Interreg North-West Europe RAWFILL

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Deliverable WP T2.1.1 Scheme with DST weighting

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1. Introduction

One of the goals of the RAWFILL project is to support the implementation of landfill mining projects across NWE regions. To achieve this, a two-level multicriteria decision support tool was developed to support sustainable decisions of companies, SME, local authorities, governments, among others.

The rationale behind this research program is the large quantity of landfills to be managed in NWE regions. 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 sites: up to 1 million (Wille, pers. com.[1]). 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. For that purpose, Enhanced Landfill Inventory Framework (ELIF) was developed within the RAWFILL project. It combines all aspects related to landfills: administrative, environmental, social, technical and economical. The added value of this landfill inventory structure is that it includes parameters regarding the economic potential and the social impact of landfill sites. Based on the ELIF's indicators, the most relevant parameters were selected and included in the two-level decision support tools (DST 1-Cedalion, DST 2-Orion).

The Decision Support tool will help policy makers to pick out the best suitable landfills for a profitable landfill mining (LFM) project by ranking all available landfills from most promising to least promising. DST 1-Cedalion will follow the same methodology but will be designed based on new insights and practical experience. This 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 framework on Dynamic Landfill Management[2], sustainable valorization of the landfills is the main objective.

The indicators that were selected from the ELIF to determine the feasibility of a landfill mining project, or another form of sustainable valorization (i.e. Interim use), are included

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

[2] 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.

in ***Deliverable T2.1.2 Table of DST indicators***. This report gives an overview of all criteria than can be used to select landfill sites that are eligible for material, energy and land valorisation or rehabilitation. In this step, the methodology that was used to determine the prioritization of the landfill sites, is described. This includes the weighting of the different indicators, or the relative importance of the indicators compared to one another. The weighting of the different indicators is based on various objectives or scenario's, based on the specific potential of the landfill site.

2. Weighting of DST 1-Cedalion

The weighting of the indicators included in the DST 1-Cedalion was done on two levels:

- At the level of the criteria to determine the potential of a landfill site;
- At the level of the specific indicators (characteristics included in the DST).

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. The adjustment of the weighting indicators might be necessary in case of major changes in the economic situation, developments in available technologies, etc.

2.1. Overview of the scenario's and criteria

To determine the potential of landfills for sustainable valorisation and landfill mining, the following four scenario's were taken into account:

- Objective 1: Waste-to-Materials (WtM) - the valorisation of the waste streams that are released from a landfill and the reuse of the waste streams as materials;
- Objective 2: 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;
- Objective 3: 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;
- Objective 4: Interim Use (IU). The concept of interim use is an inherent part of the Dynamic Landfill Management and consists of finding a suitable land use valorization for the landfill site. The duration of the interim use strongly depends on two key parameters: (1) the time needed for the landfill to reach appropriate mining conditions (e.g. no more biogas production, waste pile stability); and (2) the market price evolution for the landfilled waste resource.

The different criteria were already discussed in detail in the ***Deliverable T2.1.1 Table of the DST indicators***. To summarize, there were six different criteria defined in the DST 1-Cedalion:

- Criterion 1: type;
- Criterion 2: age;
- Criterion 3: volume;
- Criterion 4: use;
- Criterion 5: accessibility;
- Criterion 6: surroundings.

2.2. Matrix of scenario's vs indicators of the criteria

In order to develop a ranking and prioritize the landfills present in a database, a weight was assigned to each indicator defined in the ***Deliverable T2.1.1 Table of DST indicators***. Depending on the scenario's chosen (see section 2.1), the weight of the indicators changes. At the end, the DST 1-Cedalion provides a general score for each landfill present in the database based on the weights of the indicators. The weights of each indicator will be discussed per criterion in the following sections. It should be noted that the chosen weights are not absolute weights, but relative weights to compare landfill types to each other. Per indicator code or category, a score was given for each scenario, ranging from 0 (not important) up to 5 (very important).

2.2.1. Waste type

Firstly, the prioritisation of a landfill for the different scenario's depends on the waste type indicator. Per waste type, a score is given for each scenario, ranging from 0 up to 5 (**Table 1**). For the WtM scenario, there are three waste types that received a maximum score: fly ash, metal slags and mining waste. In terms of recycling options, these waste types have the highest potential. Asbestos is the only waste type that has absolutely no potential for this scenario, because of its high impact on health. Furthermore, in many countries, the use of asbestos is strictly forbidden.

The waste types that score the highest for the WtE scenario are dredging materials and waste water treatment (WWT) sludge. These types of waste materials have a higher calorific value and will be able to create more energy per volume of waste. Also municipal solid waste (MSW) and industrial waste have a higher potential in the WtE scenario.

For the WtL scenario, inert waste received a maximum score of 5 because the costs of excavation will be relatively low, based on its stable and solid characteristics. Within the interim use scenario, the effect of the waste type is more limited than in the other scenario's. Asbestos receives a higher score for interim use (3 points) because it has no potential within the other scenarios. If asbestos is excavated within a landfill mining project, it will have to be transported to another landfill for relandfilling. Therefore, an interim use will be most suitable if no impact on the environment and on human health is guaranteed.

The homogeneity of waste deposits within the landfill (i.e. monolandfill, layered landfill, heterogenous waste deposits) has an influence on the different scenarios as well. If we are talking about a monolandfill, one of the three excavation scenario's (i.e WtM, WtE, WtL) are preferred. When assessing the feasibility of a potential landfill mining project, monolandfills seem to be most promising. Currently, commodity prices and demand for recycled materials are relatively low, but monolandfills have a high grade content, are easy to process and have well-known characteristics. Therefore, they are currently the most promising landfills to mine and redevelop. Therefore, monolandfills receive a score of 0 for the IU scenario. Heterogenous landfills have a lower score for each scenario. Only in the WtL scenario, heterogenous landfills receive a score of 0, because costs for sorting and waste separation will generally be too high.

When harmful waste is spotted, one of the excavation scenario's is preferred because of the potential hazards for the environment and human health.

Table 1: Weighting scores for the waste type criterion.

Indicator	Answer	WtE	WtL	WtM	IU
Waste type?	MSW	2	1	2	1
	Industrial	2	0	2	1
	Dredging materials	3	0	1	0
	WWT sludge	3	0	1	0
	Inert	0	5	3	0
	Fly ash	0	3	5	0
	Asbestos	0	0	0	3
	Metal slags	0	0	5	0
	Mining waste	0	0	5	0
	Military waste	0	0	2	1
	Other	1	0	1	2
Mono-landfill?	Y	4	4	5	0
	N	2	1	1	2
Nature of mixed landfill?	Heterogenous	2	0	1	2
	Layered	3	0	3	0
	N/a (monolandfill)	4	0	4	0
Harmful waste spotted?	Y	2	2	2	0
	N	0	0	0	1

2.2.2. Age of the landfill

The age criterion represents the period of main landfilling activities as an indicator. The impact of this indicator on the scoring for the different scenarios strongly depends on the type of landfill. Depending on the main period of landfilling activities, the landfill content as well as its valorization potential can vary. Multiple timeframes were assigned to each type of waste material in order to reflect the variation in valorization potential based on known or documented activity of the landfill site (**Table 2**). Therefore, a different score was foreseen in function of the waste type and the period of main activities.

Table 2: the different time intervals per waste type.

Waste type	Time intervals
Municipal Solid waste	1930-1955 1955-1980 1980-1999 >1999
Industrial waste	1910-1955 1955-1980 1980-1999 >1999
Mining (high-grade metals)	1960-1980 1980-1999 >1999
Waste water sludge	1950-1980 1980-1999 >1999
Metal slag	1960-1980 1980-1999 >1999
Fly ash	1950-1980 1980-1999 >1999
Dredging materials	1940-1980 1980-1999 >1999
Inert waste	1950-1999 >1999
Asbestos	1930-1999 >1999
Mixed	1930-1955 1955-1980 1980-1999 >1999
Other	1900-1955 1955-1980 1980-1999 >1999

For the WtE scenario, only MSW, industrial waste, WWT sludge and dredging materials received a ranking score (**Table 3**). All other waste types received a score of 0 for each period of main activities. This is comparable to the scores given in **Table 1**. For these waste types, only a score of 1 was given to landfills older than 1955 because the energy recovery will be very low due to higher content of inert materials within these older landfills. From 1955 up to 1999, the potential for WtE is higher due to the higher content of plastics that will be present in the landfills. For illegal dump sites (> 1999 not documented), a lower score was given because for these sites, there are uncertainties regarding the waste content and its potential dangerosity.

The WtL scenario is less dependent on the age of the landfill. Therefore, scores for different periods of main activities within one waste type are comparable. Only the scoring is only variable in this scenario for fly ash landfills, as the fly ash within more recent landfills will be purer and easier to treat. Illegal landfills from later than 1999 receive a lower score independent of the waste type, for the same reasons as for the WtE scenario.

For the WtM scenario, the highest scores are given to the landfills that had their period of main activities from 1955 up to 1999 and if documented even up to now. These landfill sites receive a relatively high score for the IU scenario.

Table 3: Weighting scores for the age criterion in function of the waste type.

Waste type	Period of main activities	WtE	WtL	WtM	IU
MSW or Industrial	<1955	1	2	1	2
	1955-1980	4	2	4	1
	1980-1999	3	2	3	2
	>1999 documented	3	2	3	2
	>1999 not documented	1	2	1	3
Inert waste or asbestos	<1955	0	3	3	2
	1955-1980	0	3	3	2
	1980-1999	0	3	3	2
	>1999 documented	0	3	3	2
	>1999 not documented	0	2	2	2
Other	<1955	0	2	1	4
	1955-1980	0	2	4	1
	1980-1999	0	2	3	2
	>1999 documented	0	2	4	1
	>1999 not documented	0	2	2	3
WWT sludge, Military waste or dredging materials	<1955	1	1	1	1
	1955-1980	4	1	4	1
	1980-1999	3	1	3	1
	>1999 documented	4	1	4	1
	>1999 not documented	2	0	2	3
Fly ash	<1955	0	2	3	1
	1955-1980	0	3	5	1
	1980-1999	0	3	5	2
	>1999 documented	0	4	5	3

	>1999 not documented	0	2	1	4
Mining waste or metal slags	<1955	0	1	5	1
	1955-1980	0	1	5	1
	1980-1999	0	1	4	1
	>1999 documented	0	1	3	1
	>1999 not documented	0	1	2	2

2.2.3. Volume of the landfill

Using the Flemish landfill database as a reference, the definition of a small, medium and large landfill was determined. As the actual volume of many landfills is not known, the categorization (small, medium, large) was calculated by multiplying the surface area of the land plots, known historical waste deposition and an assumed average waste depth of three meters (Wille, 2013). The total number of records that was used was 3318 (**Fig. 1**). These records were divided into intervals of 1,999 m^3 (e.g. 0-1,999 m^3; 2,000-3,999 m^3 and so on). After this, the cumulative percentage of frequencies was used to determine the three categories of volume (small, medium, large):

1. All landfills with a volume less or equal to 29,999 m^3, corresponding to the lower 40% of the landfills are considered to be small;
2. All landfills between 30,000 m^3 and 299,999 m^3, corresponding to 50% of the total are considered to be average;
3. All landfills greater than 300,000 m^3, corresponding to the upper 10% of the total landfills are considered to be large.

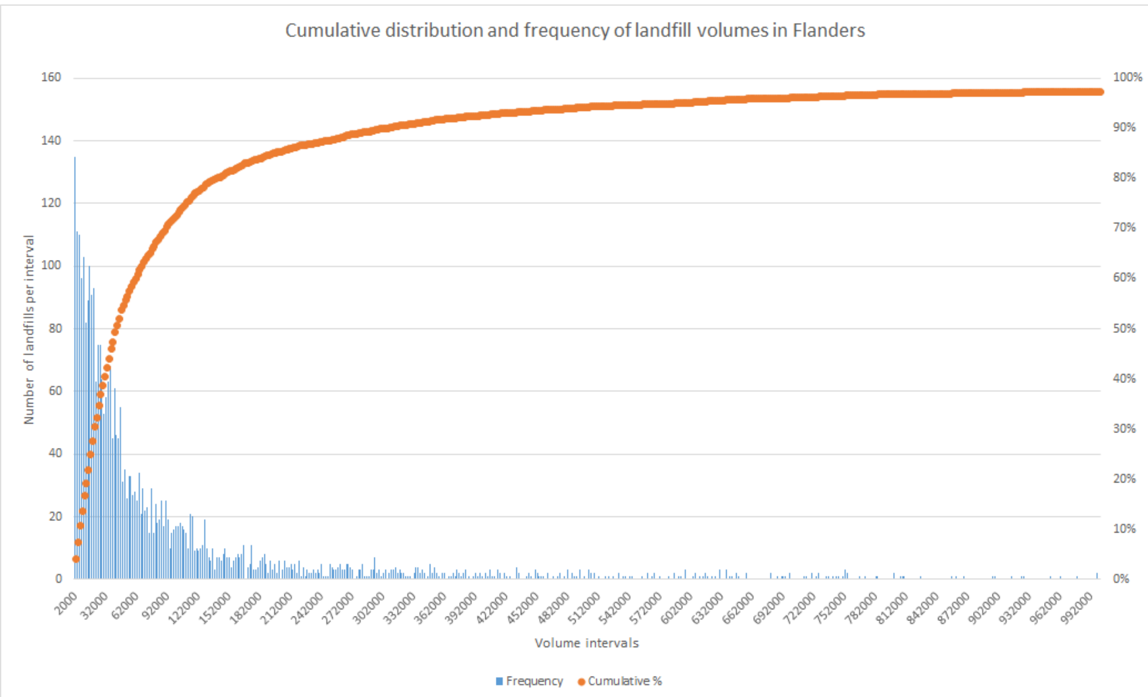

Figure 1: Cumulative distribution and frequency of landfill volumes in Flanders.

The volume can be either estimated or calculated based on for instance geophysical imaging, topographic survey. It is also possible to use default values in the DST 1-Cedalion. The volume itself is not used to decipher the priority of the LFM investigations. It requires to be coupled with the landfill content. For instance, a small landfill with a lot of metal content can have a higher priority than a large landfill filled with plastics. Another example includes the difference in the surface area between landfills, that can be many times smaller/greater while containing the same volume of waste deposits, influencing the return on investment strongly because the value of the reclaimed land is proportionate to the surface area.

As a general rule, one can say that the larger the volume of a certain landfill type, the more interesting this landfill site will be for LFM. Therefore, scores for the WtE and WtM scenarios are always higher when a large volume is present (**Table 4**).

For the WtE scenario, only the MSW, industrial waste and other waste types are expected to have a potential for the WtE scenario. The higher the volume, the higher the potential and thus the ranking score. However, despite containing a low volume of waste, these landfill types are still interesting (to a limited extent) when it comes to applying LFM (2 points as scoring).

The potential for LFM on landfill sites with metal slags or mining waste will increase linearly with the volume of waste. This is the case for the WtL scenario. For the WtM scenario, metal slags or mining waste materials always receive a score of 5 despite their volume.

For the IU scenario, all the weights are relatively low as the volume is not really determining for the potential for IU.

Table 4: Weighting scores for the volume criterion in function of the waste type.

Waste type	**Volume**	**WtE**	**WtL**	**WtM**	**IU**
MSW, industrial or Other	Small (default <35 000 m^3)	2	4	2	1
	Average (default 35 000-350 000 m^3)	3	2	3	2
	Large (default >350 000 m^3)	4	1	4	1
Dredging materials, WWT sludge, inert, fly ash, asbestos or military waste	Small (default <35 000 m^3)	0	1	3	0
	Average (default 35 000-350 000 m^3)	0	1	3	1
	Large (default >350 000 m^3)	0	1	4	0
Mining waste or Metal slags	Small (default <35 000 m^3)	0	1	5	0
	Average (default 35 000-350 000 m^3)	0	2	5	0
	Large (default >350 000 m^3)	0	3	5	0

2.2.4. Use of the landfill

The type of cover has an influence on the containment of the waste and the ease of excavation. When a geomembrane is present, the waste is contained very well and will not be mixed with e.g. soil. Furthermore, landfill gas cannot escape from the landfill, except when landfill gas is extracted in a controlled way. For this reason, the WtE scoring is highest when a geomembrane is present (**Table 5**). This counts for landfills with MSW, as no biogas will be present at landfills with inert waste. When the landfill is only covered by soil, a significant amount of landfill gas will have already left the landfill and hence, the potential for energy production will be very low. Therefore, weighting score of 0 was addressed. If a mineral cover is present, WtL will not have a very high potential because the mineral cover will require extra efforts for excavation. For the WtM scenario, a score of 3 was addressed to each landfill cover type as this has no influence on the materials that could potentially be recovered from the landfill. Lastly, for the IU scenario, the presence of topsoil obtained the highest score whereas landfill covered with geomembrane obtained the lowest score. The reason behind this low score is that the presence of geomembrane will limit the possibilities for different interim uses. For example, agricultural use could harm the geomembrane (e.g. when ploughing) or the solar panel installations could pierce the membrane. When only soil is present at the top of the landfill, these types of problems will not occur.

Also the surface condition of the landfill could have an effect on the preferred scenario for the landfill. For instance, when only grasses are present, or the terrain is a little bit rough, the landfill mining scenario's receive a score of 3 because in these cases, not much effort is necessary to clear the terrain. When shrubs are present, the effort will already increase as all the shrubs should be removed. Therefore, a score of 2 points is given for all LFM scenario's. When trees are present on the site, only the WtE and IU scenario will receive a relatively high score (3 points). Focusing on nature development as an interim use is preferred. However, when a high-energy production could be achieved when excavating the site, the cutting of the trees and burning them could provide extra energy.

Regarding the slope angle, the WtE and WtM scenarios received a score of 3 for each slope angle range. The slope angle is not determining for the excavation of the waste in terms of energy or materials. For the WtL scenario, the slope is important as the value of the land will decrease significantly if there is a steep slope. A steeper slope limits the possibilities of reusing the land as construction works or agricultural practices will be more difficult to implement due to the slope.

Concerning the erosion on site, it is preferred to have none or weak erosion on the landfill site in the WtL scenario. Therefore, severe and potential erosion receive a score of 0 for this scenario.

Table 5: Weighting scores for the use criterion.

Indicator	Answer	WtE	WtL	WtM	IU
Type of cover?	Geomembrane	3	3	3	1
	Mineral cover	2	1	3	2
	Soil	0	3	3	3
Surface conditions?	Grass	3	3	3	0
	Rough	3	3	3	0
	Shrubs	2	2	2	1
	Trees	3	1	0	3
	Other	1	1	0	3
Slope angle?	Flat	3	4	3	0
	Less than 15°	3	2	3	1
	More than 15°	3	0	3	2
Erosion?	None	2	3	0	0
	Weak	1	2	2	1
	Severe	0	0	4	0
	Potential	2	0	2	1

2.2.5. Accessibility of the landfill

As a general rule, it can be said that if there are no paved roads present on site, the cost of landfill mining operations will increase as the creation of a road will be needed for excavation activities and waste transportation. This is the reason why landfill sites with no paved roads receive a score of 0 in terms of accessibility for each landfill mining scenario (**Table 6**). The same logic was applied to the possibility to enter the site with heavy equipment. Heavy equipment is necessary to perform a landfill mining project. Therefore, all LFM scenarios receive a score of 4 if the site is accessible for heavy equipment. When a site is not accessible, the LFM scenarios will obtain 0 point whereas a score of 2 will be addressed to the IU scenario.

Table 6: Weighting scores for the accessibility criterion.

Indicator	Answer	WtE	WtL	WtM	IU
Paved roads?	Y	3	3	3	0
	N	0	0	0	1
Accessible with heavy equipment?	Y	4	4	4	0
	N	0	0	0	2

2.2.6. Surroundings of the landfill

The presence of buildings (present residential use or present industrial use) at a landfill site is not favourable when performing a landfill mining project as the inhabitants might complain about the noise and the dust generated by the excavation works. However, it is not a limiting factor. More specifically, the WtL scenario has a high potential in those cases because the land value and pressure will be higher (**Table 7**). This is also the case when the future use of the landfill is residential or industrial. In these cases, the weighting score for the WtL scenario is the maximum of 5. Furthermore, when there is no natural function or value present, the potential for a landfill mining project is higher as no nature would be sacrificed. Otherwise, an interim use that focuses on nature development and nature conservation is preferred. Whether the landfill is located in a nature area (protected area with high natural value and biodiversity), landfill mining project will be more difficult to implement and thus an interim use is the only valid option.

The location of the landfill within groundwater source protection zones is very important when prioritising landfills for landfill mining projects. If the landfill is located in a critical zone (see definition in ***Deliverable T2.1.1 Table of DST indicators***), a landfill mining project is preferred in order to safeguard the drinking water sources. Therefore, a score of 4 is addressed to each landfill mining scenario for this category. Also for the severe zone, a relatively high score of 3 is addressed because of the same reasons. Landfills located within the acceptable zone receive a weighting score of 2. Landfills located in an area with high flooding risks receive a higher score because of the potential effects on the ecological environment.

Table 7: Weighting scores for the surroundings criterion.

Criteria	Indicator	Answer	WtE	WtL	WtM	IU
6	Present residential land use	Y	0	5	2	0
		N	0	0	0	1
	Future residential land use	Y	0	5	2	0
		N	0	0	0	3
	Present recreational land use	Y	0	2	1	2
		N	0	0	0	1
	Future recreational land use	Y	0	2	1	0
		N	0	1	0	2
	Present agricultural land use	Y	0	1	0	2
		N	0	2	1	1
	Future agricultural land use	Y	0	0	0	3
		N	0	3	1	0
	Present industrial land use	Y	0	5	2	0
		N	0	0	0	1
	Future industrial land use	Y	0	5	2	0
		N	0	0	0	3
	Present natural land use	Y	0	0	0	4
		N	0	3	1	1
	Future natural land use	Y	0	0	0	4
		N	0	4	1	0

6a	Drinking water zone	None	0	0	0	2
		Critical	4	4	4	0
		Severe	3	3	3	0
		Acceptable	2	2	2	1
6b	Nature area	Y	0	0	0	4
		N	4	4	4	0
6c	Flooding risk	None	0	0	0	1
		High	4	4	4	1
		Medium	2	2	2	2
		Low	2	2	2	4

For each land use class, the difference is made into present and potential/future land use, the first one being the current occupation of the landfill body, the second one being the actual assigned land type based on local planning initiatives.

The present land use is based on the use of the landfill itself and the land use of the site surrounding in a radius of max. 50 metres, or as far as the user can see during the field visit (in case of the view is obstructed). When the user has access to local spatial development plans, these plans can be used to indicate the potential/future land use of the landfill. By means of various existing policy instruments, landfills can get a new function within new or existing spatial development plans.

Example:

A landfill and its immediate surroundings are currently partially used as a site where agricultural activities take place (Present agricultural: Y; Fig. 1). Moreover, a part of the landfill contributes to the natural open space (Present natural: Y). Because the landfill site does not contribute to a larger network of corridors for animals nor has a high ecological value, policy makers have decided not to develop the landfill into a full natural area in the future (Future natural: N). It could therefore be used completely for cultivation (Future agricultural: Y) if the safety of the site is demonstrated. However, because the landfill is located next to a large interregional road, the location could also be very interesting for commuters (Future residential: Y). For such aspects, spatial development plans need to be consulted.

2.2.7. Summary

For each landfill, a score is addressed to the four different scenario's, based on the answers provided by the user for each indicator that are defined in **Tables 2 to 7**. For each valorisation scenario, the scores within the different criteria are summed up, resulting in a total score for a landfill on each scenario per criteria.

2.3. Matrix of scenario's vs criteria

By linking the different criteria to the scenario's, the relative importance of a certain criterium can be defined for the different scenario's. In **Table 8**, an overview is given of the weighting scores for the different criteria per scenario. A value of 1 was given when the criterium had relatively low importance within a scenario, a value of 2 was given when the criterium is important within a scenario and a value of 3 was given when the criterium was of relatively high importance within a given scenario.

When assessing the WtE scenario, the type and volume of the waste are of high importance, as they determine the calorific value of the waste and the amount of energy that could be produced by mining the landfill. For the WtL scenario, the type of waste and the surroundings are the most determining criteria. The waste type should be very easy to process and excavate and the surroundings of the landfill should indicate a higher land value or pressure, t0 make landfill mining within this scenario a feasible option. The WtM scenario is mostly determined by the type, age and volume of the landfill, as these criteria are linked to the recycling and valorisation potential of the materials present in the landfill. For the interim use scenario, the surroundings of the landfill are the most determining.

The values of the criteria-scenario matrix will be multiplied by the total score that was received for a certain criteria within that specific scenario. Thereafter, these values will again be summed up, resulting in four total ranking scores: one for each scenario.

Table 8: criteria-scenario Matrix.

Criteria/scenario	**WtE**	**WtL**	**WtM**	**IU**
Type	3	3	3	1
Age	2	1	3	1
Volume	3	2	3	1
Use	1	1	1	1
Accessibility	2	2	2	1
Surroundings	2	3	2	3

3. DST 2–Orion philosophy

Within the DST 2-Orion, another approach was used to estimate the valorisation potential of a landfill and the possibilities for a landfill mining project. Instead of using weighting scores, a roadmap was created by including all indicators that are discussed in ***Deliverable T2.1.1 Table of DST indicators***. DST 2-Orion is based on the DST 1-Cedalion and its first assessment of landfills present in a landfill database based on the weighting and ranking scores. DST 2-Orion is designed for the landfills having the highest scores in the DST 1-Cedalion. DST 2-Orion can only be applied to one landfill at the time. The tool will guide the experts through a logic tree or roadmap and provide additional information to set up a business case and see if a landfill mining project is economically viable or if other redevelopment project on site could be developed. More information about the DST 2-Orion can be found in the ***Manual for the Two step DST***.

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