1 FROM GITHUB DOCUMENTATION

1.1 Introduction

The model is hosted on the web and is developed using AnyLogic simulation software. The intended usage includes:

1. Analyzing specific market scenarios
2. Analyzing a set of market scenarios through the Experiment interface

Users can upload their own location data and modify simulation parameters before and during the simulation.
Access the simulation model

1.2 Basic Concepts

This simulation is designed to help **recycled material market researchers** analyze how materials are **distributed, reused, and valued** across a spatial market. It models the lifecycle of recycled materials—**from disassembly (source sites)** to **storage hubs** to **end users (build sites)**—and simulates supply-demand dynamics using probabilistic distributions.

By adjusting parameters like material availability, transport delays, and pricing, users can explore different market scenarios and evaluate how factors like **logistics**, **cost structures**, and **site density** influence material flow, cost-efficiency, and fulfillment rates.

1.3 Simulation User Interface

1.3.1 Displays

Figure 1: Map screenshot RAKSA

Map

1. Controls for model runtime
2. Physical map view (scrollable and pannable), legend for elements:
   - Yellow warehouse: Intermediate storage location (constant)
   - Blue warehouse: Source (disassembly) site
   - Green house: User (build) site
   - Colored circles: Residuals of the respective site types
3. Panel to switch between views
4. Simulation runtime info
5. Simulation event log

1.3.2 Controls

(Screenshots pending.)

The model uses a **normal distribution** for many parameters, with a global standard deviation value `globalSigma`.

1.4 Purchasing Logic

Materials are purchased based on:

- Proximity to source or storage
- Availability windows $T_{availableFor}$
- Price minimization logic

$$\text{Cost}_{total} = \text{Price} + \text{InstallationCost} + \text{DistanceCost} \tag{1}$$

Where:

- `Price` depends on the site of purchase
- $\text{DistanceCost} = d \times costPerKm$

Sourced from AnyLogic distance library.

The simulation dynamically chooses the lower-cost path, comparing source and storage offers per material demand.

1.5 Simulation Statistics Descriptions (with Math)

- **boughtFromStorage**: Total number of purchases from storage facilities.
- **boughtFromSites**: Total number of purchases from disassembly sites.
- **kmsDrivenToStorage**:
$$\sum d_{to\_storage}$$
- **kmsDrivenToSites**:
$$\sum d_{to\_sites}$$
- **nSourceSites**: Total number of source/disassembly sites.
- **nUserSites**: Total number of user/consumer sites.
- **timesTransferedToStorage**: Count of transfers to storage.
- **materialTransferedToStorage**:

$$\sum M_{to\_storage}$$

- **paidToStorage**:

$$\sum(materialPriceStorage + installationCostStorage)$$

- **paidToSites**:

$$\sum(materialPriceSource + installationCostSource)$$

- **kmTransferedToStorage**:

$$\sum d_{transferred\_to\_storage}$$

- **totalMaterialProduced**:

$$\sum M_{produced}$$

1.6 Running a Model

1. **Open the Model Link**

   Navigate to the shared model link: https://cloud.anylogic.com/model/ae382db1-7c58-443d-9d9f-53f105e7013e

2. **Choose an Experiment Type**

   - **Simulation (Interactive):** Lets you view real-time animation and change parameters mid-run.

3. **Adjust Parameters (Optional)**

   On the params panel, adjust any of the following:

   - Source/material/user timing values
   - Costs and quantities
   - Distribution settings (mean, std. dev.)

4. **Click "Run"**

   Hit the **Run** button. The model:

   - Starts executing on the server
   - Streams updates to your browser
   - Displays the visual: map, graphs, and logs

5. **Through the model control panel you can**:

   - Pause, resume, or reset
   - View logs, statistics, and material flows
   - Switch between panels

6. **Download Results**

   Instructions coming soon.

1.7 Running Experiments

(Section to be completed)

Method description

In the basic model the spatial cost-threshold is analyzed. For the location of an intermediate storage facility, the radius containing viable customer locations calculated.

Using geographic data of Finnland's populated areas and average market conditions inputed by the user a viability radius, where it is in the interest of a customer to purchase from the facility is showcased. Beyond this radius, local purchasing directly from a deconstruction side is always preferable, meaning that every time a construction side has to purchase from a remote intermediate storage facility due to higher than local demand an economic inefficiency is created.

The radius is shown for both concrete slabs and bricks. The model is interactive and parameterized, allowing the user to visually see the radius based on the market parameters. The user can analyze it under different conditions.

1.8 Input parameters

The data from roughly 3000 Finnish waste sites was used to approximate densely populated areas, presuming that these areas would have a high construction rate. For the selected example the location of the intermediate storage facility was chosen to be in the city of Forssa.

For the reported results, the initial market conditions were modeled using data from previous project activities. This provides good baseline experiment settings at the national scale, while sticking to the basics.

1.9 User interface description

The interface consists of input fields, where default parameters can be adjusted by the user. The price advantage of each material can be changed. Price advantage represents the total difference between a baseline quality material and a material of higher quality after upcycling. This difference can be due to lower installation cost, lower costs of holding an inventory, lower environmental fees etc.. Currently the model does not model an exact advantage, instead the "black box" is used.

The same "black box" is used for representing cost per kilometer. User can also define exact coordinates of a recycling facility separate from a default one.

1.9.1 Map 1

First map represents potential cusotmer locations in relation to a recycling facility. Grey locations, cannot be optimally served under specified market conditions, based on current price advantage and cost per km for either material. Colored dots represent the fact that material can now be optimally served. Each color represents if either or both material are available for a location optimally.

1.9.2 Map 2

On the second map, a heat map is presented. The warmer the color the more locations are accessed for a hypothetical recycling location under current market conditions. This can be used for planning a potential location.

1.10 Economic decision model

Each location makes a binary decision:

1. Purchase materials locally with the higher cost, but save on transportation

2. Purchase from an intermediate storage and pay a higher logistic price

Based on the distance to the storage and current market conditions for each material, the cheapest option is taken.

Order-level cost

The customers do not purchase individual bricks or slabs, they purchase in order batches. with the price of each order determined as follows:

$$\text{order price} = \frac{\text{order size}}{\text{truck capacity}} \times \text{truck cost per km} \times \text{km to storage}$$

This is compared to the price advantage from an upcycled product.

- Towards Sustainable City: A Covering Model for Recycling Facility Location-allocation in Nilai, Malaysia

- Location and Capacity Optimization of Waste Recycling Centers: Mathematical Models and Numerical Experiments