area with significant economical restrictions, like green areas. In that case a farm only can have 2 AU/ha, one per 0,5 ha (Vlaamse Landmaatschappij, 2009). However, policy makers want to introduce an area-bound value of 2,3 AU/ha, one per 0,43 ha, that applies on all types of land (de Wit & van Veluw, 2017). The Netherlands have expressed the same target for Dutch farms (van der Schans & Padt, 2004). In other words: in our model, the user will get the possibility to enter a value between 0,2 and 0,5 ha. Based on this, the planning proposal will make a separation between agricultural and other activities.

A second limit, that will be able to define a second and third category can be fixed on three or ten hectares. Three hectares is considered to be the absolute minimum for a profitable solar park project (Eelerwoude, 2018). Ten hectares on the other hand is the minimum size for solar parks in industrial areas to deliver electricity of any relevance for the neighbouring companies (Wind Prospect Group Ltd, 2012). This can be translated in the DST as a yes/no answer on the question wheter the landfill site is located in rural or industrial environment. For this, the user of our application only needs to know the direct environment of the landfill site to be able to answer. Like previously mentioned a walkover should therefore be obligatory when using the DST of RAWFILL.

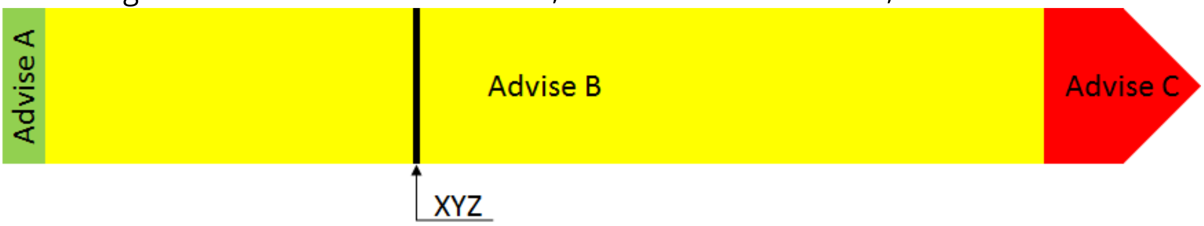
In this way, three clearly defined categories are used for the surface area criterion .

To conclude, some remarks on this criterion. Firstly, it seems easy to conclude that, when considering a landfill with a surface area of more than 10 hectares always will be selected for a solar park; and a landfill smaller than 0,2 ha never will be suitable for agricultural purposes. This is not the case. The user is able to modify the categories of this criterion, but not the weight of the criterion in relation to the other criteria.

Therefore, it is still possible that the primary function in the final planning proposal will be something completely different from the output of this single criterion.

4.3.2. Examples to clearify

Landfill XYZ, 4 ha, located somewhere in the Netherlands, is located close to zone of industrial activity. Utilities are well provided and management takes into account the future target on animal units. In this case, the used limits will be 0,4 and 10:



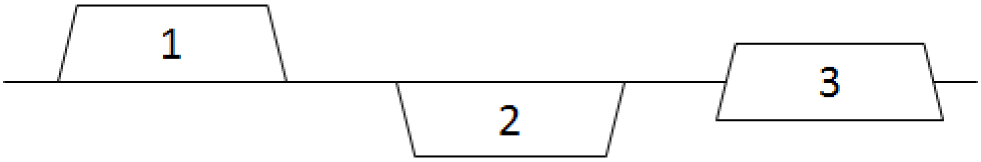
For criterion surface area, advise B will be followed by DST.

The same landfill XYZ, 4 ha, now located somewhere in Belgium in a green area. Good utilities are absent. The user will set the limits on 0,5 and 3.

In this case, advise C will be followed. It is likely this advise will contain the development of a solar park, based on the size of the landfill. Bear in mind that utilities are absent, so this scenario will most likely be rejected via the interaction of the other criteria in the DST.

4.4. Volume and thickness

Like previously mentioned in chapter 2.1.3., in Flaminco the volume of a landfill is important in the determination process for a landfill mining project, and the bigger a landfill is the bigger the chances are for a profitable landfill mining project. DST will diverge from this. Out of practical experiences we now know that large landfills are not the common standard, and are not necessarily the first landfills that are mineable in the ranking.
Also applicable in the determination process is the thickness of the waste material, to be more precise how the waste was deposited in relation to the ground level. Three categories can be distinguished:



- An embanked landfill: in this case, waste was deposited on top of the original ground level. This type of landfill offers the biggest challenge, since it concerns a surplus of material on a certain space. Equalizing the surface the the level of the direct surroundings is nearly impossible. The realization of a landfill mining project on this location is crippled by high removal costs. Also the ecological footprint of the transport is detrimental when applying for a permission.

  So, what is possible, if infrastructure works are not affordable? This is an example why the interaction and weight of the other criteria is important. The planning proposal could point at one or more forms of long-term interim use.

- A landfill, originating from a natural or artificial depression that was filled up over time, provides the highest chances on a achievable project. In this case, the terrain Is mostly at or very close at ground level, and little material needs to be removed or supplied to smoothen the terrain. A large range of applications is possible on these types of landfills. It is up to the DST to narrow down on the best proposals.
- A third possibility is an intermediate form, where both a (small) depression was filled and afterwards some embankment was done.

4.5. Slope angle

The criterion volume and thickness stated that a landfill site can have a certain height above ground level. This means that the waste was also stacked at a certain angle. This influences the possibilities to access the terrain with vehicles (agricultural, construction,…)

Vehicles are always tested for their ability to withstand rollover. Tolerances of up to 28 degrees apply in different countries (UK parliament, 1990; Tromp, 1997). However, these are values for static testing. In practice for agricutural purposes, a maximum slope of 15 degrees is handled. This is about 30%. When doing a walkover, the user will therefore be asked to estimate the maximum slope of the terrain, so that it can be determined whether vehicles can safely do their work across the entire site.

If a landfill site had a steeper angle than 15 degrees, the next thing DST will do is checking whether the angle corresponds approximately to the ideal position for solar panels. When there's an exact match, no infrastructure is necessary to tilt the panels, there is no loss due to shading and the use of the available space is at its maximum.

Slope angle (degrees)	Planning proposal
0 – 15	Advise A
15 – (latitude – 15)	Advise B
(latitude – 15) – latitude	Advise C
> latitude	Advise D

In Europe, the rule of thumb is an angle between the local latitude and 15 degrees below (Hartner, Ortner, Hiesl & Haas, 2015). For Belgium this means values between 36 and 51 degrees.
However, from practical examples in Belgium and the Netherlands, the

installation of panels at 37 degrees show that the lower limit is more applicable (Zonne-paneel.net, s.a.). In practice few or no landfills in our region will have such a steep slope. This is obviously different for Southern Europe.

4.6. Terrain conditions

Terrain conditions strongly affect the accessibility of the landfill and have consecuences for the possible

5. Literature

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