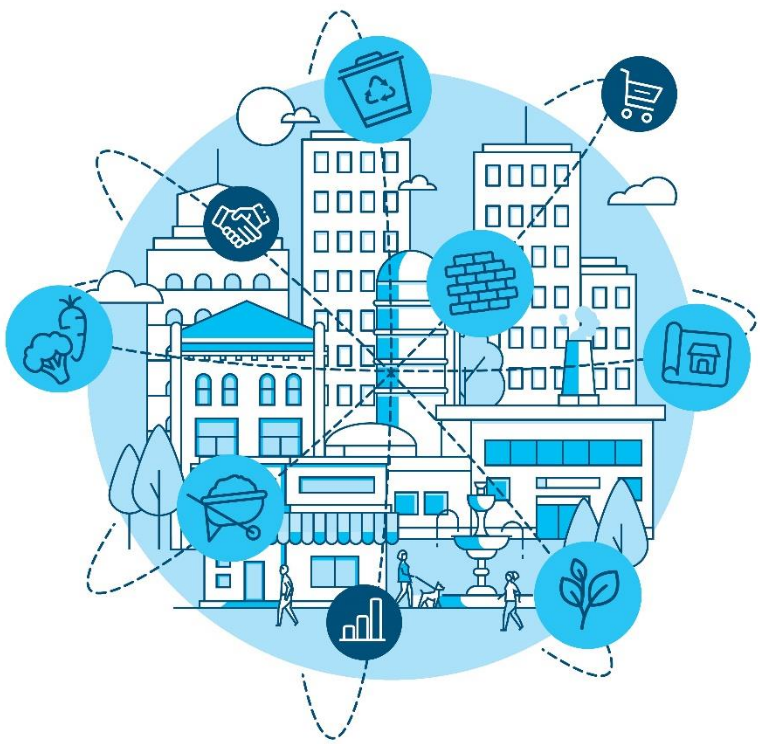
INSTRUMENT FOR PREDICTING EXCAVATED SOIL PRODUCTION RELATED TO URBAN DEVELOPMENT

Deliverable, task 2.7.4

Region Hovedstaden / Capital Region of Denmark



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Abstract	This report describes the methodology used for predicting future production (12 years) of soil volumes arising from construction works related to urban development.
Keywords	Prediction of soil production, excavation, construction works, urban development
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Appendix 1: Predicted future production (12 years) of soil generated in construction works and urban development in the Danish municipalities of Roskilde Kommune and Høje-Taastrup Kommune.

1. Introduction

This paper represents a brief description of a methodology for prediction soil production related to construction works and urban development. The prediction model is primarily based on data regarding municipal planning, urban development and urban regeneration.

The methodology described was initially developed by Niras A/S (consulting company). In the CityLoops-project the methodology has been further developed and adapted in cooperation with the Danish municipalities of Høje-Taastrup and Roskilde and the Capital Region of Denmark. In this context, strategic uses of soil predictions have been identified and explored.

The methodology is primarily based on information on municipal planning, which describes what areas are to be developed, how development is to take place and the expected timeframe of development. Based on this knowledge, preconditions for production of excavated soil relating to future construction of buildings and other construction work can be set.

In Denmark, the timeframe of urban and municipal planning is 12 years, which is the scope of the prediction model described here.

The method involves a three-step process:

1. Gathering input data
2. Setting up the prediction model and subsequent validation
3. Preparing the final prediction

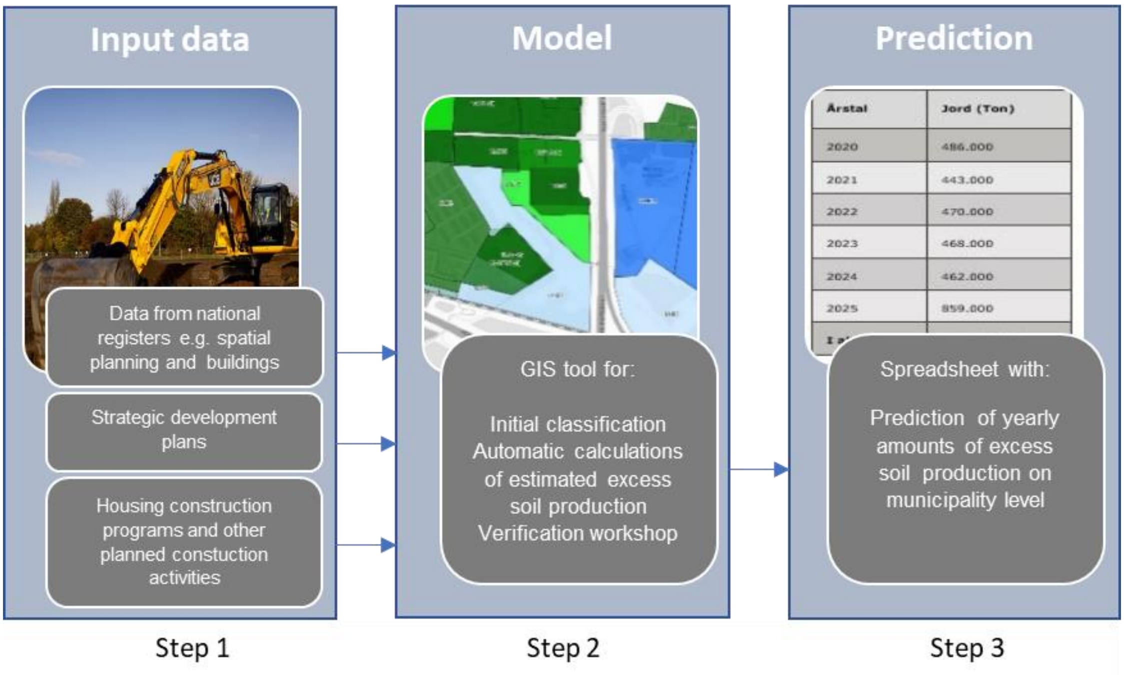

Figure 1 - Steps in preparing prediction of production of soil arising from future construction activities

In appendix 1, actual results for the predicted future production (12 years) of soil arising from construction works and urban development in the Danish municipalities of Roskilde Kommune and Høje-Taastrup Kommune are shown as a examples.

2. Input data

The prediction model is mainly based on data related to municipal spatial planning, which are the most accurate data available on a national level. The data is digital and publicly available from The National Register of Spatial Planning (Plandata).

This data is supplemented with digital information on existing buildings and constructions from The Central Register of Buildings and Dwellings (BBR).

In parallel to spatial planning, many municipalities prepare strategic construction plans and housing construction programs.These plans and programs often contain more detailed information on when building or construction work will occur. Such information is collected before the prediction tool is set up.

Also, it is important to identify and include any other activities where a significant production of excavated soil is likely, e.g. construction and renovation of roads and utility supply lines. Municipal planning departments and road and utility departments often have information on this, but information from utility suppliers and other market players is equally important.

3. Prediction model

The prediction model is integrated with a GIS-tool (figure 1), where all collected spatial data is stored, and all data processing is performed.

Any data on future production of excavated soil where no definitive spatial information is available are entered directly into the final prediction spreadsheet (see section 4).

3.1. Initial classification of planning areas

As a first step, planning data and data on existing gross floor areas from The Central Register of Buildings and Dwellings is imported into the GIS-tool.

When importing data into the GIS-tool, the planning areas are divided into five categories based on the size of the planning area, plot ratio (i.e. the intensity of land usage of a piece of land, as it is the determinant to calculate the maximum gross floor area (GFA) of the development) and the sum of existing building gross floor areas in the planning area.

The categories and details on the initial classification are listed in table 1 (The % ratios are set as a default value for dividing the areas into categories).

AREA CATEGORY	DESCRIPTION	DETAILS ON THE INITIAL CLASSIFICATION
Areas for future development	Specific areas with expected development within the next 12 years.	Areas where less than 10 % of the permitted gross floor-area has been built, and planned land use is housing, business area, shopping mall etc.
Possible areas for future development	Specific areas where development is possible but less likely to occur within the next 12 years.	Areas where "between 10 and 25 % of the permitted gross floor area" has been built, and planned land use is housing, business area, shopping mall etc. and all recreative and public areas.
Fully developed areas	Areas with no planned urban development.	Areas where more than 25 % of the permitted gross floor-area has been built, and planned land use is housing, business area, shopping mall etc.
Other areas	Areas where urban development is not planned for.	Areas planned for holiday houses, agricultural land, technical facilities, and areas without planning.
Initial classification not possible	If a plot ratio is not present in Plandata, a classification cannot be calculated.	Areas where planned land use is housing, businesses, shopping mall etc., and plot ratio was missing in Plandata at time of download.

Table 1 - Area categories

Besides categorising planning areas when loading data into the GIS tool, the tool also automatically calculates an estimated volume of soil produced in each area due to (expected) development activities. The calculations are also done whenever a planning area is edited.

The soil volume estimates are based on the plot ratio of the individual planning areas and are calculated as the sum of three variables:

- The building footprint (construction percentage)
- Proportion of land area affected by building and construction work (land percentage)
- Proportion of the buildings' footprints that make up the basement (basement percentage).

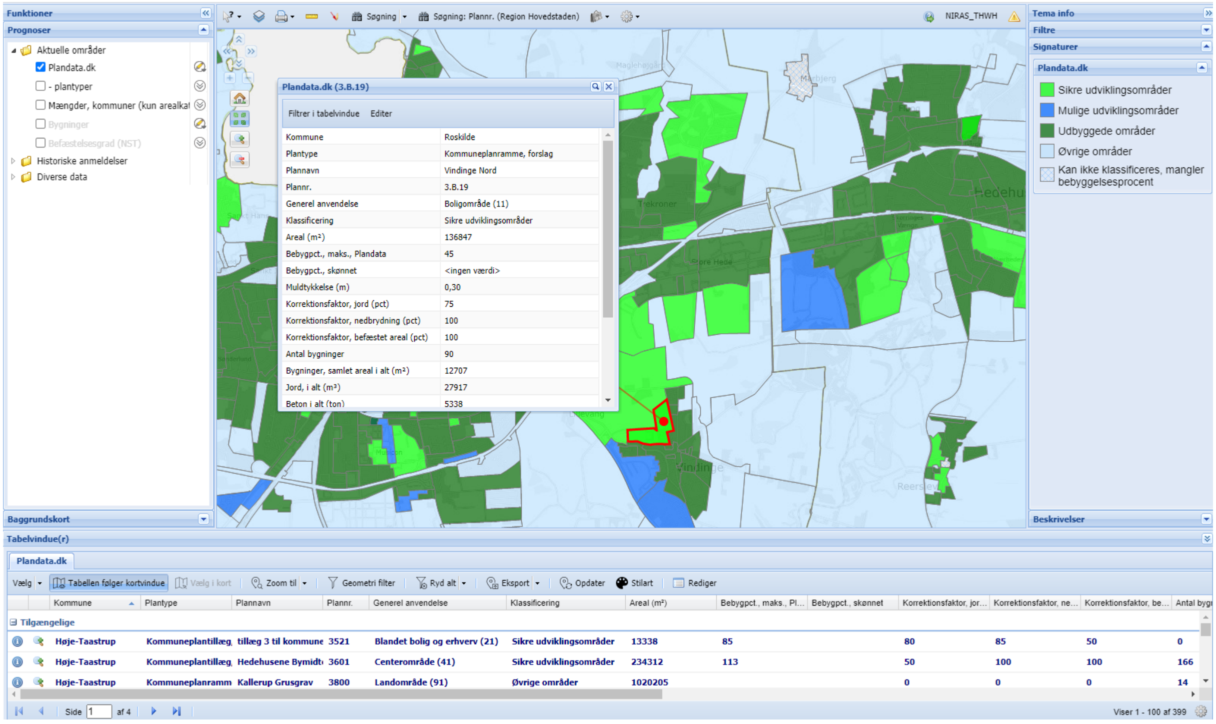

Figure 2 - The prediction GIS tool. The legend to the right lists the categories in the same order is table 1, e.g. areas for future development are shown in bright green

The formulas for determining construction percentage, land percentage and basement percentage are based on experience from actual urban planning and the realized construction works within individual planning areas. The established percentages apply to all construction types, as the proportion of basements is generally dependent on the plot ratio, regardless of the use.

Finally, any relevant information (e.g. specific years for planned activities) in strategic construction plans and housing construction programs and any other collected materials are added to the GIS tool.

3.2. Validation

When the prediction tool is set up, the initial classification and results have to be validated. This can be done at a workshop with the participation of municipal planning experts and the modelling consultants.

The validation workshop aims to ensure:

1. that all areas where urban development will take place in the current planning period are placed in the category "Areas for future development" as this is the only category that is included in the spreadsheet with the final predicted soil volumes,
2. that all areas in category "Areas for future development" has a plot ratio attached – either from Plandata or an estimated plot ratio,

3. that if the estimated (future) soil production for an area is unrealistic, e.g. because the area is already partially developed (a smaller soil volume is likely to be produced) or the land use of an area does not trigger a basement contribution in cases where the planning experts know for a fact that a basement is going to be built (a larger soil volume is likely to be produced) – an appropriate correction percentage is entered in the GIS tool,
4. that the estimated future soil production for every area in the category "Areas for future development" are allocated to the corresponding years where soil production is expected to take place. Details on how the allocation is done are shown in section 4.

The validation is carried out by reviewing the areas in the GIS tool.

Areas in the category "Areas for future development" where significant urban development is not going to occur within the next 12 years are transferred to "Other categories".

Correspondingly, areas not in the category "Areas for future development" where the municipal planning experts know that urban development will occur in the current planning period are transferred to "Areas for future development" category.

At this stage, any areas designed for future development (with spatial information available) can be added manually to the GIS-tool if they are not yet registered.

Additionally, any knowledge the municipal planning experts may have on plot ratios, correction percentages and the years with actual activity must be entered into the GIS tool.

4. Strategic use of prediction

4.1. Soil management strategy

On a municipal or urban level, soil management strategies can be developed, including policies, procedures and instruments (including soil predictions), etc., with a focus on sustainability achieved by reducing the generation of excavated soil related to construction and development works.
A soil management strategy may be integrated in a wide range of activities where a municipality acts in the capacity of a builder, planning authority, building authority, environmental authority, service and utility provider etc.

4.2. Prediction and municipal planning

The prediction establishes an overview of the expected production of soil in specific geographical areas within a certain timeframe. This knowledge can be integrated into municipal and urban planning, enabling planners to:

- Evaluate options for reducing the future generation of soil at an early planning stage
- Adapt development plans to minimize soil generation and to ensure that excess soil can be reused within the area in question
- Explore potential options for sustainable local reuse related to climate mitigation, liveability, infrastructure or recreational uses, etc.

In this context, it is important that information on soil is available at an early stage, as options for reuse of (excavated) soil depend heavily on soil quality and soil properties.

4.3. Prediction as an indicator

The soil prediction can be used as an indicator of behavioral change. Provided that construction and development activities are carried out according to data used for modelling and prediction, the predicted annual soil volumes can serve as a baseline, illustrating a *business as usual scenario*.

Any relevant behavioral change can be compared with this baseline: If municipal plans or construction works are adjusted in one particular year in order to prevent or reduce the generation of excavated soil, the effect can be directly measured in terms of differences in volumes predicted for the following years and volumes realized.

5. Final prediction results

After being validated, results in the GIS-tool are exported to a spreadsheet template with five tables.

Table 1 – Predicted soil production in areas designated for future housing projects

In this table the annual distribution is shown as the number of houses to be built each year:

Område BOLIG		Antal boliger pr. år jf. Boligbyggeprogram, befolkningsvækst												Samlet beregnet jordmængde
Plannavn	Boligbyggeprogam	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	m³
Hentes fra trin 1	Unikt navn eller områdekode fra boligbyggeprogram eller lign.	Angiv antallet af boliger fra boligbyggeprogrammet												Hentes fra trin 1
Boligområde syd for Gadebakken				15	10	30								22.476
Bolig område syd for Hvolbækvej			10	10	10									12.351

Table 2 – Predicted soil production in areas designated for future businesses

In table 2, years with construction activity are marked with the number 1, allowing the predicted soil volumes to be evenly distributed over the marked years.

Område ERHVERV		Angiv de år hvor der forventes byudvikling med ét ettal for hvert område												Samlet beregnet jordmængde
Plannavn		2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	m³
Hentes fra trin 1		Fordelingen af jord sker ligeligt inden for de år som angives i arket. Dvs. at angives et år forventes der byggeri eller anden byudvikling i området inden for det pågældende år.												Hentes fra trin 1
Erhvervsområde ved Vroldvej		1	1											136.347
Anebjerg O2										1				3.109

Table 3 – Predicted soil production from future road and utility supply line construction and renovation.

Data on future road and utility supply line construction is usually not spatial. Any data on estimated soil production received from stakeholders is entered directly into the spreadsheet. Years with activity are marked with the number 1, allowing the predicted soil volumes to be evenly distributed over the marked years.

Producent	Område	Angiv de år hvor der forventes jordproduktion med ét ettal for hvert område og år													Fra jordproducent
		2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	m³
Indtast producent til jord	Her indtastes beskrivelse og område for jordproduktion fx forsyning i område xx	Fordelingen af jord sker ligeligt inden for de år som angives i arket. Dvs. at angives et år med et 1-tal (brug kun et 1-tal, da formlen optælle antal år) forventes der byggeri eller anden byudvikling i området enden for det pågældende år.													Samlet jordmængde
Fjernvarme			1	1	1										100000

Table 4 – Predicted soil volumes based on data from tables 1, 2 and 3

Område bolig			Jordmængde, m³ pr. år												Fra Trin 1
Plannummer	Plannavn	Boligbyggeprogam	2.019	2.020	2.021	2.022	2.023	2.024	2.025	2.026	2.027	2.028	2.029	2.030	Samlet beregnet jordmængde
14.B.04	Boligområde syd for Gadebakken		0	0	6.130	4.087	12.260	0	0	0	0	0	0	0	22.476
14.B.05	Bolig område syd for Hvolbækvej		0	4.117	4.117	4.117	0	0	0	0	0	0	0	0	12.351

Table 5 – A table with the overall predicted soil production in the current planning period for the municipality

Samlet Jordressource pr. år.	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
m³	68.174	105.624	43.580	41.537	12.260	0	0	0	3.109	0	0	0	274.283

6. Further development

The prediction tool is undergoing continuous development, and work on the CityLoops-project has identified several functionalities that are being considered for further development:

- Incorporation of geological data on soil type, making it possible to divide the predicted soil volumes into different fractions, e.g. sand, clay and till.
- Incorporation of data on sealed surfaces, making it possible to estimate production of gravel etc., from the substratum in case of demolition/removal. Also, volumes of sealing materials (asphalt, concrete etc. could be estimated).
- In the current version of the prediction tool, data is downloaded from the national registers (Plandata and BBR, i.e. cadaster on existing buildings) at the time of project initiation. As the timeframe of municipal planning is 12 years, it would ease ongoing assessments of expected soil production if data from Plandata and BBR were updated automatically.

In the current version, the final step involves exporting data from a GIS tool to a spreadsheet. It would be more user friendly if the finished spreadsheet could be exported directly from the GIS tool, thus eliminating the final manual step.

Appendix 1

The municipalities of Roskilde Kommune and Høje-Taastrup Kommune are CityLoops partners and have served as testbeds for this prediction instrument. Both municipalities are located in the vicinity of Copenhagen (København).

General information on the municipalities can be found in table 2. Predicted soil production in the planning period (2020-2031) is shown in tables 3 and 4.

MUNICIPALITY	AREA	POPULATION	REGION
Høje-Taastrup	78,32 km²	50.759 (2020)	Capital Region of Denmark
Roskilde	212,05 km²	87.914 (2020)	Region Zealand

Table 2- General Information

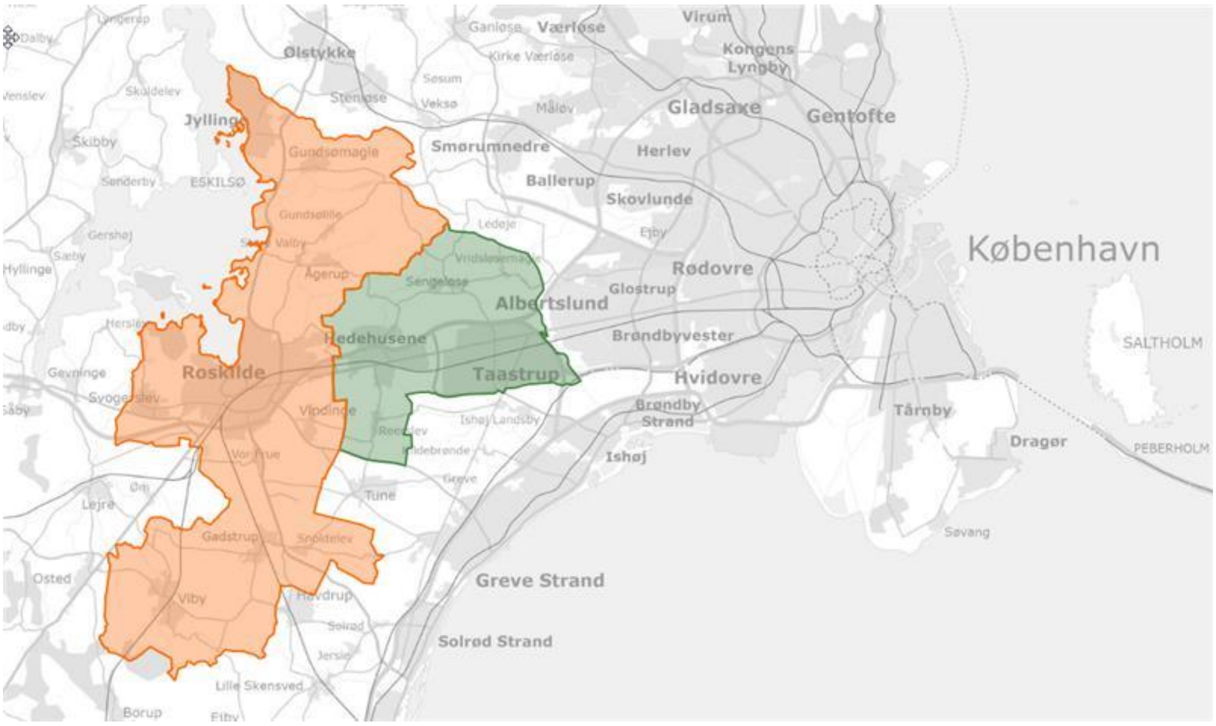

Figure 3 - Location of Roskilde Kommune (orange) and Høje-Taastrup (green) Kommune. Grey shades represent urban areas, light areas mainly represent agricultural use.

Municipal activities and investments are reflected in the prediction

The level of municipal development and construction activity is relatively high in the two municipalities, cf. *Municipal construction projects 2020-2023*[1]. This applies in particular to Høje-Taastrup municipality.

In Høje-Taastrup municipality, planned investments in municipal building and construction projects are the second highest at the national level when measuring in DKK per. capita and amounting to a total of approx. DKK 1.12 billion, corresponding to approx. DKK 22,000 / capita, (equivalent to appx. € 3000).

Roskilde municipality expects to invest DKK 0.98 billion in construction and development activities in the near future. This corresponds to approx. DKK 11,200 / capita, equivalent to appx. € 1500, which is slightly below the national average.

Referring to tables no. 3 and 4, the predicted annual soil volumes produced in Høje-Taastrup are larger than the volumes predicted for Roskilde, thus reflecting a higher level of municipal activities and investments in Høje-Taastrup.

Roskilde Kommune - predicted annual production of soil

For the municipality of Roskilde Kommune, the predicted annual production of soil is presented in table 3. The prediction is based on a "business as usual" scenario, i.e. a situation where municipal planning and construction activities are performed without paying particular attention to excavation and production of soil.

YEAR	TON
2020	150.000
2021	250.000
2022	200.000
2023	250.000
2024	200.000
2025	300.000
2026	300.000
2027	200.000
2028	150.000
2029	100.000
2030	100.000
2031	100.000
In total approx.	2.3 million tons

Table 3- Predicted volumes of soil produced in the current 12-year planning period for the municipality of Roskilde Kommune

[1] Kommunale byggeprojekter 2020-2023. Et overblik over de 98 kommuners bygge- og anlægsinvesteringer. Byggefakta, 2020.

Høje-Taastrup Kommune - predicted annual production of soil

The predicted annual production of soil in the municipality of Høje-Taastrup Kommune is presented in table 4.

The prediction is based on a “business as usual” scenario, i.e. a situation where municipal planning and construction activities are performed without paying particular attention to excavation and production of soil.

YEAR	TON
2020	300.000
2021	250.000
2022	900.000
2023	450.000
2024	200.000
2025	250.000
2026	400.000
2027	250.000
2028	250.000
2029	250.000
2030	90.000
2031	90.000
In total approx.	3.7 million tons

Table 4- Predicted volumes of soil produced in the current 12-year planning period for the municipality of Høje-Taastrup Kommune

CITYLOOPS

CityLoops is an EU-funded project focusing on construction and demolition waste (CDW), including soil, and organic waste (OW), where seven European cities are piloting solutions to be more circular.

Høje-Taastrup and Roskilde (Denmark), Mikkeli (Finland), Apeldoorn (the Netherlands), Bodø (Norway), Porto (Portugal) and Seville (Spain) are the seven cities implementing a series of demonstration actions on CDW and OW, and developing and testing over 30 new tools and processes.

Alongside these, a sector-wide circularity assessment and an urban circularity assessment are to be carried out in each of the cities. The former, to optimise the demonstration activities, whereas the latter to enable cities to effectively integrate circularity into planning and decision making. Another two key aspect of CityLoops are stakeholder engagement and circular procurement.

CityLoops runs from October 2019 until September 2023.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 821033.