Deliverable 1.2

Knowledge Base – Reference Models

Deliverable number: (D.1.2)
Author(s): Rodrigo Tapia, Ioanna Kourounioti
Author’(s’) affiliation (Partner short name): TUDelft

Deliverable No.		1.2	
Work package No.	1	Work package Title	Adaptive city logistics Framework and Value Cases
Task No.	1.2	Task Title	Knowledge Base – Reference Models
Date of preparation of this version:		25/01/2021	
Authors:		Rodrigo Tapia, Ioanna Kourounioti	
Status (F: final; D: draft; RD: revised draft):		F	
File Name:		LEAD – D1.2 KnowledgeBase_ReferenceModels_ReviewsV3.docx	
Version:		3.0	
Task start date and duration		01/06/2020 – 31/12/2020	

This document is issued within the frame and for the purpose of the LEAD project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 861598.

Revision History

Version No.	Date	Details
1.0	08/12/2020	First draft
2.0	30/12/2020	Revised version
3.0	31/12/2020	Revised version for final comments
3.1	25/01/2021	Final version

Reviewers List

Name	Company	Date	Signature
B.Groothedde	Argusi	15/12/2020	
Edoardo Marcucci	MOLDE	17/12/2020	
Valerio Gatta	MOLDE	17/12/2020	
Dimitra Politaki	Inlecom	19/01/2021	

Contents

List of tables

List of figures

Abbreviations

Abbreviation	Explanation
ABM	Agent Based Model
DT	Digital Twin
KB	Knowledge Base
LoS	Level of Service
LL	Living Lab
ML	Model Library
PI	Physical Internet
PT	Physical Twin
SP	Stated Preference
UCC	Urban Consolidation Centre
UFT	Urban Freight Transport

Executive Summary

The LEAD project relies on Digital Twins (DT) in order to test low emission logistic strategies implemented by Living Labs. In order to develop the DT, the Living Labs (LLs) must identify the models needed in order to incorporate the physical elements of the Living Lab into the DT. The aim of this deliverable is to build a Knowledge Base (KB) and collect a reference Model Library (ML) in order to assist Living Labs to detect the relevant models.

D1.2 describes the conceptual model that is the base of the KB, its components, and the models available in the ML. Additionally, it describes the way it can be used to identify the models for the DT and the key gaps to address in order to generate the DT ML.

The KB is a systematization of the knowledge gathered from the models that compose the ML. The systematization consists in categorizing the inputs, outputs, measures and the modelling method in a consistent way in order to generate relationships between these components. The KB and ML presented in this deliverable work as a starting point for LLs to identify the models needed to implement their DT.

The KB aids the Living Labs to identify the models by relating the needs of the LL (the combination of measures and desired outputs) with the ML. Additionally, the KB further helps to identify auxiliary models and the inputs needed by them. As a result, by using the KB, the LLs will have an idea of which models can be used to model their measures, how to retrieve their KPIs and what inputs are needed.

The reference ML consists of 21 models shared by the partners of the project. The ML consists of city logistics models (optimization and network models), impact assessment models, stakeholder acceptability models, agent-based models, demand models and data collection tools.

Overall, the reference ML provides a broad coverage of the main agents involved in urban freight transport and the main categories of measures and outputs. The ML provides a solid and reliable starting point for developing the DT model library for Task 2.2 and provides impact assessment models for Task 3.8 and data flows and data ingestion solutions needed for Task 2.1.

However, some gaps were identified in the ML. Firstly, there is a lack of common framework of the models which can cause inconsistencies between them. Secondly, there are lack of tools to model physical internet approaches. Finally, there are no models that deal with the changes of the patterns of consumption and land use related models. These weaknesses will have to be addressed further in the project, specifically in Task 2.2.

1 Introduction

1.1 Project Summary

LEAD aims to develop a range of logistics solutions for shared, connected and low-emission logistics operations, empowered by an adaptive modelling approach and Digital Twin models. For this, data-driven models need to work in parallel with real-life experiments to reproduce findings first and predict results of response actions after. The models are typically agent-based (ABM), which can enable city logistics stakeholders to recognize their own roles and business models. All relevant operational, tactical and strategic decisions are included in the Digital Twin, which mirrors value cases in the reality of city life.

LEAD will create Digital Twins of urban logistics networks in six cities (TEN-T urban nodes), to support experimentation, planning and decision making with on-demand logistics operations in a public-private urban setting. City logistics solutions will be represented by a set of value case scenarios that address the requirements of the on-demand economy and the pressures caused by the increase of parcel deliveries, while aligning competing interests and creating value for all stakeholders. Each value case will combine a number of measures - referred hereafter as LEAD Strategies: a) innovative business models, b) agile urban freight storage and last mile distribution schemes, c) low emission, automated, electric or hybrid delivery vehicles, and d) smart data-driven logistics solutions (Figure 1-1). Balanced city measures will most likely have combinations of these strategies in place to cover the complete dynamics and complexity of a city's logistics challenges.

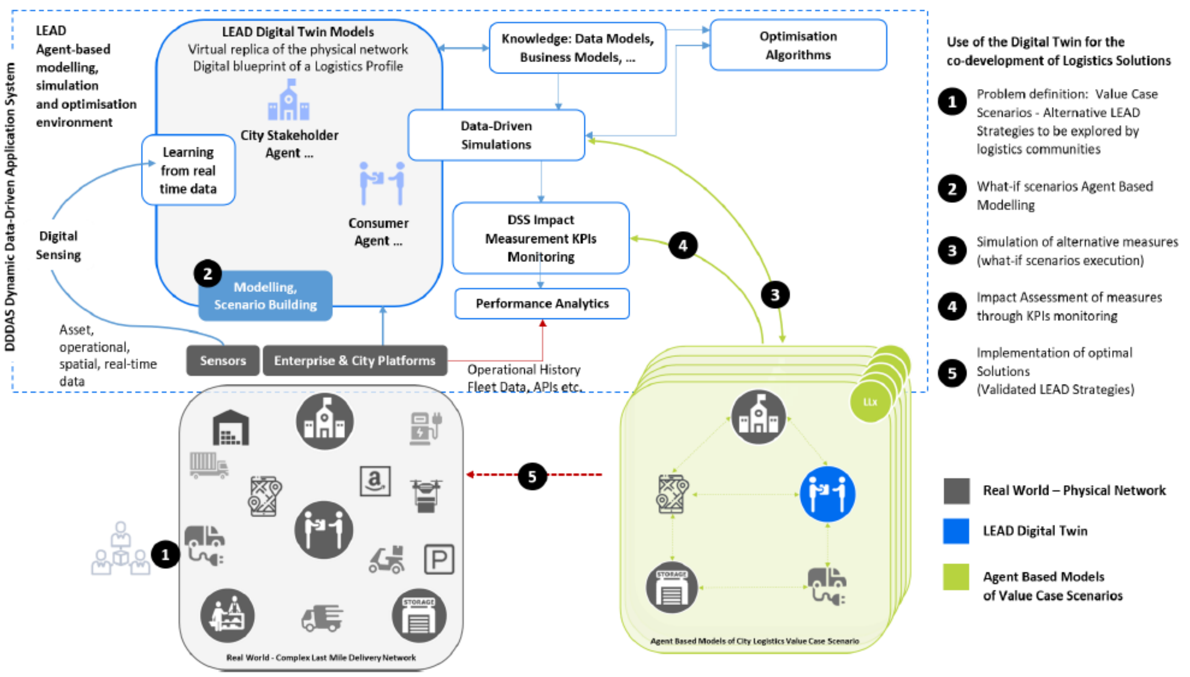

Figure 1-1 Methodological Framework of LEAD project

1.2 Scope of the deliverable

The aim of D1.2 is to consolidate best practices and develop a knowledge base (KB) and library of reference models (ML) for urban logistics and to describe the models that are to be included in the LEAD model knowledge base. The KB is a tool that aims to help LEAD LLs and cities in general to identify the most suitable model, or combination of models, to solve their UFT related challenges. By relying on the KB, the modeller can not only relate the measures and the desired outputs with the models, but identify other complementary models and the inputs needed to run them. The reference ML is a starting point for the LLs to locate the models that they can use to develop their DTs.

The models that are included and described in D1.2 fulfil the following requirements in order to be included:

1. **Open source models**: The models are or can be implemented in open source software or programming languages.
2. **Publicly available**: Model main components and documentation are available for the general public.
3. **Transferable models**: The models, although specific to their development context, can be calibrated to be transferred to other cities.
4. **Urban freight models**: The models have to be developed for city logistics or being able to be easily applied to the freight context. An exception for this rule has been passenger ABMs for their role in generating synthetic households and the interaction of crowdshipping with passenger flows.

D1.2 and the ML will provide input to the technical requirements of the DTs (T2.1) and the LLs impact assessment framework (T3.8). The ML will also serve as a base for the DT ML to be carried out in T2.2.

1.3 Structure of the document

The remaining of the D1.2 structure is as follows:

- Section 2: Describes the knowledge base. Specifically, it explains how the knowledge base will be designed to cover the requirements of a DT, the methodological framework of the knowledge-based design and the model data collection.
- Section 3: Describes in detail each model included in the model library.
- Section 4: Synthesizes model library and the knowledge base.
- Section 5: Concludes the report.

2 Knowledge Base

2.1 Requirements of a Digital Twin

LEAD aims to develop Digital Twins (DT) of six cities to experiment with various UFT innovations. A DT is a virtual counterpart of a physical element/system, called physical twin (PT), which contains all relevant information to describe and emulate the PT. The DT has 3 basic elements (Grieves, 2014): the Digital environment, the physical environment and the bi-directional data connections. This bi-directional data connections allow the “twinning” process, that is the update of the DT entity because of changes in the PT, or the inverse: a change of the PT triggered by simulations from the DT (Jones et al., 2020).

Figure 2-1 presents the relationship between the PT and the DT. The Physical environment consists of all elements of the physical world. According to Jones et al. (2020) classification, the most basic element is the physical entity, which is a real-world element that needs to be analysed in the DT. The physical processes are all the real-world processes that engage the PT, acting or being acted upon. Another crucial aspects consists of the metrology, the act of measuring the current state of the PT, and the twinning process, that is the change of state of the PT due to changes in the virtual environment (Jones et al., 2020).

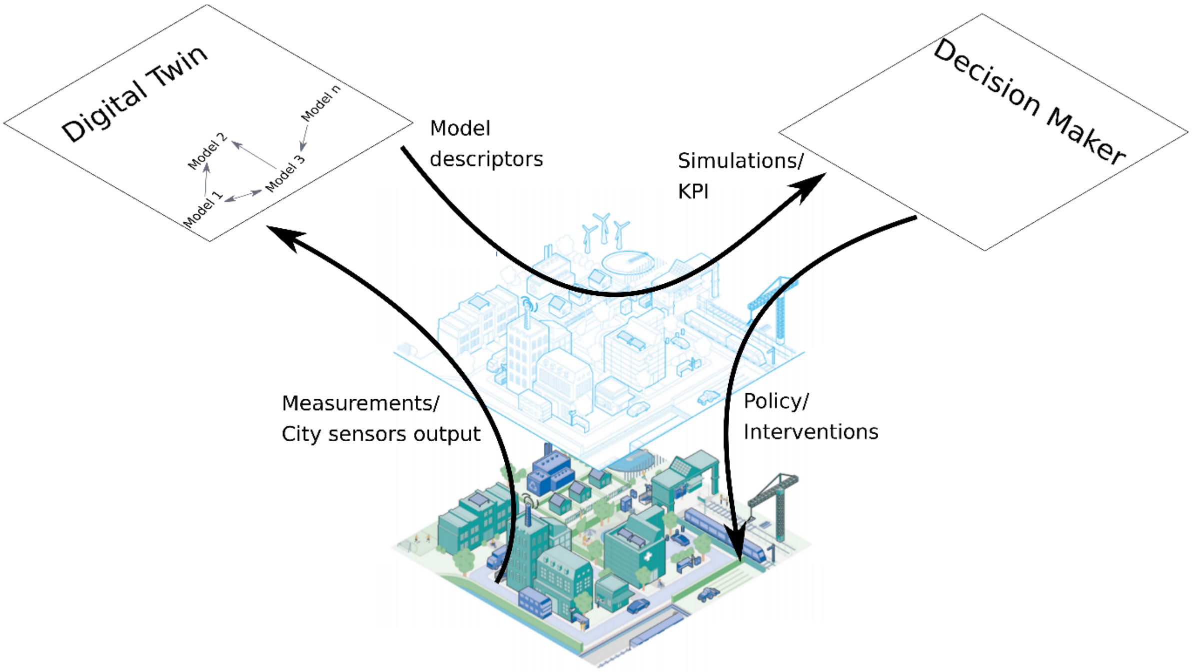

Figure 2-1 Relationship between the physical and the Digital Twin

Each component of the DT matches its physical counterpart. The digital entity is the virtual representation of the physical equivalent. The virtual process consists of the models and models interactions that occur within the DT framework. The metrology aspect is present in the virtual environment part, which is the measurement of model outputs and KPIs, while the twinning process is part of the updates from the PT and incorporated into the DT. The models used in the DT are designed to be well aligned and relevant to represent the PT (Boschert & Rosen, 2019).

The data relationships between the physical and digital environments are related to the twinning process (Jones et al., 2020). The twinning process is the synchronization of the states (current value of variables): digital and physical environments. The twinning process is a twoway communication, where changes in the PT are communicated to the DT and vice-versa when results of the simulations fuel changes in the physical world. The twinning frequency is known as the twinning rate that depend on the overall cycle of measurement and communication between the physical and virtual world. This twinning rate or cycle can be very short, like in mechanical applications and industry (Weyer et al., 2016), or of much longer cycles, like in complex social systems like city logistics.

The systematization of the twinning process is probably what makes DT unique and different from traditional modelling strategies. Traditional model strategies consist of an ad-hoc process: the data collection is defined per case basis, and so is the modelling process. This means that the cycles of evaluating a certain policy are long ones, from the definition of the strategy to the final implementation and posterior evaluation. In DTs, the data collection and evaluation processes are internalized, implying a constant update of the DT. This implies that the modelling cycle becomes more agile and allows adaptability before the end of the execution of the whole policy evaluation cycle.

A DT adds value in 4 main ways (DHL, 2019).The first one is its descriptive value by allowing to know the current state of the PT. The DT can allow the LLs to visualize the current state of the PT by giving KPIs and processing data collected at that moment.

The second way is providing Analytical value, by simulating scenarios and provide data otherwise difficult or impossible to measure. DTs can infer KPIs from the data by simulating other non-observable KPIs that give insights to the decision makers.

The third added value process is by being able to diagnose and provide better understanding of the functioning of the PT. The models can provide the most likely roots of the problems that the PT have. This is a key input to generate policies based on evidence.

Finally, its predictive value allows to predict future status of the PT. DT can provide tools for simulating future states of the PT, including the do-nothing scenario and policies to address them. This allows the decision makers to have more information to enforce the best measure

As mentioned in section 2.1 LEAD project focuses on developing DTs to test various UFT strategies in cities in Europe. The physical environment becomes the whole city and the physical entity to be modelled are the urban freight agents. Figure 2-1 shows the relationship and main elements between the PT and the DT in the context of UFT.

2.2 Conceptual Model

This section presents a description of the UFT conceptual models. Figure 2-2 represents the engaged agents and their interactions. Agents can exchange goods in return for money and, also information on the status of the various orders.

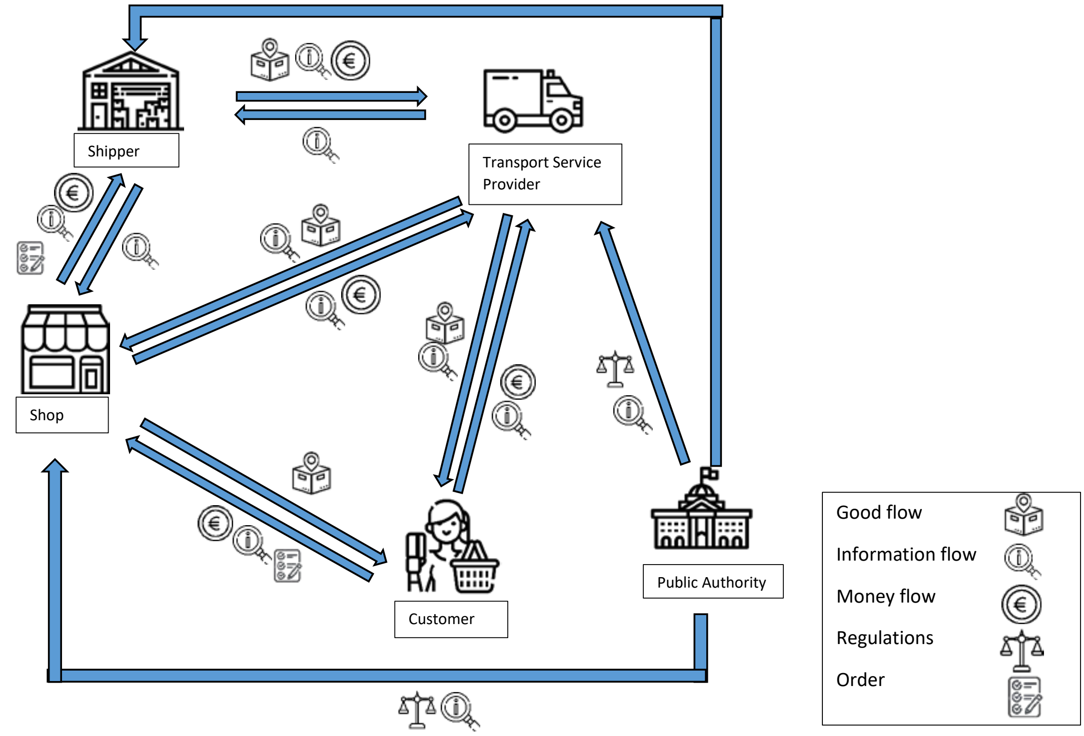

Figure 2-2 UFT conceptual model.

In general, UFT is characterised by five major actors, namely: customers, shop owners, shippers, carriers and public authorities.

- **Customers** are the individuals living in urban areas and they consume the goods.
- **Shop owners** are the retailers in the system and they sell products/goods to customers either physically or electronically.
- **Shippers** supply the goods to shops.
- The **Transport Service Provider** offer transportation services.
- **Public authorities** are the regional governments and local municipalities that set the legal and regulatory framework and design the policy measures in order to ensure efficient and sustainable transport in cities.

Some organizations can have multiple agent roles. An example of these are large retailers and supermarkets with their own transport, since they fulfil the tasks and objectives of shops and transport service providers.

It is important to define each of the stakeholders' decisions and expectations since their needs can be different regarding sustainable urban logistics (Anand et al., 2014).Even though all stakeholders share mutual objective which is transferring the goods from supplier to its receiver, their individual interest can generate conflicts due to each agent optimizing its own cost function rather than the whole system (Anand et al., 2014).

2.2.1 Customer

The agent starts the process with an order depending on their needs thereby customers generate the freight demand in the process. There are various decisions involved regarding customer behaviour. According to Stathopoulos et al. (2011), customers require shorter delivery times together with minimum product price. Besides that, customers choose shopping place to buy goods which can be online or physical. Customers also determines the amount of goods to be delivered, place and day of the delivery (Anand et al., 2014; Stathopoulos et al., 2011). Meeting the requirements of the decision makers increases the complexity of UFT.

2.2.2 Shops

The shop agent orders goods from a shipper to be able to meet customer's needs. Shops can have physical places, as in the case of retailers, or they can be virtual like online platforms. This agent has considerable influence in urban freight logistics since the agent decides the amount of delivery, selling price of the goods and the stock policy (Anand et al., 2014). Shops interact with shipper and transport service provider which sometimes results in conflict among agents, since each individual agent would try to minimize its own total logistic cost function. One of the most important aims that shops try to achieve is that they intend to optimize their inventory cost. To be able to minimize inventory cost, shop agents need optimize their ordering quantity which can be sometimes an issue among shop and shipper agent (Anand et al., 2014).Shops require to make an order from shipper with a minimum price while shipper has an aim to generate maximum profit. Besides that, the agent can have preferences regarding delivery time and place which increases the delivery cost for transport service provider.

2.2.3 Shippers

Shipper agent is the supplier of the goods. This agent usually selects the logistic service provider to deliver the ordered goods to shop. Shippers also decide the location of distribution centres. They plan the efficient application of the distribution centres and have an important role in the definition of shipment size. Transportation and inventory costs constitute considerable part of the cost function of a shipper. Lastly, shippers aim to improve their level-of-service in order to cope with competition.

2.2.4 Transport Service Provider

The Transport Service Provider, also known as carrier, is the actual transporter of the goods to the customer/shop (Anand et al., 2014). The transport service provider agent tries to consolidate shipments by maximising vehicle load factors for the delivery of customers/shops. Some larger transport service providers have their own consolidation centres where they can consolidate freight. There are several choices that the transport service provider agent performs namely, route choice, vehicle choice and have an important role in time of the day choice. It is important to mention that while transport service providers decide route and delivery time, they have to meet the requirements of customers/shops. Besides that, transport service provider's vehicle choice has to comply with regulations of authority.

2.2.5 Public Authorities

Public authorities plan, organise and control policy measures by setting regulatory measures. These measures deal with the development of new infrastructure, and the efficient usage of existing infrastructure. Public authorities set the rules accessing the city centre and other policies related to land use and environmental protection. The regulations that public authorities apply can have several impacts. They can restrict carries to use specific vehicles for delivering goods, to modify their loading and unloading times and locations. They also influence the location of consolidation centres.

2.2.6 Assets

The assets are passive elements that affect or are affected by the urban freight system. These can be exclusive of the urban freight system, such as warehouses or shared with the rest of the community, like roads and the environment. The warehouses include storage facilities outside of shops. Urban Consolidation Centres (UCC) fall under this type of assets. The storage facilities help to maintain the level of service of the deliveries and their geographical location and capacity affect directly the urban freight system. They can be considered to be part of the shipper or transport service provider and affect their interaction.

The road network includes or the roads of the city. Local public authorities own and maintain networks. Congestion, one of the most visible disruptions of the urban domain, is the result of mismatch between road supply and its demand. The transport service provider is the main agent that affects this interaction.

The environment combines both environmental and social aspects. Its definition goes beyond the GHG emissions, but also includes other elements, such as noise, habitat loss and landscape losses. Figure 2-3 presents a simplified version of the UFT conceptual model that includes the assets.

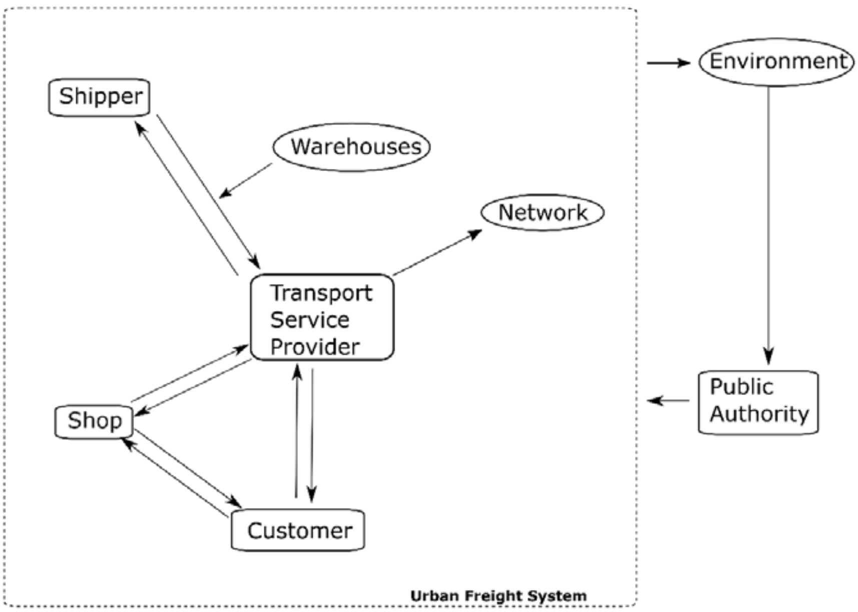

Figure 2-3 Simplified model

Vehicle fleets are a key and characteristic asset of the transport service provider. This makes it that the decisions regarding vehicle fleets become part of the analysis of the transport service provider.

2.3 Model Collection Template

To facilitate partners in describing the models they will share with the LEAD knowledge base a excel template was created. The template consisted of 7 sections:

1. **Model description:** A brief description of the scope, type and characteristics of the model, besides the name, year and current version of the model.
2. **Modelling approach:** An overall view of the main method used, sub models, agents involved, and any possible interactions with external models.
3. **Model inputs:** A description of the main type of data inputs that the model needs. For each data input we asked for a description, main units/categories, whether it is updated continuously (static/dynamic) and if it uses aggregated or disaggregated data. Another important question is related to the feedback information loop from the city (physical twin), that is what type of measurements and information can be fed to the model to keep it updated in order to accurately describe the city.
4. **Model outputs:** A description of the main outputs and KPIs that can be obtained from the model and sub models. Also, a subsection of city logistics problems that can be solved using the model.
5. **Software:** Here we asked for the main software/programming languages necessary to run the model.
6. **Future developments**: In this section we required partner to indicate if they plan for future model developments or for possible improvements.
7. **Documentation**: Partners provided any available documentation (URL or DOI) that describes the model in more detail.

Appendix I presents the template used to collect information for the available model.

The partners provided the category of the models, although some measures to enhance their compatibility were done. In most cases, the models presented here include different modules (or sub-models). The model type has been identified with the objective or main tool of such model. For example, if a model uses an optimization module to estimate the amount of km travelled to measure the GHG emissions, it will be categorized as an externality model and not as an optimization one.

The data collection was made via a template sent to the partners. The template considers the key aspects to characterize a model while also considering extra inputs for their adaptation to the context of DTs.

2.4 Knowledge Base Structure

The Living Labs are the confluence of multiple stakeholders in a partnership in order to take part into a certain set of actions and jointly generate knowledge. The LL process follows the interaction among multiple stakeholders with different desired outputs and capability to perform certain actions. During this process there are iterations between the desired outputs and the possible actions to achieve them.

In the PT the different agents interact in the urban freight system, as described in section 2.2. On their digital counterpart, they interact in the LL by defining a set of actions or measures and outputs of interest. The Knowledge Base (KB) is a tool at disposal of the LL that helps stakeholders identify the combination of models able to recreate the DT. In their interaction they rely on the KB to identify the relevant models from the Model library (ML) in order to generate the DT. Figure 2.4 illustrates the role of the KB in the context of LEAD LLs.

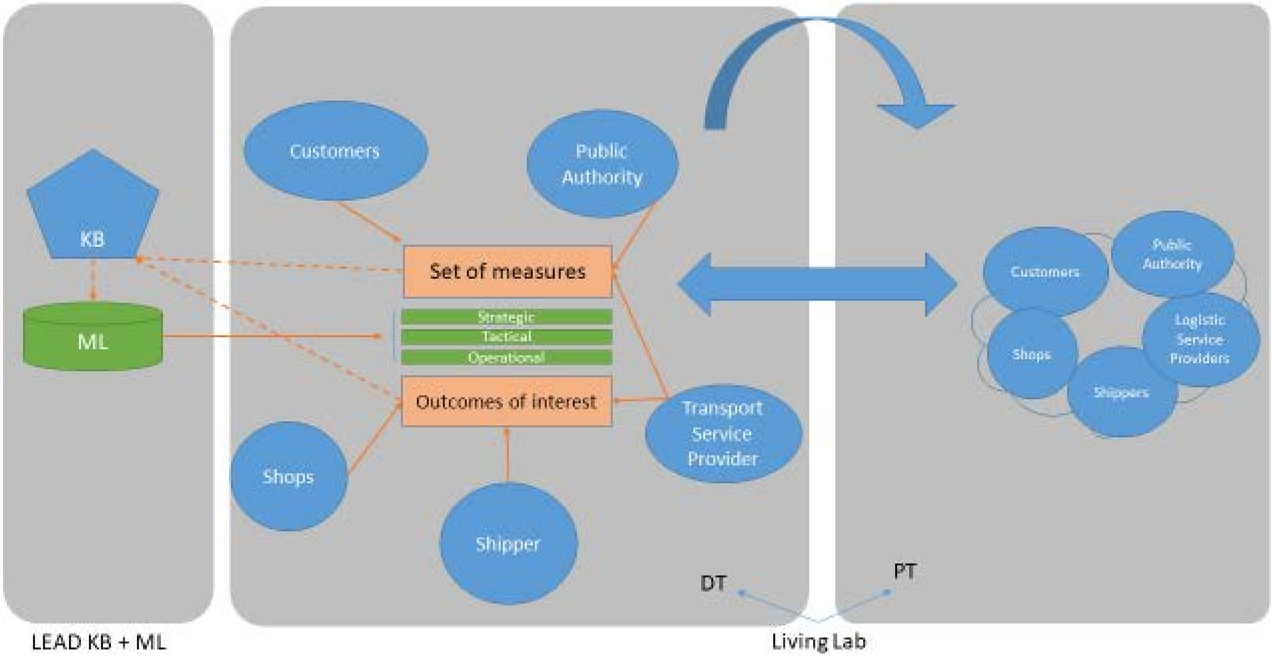

Figure 2-4 Role of the knowledge base

Each LL identifies both a set of measures (such as introducing a new service) and some desired outputs, such as emission reduction or cost reduction. After identifying the set of measures the LL set up a DT by applying a set of models. The KB is a tool at disposal of the LL that helps stakeholders identify the combination of models able to recreate the DT. The KB aids the LL modellers to identify the main and auxiliary models necessary for setting up the DT.

The KB is a systematization of information designed to answer one or several questions. In the LL context, the question revolves around how to make these actions compatible with the desired outputs of the stakeholders. Moreover, in the DT framework, the question refers on how to build the models necessary to replicate the LL in the digital environment. Combining these needs, the two main questions are:

- *How can the objectives of the LL be represented in the DT?*
- *What is it needed to be measured to develop the DT?*

The first question is answered by combining the desired outputs and actions that the LL can take and understanding which models can contribute to represent them in the DT framework. This combination in the framework of a KB is the systematization of the possible outputs of the possible actions. Section 4.1.3 shows this relationship.

The first step in the systematization consists of combining and allocating the possible outputs and actions into different categories. The second step involves different models which measures can be evaluated with them and identify what type of outputs are estimated with them. Finally, the combination of the three pieces of information is comes together in order to generate knowledge for the LL by relating their actions and desired outputs with the models that can convert their physical environment to the digital one.

The second question relates to which information the different stakeholders would have to obtain in order to generate the digital instances and provide their desired outputs. The different models needed according to the answers to the last question relate these inputs, once systematized and categorized, to the outputs. In this step, additional models can be identified that can provide inputs that cannot be directly measured by the stakeholders. Section 4.1.4 shows this relationship between inputs, outputs and models.

By responding to the two questions above, the modeller can populate the DT with the necessary models to obtain the relevant outputs and identify the main inputs in order to determine the effectiveness of the proposed measures.

From the above, the KB has 5 main components: i) The outputs of interest, where the LL are helped to identify the aimed KPIs; ii) the set of measures, that are the actions that the LL is interested in taking; iii) the model library, that is a systematized compilation of models; iv) the inputs, that are the information that the models need in order to generate their outputs and; v) the agents that affected by the urban freight setting. Figure 2-5 illustrates the components and their interactions.

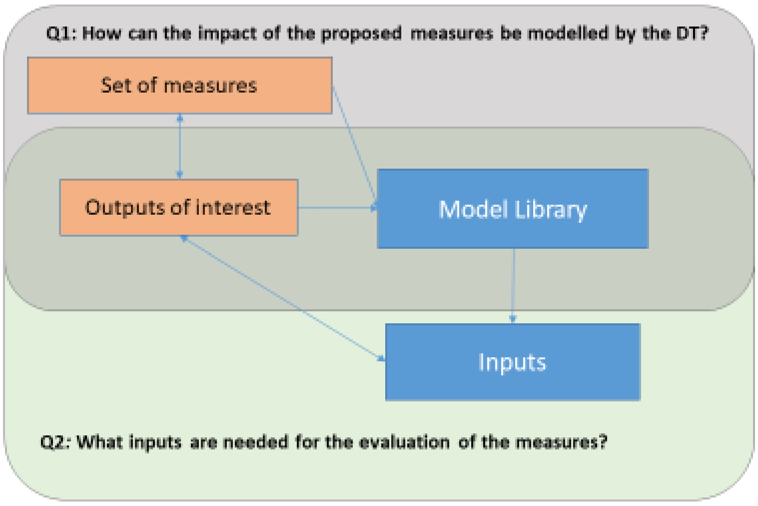

Figure 2-5 Components of the Knowledge Base

The main model types going to be included in the ML are optimization, network, impact assessment, stakeholder acceptability, agent based and demand models. Data collection methods are included as well.

Optimization models usually take an objective function to minimize or maximize subject to some restrictions. Network models deal with the allocation of fleets (or traffic if they refer to passengers) into the transport network. Impact assessment models quantify the impact of freight transport in the urban environment by measuring externalities (such as emissions and noise). They also evaluate the effectiveness of certain policy measure by calculating various KPIs. Stakeholder acceptability models evaluate, ex-ante, any innovation in urban freight transport in terms of acceptance, adoption and reactions. Agent based models simulate each agent taking into account their individual objectives and interactions. Demand models are models that measure the overall demand for parcels or transport services. Finally, the data collection methods like Stated Preference or gaming aimed to record preferences that normal data collection methods do not consider. In the ML models are included that consist of various modules that can belong to more than one categories.

3 Description of Models

3.1 Overview

In total, the KB will consist of 20 models made available by the LEAD partners or other available resources such as CIVITAS Polis initiative. The models were sent by the different partners by filling the template described in section 2.3 and the method for including them in the ML is described in section 4.1.5.

From the models made available by the partners there were 6 types of models that will be described in the remaining of the section. The first model type are **optimization** models that minimize a cost-related function. The second type are **network** models that deal with routing and allocation to road networks. The third model type are **impact assessment** models that analyse and measure the impact of different policies. The next model type is the **stakeholder acceptability**, where each agent's individual acceptability to policies is analysed. Additionally, **Agent Based Models** (ABM) simulate each agent individual behaviour to evaluate a specific situation, while **demand models** focus on obtaining and analysing the preferences of different agents. Finally, **data collection** models provide tools for obtaining data. Table 3-1 presents the abbreviation of the LEAD KB models as it will be applied from here on in D1.2.

Table 3-1 Models Abbreviation

Abbreviation	Name	Partner
ZLC1	Joint replenishment and delivery problem	Fundación Zaragoza Logistic Center
ZLC2	Two Echelon capacitated vehicle routing problem	Fundación Zaragoza Logistic Center
ZLC3	Two echelon distribution with mobile depots	Fundación Zaragoza Logistic Center
ZLC4	Models for Evaluating and Planning City Logistics Systems	Fundación Zaragoza Logistic Center
ZLC5	Two echelon location-routing problem	Fundación Zaragoza Logistic Center
UPM1	Design Manual for Roads and Bridges; Air quality	Universidad Politecnica de Madrid
UPM2	Computer programme to calculate emissions from road transport	Universidad Politecnica de Madrid
UPM3	"Simulation of Urban MObility"	Universidad Politecnica de Madrid
UPM4	Handbook on the external costs of transport	Universidad Politecnica de Madrid
UPM5	Sustainability Tool for the Appraisal of Road Projects (STAR)	Universidad Politecnica de Madrid
SZE1	Performance need of roundtrips based on time capacity assuming optimal vehicle capacity utilization	Szchenyi Istvan University
MOLDE1	Interactive stakeholder acceptability for policy acceptance	Hogskolen I Molde No
MOLDE2	Experimental Design for Stated Preference (SP) data acquisition	Hogskolen I Molde No
IRTX1	The Multi-Agent Transport Simulation MATSim	Institut De Recherche Technologique SystemX
IRTX2	Synthetic population	Institut De Recherche Technologique SystemX
TUDELFT1	MASS-GT	Technische Universiteit Delft
TUDELFT2	Bi-level Acceptance model	Technische Universiteit Delft
BKK1	The Macroscopic Transport Model of Budapest	BKK
ARGUSI1	Network Design | City Logistics	Argusi BV
ARGUSI2	City Logistics Game	Argusi BV
POLIS1	Noveleg evaluation tool	Polis

3.1.1 Optimization Models

LEAD KB includes the following optimisation model.

1. **ZLC1:** Optimizes inventory and distribution system(s) that consist of a distribution centre, multiple retailers and multiple products. The ZLC1 optimisation model considered budget constraints.
2. **ZLC2:** Modelled the cost-effectiveness of alternative distribution set-ups in improving the efficiency of fragmented freight flows. The model is based on logistics processes and takes into account receiver attributes and local supply chain configuration.
3. **ZLC4:** Modelled the problem of route choice and vehicle departure time scheduling for two fleets. Route choice is optimised to meet the customer demand for deliveries from distribution centres to the final customer. Coordination and time-synchronization of the operations of the two fleets are central elements. Achieving coordination and time-synchronization of both fleets is central for the optimisation model.
4. **ZLC5:** Developed there different mixed integer programming to find the location and numbers of two types of capacitated facilities, the sized of two different vehicle fleets and the related routes.

Each of the models had different optimization components based on their objectives. They all have some core optimization routine, such as the delivery network composition, the fleet management, inventory or delivery sequence (routing). Different sub-models were also included depending on the nature of the problem, such as a demand simulation, delivery network configuration or information share.

The central agent of the models was the Transport Service provider, as it is expected in the urban transport context. However, it is not necessarily the most important agent, since an important application of the optimization routines includes the inventory costs, where warehouses, shippers and shops are involved. The simultaneous optimization is not a surprise, though, since transport costs and delivery times affects the relationship between replenishment frequency and shipment size. Figure 3-1 shows the agents involved in the optimization modelling from the ML.

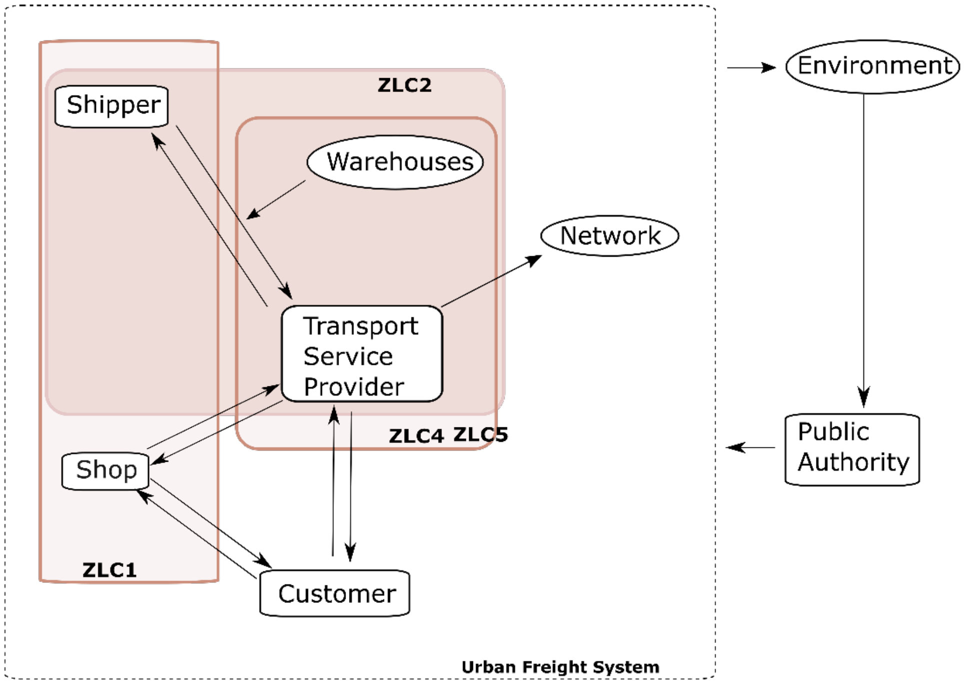

Figure 3-1 Optimization models

The main inputs needed by the optimization models were cost, demand, supply chain and transport service data and policy restrictions. Cost data consists basically of transport or storage data with different levels of details depending on the model. Demand data focus on the characteristics of the involved items, their replenishment rate and recipients.

The supply chain data consists of the geographical layout and performance of the delivery network. It contains information like the location and distances between stops, storage capacity and network speeds. The transport service data complements this, by providing information about the capacity and service time of the customers.

Finally, the policy constraints such as time windows or vehicle size/fuel restrictions are the last inputs needed. Optimization models are able to assess the impacts of these measures on individual supply chains and can be used as guidance of the behaviour of the agents involved.

The results from the optimization models provided can be categorized into 3 main categories: Cost, demand, logistics and supply chain. Costs are the main results of the optimization, in general being able to compute inventory or transport costs. Logistics show the flows, inventory policy (shipment size and frequency) and level of service. Finally, the geographical configuration of the supply chain can also be a valuable insight gained by optimization models.

3.1.2 Network Models

In the ML the following two network models are included:

1. **UPM3:** A microscopic and continuous traffic simulation package designed to handle large networks.
2. **SZE1:** Is a tour formation model that does analytical calculations of deliveries in various parts of the network under the constraint of delivery windows.

Although both models are network models, they differ substantially. UPM3 is a traffic allocation model using simulation via an open source software. It relies on 3 main submodules: 1) a traffic generation, 2) a distribution and 3) a traffic assignment. It mainly focuses on the interaction between the transport service providers and the network.

The SZE1 model analytically calculates the distances of round trips. It utilizes service, demand and distance information and generates distance and cost measurements, similar to those of a tour formation software (Paragon vehicle routing and scheduling system v 5.60). Even though it is not a traditional network model and does not generate individual flows, it does estimate similar KPIs to other routing models, so it is categorized as a network model. Figure 3-2 shows the agents involved in the network modelling from the ML.

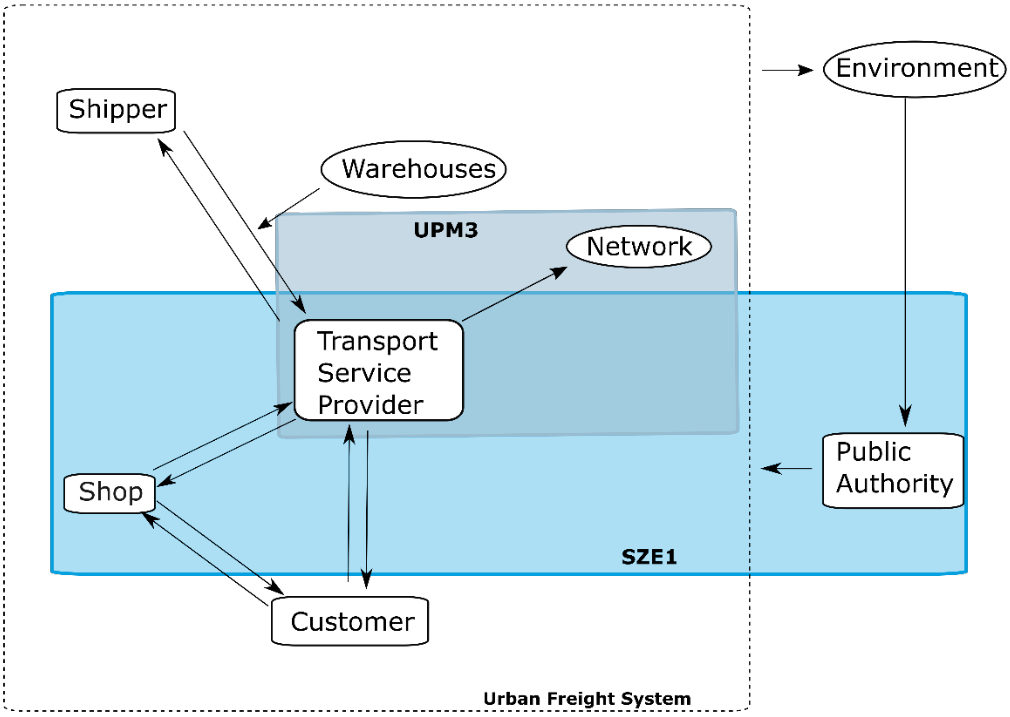

Figure 3-2 Network Models

3.1.3 Impact Assessment Models

The ML includes 5 impact assessment models:

1. **UPM1:** Is a Green House Gases (GHGs) emissions calculation model that provides a method for calculating the impact on local air quality and emissions of C.O., H.C., NOx, and particles. Traffic flow data combined with speed-related emission data is used to calculate emissions for the different road links.
2. **UPM2:** The methodology mixes the vehicle technical data and the vehicle activity data (vehicle-km) to obtain a total emission estimate.
3. **UPM4:** Is a handbook that provides an overview on the state-of-the-art methods on how to calculate the externalities in transport projects.
4. **UPM5:** Proposes a multicriteria analysis using multiple inputs to do an appraisal analysis of the sustainability of road projects via applying a 3-step process: identification of the criteria, weighting the criteria and evaluating the alternatives.
5. **ZLC3:** Applies Monte Carlo simulation techniques to assess the environmental benefits of mobile depots as micro platforms by estimating the reduction in GHG emissions attributable to the adoption of smaller, more agile last-mile delivery vehicles.
6. **POLIS1:** The model considers several inputs from the cities in order to estimate the impact of different policies.

The impact assessment models have as an objective to measure the impact of a policy. Some, such as UPM1, give a method to calculate the impacts given a certain state of the transport network. Others, like ZLC3, include their own simulations and assess the externalities of the different outputs. As a general rule, they rely on ponderations to convert physical outputs (such as number of vehicles and their speed) into a measurement of the externalities. The components of these models depend on which externalities they measure. The list includes: Accidents, air pollution, emissions, network (congestion) and wildlife habitat.

Except for POLIS1 that focuses on the decision maker (public authority), the rest of the models tend to assess the impact on the overall environment. The environment should be interpreted not only as emissions but it also takes into account social impacts of UFT. Figure 3-3 shows the agents involved in the impact assessment modelling from the ML.

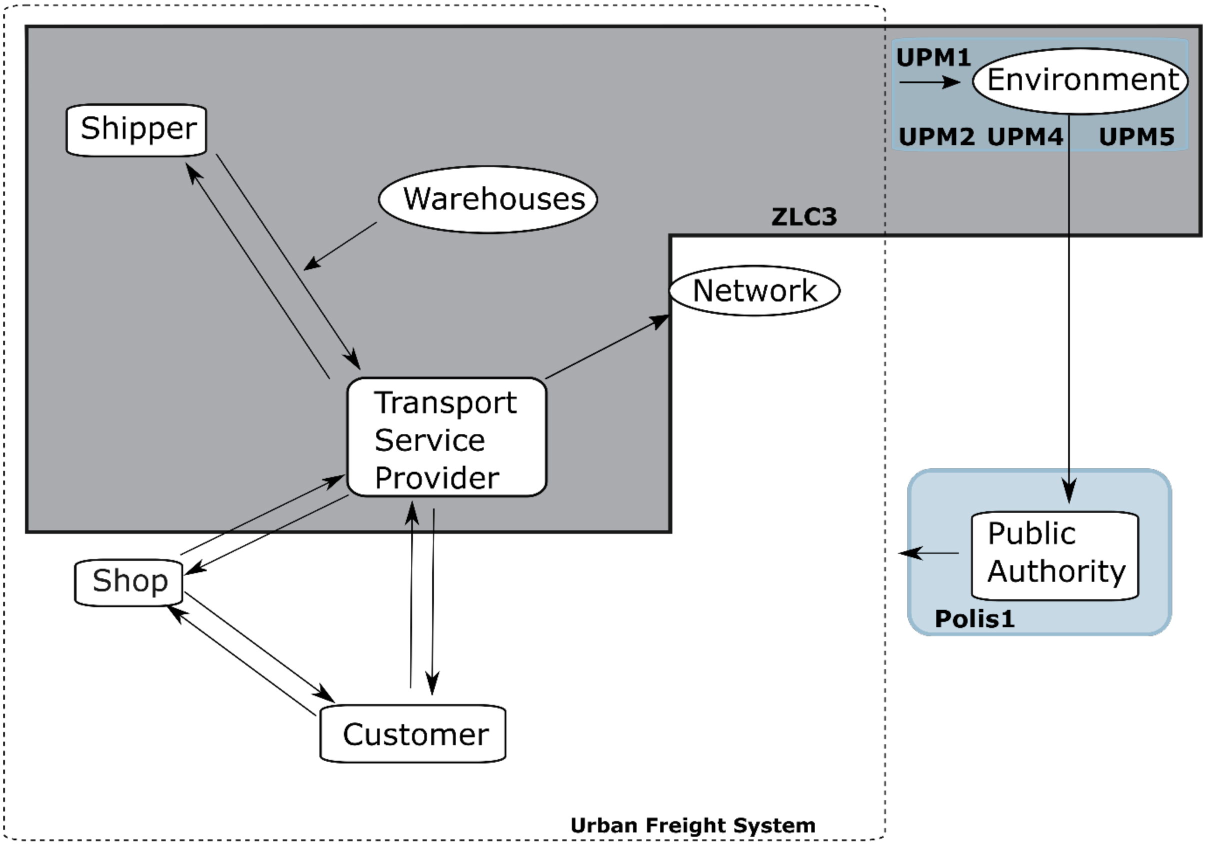

Figure 3-3 Impact Assessment Models

In order to run these models two basic inputs are needed. The first one is relative to the externalities, being these measured directly (accidents) or supplies for the estimation of them (traffic volume and speed). The second big category are the ponderations that convert the previous inputs into externalities or into a performance index. Some other inputs can be needed as well, such as market shares or cost data.

The results of the impact assessment models are basically measures of the externalities, such as GHG emissions, or some sort of index that condenses the performance of the system. The indexes can be specific of the model or other well-known indicators such as the Social Cost Benefit Analysis ratio (SCBA).

3.1.4 Stakeholder Acceptability Models

The ML includes 1 stakeholder acceptability model:

1. **MOLDE1:** This approach, based on the combination of Discrete Choice Modelling and Agent-Based Modelling, helps ex-ante evaluating any innovation in urban freight transport in terms of acceptance, adoption and reactions. It allows forecasting how stakeholders might behave should something new be introduced in the market, both from a public and private perspective.

MOLDE1 relies on an ABM interaction module in order to allow analysing motivations explaining behaviours and provide an ex-ante evaluation of new solution/policy acceptance. It allows both forecasting how stakeholders might behave should something new be introduced in the market as well as explaining the motivations underlying behaviours. This is also useful to stimulate an effective, well-informed and participated planning process. Their main inputs are preference of the agents, normally collected by SP surveys (see section 3.1.7 for data collection models). Figure 3-4 shows the agents involved the stakeholder acceptability model.

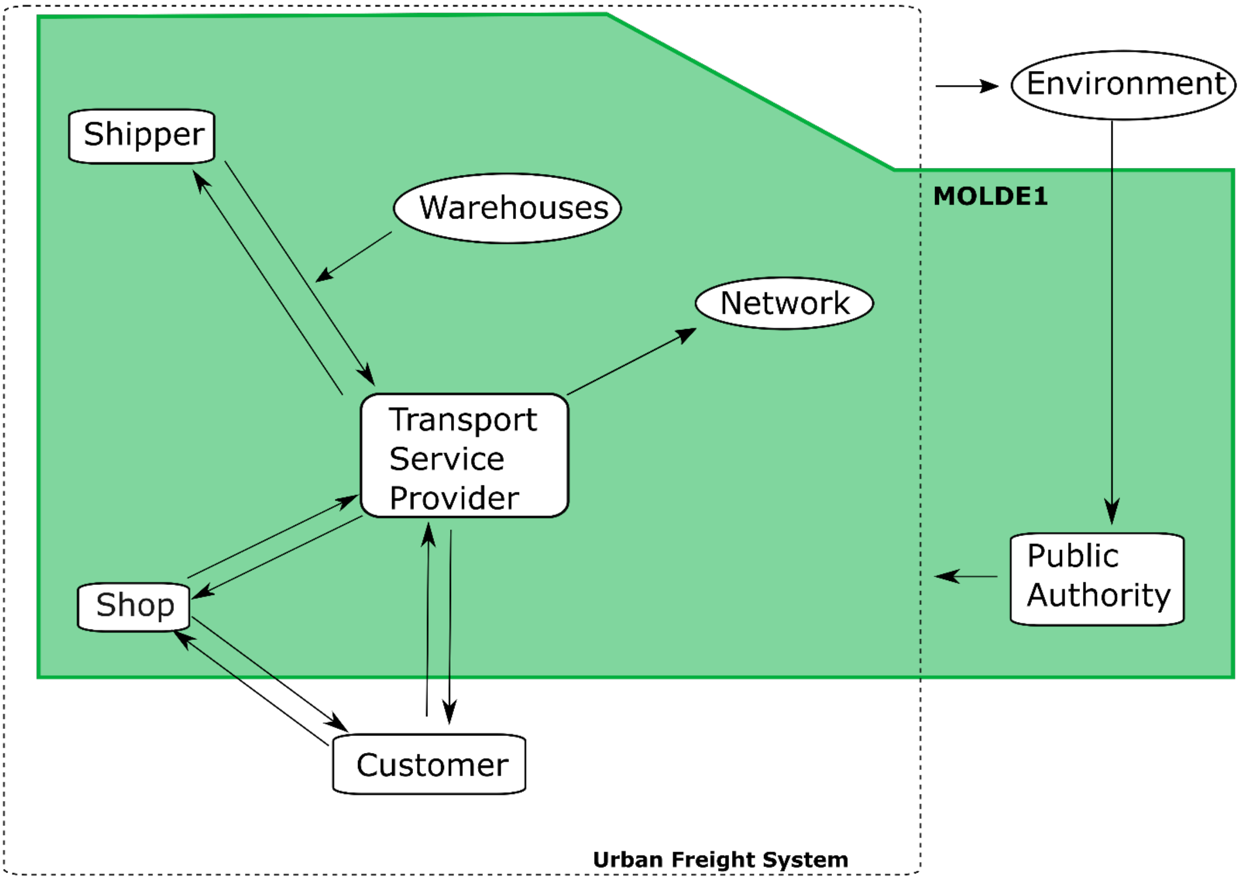

Figure 3-4 Stakeholder Acceptability Models

3.1.5 Agent Based Models

In this KB there were made available the following models:

1. **IRTX1:** MATSim is an agent-based transport simulation that allows to study the detailed interplay between travellers and freight vehicles during an average day, which allows to estimate the impact of policies and new transport solutions on the territory and the population.
2. **TUDELFT1:** MASS-GT is a multi-agent simulation model of the logistics decisions in the urban freight context. MASS-GT models urban freight demand in a long term and short-term tactical level.

ABMs rely on the simulation of the individual agents and their interactions in order to reach and equilibrium and aggregate their behaviour. Both models above have very different goals and thus very different components.

IRTX1 and TUDELFT1 have several modules interacting with each other. TUDELFT2 is a freight focused ABM with several freight specific modules, such as parcel and scheduling modules and a KPI measurement component.

IRTX1's modules consist of passenger generation and choices and allocation to the network to provide its results. Although it is a passenger model it has been included due to the importance of ABMs in the LEAD project and the need of a passenger flow model as an input for crowdshipping offer models. Figure 3-5 shows the agents involved in the ABMs from the ML.

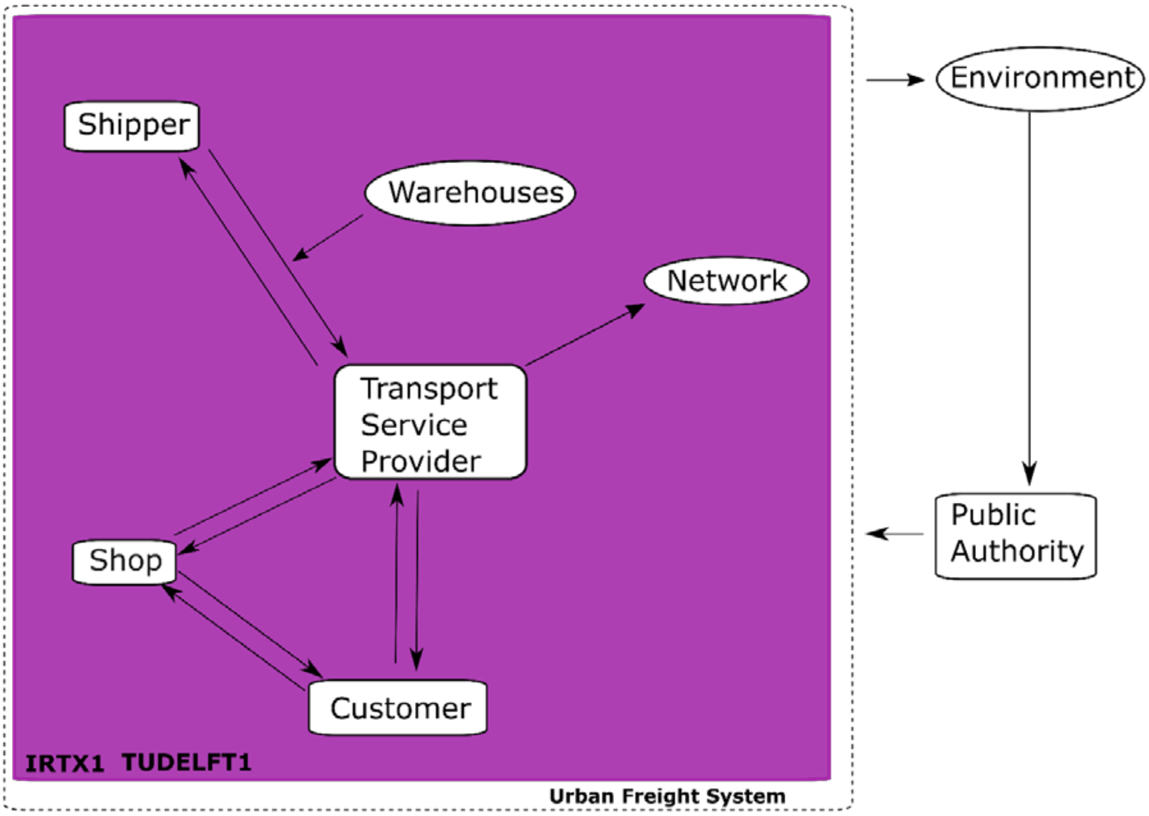

Figure 3-5 Agent Based Models

The basic component of the AMB is the behavioural nature. This implies that in the core of it some sort of preference data is needed, for policy or mode choices for example. For IRTX1 and TUDELFT1 additional information on the generation on passenger/parcels is needed, as well as network information.

As a result, IRTX1 and TUDELFT1 generate market shares and OD matrices, together with network flows. Additionally, the quantification of some externalities can be estimated with these values.

3.1.6 Demand Models

In this ML there were made available the following models:

1. **BKK1:** The model is a multimodal, macroscopic strategy transport model of Budapest. It represents the current situation and it can also be used for modelling future scenarios. The transport model enables to select and prioritise development suggestions, alternatives and technical versions within the project proposal during the decision-preparatory studies.
2. **IRTX2:** Creates synthetic populations based on open data with households, persons and daily activity chains to represent the daily mobility and activity patterns of regions and cities.
3. **TUDELFT2:** The model combines a demand model for crowdshipping services together with a willingness to be crowdshipper model in order to obtain an equilibrium price.

BKK1 relies on the traditional 4 step model to generate the demand for freight and passengers, with the traditional components of generation, distribution, modal choice and allocation to network. IRTX2 is a passenger tour generator, where a synthetic population is created and their destinations produced.

TUDELFT2 combines two choice models, one that estimates the transport service demand by the households and another that estimates the commuters' willingness to be crowdshipper. An independent module that generates the equilibrium makes the combination of the supply and demand models. Additionally, it relies from a passenger and freight OD generator.

Overall, these models can model all aspects and agents of the UFT. They model shipper, shop, customer and transport service and the assets involved, such as warehouses and road network. Figure 3-6 shows the agents involved in the demand models from the ML.

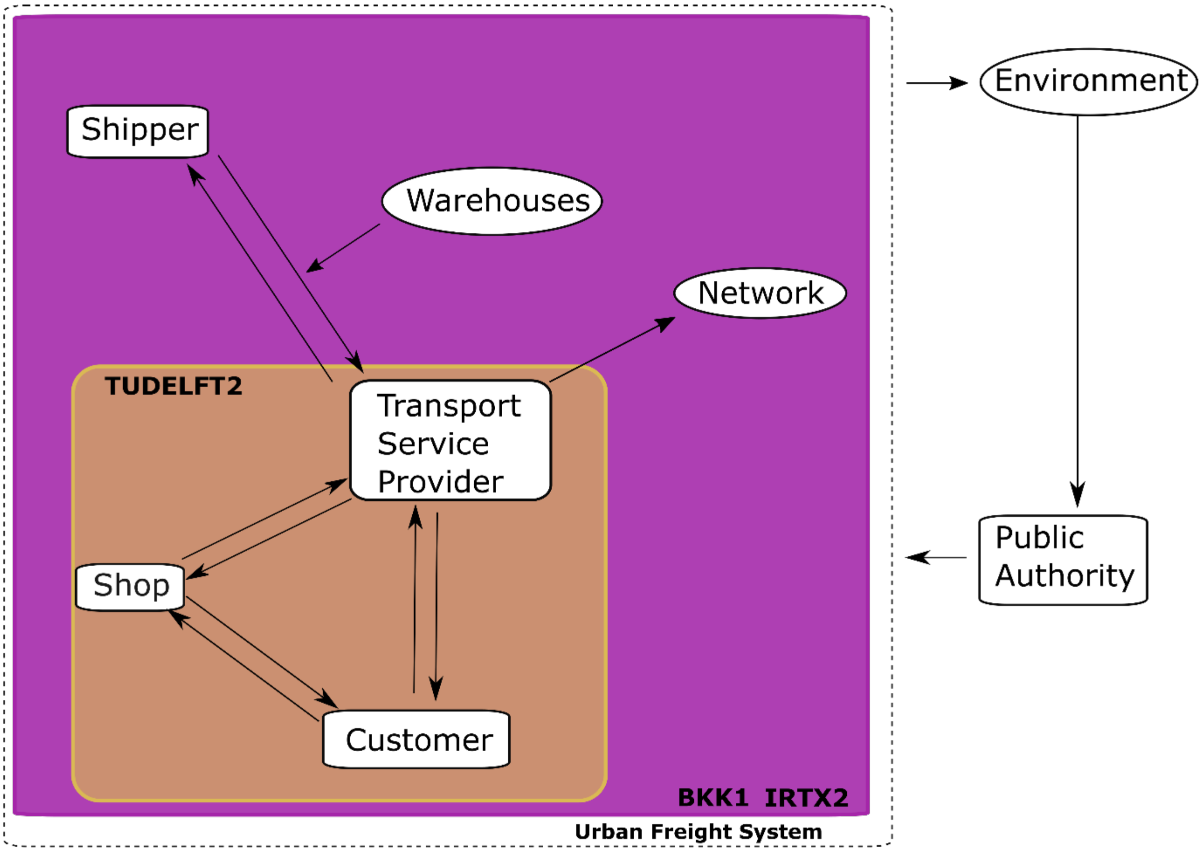

Figure 3-6 Demand Models

The inputs needed for the models range from already processed OD data to road and logistics network data. In the case of IRTX2 census and household data is needed for the population synthesiser.

The main results to be expected from these models are the modal split (passenger or freight), OD matrices and network loadings. Additionally, TUDELFT2 also provides equilibrium prices and profits for a crowdshipping service.

3.1.7 Data Collection

The ML also includes data collection models:

1. **MOLDE2:** Provides a modular, cost-efficient method to acquire stakeholder-specific behaviourally relevant data to be used for Stated Preference (SP) evaluation.
2. **ARGUSI1:** Is a design game that illustrates the trade-off between different KPI's in a realistic city environment. The players can implement their own scenarios and solutions and get direct feed-back on their decisions in terms of costs, emissions, kilometres and performance.
3. **ARGUSI2:** Proposes a city logistics game (board game, supported by simulation) with the perspective of different stakeholders. The game is played in the City of Innoville. The game is played on the game board and is supported with an interactive interface, trading-off Quality of life, Economy, Accessibility, and Health & Safety.

MOLDE2 proposes a SP data collection method that can be used to gather agent-specific preferences. Preference data need information about the attributes of the alternatives and have the possibility to obtain market shares and preference data. Models that rely on agent's preference, like TUDELFT1, TUDELFT2, IRTX1 and MOLDE1, use this kind of data.

ARGUSIi1 and ARGUSIi2 have a game-like settings that allow participants to understand the trade-offs involved in urban freight and the multi-agent dynamic of the urban logistics system. ARGUSIi1 and ARGUSIi2 are not data collection models *per se*, but can provide alternatives to generate data collection instances for the players when faced with trade-offs and decisions. Additionally, they have an educational potential to provide a more complete understanding of the urban freight setting.

The inputs needed for ARGUSIi1 and ARGUSIi2 models are network data, cost components of the freight system and externality data to categorize the urban system. As a result, they provide emissions approximations, cost data and service metrics.

3.2 Models

The detailed templates of all the models shared by the partners are in the Annex II. These templates have been modified in order to unify the terminology used across all the KB. A column was added for the subcomponents of the models, the inputs and outputs in order to show in the template to which category they belonged.

Additionally, Annex IV contains all the list of outputs of all the models with their categorization highlighting which of them were considered as KPIs by the partners. Annex V contains the list of inputs with the categories and subcategories.

4 Synthesis

4.1 Structure and components of Knowledge Base

The objective of the KB is to assist the LLs in identifying the models necessary to develop the DT and to serve as a reference for stakeholders when developing their modelling strategy. The KB aims to answer two fundamental questions for the LL:

- *How can the impact of the proposed measures be modelled by the DT?*
- *What inputs are needed for the evaluation of the measures?*

The first question is answered by relating the desired outputs and the measures to be implemented with the models. The second question is solved by relating the models with their inputs and outputs. Thus, the main components are the outputs, measures, inputs and models.

4.1.1 Outputs

The outputs can be broadly categorised into 7 groups: policy analysis, cost, demand, externality, network, logistic service data and logistical infrastructure. The groups are generated by grouping the outputs presented by the models included in the ML. Each of these groups of outputs can be of a descriptive nature (i.e. to be able to quantify the effect of something) or of design nature (i.e. to provide the most advantageous solution to a problem). From the categories, policy analysis, cost, demand and externality provide descriptive outputs, while logistic service and logistical infrastructure provide design outputs. Network can provide both types of outputs, routing optimizations provide design measures whereas simulation and network use metrics are descriptive.

The first group, **policy analysis**, correspond to the measurements for the effectiveness, impacts and acceptance of policies and actions, such as risk valuations and Social Cost Benefit Analysis (SCBA). In the model library this has been accomplished by Stakeholder Acceptability model (MOLDE1) and an impact assessment one (POLIS1).

Cost related outputs are important aids in the decision making of both private stakeholders and public authorities. The most important KPI is the total logistic costs incurred, either by individual firms or by the urban logistic system. Additional partial costs can also be considered, such as transport, investment, storage and operating costs. The main models that calculate these are impact assessment models (POLIS1, UPM4 and ZLC3) and optimization models (ZLC1, ZLC2, ZLC4 and ZLC5). ARGUSI1 and ARGUSI2 also estimate cost outputs as part of the game that simulates different configurations for the location of UCCs. The impact assessment models apply different approaches for cost estimations. POLIS1 operates at an aggregated level, providing overall project costs estimations; while ZLC3, includes operating costs in their objective functions and UPM4 internalizes externalities costs.

Demand outputs measure the flow of goods within the city. They can be expresses as OD matrices of commodities, both for parcels and regular shipments, or as a receiver's preferences and transport modes market shares. ABMs are models that allow to evaluate all these metrics by simulating the behaviour of the agents involved. In this group, TUDELFT1 presents the most detailed agent behaviour, while IRTX1 focuses on the network interaction of passengers and freight. MOLDE1 can provide mode market shares and insights on agent's decision process. Demand models, such as BKK1 and TUDELFT2, estimate demand outputs, such as OD matrices for the former and the demand for crowdshipping services for the latter. POLIS1, an impact assessment model, has as one of the outputs the propensity to shift towards more sustainable models. The last group refer to the data collection models from ARGUSIi1, that simulates the orders from the participants and MOLDE2 that prepares a Stated Preference survey in order to capture preferences of the agents, which is a crucial support to understand the behaviour of the agents and the policies needed to induce their change. IRTX2 provides potential customers for logistical solutions by generating households from census data. Finally, MOLDE1 and MOLDE2 provide Willingness to pay measurements that are used to weight time and other non-monetary effects of transport activities.

The **externality** category refers to the measurement of externalities of UFT. The main KPI here is the volume of emissions usually by Impact Assessment Models, such as UPM1, UPM2, UPM4 and UPM5, but are also estimated by TUDELFT1 (an ABM) and UPM3 (Network model). POLIS1 and UPM5 provide also an overall assessment of the environmental impacts of the policies. IRTX2 measures the impact population of different policies.

Network outputs are measurements of the state and use of the road network. These measures can be KPIs of different partners, such as travel distance (total or per vehicle type), travelled times, vehicle kilometres and transported tonnes, all of them outputs of descriptive nature. Additionally, descriptive measurements of network usage, travel times, travel distances, traffic flows and network load also belong to this category. Many models from different model types can obtain network outputs, such as ABMs (TUDELFT1), demand models (BKK1), optimization models (ZLC1, ZLC4 and ZLC5) and, of course, network models (UPM3). The approaches taken by all these models vary significantly. While ABMs rely on individual simulation to reproduce network loadings, demand and some network models rely on traditional traffic allocation techniques, such as all-or-nothing assignment. Optimization models outputs mostly focus in on identifying the best routes and estimate travel times and travel distances and are design outputs.

The **logistic service outputs** include measurement of the Level of Service (LoS) and service attributes of different alternatives (such as crowdshipping prices with TUDELFT2). In this category, optimization models (ZLC1, ZLC2, ZLC5 and the optimization subcomponents of ZLC3) provide LoS measures, like percentage of attended clients or unattended orders. SZE1 estimates distribution times. ARGUSIi1 also provides client coverage of the different UCCs and an overall metric for the company. TUDELFT1 simulates with an ABM the interaction between the city logistics agents and thus generate logistic service KPIs such as average loads per truck and service times.

Finally, **logistical infrastructure metrics** refers to the location of UCC and warehouses. The only model that addresses this is ZLC5 that obtains the optimal facility location for the city distribution problem.

4.1.2 Measures

The main actions analysed in the KB are either active measures taken by the stakeholders or passive by the overall economy or societal trends that models can potentially address. The 7 measures that have been defined are shorted from the ones that have the longest/term effect to ones with the shorter term. These are: consumer habits changes, land use shifts, road infrastructure development, logistic infrastructure, logistic management, transport market and infrastructure use. The categories were adapted from Tavasszy & de Jong (2014) to include different measures and temporal application scopes. The categories of externality measures and complementary have been added to include other models that do not address a particular issue but are relevant in the DT context.

Consumer preferences refer to changes in consumers preferences over time. The increase in e-commerce, or increasing consumer demand for services with a lower environmental impact are included in this category. Although some models can include trends as input, there was no model that could solely calculate consumer preference changes. However, SP data collection tools, such as the ones developed in MOLDE2, can help with the preferences data gathering and can provide the tools to model it.

Land use englobes the measures that change the land uses patters. These measures create new commercial production and residential areas and they modify the production and attraction of products. The models in the ML that can assess the impact of land use changes are TUDELFT1, BKK1, POLIS1 and UPM5. POLIS1 and UPM5 are general impact assessment methods that provide tools for evaluating the general impact of large interventions and MOLDE1 can assess the acceptance of the different agents of city logistics. BKK1 is a four-step model that includes land use to the attraction and generation steps. With a similar strategy, TUDELFT1 has subcomponents hat can assess the impact of changes in firm locations.

An important measure that public authority can introduce that can have important effects is the **construction of new transport network infrastructure**. The new infrastructure refers to new roads, development of bike lanes or of new electric charging infrastructure or expanding the capacity of existing ones. For a model to be able to evaluate these measures MOLDE1, POLIS1 and UPM5 are sensitive to the introduction of new infrastructure. UPM3, BKK1, IRTX1 and TUDELFT1 also have route assignment and mode choice modules that take into consideration the capacity of current or future roads.

Other infrastructure dedicated to logistics such as warehouses, UCCs, terminals and transhipment facilities can also be developed. **Logistics infrastructure** related decisions are medium term and affects the location and distribution of inventory, affect transport costs and influence the LoS. These decisions are related to the infrastructure location and capacity to the inventories. The effects of the development of logistics infrastructure is modelled by models that are sensitive to the location and capacity of warehouses, like optimization models (ZLC1 and ZLC5). TUDELFT1 (an ABM) that takes into consideration their location for the shipment tour formation. As for the new infrastructure and land use, UPM5, POLIS1 and MOLDE1 can also provide weighted scores for the new infrastructure.

The **logistic management** covers the different management strategies that can affect the supply side of the supply chain. Inventory policies, including shipment size and replenishment frequency fall in this category as well as vehicle load factors. Optimization models (ZLC1, ZLC2, ZLC4 and ZLC5) that aim to minimize inventory cost are particularly relevant because they can mix all the above policies. TUDELFT1 can simulate different strategies of vehicle size and shipment frequency by simulating each agent's strategies and MOLDE1 can provide insights on the interactions between the agents affected by the logistic management strategies.

The **transport market** related measures affect the choice of the transport service providers. It covers both the supply and demand side of the transport services. A new alternative, such as crowdshipping, price strategies or the client's response to changes in LoS are examples of these actions and that models covering this category might be able to address. It contrasts with the logistic management by focusing on the demand side. TUDELFT2 explicitly takes into consideration the introduction of a crowdshipping alternative with different prices and LoS, while TUDELFT1 can simulate new alternatives or change their attribute in their ABM to analyse their effects. MOLDE2 can provide valuable data with SP experiments.

Network infrastructure utilisation refer to the short-term operational decisions of deliveries. From the supply side they correspond to scheduling, network allocation and routing deliveries. For the demand side they could relate to receiving windows for shops. Public authorities can set restrictions on certain roads, such as weight restriction, emission restrictions and time restrictions that would fall in this category. In this category, most type of models can provide insights such as ABM (IRTX1 and TUDELFT1), Optimization (ZLC4 and ZLC5), demand (BKK1) and network models (SZE1 and UPM3).

The two additional categories correspond to **externalities** for models that focus only on the evaluation of externalities and **complementary models** that provide data collection or broader impact assessment tools that do not fit in other categories. The externality models of UPM1, UPM2 and UPM4 provide tools for weighting the impact in the environment. The complementary models are ARGUSIi1 and ARGUSIi2 that provide a game-like setting to simulate urban freight, MOLDE2 for preference data collection, IRTX2 that simulates households, POLIS1 and UPM5 that provide a general impact assessment tools.

4.1.3 Output-measure relationship

The question of how can do objectives of the LL can be represented in a DT can be answered by connecting the desired measures with the models that can provide the KPIs needed. This means that the models have to be sensitive to the actions proposed and provide the desired outputs to the participants of the Living Labs. This relationship is summarised in table 4-1, where the models that can potentially address a particular combination of outputs and measures can be obtained. It is worth noting that the appearance of a model in a cell, or how full the cell is does not automatically mean how effective the model is for addressing the issue, but an indication on what models are available in the ML to investigate it further to see if it is fit for the LL purpose.

Table 4-1 Relationship between measure and Output-category

Type	Descriptive					Design		
	Policy analysis	**Cost**	**Demand**	**Externality**	**Network**	**Logistical service**	**Logistical infrastructure**	**External to Freight**
Consumer preferences			MOLDE 2					
Land use	MOLDE 1, POLIS1	POLIS 1	TUDelft 1, BKK1, POLIS1, MOLDE 1	UPM5, MOLDE 1, POLIS1, TUDelft 1	TUDelft 1, BKK 1	TUDelft 1		
Network infrastructure construction	MOLDE 1, POLIS1	POLIS 1	TUDelft 1, BKK1, POLIS1, MOLDE 1, IRTX1	UPM5, MOLDE 1, POLIS1, TUDelft 1, UPM3	TUDelft 1, BKK 1, UPM3, IRTX 1	TUDelft 1		
Logistic infrastructure	MOLDE 1, POLIS1	POLIS 1	TUDelft 1, POLIS1, MOLDE 1	UPM5, MOLDE 1, POLIS1, TUDelft 1	TUDelft 1	ZLC1, ZLC5, TUDelft 1		
Logistics management	MOLDE 1	ZLC1, ZLC2, ZLC5, ZLC4	TUDelft 1	TUDelft 1	TUDelft 1, ZLC4, ZLC1, ZLC5	TUDelft 1, ZLC4, ZLC1, ZLC5		
Transport market	MOLDE 1		TUDelft 1, TUDelft 2, BKK1, MOLDE 2, MOLDE 1	TUDelft 1, MOLDE 1	TUDelft 1, BKK 1	TUDelft 2, TUDelft 1		
Infrastructure Use	MOLDE 1	SZE1, ZLC4, ZLC5, UPM 4	MOLDE 1, IRTX1, TUDelft 1, BKK1	UPM3, UPM5, MOLDE 1, TUDelft 1	ZLC4, ZLC5, UPM3, BKK 1, TUDelft 1, IRTX 1	ZLC5, SZE1, TUDelft 1, ZLC4	ZLC5	
Externality analysis				UPM1, UPM2, UPM4				
Complementary models	MOLDE 1	Argus 2, Argus 1	MOLDE 2, IRTX2, Argus1, MOLDE 1	Argus1, MOLDE 1, IRTX2		ZLC3, Argus1		IRTX2, Argus 2

Optimization | Network | Impact assessment | ABMs | Demand | Data collection | Stakeholder acceptability

4.1.4 Inputs

The second question that the KB aims to answer relate to the inputs required to obtain the desired outputs from specific models. Inputs are classified in 8 main categories: Cost data, demand data, external to freight, externalities, network data, logistics infrastructure data, logistics service and supply chain related data. The categories have been selected by categorizing the data from the ML.

Cost inputs are different data related to the different cost components of urban logistics. Even though there are different particular aspects that each model uses, the cost data has been separated into five subcategories: cost structure, transport cost, infrastructure cost, storage cost and labour costs. **Demand data** refer to the attitudes, preferences and characteristics of clients. This category can be decomposed into preference data, product demand, logistic service demand and geographical location of customers.

Elements that are not strictly within the boundaries of city logistics affect can affect the models. In some models, passenger transport has an effect (for example in network loading) or general contextual information about the city is needed. **External to freight** includes population data, passenger trip data and other contextual information (like land use or economic activity data).

The measurements of the impacts of UFT fall into the **externality data** category, where measurement of the effect of the UFT in the environment and the society are measured such as GHG emissions and accidents. Additionally, this category includes inputs for estimating externalities, such as fuel consumption and the monetary value of emissions and travel time.

Models that estimate routing or have a component that is sensitive to the structure of the road network require transport network related data. This category has two broad sub items. The first one is network structure that refer to the geographical disposition of the network and consist of arch and nodes. The second category are network LoS inputs, such as travel times (or speeds), traffic flows and network restrictions.

The last 3 inputs categories refer to city logistics. The first one, **supply chain,** contemplate the configuration of the supply chain, that is the agents' relationship and the logistic market (attributes of the alternatives within the transport service providers). The second category refers the **logistical service**, where information about shipments, their frequency and fleets are included. Finally, **logistical infrastructure** involves the geographical location and capacity of the warehouses and UCCs of the system.

Table 4.2 shows the simplified relationships between models and their inputs and outputs, just considering the main category of inputs. The table allow not only to analyse the inputs of the model that is being considered due to the analysis from table 4.1, but it also can map which models can provide the inputs needed. Even when the exact variable is not estimated, it might imply that the model can be adapted to suit the LL needs. The complete version of this table, including the subcategories within the inputs, is located in Annex III. Annex IV has the complete list of outputs and their categories and Annex V has the complete list of inputs and their categories.

Table 4-2 Input-Output relationship

		ZLC1	ZLC2	ZLC4	ZLC5	UPM3	SZE1	UPM1	UPM2	UPM4	UPM5	POLIS1	ZLC3	MOLDE1	IRTX1	TUDELFT1	BKK1	IRTX2	TUDELFT2	ARGUSI1	ARGUSI2	MOLDE2
Input	Cost Data	X	X								X	X	X							X		
	Demand data	X	X	X	X		X						X	X	X	X			X			
	External to Freight		X						X		X	X			X	X	X	X	X		X	X
	Externalities data							X	X	X	X	X	X									
	Supply chain											X		X								X
	Logistical infrastructure		X	X	X											X	X			X		
	Logistical service		X	X	X		X						X			X			X			
	Network		X	X		X		X	X	X	X		X		X	X				X		
Output	Cost Data	X	X	X	X		X			X		X	X							X	X	
	Demand data											X		X	X	X	X	X	X	X		X
	External to Freight																	X			X	
	Externality					X		X	X	X	X	X	X	X		X		X		X		
	Logistical infrastructure				X																	
	Logistical service	X		X			X						X			X			X	X		
	Network Data	X			X	X									X	X	X					
	Policy											X		X								

Optimization	Network	Impact assessment	ABMs	Demand	Data collection	Stakeholder acceptability

4.1.5 Model Library

The ML is the collection of models that are available to allow the LLs to mount, calibrate and execute the DT. The most important information of the model is incorporated in the template, where the model type, modelling approach, submodels, inputs and outputs are detailed.

The first step to add a model to the KB is to fill the template so it can be included in the ML. From the template, information regarding the model type, agents modelled, inputs and outputs are extracted and the type of measures that they can address. With this information Table 4-1 and 4-2 are updated so that the models can be used by the LLs.

In Annex II the filled templates of the models made available within the consortium of LEAD (with some changes to make them compatible and traceable). It is worth highlighting that the ML compiled in this task is not the LEAD DT library, but a reference ML with the objective to obtain the models that are available by the project partners.

4.1.6 Use of the Knowledge Base

The use of the KB relies on the use of the relationships of outcomes, measures and models and the relationships between inputs, outputs and models (Table 4-1 and Table 4-2). The user of the KB wants to test what will be the impact of a measure or a set of measures in a city and/or stakeholders would apply the LL for the achievement of specific goals such as sustainability or cost reductions, quantified in KPIs. In this case the user knowing which outputs need to be measured via the KB identifies the adequate models that can provide the necessary output.

Figure 4-1 represent how the KB can be used. In the first step, the LL stakeholders, after agreeing which measure, policy or common objective they would like to test, apply the KB. Then the KB is checked to identify if one or a set of models can be used to help the decision making of the LL. By entering the component of the KB that relates measures to models outputs, namely table 4-1 with these, the user can identify the available models.

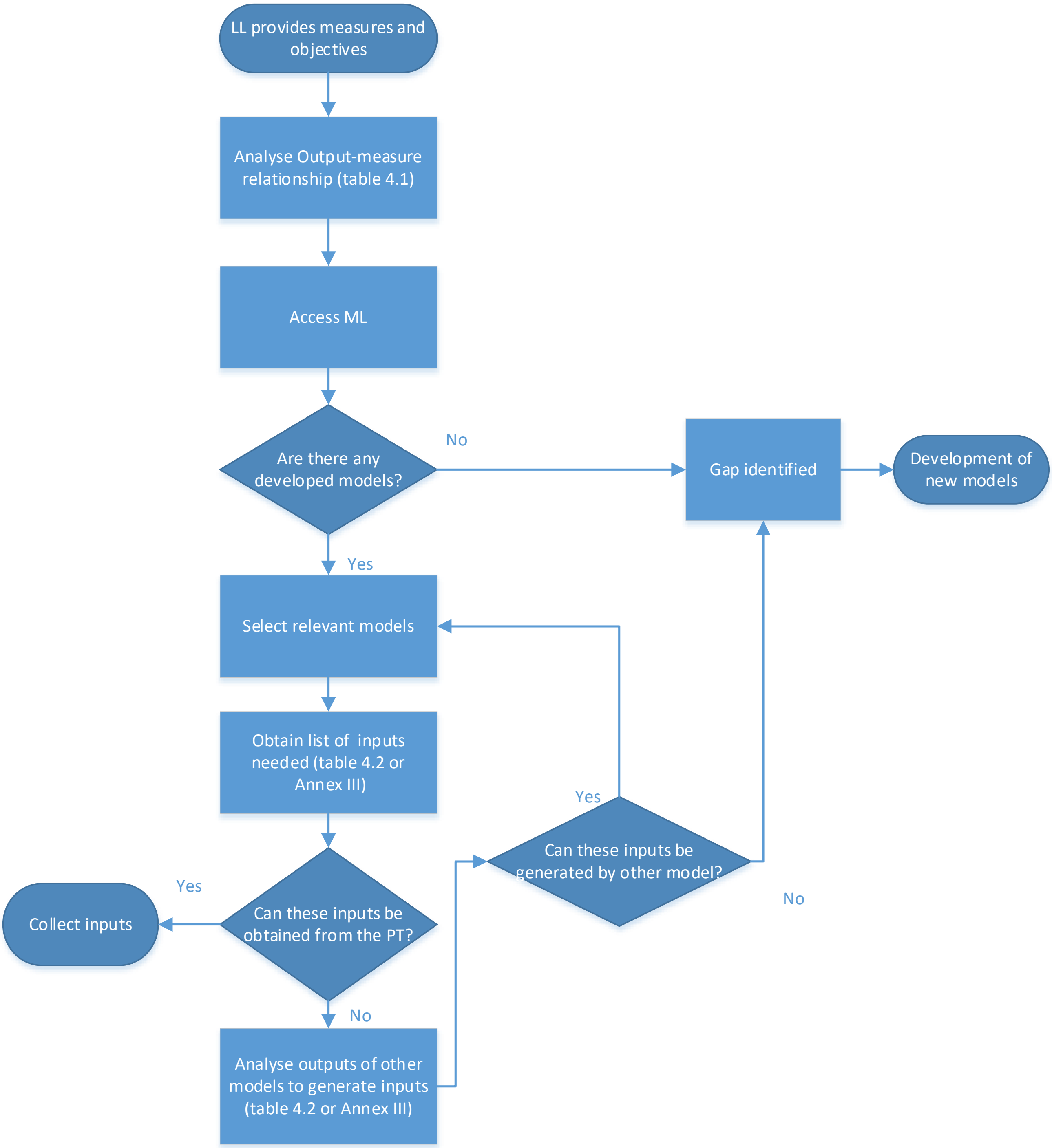

Figure 4-1: Model selection using the Knowledge Base

Once the suitable model is selected, then the second component of the KB (table 4-2 or the more complete version in Annex III) can be used. This component identified which are the necessary inputs for the models. By entering the table with the main model, the user can identify which other outputs can be estimated and which inputs are needed. With the inputs identified, the users can decide whether they can measure them directly or need an auxiliary model. If the latter option is needed, table 4-2 can be used to recognise the models that generate that specific output and which new inputs the model needs. This last step can be repeated until the inputs can be obtained directly from exogenous sources (like sensors, surveys, census data, etc.). If in any case there are no models that are relevant for the LL, the development of new ones is needed.

For example, in the case where a LL that wants to find out the effect of introducing a new delivery method, such as crowdshipping and wants to know its effect in the demand for the new service, its effect in the network performance and what externalities it might create. Using the first component of the KB that relates desired measure to the outputs that can evaluate them, namely table 4-1, the LL can identify that that the following models:

1. TUDELFT1 and BKK1 can analyse the transport market and provide outputs related to the network;
2. TUDELFT1, BKK1, TUDELFT2, MOLDE1 and MOLDE2 can analyse the transport market and provide demand outputs and;
3. TUDELFT1 can provide emission related outputs.

Once this “menu” of models has been identified, the LL proceeds to select which of these are the most suitable for the case by analysing the complete templates. TUDELFT1 is an ABM that considers all the KPIs necessary for the LL, so it makes it an intuitive choice. BKK1 is a 4-step model and it is considered too aggregated for this particular case. TUDELFT2 is a demand model that can replicate the decision of a passenger to offer crowdshipping services and of a consumer to choose it and can potentially be adapted to an ABM. MOLDE1 can provide ex-ante acceptance metrics and preferences from the crowdshippers and the consumers. MOLDE2 provides preference data for the choices of consumers, which can be used in MOLDE1, TUDELFT1 and TUDELFT2. For these reasons, the LL will use TUDEFLT1, TUDELFT2 and MOLDE2.

The LL has the following information available: network and statistical data. The next step is to identify which data are necessary and which data are available. From table 4-2 (and more detailed in Annex III) it can be seen that TUDEFLT1 requires preference data, product demand data, passenger trips, logistic market (transport alternatives) data and shipment sizes. Most of this information can be obtained from statistical data (like the Central Bureau of Statistics) and municipality network data, except for preference data and information on the crowdshipping service itself. MOLDE2 can generate agent’s preferences and TUDELFT2 can generate the information required about the crowdshipping service. MOLDE1 also needs preference data from MOLDE2 and the relationships between the agents, which is given by the LL.

Further, MODLDE2 only needs data on the other transport alternatives, covered by the TUDELFT1 inputs. TUDELFT2 needs individual passenger trips in order to generate the crowdshipping offer and be included in an ABM. From table 4-2 it can be seen that IRTX2 offers a population synthesizer that generates this information using census information.

As a conclusion of the use of the KB, this LL will apply the models:

1. TUDELFT1, will simulate the network and the new service.
2. TUDELFT2, will develop the demand and the behaviour of the crowdshipping agents to add in TUDELFT1.

3. MOLDE1, will produce stakeholder acceptability metrics and provide with agents' preferences to TUDELFT1 and TUDELFT2.
4. MOLDE2 will be applied for the data collection of data for MOLDE1, TUDELFT1 and TUDELFT2.
5. IRTX2 to do generate the households' OD matrix.

The information needed comes from network data from the municipality and from statistical data. At this stage of the project, the LL would have to do the customizations necessary to adapt the models to the DT. In future stages, this adaptation would be not entirely necessary because the DT ML would be made in a unified framework and more compatible.

4.2 Coverage of the reference Model Library

The 21 models available in the reference model library cover the majority aspects of the city logistic system. The most covered outputs of the models were externalities, demand and costs. Volume (and cost) of GHG emissions, number and volume of shipment tours, modal split, inventory, distribution and total costs are the most relevant impacts measured by the models and reflect the most important outputs of city freight, especially because they provide an overview of the urban freight system.

A large disparity can be seen in the outputs obtained in the logistics areas. While there are several models that obtain measurements of logistics service, including ABMs, optimization and demand models, there is only one model that focuses on the optimal location of UCCs and warehouses. There is an interaction between the two, though. In some of the optimization models, a series of KPIs regarding location and size of inventories in different warehouses is estimated, but they do not address the warehouse location problem.

Network congestion is arguably one of the most major impacts of urban freight. However, the models in the ML do not adequately represent this. Only one of the four models that allocate traffic to the network focuses mainly on calculating network LoS by explicitly identifying possible congestion due to UFT, while the other three perform traffic allocation as auxiliary models.

Only two dedicated policy appraisal models are included in the ML. These 2 models provide complementary results as one deals with the agents' acceptance of a policy while the other focuses on weighting the different effects of the implemented policies.

As it is for the measures' coverage of the KB and ML, it can be seen that all the relevant actions are covered in certain degree. There is, however, a lower number of models that address long term actions compared to the shorter term ones.

A few models can potentially address the strategic level of policies, such as changes in land use or the development of new large infrastructure projects. The models that consider land uses are broad rely on relatively aggregate data such as average trip generation or firm location. A lack of detailed land use models is a weakness of the current ML. Roads and warehouses have a more direct impact on the freight system and routing, so the assumptions made to generate the model are more reliable.

Tactical decisions, such as inventory policies, fleet utilization, shipment frequency and transport provider choice are represented in the ML. These measures are included in the transport market and logistics management categories, are assessed by ABMs and demand models that focus on agent's choices and optimization models that identify possible inventory networks via logistics cost minimisation.

Although fleet use models and vehicle routing models are being dealt with, they are present in the ML as subcomponents of some optimization models. This means that in order to address situations where this represents the core objective of the model, such as testing new modes technologies, the current ML may be insufficient to effectively model them.

The operational decisions, such as vehicle routing and scheduling and traffic allocation are included in the infrastructure use category. The ML contains are satisfactory amount of models from ABMS to traffic allocation model that focus in these operational decisions.

The input needed for the models in the KB are varied in 8 categories and 22 sub-categories. Fortunately the majority of the data requirements are easy to fulfil. Cost, demographics and road network data tend to be readily available for the LL stakeholders. Nevertheless, disaggregate data on shipper, consumer and shop preferences are not easily available. The ML however, provides data collection provides data collection tools.

In relation with the agents, it can be seen that the available models explicitly cover all the agents engaged in UFT (Figure 2-2). The agent most frequently represented is the transport service provider, who plays a central role in the urban logistic system. Shippers and consumers are also represented and can be used for identifying the demand for new freight transport services. Only 2 models that address policy making and planning, making public authorities underrepresented.

The biggest advantage of the ABMs that they can model the interaction between the various agents. The ML also include a passenger ABM which can be useful in the future for modelling passenger and freight interaction in the transport network, but it is not integrated to the freight ABM. In order to model this interaction, it is crucial to first identify the demand and supply for UFT and its interaction with passenger transport. The integration between passenger and freight goes beyond the interaction in the road network that it is covered in the ML, but it is also related to the consumer behaviour of households. For example, a larger proportion of home deliveries and the boom of e-commerce will reduce shopping trips and increase the direct shipper-customer interaction.

A weakness of the reference ML lies in the absence of network models that solely focus in traffic allocation. There is only one model that focuses exclusively on the assignment to the network and it is not specific to freight. The ABMs include some network assignment, but only one of them (TUDELFT1) includes a route choice and shipment scheduling module. The other network model provides only analytical calculations, and it is not useful to obtain network flow data. This shortcoming will make it difficult measuring network related KPIs, and also identify the UFT externalities especially the ones related to GHG emissions.

Another gap in the ML is the lack of models that can address asset sharing, which is at the core of the Physical Internet (PI). There are no models that address this specific issue and the current optimization models available are not created to minimize the cost considering the option of external inventory location. The use of PI models could potentially become an issue that can be overcome with ad-hoc models for the LL and with the collaboration with other European project that have advanced in the implementation of PI models, such as ICONECT. Task 4.2 has the objective of generating the liaison with other projects, and the contact with ICONECT has already started.

4.3 Suitability for digital twin development

Models identifying the demand and the supply for UFT stand at the core of DTs. The quality of the representation of the PT rely on the ability of models to represent the physical environment. Naturally, there is not one stand-alone model that can recreate all of present (and future) aspects of urban logistics. This means that multiple interactive and interconnected models are required in order to recreate the relevant aspects of DT, which are case-specific.

As described in section 2.1, DT has three basic components: the Digital environment, the physical environment and the bi-directional data connections. The suitability of a model to be included in the DT depends on its ability to represent as accurately as possible decisions, interactions and issues faced in the PT.

The agents (as the virtual entities), their interactions, and the UFT related processes compose the digital environment in the case of urban logistics. The models included so far in the ML provide representation for the main actors, decisions and interactions in urban logistics.

The ABMs are the broadest models of the ML. Although there is some overlapping between the models regarding how the road network is used, there is a lot of complementarity between them. TUDELFT1 provides a more detailed process for the freight delivery process while IRTX1 provides a more detailed passenger generation modules.

Two of the demand models (IRTX2 and TUDELFT2) provide a more detailed understanding of some components of the ABMs. IRTX2 is a household simulation to provide input for the travelling generation component of IRTX1 and TUDELFT2 provides the interaction of commute with the offer of crowdshippers. BKK1, the other demand model, is a four-step model, so it can work as a replacement of the AMBs where a more aggregated approach is needed.

The optimization models available can provide the DT with the tools to simulate the inventory policies (ZLC1 and ZLC2), route choice (ZLC4), vehicles departure time (ZLC4) and the location of distribution centres (ZLC5). They can become useful to provide details on the behaviour of individual firms in a larger ABM context and could be integrated within that framework.

Regarding the network models, other models cover both UPM3 and SZE1. However, they can still have a role in the application of DTs. UPM3 can provide a more detailed and more tools to the assignment module of BKK1 for example. SZE1 is an analytical model to estimate transport distances, and as such it can be used to estimate transport cost to generate transport attributes (such as cost or time) more quickly than by simulation.

Within the impact assessment models there are several overlaps identified, especially in the measurement of emissions (UPM1, UPM2, and UPM4). However, there are other models (UPM5 and POLIS1) that are broader and provide consolidated KPIs for the LLs decision makers to choose the intended measures. Moreover, these models provide outputs that can later be used to calibrate the DT once the measure is implemented. It is also worth noting the stakeholder acceptability model

(MOLDE1) to provide ex-ante insights to the LLs regarding the attitudes of the stakeholders before applying a policy.

However, there are some relevant policies that cannot be simulated with the current models. Changes of consumers' preferences is a valid example. Agents might change their preferences due to marketing or external shocks (e.g. Covid-19 in e-commerce). The only available model that can potentially capture these trends are SP data collections (MOLDE2), which have weaknesses regarding hypothetical biases.

There is a difference in availability of modelling options depending on the time horizon of the impacts. On one hand, a limited number of tools that perform complex simulations and model estimations can assess strategic measures, such as land use changes and development of new road or logistic infrastructure. On the other hand, there is a wider number of models that can assess short term and more operational measures, such as logistical service choice or infrastructure use. Optimization and network models, as well as simulation and ABMs are available to generate the digital environment.

There is a lack of unified framework that combines all models in DT. The dynamic and complex UFT makes it even more challenging to create a unified approach for the DT. The interactions among agents and the speed of trends change demand flexible and adaptive models. One barrier to achieve effective DT is the unification and standardization of the communication between the models. This way, it can evolve from a collection of models to a comprehensive tool that can emulate the behaviour of city logistics.

The models in the ML lack integration and connectivity between each other due to the absence of unified framework. The lack of integration is seen by the discrepancies of inputs and outputs, where models generate similar KPIs or use similar inputs, but not the same ones. This poses the challenge to make the models compatible and modular. Yet, all the models are generic and adaptable enough to be modified into the common framework once the inputs and outputs are harmonized.

The KPI generation is the communication of the results of the DT to the decision maker or the calibration stage. The KB provides a broad coverage of the KPI's main categories. There is a lack of models for the location of UCCs and warehouses, though. This can also affect the possibility of simulating the effects of sharing logistical infrastructure between different supply chains.

The data connections are the bidirectional communications between the DT and the PT. They are not only the measurements from the city, but also description of the policy interventions from the decision makers. The only data collection model that can be implemented is the SP data to study agent's preferences.

All the models require pre-processed or semi processed inputs, such as census data. In this scenario, the models have internalized the processing of the data. However, there are other models that rely on pre-processed inputs, such as OD matrices. Currently there is no tool available that can directly process raw input and transform it into the data form needed for the model. This *data ingestion* models and processes still have to be set up, but the similar characteristics of the inputs is expected to make it easier possibility to generate these solutions.

Another aspect that is relevant for the development of DT is the calibration phase. This calibration phase occurs when the state of the variables in the DT and the PT are compared and updates are executed. Not only data ingestion solutions have to be developed to measure the current state of the relevant variables in the urban context, but also calibration procedures within the models have to be implemented. Except for the ABMs and UPM3's network model, there are not calibration tools readily available.

The other relevant element of twinning is the communication from the DT to the PT. There can be two main routes from this, either the DT makes the decision "by itself" or an external decision maker (such as the LL) takes an action. The former way is an automatic decision support system that can simulate different scenarios and can act accordingly. This type of synchronization is more common for short loops, such as short-term route optimization. The current ML can provide different measurements in order to assist the decision support and offers tools for weighting different competing alternative actions.

The second communication from DT to PT is through a human decision. This case tends to be at a long-term scale, such as tactical or strategic planning. The ML and the KB provide a set of tools that can provide the decision makers with a set of KPIs and different weighting and categorizing of alternatives.

5 Conclusions and Recommendations

The LEAD project aims to develop low emission logistic operations by the implementation of DTs. To do so, LLs are created in order to generate valuable low emission policies and to generate the first versions of the DT. In order to assist LEAD or future LLs to implement DT, a KB based on a reference ML is generated. The aim of this deliverable is to describe the structure of the KB and the reference ML of models provided by the LEAD project partners. A KB is the systematization of the information from the ML in order to assist LLs in the DT design. The information to be obtained from the KB can be summarized into two questions that provide structure to the KB: *How can the impact of the proposed measures be evaluated by the DT?* and *What inputs are needed for the evaluation of the measures?*

The KB relates the outputs, inputs, measures and models. LLs identify the measures they would like to test, and the KB applied the models in the ML, synthesizes data and models and identifies KPIs. Once the core modelling resources have been identified, it is necessary to find the data inputs required in order to calibrate and run the models. With these inputs, the LL can analyse whether they can measure the value directly from the physical environment or identify further models (with their own inputs) that can provide as an output the necessary parameters.

Overall, the models in the reference ML provide a satisfactory coverage of the UFT. All of the agents and assets described in the conceptual model of UF are included, as are most of the actions and outputs that can be used from LLs.

The reference ML consists of 21 different models combined into 7 model groups depending on their method. The first one is optimization models (4 models), which aim to minimize a cost-related objective function. The second group (2 models) are network models that aim to solve the routing and traffic allocation to the road network. These two groups belong to the city logistics models.

Impact assessment models (6 models) are the third group. They focus on the measurement of the impacts of policies/infrastructure, being those a value of their externalities, or provide a weighted score or assess their risk. The next group are stakeholder acceptability (1 model) that analyse the motivations of each agent and provide their overall acceptability of a policy. The fifth group are the Agent Based Models (2 models). ABMs simulate the behaviour of each individual agent and their interactions and are at the core of the DT modelling effort.

The sixth group are the demand models (3 models), which focus on the preferences of the decision makers. Finally, data collection models (3 models) concentrate on the acquisition of preference data by creating a stated preference experiment or by gamification.

There are, however, some weaknesses of the reference ML as presented. The ML lacks specific models to deal with consumer habits and choices as well as detailed land use and freight generation models and fleet management models (fleet optimization and vehicle routing) are only superficially tackled. Additionally, Physical Internet related methods are not included, and network models has a shortage of variety and specific freight applications.

Moreover, few data collection models were available, and several other models use pre-processed inputs in order to run. The raw data collection and processing is crucial in order to have a successful twinning process of the DT. This will be taken care further in the project, as Task 2.4 deals with the data ingestion solutions.

Since the ML presented in this deliverable is a reference ML made from the models that were available for the partners, there are some lack of compatibility regarding the inputs and outputs that each model generate. All of these models that were included were created to fulfil their own particular purpose, meaning that there is a lack of common framework and compatibilities in order to combine the models in their present form.

The results of this deliverable will be used as inputs to generate the Digital Twin Models Library in Task 2.2. The reference ML will be use as a starting point for the building blocks of the DT ML. In Task 2.2 the ML will be enhanced with more models. The new models will address the needs of the LLs and their corresponding DTs. The results from using the KB with the needs of the LLs, that is the models and inputs needed, are also elements needed to generate the data flows and identify data ingestion. These two processes are subtasks within the creation of the solution architecture in Task 2.1. The impact assessment models collected in the ML will also be of value for Task 3.8, where the general impact assessment framework of the project is developed.

6 Bibliography

Anand, N., van Duin, R., & Tavasszy, L. (2014). Ontology-based multi-agent system for urban freight transportation. *International Journal of Urban Sciences*, *18*(2), 133–153. https://doi.org/10.1080/12265934.2014.920696

Boschert, S., & Rosen, R. (2019). Digital Twin - The simulation aspect. In *Mechatronic Futures: Challenges and Solutions for Mechatronic Systems and Their Designers*.

DHL. (2019). *Digital Twins in Logistics*. https://www.logistics.dhl/content/dam/dhl/global/core/documents/pdf/glo-core-digital-twins-in-logistics.pdf?j=330813&sfmc_sub=108058070&l=59_HTML&u=20126700&mid=7275327&jb=69

Grieves, M. (2014). Digital Twin : Manufacturing Excellence through Virtual Factory Replication This paper introduces the concept of a A Whitepaper by Dr . Michael Grieves. *White Paper*, *March*. https://www.researchgate.net/publication/275211047_Digital_Twin_Manufacturing_Excellence_through_Virtual_Factory_Replication

Jones, D., Snider, C., Nassehi, A., Yon, J., & Hicks, B. (2020). Characterising the Digital Twin: A systematic literature review. *CIRP Journal of Manufacturing Science and Technology*, *29*, 36–52. https://doi.org/10.1016/j.cirpj.2020.02.002

Stathopoulos, A., Valeri, E., Gatta, V., Nuzzolo, A., & Comi, A. (2011). Urban freight policy innovation for Rome's ltz: A stakeholder perspective. *City Distribution and Urban Freight Transport: Multiple Perspectives*, 75–100. https://doi.org/10.4337/9780857932754.00011

Tavasszy, Lóránt, & de Jong, G. (2014). Modelling Freight Transport. In Lorant Tavasszy & G. de Jong (Eds.), *Modelling Freight Transport*. Elsevier Inc.

Weyer, S., Meyer, T., Ohmer, M., Gorecky, D., & Zühlke, D. (2016). Future Modeling and Simulation of CPS-based Factories: an Example from the Automotive Industry. *IFAC-PapersOnLine*, *49*(31), 97–102. https://doi.org/10.1016/j.ifacol.2016.12.168

7 Annex I – Model Templates

LEAD Task 1.2			
Reference Models Template			
Model Description			
Model Name			
Author/Owner (please state the name of the developer and the owner of the model)			
Year			
Version			
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)			
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)			
Model Summary (please provide us with a brief description of the model in max 3 lines)			

Modelling approach			
Model structure, methods and techniques			
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Name**	**Description**
	1		
	2		
	3		
	4		
	5		
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***		
	2		
	3		
	4		
	5		
Dependence of other external models			
Interactions (Please describe possible interactions with other models)			

Model Inputs

		Short description	Main measurement units	Static/ Dynamic	Aggregate/ Dissagregate
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) PLEASE FEEL FREE TO ADD MORE LINES	1				
	2				
	3				
	4				
	5				
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)					

Model Outputs

		Short description	Main measurement units	Static/ Dynamic	Aggregate/ Dissagregate
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) PLEASE FEEL FREE TO ADD MORE LINES	1				
	2				
	3				
	4				
	5				

		Short description	Main measurement unit
KPIs (Please indicate which KPIs the model uses for evaluation of policies KPIs (GHG emissions, logistics costs, vehicle kms, travel time) PLEASE FEEL FREE TO ADD MORE LINES	1		
	2		
	3		
	4		
	5		

		Description	Category	Already analysed in the model? (Yes/No)
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) PLEASE FEEL FREE TO ADD MORE LINES	1			
	2			
	3			
	4			
	5			

Software

Software (please describe in which software programming languages the model has been developed for the different parts of the model) PLEASE FEEL FREE TO ADD MORE LINES	1	
	2	
	3	
	4	
	5	

	Open source	Public domain	Permisive	Copyleft	Commercial
Type of Access (which type and name)					

Future Model Developments

Next planned extensions and updates (expected date of release and content)	
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	

Documentation

		Title	URL
Online documentation: For documentation available online PLEASE FEEL FREE TO ADD MORE LINES	1		
	2		
	3		
	4		
	5		

		File name
Attached documentation: For attached documentation in an email PLEASE FEEL FREE TO ADD MORE LINES	1	
	2	
	3	
	4	
	5	

8 Annex II – Filled Model Temperature

8.1 ZLC1

Model Description	
Model Name	Joint replenishment and delivery problem
Author/Owner (please state the name of the developer and the owner of the model)	Jimmy Carvajal, Fabian Castaño, William Sarachea, Yasel Costa; Zaragoza Logistic Centre
Year	2019
Version	
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Efficiency
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Optimization
Model Summary (please provide us with a brief description of the model in max 3 lines)	Optimizes inventory and distribution system consisting of a DC, multiple retailers and multiple items considering budget constraints

<table>
<tr><th colspan="6"><u>Modelling approach</u></th></tr>
<tr><td><u>Model structure, methods and techniques</u></td><td colspan="5">The model assumes a unique DC that manages several items that are sent to multiple retailers. The (most effective) model estimates a higher and lower bound solutions to reduce the search space. Using a MILP solver, it optimizes the master and auxiliary problems. It assumes that the DC makes the decisions for the retailers</td></tr>
<tr><td rowspan="6"><u>Submodels</u> (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment)
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td></td><td>Name</td><td>Description</td><td>Subtype</td><td>Type</td></tr>
<tr><td><u>1</u></td><td>Inventory shipper</td><td></td><td>Inventory</td><td>Optimization</td></tr>
<tr><td><u>2</u></td><td>Inventory shop (retailer)</td><td></td><td>Inventory</td><td>Optimization</td></tr>
<tr><td><u>3</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td><u>4</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td><u>5</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="5">Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)</td><td><u>1</u></td><td colspan="4">Shipper</td></tr>
<tr><td><u>2</u></td><td colspan="4">Shops</td></tr>
<tr><td><u>3</u></td><td colspan="4"></td></tr>
<tr><td><u>4</u></td><td colspan="4"></td></tr>
<tr><td><u>5</u></td><td colspan="4"></td></tr>
<tr><td><u>Dependence of other external models</u></td><td colspan="5">Demand models</td></tr>
<tr><td><u>Interactions</u> (Please describe possible interactions with other models)</td><td colspan="5">Distribution models</td></tr>
</table>

Model Inputs				
	-	**Short description**	**Subtype**	**Type**
	1	Cost per item	Storage cost	Cost data
	2	Setup costs	Storage cost	Cost data
	3	Storage costs	Storage cost	Cost data
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	**4**	Transport Costs	Transport cost	Cost Data
	5	Demand per item	Product demand	Demand data
	6	Number of items	Product demand	Demand data
	7	Number of retailers	Geographical location	Demand data
	8	weight per item	Product demand	Demand data
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)				

Model Outputs

		Short description (KPIs in red)	Type
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***	1	Total inventory cost	Cost Data
	2	Inventory policy	Logistical service
	3	Shipment size	Logistical service
	4	Commodity flows	Network Data
	5		

	-	Description	Category	Already analysed in the model? (Yes/No)
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	1			
	2			
	3			
	4			
	5			

Software

Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	1	
	2	
	3	
	4	
	5	

	Open source	Public domain	Permissive	Copyleft	Commercial
Type of Access (which type and name)					

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	n.a
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	Does not contemplate dynamic demand. Routing or distribution costs not included
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Estimates inventory policies of DC that handle multiple retailers with multiple items (e.g. supermarkets)

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Title**	**URL**
	1	Heuristic approaches for a two-echelon constrained joint replenishment and delivery problem	https://doi.org/10.1016/j.ijpe.2019.06.016
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**File name**	
	1		
	2		
	3		
	4		
	5		

8.2 ZLC2

Reference Models Template	
Model Description	
Model Name	Two Echelon capacitated vehicle routing problem
Author/Owner (please state the name of the developer and the owner of the model)	Bram Kin, Joeri Spoor, Sara Verlinde, Cathy Macharis, Tom Van Woensel
Year	2018
Version	
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Modelling: Mathematical model to calculate the costs of alternative distribution set-ups for last mile transportation in a supply chain with small fragmented volumes. It compares 4 distribution models' set-ups.
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Modelling the cost-effectiveness - Logistics cost model (optimization)
Model Summary (please provide us with a brief description of the model in max 3 lines)	Modelling the cost-effectiveness of alternative distribution set-ups to improve the efficiency of fragmented freight flows. The model is based on logistics processes and takes into account receiver attributes and local context.

<table>
<tr><td colspan="6"><u>Modelling approach</u></td></tr>
<tr><td><u>Model structure, methods and techniques</u></td><td colspan="5">1st echelon Transport time costs, 2nd echelon transport time costs; Logistics space costs (renting a space for handling or crossdocking). Not inventory costs.</td></tr>
<tr><td rowspan="6"><u>Submodels</u> (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment)
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td></td><td>Name</td><td>Description</td><td>Subtype</td><td>Type</td></tr>
<tr><td><u>1</u></td><td>VRP - Daganzo (2005)</td><td>Estimate the total distance of a route in areas where the number of stops is large (2nd echelon)</td><td>Routing</td><td>Optimization</td></tr>
<tr><td><u>2</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td><u>3</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td><u>4</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td><u>5</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="5">Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)</td><td><u>1</u></td><td colspan="4">retailers</td></tr>
<tr><td><u>2</u></td><td colspan="4">3 Logistics service providers</td></tr>
<tr><td><u>3</u></td><td colspan="4"></td></tr>
<tr><td><u>4</u></td><td colspan="4"></td></tr>
<tr><td><u>5</u></td><td colspan="4"></td></tr>
<tr><td><u>Dependence of other external models</u></td><td colspan="5"></td></tr>
<tr><td><u>Interactions</u> (Please describe possible interactions with other models)</td><td colspan="5"></td></tr>
</table>

Model Inputs				
		Short description	**Subtype**	**Type**
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) **PLEASE FEEL FREE TO ADD MORE LINES**	1	Fuel consumption	Transport cost	Cost Data
	2	fuel price	Transport cost	Cost Data
	3	Rent cost	Infrastructure cost	Cost Data
	4	Shift length	Salary cost	Cost data
	5	Transport Costs	Transport cost	Cost Data
	6	wage	Salary cost	Cost data
	7	Average distance between stops	Geographical location	Demand data
	8	Average distance depot to stop	Geographical location	Demand data
	9	Average stop	Geographical location	Demand data
	10	Number of receivers	Product demand	Demand data
	11	Replenishment frequency	Product demand	Demand data
	12	Size area	Geographical location	Demand data
	13	stop density	Geographical location	Demand data
	14	Value per item	Product demand	Demand data
	15	Volume per item	Product demand	Demand data
	16	Population	Population	External to Freight
	17	Depot capacity	Logistical infrastructure	Logistical infrastructure
	18	Depot/UCC/warehouse capacity	Logistical infrastructure	Logistical infrastructure
	19	Delivery vehicle capacity	Fleet	Logistical service
	20	Service time per customer	Shipment	Logistical service
	21	Average speeds	Network LoS	Network
	22	Congestion factor	Network LoS	Network
	23	Time restrictions	Network LoS	Network
	24	Vehicle restrictions	Network LoS	Network

Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	Mathematical model for estimating costs of different distribution setups and transport flows considering different variables (type of receiver, type of city; type of logistics parameters). QGIs to obtain the city variable values from shapefiles.

Model Outputs

Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description (KPIs in red)**	**Type**
	1	Driver wages	Cost Data
	2	Logistics space costs	Cost Data
	3	Transport distance costs	Cost Data
	4	Transport time costs	Cost Data
	5		

Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Different distribution setups	Planning and infrastructure	yes
	2	Impacts and dependencies at city level	policy implications are drawn	yes
	3			
	4			
	5			

Software

Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Modelling the city area - Qgis (not mentioned)
	2	
	3	

	4				
	5				
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**
	QGIS				

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	Further improvement relates to including a variable stop time depending on the drop size, variable demand levels and replenishment frequencies and adding more restrictions. Examples of the latter are weight limits or distance limits to vehicles in the case of electric vehicles.
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Model the transport flows in 2-echelon distribution setups and calculate costs and other KPIs can be estimated from the type of vehicle, fuel, distance and weight (fixed depots are considered)

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Title**	**URL**
	1	Modelling alternative distribution set-ups for fragmented last mile transport: Towards more efficient and sustainable urban freight transport	https://www.researchgate.net/publication/321693332_Modelling_alternative_distribution_set-ups_for_fragmented_last_mile_transport_Towards_more_efficient_and_sustainable_urban_freight_transport
	2		
	3		
	4		
	5		
Attached documentation: For attached	-	**File name**	
	1		
	2		

documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	***3***	
	4	
	5	

8.3 ZLC3

Model Description	
Model Name	Two echelon-distribution with mobile depots
Author/Owner (please state the name of the developer and the owner of the model)	Lino G. Marujoa, George V. Goesa, Márcio A. D'Agostoa, Amanda Fernandes Ferreirab,e, Matthias Winkenbachc, Renata A.M. Bandeirad
Year	2018
Version	
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Method to identify the impact on service level, emission footprint and delivery distribution costs of transforming last mile deliveries with the use motorized cargo tricycles alongside conventional trucks in a mobile depot.
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Eco-efficiency assessment procedure
Model Summary (please provide us with a brief description of the model in max 3 lines)	Assess the environmental benefits of considering mobile depots as micro-platforms by estimating the reduction in various pollutant emissions attributable to the adoption of smaller, more agile last-mile delivery vehicles. Based on Monte Carlo simulation techniques.

<table>
<tr><th colspan="6"><u>Modelling approach</u></th></tr>
<tr><td><u>Model structure, methods and techniques</u></td><td colspan="5">Impact assessment method using Monte Carlo simulation techniques</td></tr>
<tr><td rowspan="6"><u>Submodels</u> (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment)
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td></td><td>Name</td><td>Description</td><td>Subtype</td><td>Type</td></tr>
<tr><td><u>1</u></td><td>Environmental assessment method</td><td>Bottom up analysis to estimate GHG emissions and air pollution (PM; CO; NOX; NMCH)</td><td>Environmental</td><td>Assessment</td></tr>
<tr><td><u>2</u></td><td>Economic assessment method</td><td>Bottom up analysis and data collection phase to estimate the level of service and the operation costs.</td><td>Economic</td><td>Assessment</td></tr>
<tr><td><u>3</u></td><td>Operating costs</td><td>Cost model to compare the distance travelled, time of operation, number and duration of delivery stops and the total delivery cost of two delivery setups.</td><td>Operating cost</td><td>Cost model</td></tr>
<tr><td><u>4</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td><u>5</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="5">Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)</td><td><u>1</u></td><td colspan="4">Beverage company</td></tr>
<tr><td><u>2</u></td><td colspan="4">Logistic service provider</td></tr>
<tr><td><u>3</u></td><td colspan="4">retailer</td></tr>
<tr><td><u>4</u></td><td colspan="4"></td></tr>
<tr><td><u>5</u></td><td colspan="4"></td></tr>
<tr><td><u>Dependence of other external models</u></td><td colspan="5"></td></tr>
<tr><td><u>Interactions</u> (Please describe possible interactions with other models)</td><td colspan="5"></td></tr>
</table>

Model Inputs				
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**Short description**	**Subtype**	**Type**
	1	Fixed cost truck	Transport cost	Cost Data
	2	Variable cost truck	Transport cost	Cost Data
	3	Consumer demand	Product demand	Demand data
	4	Market share	Logistic service demand	Demand data
	5	Market Share	Logistic service demand	Demand data
	6	Circuity multiplier	Externality ponderations	Externalities data
	7	Externalities weights	Externality ponderations	Externalities data
	8	Average capacity utilization	Fleet	Logistical service
	9	Average capacity utilization (tricycle)	Fleet	Logistical service
	10	Service time truck (min/client)	Shipment	Logistical service
	11	Truck inner velocity	Network LoS	Network
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	Mathematical model for estimating costs and environmental impacts of the different transport flows.			

Model Outputs			
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description (KPIs in red)**	**Type**
	1	Operating costs	Cost Data
	2	GHG emissions	Externality
	3	PM, CO, NOx, NMHC	Externality
	4	service level (image on the right)	Logistical service
	5		

Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Compares distribution setups	planning and infrastructure	Yes
	2			
	3			
	4			
	5			

Software		
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	
	2	
	3	
	4	
	5	

Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Model the transport flows in 2-echelon distribution setups and calculate costs and other KPIs can be estimated from the type of vehicle, fuel, distance and weight (mobile depots are considered)

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Title**	**URL**
	1	Assessing the sustainability of mobile depots: The case of urban freight distribution in Rio de Janeiro	https://www.researchgate.net/publication/323881992_Assessing_the_sustainability_of_mobile_depots_The_case_of_urban_freight_distribution_in_Rio_de_Janeiro
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email	-	**File name**	
	1		
	2		
	3		
	4		
	5		

PLEASE FEEL FREE TO ADD MORE LINES		

8.4 ZLC4

Model Description	
Model Name	Models for Evaluating and Planning City Logistics Systems (two-echelon, synchronized, scheduled, multi-depot, multiple-tour, heterogeneous vehicle routing problem with time windows problem
Author/Owner (please state the name of the developer and the owner of the model)	Crainic, Teodor Gabriel Ricciardi, Nicoletta Storchi, Giovanni
Year	2007
Version	
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	It presents the developments for the general case 2-tier city logistics systems (literature is very scarce) where a satellite (eg. Urban Consolidation Centres) platform is used to tranship loads from vehicles arriving from the City Distribution Centres (CDC) on the outskirts of urban zone to smaller, centre-city-friendly vehicles. (Selection of routes and the scheduling of departures for the two tiers).
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Tactical planning model (the day before problem) for two tier city logistics systems. It considers the models for the operational vehicles at each tier, but also consideration of the synchronization and coordination of the fleets and terminal operations. It combines two problems: a) departure time of each urban-truck service and satellites it visits (schedules and routes); b) routing and scheduling city -freighters (eg. Cargo bikes) to provide timely delivery of goods to customers and the adequate supply of vehicles at satellites.
Model Summary (please provide us with a brief description of the model in max 3 lines)	The problem concerned the selection or routes and the scheduling of departures for the vehicles of the two fleets involved, as well as the selection of the delivery routes for customer demands from the CDCs through satellites to the final customer. Strict coordination and time-synchronization of the operations of the two fleets are central elements of the problem.

Modelling approach						
Model structure, methods and techniques	Two-echelon, synchronized, scheduled, multi-depot, multiple-tour, heterogeneous vehicle routing problem with time windows problem (2SS-MDMT-VRPTW).					
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Name**	**Description**	**Subtype**	**Type**	
	1	Logistic structure	Satellites location, corridor, (capacity in terms of type of vehicles and number of vehicles); open (not time windows)	Delivery network	Network	
	2	Vehicles	Urban trucks and city-freighters are known (not specified)	Fleet	Optimization	
	3	Demand	Static	Generation	Demand	
	4	Efficient TMS	Assume efficient exchange of information among participants; traffic related data	Information share	Other	
	5					
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***	Consumers demands				
	2	City freighter types				
	3	Urban truck types				
	4					
	5					
Dependence of other external models						

Interactions (Please describe possible interactions with other models)	

Model Inputs				
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Short description**	**Subtype**	**Type**
	1	Consumers demand	Product demand	Demand data
	2	Satellites capacity	Logistical infrastructure	Logistical infrastructure
	3	Loading time	Shipment	Logistical service
	4	Unloading time	Shipment	Logistical service
	-	vehicles capacity	Fleet	Logistical service
	5	Travel time	Network LoS	Network
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)				

Model Outputs					
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description (KPIs in red)**			**Type**
	1	Total Costs			Cost Data
	2	number of vehicles (Urban trucks, city freighters)			Logistical service
	3				
	4				
	5				
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**		**Already analysed in the model? (Yes/No)**
	1	Analyse different distribution setups	Planning and infrastructure		Yes
	2				
	3				
	4				
	5				

Software		
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	
	2	
	3	
	4	
	5	

Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Model the transport flows in 2-echelon distribution setups and calculate costs and other KPIs can be estimated from the type of vehicle, fuel, distance and weight.

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**Title**	**URL**
	1	Models for Evaluating and Planning City Logistics Systems	https://www.researchgate.net/publication/220413309_Models_for_Evaluating_and_Planning_City_Logistics_Systems
	2		
	3		
	4		
	5		
Attached documentation:	_	**File name**	
	1		

For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	***2***	
	3	
	4	
	5	

8.5 ZLC5

Model Description	
Model Name	Two echelon location-routing problem
Author/Owner (please state the name of the developer and the owner of the model)	Teodor Gabriel Crainic, Antonio Sforza, Claudio Sterle
Year	2011
Version	
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Decision problem of designing a two echelon freight distribution system; location of facilities on two adjacent echelons of a distribution system, together with the routing of vehicles at both echelons.
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Optimization
Model Summary (please provide us with a brief description of the model in max 3 lines)	Propose 3 mixed integer programming to find the location and numbers of two types of capacitated facilities, the sized of two different vehicle fleets and the related routes.

Modelling approach					
Model structure, methods and techniques	Mixed integer programming with three variants: using 1 index, using 2 index and using 3 index				
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Name**	**Description**	**Subtype**	**Type**
	1	LRP	Determine the location and the number of platform and satellites	Delivery network	Optimization
	2	MDVRP	Allocation of customers to satellites (micro-depots) and satellites to one of the selected platforms	Fleet	Optimization
	3	MDVRP	Determine the number of vehicles to use in each fleet and the associated route at each echelon	Fleet	Optimization
	4				
	5				
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***				
	2				
	3				
	4				
	5				

Dependence of other external models	
Interactions (Please describe possible interactions with other models)	

Model Inputs				
	-	**Short description**	**Subtype**	**Type**
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Demand data	Product demand	Demand data
	2	Facilities capacity	Logistical infrastructure	Logistical infrastructure
	3	vehicles capacity	Fleet	Logistical service
	4			
	5			
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)				

Model Outputs

Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description (KPIs in red)**			**Type**		
	1	Total Costs			Cost Data		
	2	facilities location			Logistical infrastructure		
	3	Commodity flows			Network Data		
	4						
	5						

Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Analyse different distribution setups	Planning and infrastructure	Yes
	2			
	3			
	4			
	5			

Software

	1	
	2	

Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***3***					
	4					
	5					
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**	

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Model the transport flows in 2-echelon distribution setups and calculate costs and other KPIs can be estimated from the type of vehicle, fuel, distance and weight.

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Title**	**URL**
	1	Location Routing models for two -echelon freight distribution systems design	https://www.cirrelt.ca/documentstravail/cirrelt-2011-40.pdf
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**File name**	
	1		
	2		

	3	
	4	
	5	

8.6 UPM1

Model Description	
Model Name	Design Manual for Roads and Bridges; Air quality
Author/Owner (please state the name of the developer and the owner of the model)	Highways England
Year	2019
Version	0
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Environmental
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Externality model: Emissions; Impact assessment
Model Summary (please provide us with a brief description of the model in max 3 lines)	It is a method for calculating the impact on local air quality and emissions of C.O., H.C., NOx, and particulate. Traffic flow data combined with speed-related emission data is used to calculate emissions for the different road links.

<table>
<tr><th colspan="6"><u>Modelling approach</u></th></tr>
<tr><td><u>Model structure, methods and techniques</u></td><td colspan="5">Consists of projecting traffic flows and speed in order to assess and mitigate air pollution of a road intervention</td></tr>
<tr><td rowspan="6"><u>Submodels</u> (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) <u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td></td><td>Name</td><td>Description</td><td>Subtype</td><td>Type</td></tr>
<tr><td><u>1</u></td><td>Air quality model</td><td>A model to assess the baseline air quality</td><td>Emissions</td><td>Externality</td></tr>
<tr><td><u>2</u></td><td>Emission prediction model</td><td>A model to predict the future emissions of different contaminants</td><td>Emissions</td><td>Externality</td></tr>
<tr><td><u>3</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td><u>4</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td><u>5</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="5">Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)</td><td><u>1</u></td><td colspan="4">Public authorities</td></tr>
<tr><td><u>2</u></td><td colspan="4"></td></tr>
<tr><td><u>3</u></td><td colspan="4"></td></tr>
<tr><td><u>4</u></td><td colspan="4"></td></tr>
<tr><td><u>5</u></td><td colspan="4"></td></tr>
<tr><td><u>Dependence of other external models</u></td><td colspan="5">Traffic models</td></tr>
<tr><td><u>Interactions</u> (Please describe possible</td><td colspan="5">Receives inputs from traffic models</td></tr>
</table>

interactions with other models)	

Model Inputs				
	-	**Short description**	**Subtype**	**Type**
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Air quality receptors	Externalities value	Externalities data
	2	Speed band emission factors	Externality ponderations	Externalities data
	3	Traffic flow	Network LoS	Network
	4			
	5			
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	Traffic sensors, actual emissions measurement			

Model Outputs				
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description (KPIs in red)**		**Type**
	1	emissions		Externality
	2	GHG emissions		Externality
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Mitigation measures	Policy	NO
	2			
	3			
	4			
	5			

Software						
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Spreadsheet				
	2					
	3					
	4					
	5					
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**	

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	NA
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Analyse potential changes in emissions derived from interventions

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**Title**	**URL**
	1		_
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**File name**	
	1	LA 105 Air quality-web.pdf	
	2		
	3		
	4		
	5		

8.7 UPM2

Model Description	
Model Name	Computer programme to calculate emissions from road transport
Author/Owner (please state the name of the developer and the owner of the model)	European Environment Agency
Year	2000
Version	2.1
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Environmental
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Emissions model
Model Summary (please provide us with a brief description of the model in max 3 lines)	The methodology mixes the vehicle technical data and the activity data to obtain a total emission estimate.

Modelling approach					
Model structure, methods and techniques	Emission estimates using average speed-dependent factors for hot emissions. The model includes expressions for cold start and evaporative emissions and accounts as far as possible for national variations in such parameters as vehicle parking duration, vehicle age, driving patterns, fuel composition, and climate.				
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Name**	**Description**	**Subtype**	**Type**
	1	Emission estimation	Estimates emission based on the type of vehicle, climate, usage, etc	Emissions	Externality
	2				
	3				
	4				
	5				
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***	Outside UF			
	2				
	3				
	4				
	5				
Dependence of other external models	Network models for speed and vehicle-km				

Interactions (Please describe possible interactions with other models)

Model Inputs				
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Short description**	**Subtype**	**Type**
	1	Activity data	City	External to Freight
	2	Emission factors	Externality ponderations	Externalities data
	3	Fuel variables	Externality ponderations	Externalities data
	4	location-specific factors	Externality ponderations	Externalities data
	5	Driving conditions	Network LoS	Network
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	Real emissions measurements			

Model Outputs				
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description (KPIs in red)**		**Type**
	1	Emission factors		Externality
	2	GHG emissions		Externality
	3	Total emissions		Externality
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	N.A,		
	2			
	3			
	4			
	5			

Software					
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Spreadsheet			
	2				
	3				
	4				
	5				
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	n.a.
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Converts vehicle km into emissions

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**Title**	**URL**
	1	COPERT III Computer programme to calculate emissions from road transport Methodology and emission factors (Version 2.1)	https://www.eea.europa.eu/publications/Technical_report_No_49
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**File name**	
	1		
	2		
	3		
	4		

	5	

8.8 UPM3

Model Description	
Model Name	"Simulation of Urban MObility" (SUMO)
Author/Owner (please state the name of the developer and the owner of the model)	Pablo Alvarez Lopez, Michael Behrisch, Laura Bieker-Walz, Jakob Erdmann, Yun-Pang Flötteröd, Robert Hilbrich, Leonhard Lücken, Johannes Rummel, Peter Wagner, and Evamarie Wießner
Year	2020
Version	1.7.0
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Infrastructure and Management
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Network model
Model Summary (please provide us with a brief description of the model in max 3 lines)	microscopic and continuous traffic simulation package designed to handle large networks

Modelling approach					
Model structure, methods and techniques	The model is an implementation of various assignment methods. It takes a network and the ODs and allocates them to the nodes and arcs				
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Name**	**Description**	**Subtype**	**Type**
	1	Demand synthesiser	Translates trips/flows/routes into micro-simulates trips	Generation	Demand
	2	traffic assignment	Microsimulation assignment of demand flows	Traffic assignment	Network
	3				
	4				
	5				
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***	outside UF			
	2				
	3				
	4				
	5				
Dependence of other external models	Demand models				
Interactions (Please describe possible interactions with other models)	ABMs; externalities models				

<table>
<tr><th colspan="5"><u>Model Inputs</u></th></tr>
<tr><td rowspan="6"><u>Data Inputs (</u>Please describe the data input of the mode, such as:

Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.)
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td>-</td><td>Short description</td><td>Subtype</td><td>Type</td></tr>
<tr><td><u>1</u></td><td>Network demand data</td><td>Product demand</td><td>Demand data</td></tr>
<tr><td><u>2</u></td><td>Network Data</td><td>Network structure</td><td>Network</td></tr>
<tr><td><u>3</u></td><td></td><td></td><td></td></tr>
<tr><td><u>4</u></td><td></td><td></td><td></td></tr>
<tr><td><u>5</u></td><td></td><td></td><td></td></tr>
<tr><td><u>Feedback from Physical twin (</u>What type of measurements are needed from the city in order to keep the model updated)</td><td colspan="4">Traffic and emissions measurements</td></tr>
</table>

Model Outputs

Descriptors	#	Short description (KPIs in red)			Type
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***	1	emissions			Externality
	2	GHG emissions			Externality
	3	Network usage			Network Data
	4	Traffic flows			Network Data
	5				

Solution approach	-	Description	Category	Already analysed in the model? (Yes/No)
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	1	New infrastructure	planning and infrastructure	No
	2	Changes in spatial distribution of logistic facilities	planning and infrastructure	No
	3			
	4			
	5			

Software

Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	1	sumo
	2	
	3	
	4	
	5	

	Open source	Public domain	Permissive	Copyleft	Commercial
Type of Access (which type and name)	sumo				

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	N.a
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	The model can take demand model's outputs and simulate the traffic flows

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**Title**	**URL**
	1		https://sumo.dlr.de/
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**File name**	
	1		
	2		
	3		
	4		
	5		

8.9 UPM4

Model Description	
Model Name	Handbook on the external costs of transport
Author/Owner (please state the name of the developer and the owner of the model)	European commission
Year	2019
Version	2019
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Environmental
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Externalities model
Model Summary (please provide us with a brief description of the model in max 3 lines)	The handbook provides an overview on the state-of-the-art methods in incorporating the externalities in transport projects

Modelling approach

Model structure, methods and techniques	

Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment)
PLEASE FEEL FREE TO ADD MORE LINES

	Name	Description	Subtype	Type
1	Accidents		Accident	Externality
2	Air pollution		Emissions	Externality
3	climate change		Emissions	Externality
4	noise		Noise	Externality
5	congestion		Network	Externality
6	well to tank emissions		Emissions	Externality
7	habitat damage		Habitat	Externality

Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)

1	Outside UF
2	
3	
4	
5	

Dependence of other external models	Traffic network models
Interactions (Please describe possible interactions with other models)	Cost benefit models

Model Inputs

	#	Short description	Subtype	Type
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Accident statistics	Externalities value	Externalities data
	2	Emission factors	Externality ponderations	Externalities data
	3	People/habitat exposed	Externalities value	Externalities data
	4	WTP/cost valuations	Externality ponderations	Externalities data
	5	Network activity data	Network LoS	Network
	6			
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	Network activity data; Accident statistics			

Model Outputs

	#	Short description (KPIs in red)	Type
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Cost per externality	Cost Data
	2	GHG emissions	Externality
	3	Transport externalities	Externality
	4		
	5		

	-	Description	Category	Already analysed in the model? (Yes/No)
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	n.a.		
	2			
	3			
	4			

Software					
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Spreadsheet			
	2				
	3				
	4				
	5				
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	n.a.
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Measurement of externalities to evaluate

<table>
<tr><th colspan="4"><u>Documentation</u></th></tr>
<tr><td rowspan="6"><u>Online documentation:</u> For documentation available online
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td>-</td><td>Title</td><td>URL</td></tr>
<tr><td><u>1</u></td><td>Handbook on the external costs of transport</td><td>https://op.europa.eu/en/publication-detail/-/publication/e021854b-a451-11e9-9d01-01aa75ed71a1/language-en</td></tr>
<tr><td><u>2</u></td><td></td><td></td></tr>
<tr><td><u>3</u></td><td></td><td></td></tr>
<tr><td><u>4</u></td><td></td><td></td></tr>
<tr><td><u>5</u></td><td></td><td></td></tr>
<tr><td rowspan="6"><u>Attached documentation:</u> For attached documentation in an email
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td>-</td><td colspan="2">File name</td></tr>
<tr><td><u>1</u></td><td colspan="2"></td></tr>
<tr><td><u>2</u></td><td colspan="2"></td></tr>
<tr><td><u>3</u></td><td colspan="2"></td></tr>
<tr><td><u>4</u></td><td colspan="2"></td></tr>
<tr><td><u>5</u></td><td colspan="2"></td></tr>
</table>

8.10 UPM5

Model Description	
Model Name	Sustainability Tool for the Appraisal of Road Projects (STAR)
Author/Owner (please state the name of the developer and the owner of the model)	UPM
Year	2013
Version	1
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Sustainability assessment (Economic, Social and Environmental)
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Impact assessment model
Model Summary (please provide us with a brief description of the model in max 3 lines)	Offer a multicriteria analysis using multiple inputs to do an appraisal of sustainability for road projects It requires 3 steps in doing so: identification of the criteria, weighting the criteria and evaluating the alternatives

Modelling approach					
Model structure, methods and techniques	The model consists of identifying the sustainability criteria and evaluation for each alternative. Then it proceeds to calculate weights for the criteria and impacts in order to finally estimate the evaluation performance				
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Name**	**Description**	**Subtype**	**Type**
	1	Weighting Model	Calculation of criteria weights through the REMBRANDT technique	Weighting	Assessment
	2				
	3				
	4				
	5				
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***	Public Authorities			
	2	Experts			
	3				
	4				
	5				
Dependence of other external models	n.a.				
Interactions (Please describe possible interactions with other models)	n.a.				

<table>
<tr><th colspan="5"><u>Model Inputs</u></th></tr>
<tr><td rowspan="17"><u>Data Inputs </u>(Please describe the data input of the model, such as:

Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.)
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td><u>-</u></td><td>Short description</td><td>Subtype</td><td>Type</td></tr>
<tr><td><u>1</u></td><td>Investment costs</td><td>Infrastructure cost</td><td>Cost Data</td></tr>
<tr><td><u>2</u></td><td>Maintenance costs</td><td>Infrastructure cost</td><td>Cost Data</td></tr>
<tr><td><u>3</u></td><td>Road operation costs</td><td>Transport cost</td><td>Cost Data</td></tr>
<tr><td><u>4</u></td><td>Vehicle operation costs</td><td>Transport cost</td><td>Cost Data</td></tr>
<tr><td><u>5</u></td><td>Macroeconomic Effects</td><td>City</td><td>External to Freight</td></tr>
<tr><td><u>6</u></td><td>Accident costs</td><td>Externality ponderations</td><td>Externalities data</td></tr>
<tr><td><u>7</u></td><td>CO2 Emissions</td><td>Externalities value</td><td>Externalities data</td></tr>
<tr><td><u>8</u></td><td>Community disruption</td><td>Externalities value</td><td>Externalities data</td></tr>
<tr><td><u>9</u></td><td>Employment effects</td><td>Externalities value</td><td>Externalities data</td></tr>
<tr><td><u>10</u></td><td>Habitat fragmentation and negative effects on species</td><td>Externalities value</td><td>Externalities data</td></tr>
<tr><td><u>11</u></td><td>Impacts on businesses and community services</td><td>Externalities value</td><td>Externalities data</td></tr>
<tr><td><u>12</u></td><td>Landscape degradation/visual negative impacts</td><td>Externalities value</td><td>Externalities data</td></tr>
<tr><td><u>13</u></td><td>Noise Pollution</td><td>Externalities value</td><td>Externalities data</td></tr>
<tr><td><u>14</u></td><td>Travel time</td><td>Network LoS</td><td>Network</td></tr>
<tr><td><u>15</u></td><td></td><td></td><td></td></tr>
<tr><td><u>16</u></td><td></td><td></td><td></td></tr>
<tr><td><u>Feedback from Physical twin </u>(What type of measurements are needed from the city in order to keep the model updated)</td><td colspan="4"></td></tr>
</table>

Model Outputs			
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) PLEASE FEEL FREE TO ADD MORE LINES		**Short description (KPIs in red)**	**Type**
	1	Alternatives sustainable performance	Externality
	2	Overall sustainability performance	Externality
	3		

Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) PLEASE FEEL FREE TO ADD MORE LINES	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Sustainability performance of different scenarios		No
	2			
	3			
	4			
	5			

Software		
Software (please describe in which software programming languages the model has been developed for the different parts of the model) PLEASE FEEL FREE TO ADD MORE LINES	1	Spreadsheet
	2	R
	3	
	4	
	5	

Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**
	x				

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	n.a.
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	n.a.
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Chose the sustainability impact of different measures and solutions.

Documentation			
	-	**Title**	**URL**
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	1	Helping Decision-Makers Select the Most Adequate Road Infrastructure Design from the point of view of Sustainability: A Practical Approach	http://oa.upm.es/37004/
	2	Road infrastructure design for optimizing sustainability	http://www.transyt.upm.es/index.php/es/mnu-difusion/working-papers.html
	3		-
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**File name**	
	1		
	2		
	3		
	4		
	5		

8.11 SZE1

Model Description	
Model Name	Performance need of roundtrips based on time capacity assuming optimal vehicle capacity utilization
Author/Owner (please state the name of the developer and the owner of the model)	Hirkó, B. ;Horváth, A; Nagy, Z.
Year	2014
Version	
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Efficiency
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Network model
Model Summary (please provide us with a brief description of the model in max 3 lines)	The model does analytical calculations for goods receptions under the constraint of delivery windows.

Modelling approach					
Model structure, methods and techniques	The model takes into account the number of clients, size of service area, vehicle characteristics and loading times in order to algebraically estimate the effect of time windows				
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Name**	**Description**	**Subtype**	**Type**
	1	Distribution Model	Analytical estimation of distribution costs and times	Distribution	Demand
	2				
	3				
	4				
	5				
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***	Transport service providers			
	2	Shops			
	3				
	4				
	5				
Dependence of other external models	Demand models				
Interactions (Please describe possible interactions with other models)	Cost models, Inventory models				

<table>
<tr><th colspan="5"><u>Model Inputs</u></th></tr>
<tr><td rowspan="6"><u>Data Inputs (</u>Please describe the data input of the mode, such as:

Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.)
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td>-</td><td>Short description</td><td>Subtype</td><td>Type</td></tr>
<tr><td><u>1</u></td><td>Client data (Location, demand)</td><td>Product demand</td><td>Demand data</td></tr>
<tr><td><u>2</u></td><td>Fleet data (Size, speed)</td><td>Fleet</td><td>Logistical service</td></tr>
<tr><td><u>3</u></td><td></td><td></td><td></td></tr>
<tr><td><u>4</u></td><td></td><td></td><td></td></tr>
<tr><td><u>5</u></td><td></td><td></td><td></td></tr>
<tr><td><u>Feedback from Physical twin (</u>What type of measurements are needed from the city in order to keep the model updated)</td><td colspan="4">Speed in main roads</td></tr>
</table>

Model Outputs				
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description (KPIs in red)**		**Type**
	1	Distribution Costs		Cost Data
	2	Number of vehicles/drivers		Cost Data
	3	Distribution Time		Logistical service
	4			
	5			
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Time windows	Policy	Yes
	2			
	3			
	4			
	5			

Software					
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Spreadsheet/ general estimation			
	2				
	3				
	4				
	5				
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Title**	**URL**
	1		-
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**File name**	
	1	Performance need of roundtrips based on time capacity assuming optimal vehicle capacity utilization.pdf	
	2		
	3		
	4		
	5		

8.12 MOLDE1

Model Description	
Model Name	Interactive stakeholder acceptability for policy acceptance
Author/Owner (please state the name of the developer and the owner of the model)	Edoardo Marcucci, Michela Le Pira , Valerio Gatta, Giuseppe Inturri, Matteo Ignaccolo, Alessandro Pluchino
Year	2017
Version	1.0
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	users'/stakeholders' behaviour, reactions, acceptance, engagement; demand management; ex-ante policy/solution analysis
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Demand model; ABM; choice modelling
Model Summary (please provide us with a brief description of the model in max 3 lines)	This approach, based on the combination of Discrete Choice Modelling and Agent-Based Modelling, helps ex-ante evaluating any innovation in urban freight transport in terms of acceptance, adoption and reactions. It allows forecasting how stakeholders might behave should something new be introduced in the market, both from a public and private perspective.

Modelling approach					
Model structure, methods and techniques	Consists on the preference collection with an SP, modelling the utilities of all the agents using discrete choice models (e.g. Latent class model). Using the preferences estimated, use the social interactions of the agents for them to cooperate and negotiate to find out the global acceptance of a policy				
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Name**	**Description**	**Subtype**	**Type**
	1	Choice model	Determining agent specific utilities	Demand	
	2	Agent Base model	Agent behaviour in an opinion dynamic model	Agent Base model	
	3				
	4				
	5				
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***	Shops			
	2	Transport service providers			
	3	Consumers			
	4	Public authorities			
	5	Shippers			
Dependence of other external models	n.a.				
Interactions (Please describe possible interactions with other models)	Other ABMs				

Model Inputs				
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Short description**	**Subtype**	**Type**
	1	Preference data	Preference data	Demand data
	2	Agents relationships	Agent relationship	Logistic system
	3			
	4			
	5			
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	Stated Preference surveys and Revealed Preference data on specific policies implemented			

Model Outputs				
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description** **(KPIs in red)**		**Type**
	1	Decisions process insights		Demand data
	2	Market shares		Demand data
	3	WTP		Externality
	4	Global satisfaction		Policy
	-	Overall Policy acceptance		Policy
	5	stakeholder-specific policy acceptance		Policy
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Entrance fee increase	Policy	Yes
	2	Alternative loading bays	Planning and Infrastructure	Yes
	3	Time of Day restrictions	Policy	No

	4	...model flexibility allows testing, virtually, any policy/problem	any	n.a
	5			

Software						
Software (please describe in which software programming languages the model has been developed for the different parts of the model) **PLEASE FEEL FREE TO ADD MORE LINES**	1	Netlogo				
	2	Nlogit (Could be R)				
	3					
	4					
	5					
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**	
	R			Netlogo	Nlogit	

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	Model applied to predict market interactions and market shares
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	Preferences are made for policies defined ex-ante
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	It can be used as a starting point to define/fine-tune the implementation to be tested It can be useful, especially in the transition to a full DT, for evaluating possible reactions to disruptive changes.

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**Title**	**URL**
	1	Towards a decision-support procedure to foster stakeholder involvement and acceptability of urban freight transport policies	dx.doi.org/10.1007/s12544-017-0268-2
	2	Integrating discrete choice models and agent-based models for ex-ante evaluation of stakeholder policy acceptability in urban freight transport	dx.doi.org/10.1016/j.retrec.2017.08.002
	3	Simulating participatory urban freight transport policy-making: Accounting for heterogeneous stakeholders' preferences and interaction effects	dx.doi.org/10.1016/j.tre.2017.04.006
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**File name**	
	1		
	2		
	3		
	4		
	5		

8.13 MOLDE2

Model Description	
Model Name	Experimental Design for Stated Preference (SP) data acquisition
Author/Owner (please state the name of the developer and the owner of the model)	Valerio Gatta, Edoardo Marcucci
Year	2016
Version	1.0
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Development of various approaches for constructing SP experiments
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	SP data collection
Model Summary (please provide us with a brief description of the model in max 3 lines)	Provide an efficient, modular, cost-efficient method to acquire stakeholder-specific behaviourally relevant data to be used for SP evaluation.

<table>
<tr><td colspan="7"><u>Modelling approach</u></td></tr>
<tr><td><u>Model structure, methods and techniques</u></td><td colspan="6">Definition of alternatives, attributes, levels to be appropriately combined to construct choice tasks</td></tr>
<tr><td rowspan="6"><u>Submodels</u> (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment)
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td></td><td>Name</td><td>Description</td><td>Subtype</td><td colspan="2">Type</td></tr>
<tr><td><u>1</u></td><td></td><td></td><td colspan="3"></td></tr>
<tr><td><u>2</u></td><td></td><td></td><td colspan="3"></td></tr>
<tr><td><u>3</u></td><td></td><td></td><td colspan="3"></td></tr>
<tr><td><u>4</u></td><td></td><td></td><td colspan="3"></td></tr>
<tr><td><u>5</u></td><td></td><td></td><td colspan="3"></td></tr>
<tr><td rowspan="5">Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)</td><td><u>1</u></td><td colspan="5">…any type of stakeholders</td></tr>
<tr><td><u>2</u></td><td colspan="5"></td></tr>
<tr><td><u>3</u></td><td colspan="5"></td></tr>
<tr><td><u>4</u></td><td colspan="5"></td></tr>
<tr><td><u>5</u></td><td colspan="5"></td></tr>
<tr><td><u>Dependence of other external models</u></td><td colspan="6">none</td></tr>
<tr><td><u>Interactions</u> (Please describe possible interactions with other models)</td><td colspan="6">Interactive stakeholder acceptability for policy acceptance</td></tr>
</table>

Model Inputs

	-	Short description	Subtype	Type
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	1	Alternatives	Logistic market	Logistic system
	2	Attribute levels	Logistic market	Logistic system
	3	Attributes characterising the alternatives	Logistic market	Logistic system
	4			
	5			
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	Whenever appropriate, information on alternatives/attributes/levels to be tested			

Model Outputs

		Short description (KPIs in red)		Type
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***	1	Preference data		Demand data
	2	WTP		Externality
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Policy; design of Rome's logistics zone	Policy	Yes
	2	Design of crowdshipping services	Policy	Yes
	3	Efficient gamification designs	Other	Yes
	4	…model flexibility allows testing, virtually, any policy/problem		
	5			

Software		
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	NGENE (could be R)
	2	
	3	
	4	
	5	

	Open source	Public domain	Permissive	Copyleft	Commercial
Type of Access (which type and name)	R				NGENE

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	NA
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	Limitations inherent to the SP experiments
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Data collection method

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**Title**	**URL**
	1		_
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**File name**	
	1	Sustainable urban freight transport adopting public transport-based crowdshipping for B2C deliveries	
	2	Urban freight transport and policy changes: Improving decision makers' awareness via an agent-specific approach	
	3	Gamification design to foster stakeholder engagement and behaviour change: An application to urban freight transport	
	4	Stakeholder-specific data acquisition and urban freight policy evaluation: evidence, implications and new suggestions	
	5		

8.14 IRTX1

Model Description	
Model Name	MATSim
Author/Owner (please state the name of the developer and the owner of the model)	Open source community, development mainly coordinated by TU Berlin and ETH Zurich
Year	more than 10 years
Version	12 / 13
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Calculation of city-wide mobility metrics, based on detailed analysis of agent movements Simulation of agent choice behaviour in reaction to policies and changes in infrastructure
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Transport simulation model, Agent-based model, Impact Assessment
Model Summary (please provide us with a brief description of the model in max 3 lines)	MATSim is an agent-based transport simulation that allows to study the detailed interplay between travellers and freight vehicles during an average day, which allows to estimate the impact of policies and new transport solutions on the territory and the population.

Modelling approach	
Model structure, methods and techniques	MATSim is an agent-based transport simulation framework. It consists of two major components: the mobility simulation and the demand simulation. In the mobility simulation part, MATSim simulates an average day of a city based on the movements of individual agents. Each agent has a daily activity plan (for instance starting at “home”, then going to “work”, then going to a “shop”, then going back “home”). The activities in these plans have departure times and they are connected by trips. Trips can have different modes of transport, for instance, “car”, “public transport”, “cycling”, or “walking”. During the mobility simulation all agents with their activity chains are simulated, which may lead to congestion if too many agents, for instance, want to use the same road. Therefore, metrics such as travel times are used to let agents change their decisions in the demand simulation phase. There, agents may choose new routes, different modes of transport, or departure times to optimize their daily plans. After running the two phases iteratively until convergence, we arrive at a state in which all agents found their best plan, given all the choices of the other agents. MATSim allows to measure various metrics from the transport system, for instance, the emissions caused on each road by time of day (and by who, i.e. which user groups). It allows to assess changes in congestion levels, travel times and accessibility if new roads or transport lines are added. Recently, MATSim has become an important tool to assess highly dynamic mobility services, such as on-demand busses and taxis, or automated vehicles. Such services require a detailed modelling of the interaction of travellers and operators to correctly assess the impacts of dispatching strategies, cost assumptions, recharging demand, etc. A couple of extensions exist for MATSim that cover freight traffic. They can be divided in two major fields: Statically planned transport, such as deliveries and tours planned before the

<table>
<tr><th colspan="6"><u>Modelling approach</u></th></tr>
<tr><td></td><td colspan="5">simulated day; and dynamically operating services that react on an hour-by-hour or minute-by-minute basis on signals that occur in the simulation. In general, we will treat freight demand based on “senders” and “receivers”, and it will need to be defined, also in connection with the other models and specific use cases, how much of the demand generation part can inside the simulation or outside.

A more detailed description of MATSim can be found in Ch 2: https://www.research-collection.ethz.ch/handle/20.500.11850/419837</td></tr>
<tr><td rowspan="6"><u>Submodels</u> (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment)
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td></td><td>Name</td><td>Description</td><td>Subtype</td><td>Type</td></tr>
<tr><td><u>1</u></td><td>Mobility simulation</td><td>See above</td><td>Generation pax trips</td><td>Demand</td></tr>
<tr><td><u>2</u></td><td>Demand simulation</td><td>See above</td><td>Generation</td><td>Demand</td></tr>
<tr><td><u>3</u></td><td>Mode choice model</td><td>Discrete choice model governing the behaviour of travellers (with respect to travel times, etc.)</td><td>Choice model</td><td>Demand</td></tr>
<tr><td><u>4</u></td><td>Jsprit</td><td>Given a list of services or shipments, it applies heuristics to generate freight vehicle tours</td><td>Scheduling</td><td>Optimization</td></tr>
<tr><td><u>5</u></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)</td><td><u>1</u></td><td colspan="4">Customer, Carrier, Shipper, Shop (but in a more generic way, as “senders” and “receivers”)</td></tr>
<tr><td><u>2</u></td><td colspan="4"></td></tr>
<tr><td><u>3</u></td><td colspan="4"></td></tr>
<tr><td><u>4</u></td><td colspan="4"></td></tr>
<tr><td><u>5</u></td><td colspan="4"></td></tr>
<tr><td><u>Dependence of other external models</u></td><td colspan="5">Synthetic population model , see next page</td></tr>
</table>

Modelling approach	
Interactions (Please describe possible interactions with other models)	MASS-GT: provides demand generation for freight trips, they can then be simulated in MATSim to derive metrics on emissions, how much congestion they cause on the population, how much space they occupy, which (sociodemographic and socioprofessional) groups of agents are affected by the trips and so on. FRETURB: is a model developed by LAET in Lyon, which generates logistics OD matrices for areas in France. It may be a potential input to MASS-GT for the case study of Lyon, as part of a pipeline FRETURB → MASS-GT → MATSim

Model Inputs				
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description**	**Subtype**	**Type**
	1	Choice model	Preference data	Demand data
	2	Synthetic population	Population	External to Freight
	3	Transit schedule (GTFS)	Pax trips	External to Freight
	4	Flow / travel time data for validation	Network LoS	Network
	5	Network data	Network structure	Network
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	To update the model continuously, we can feed travel time information (for instance from zone to zone, like Uber Movements data) into the simulation for calibration. We can also regularly update the road network or the transit schedule whenever changes are made. Note that MATSim is an equilibrium model that takes long to run! So when we talk about updating we talk at most once a day.			

Model Outputs				
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description (KPIs in red)**		**Type**
	1	Events file with detailed activities, movements and interactions of the agents		Demand data
	2	OD matrix		Demand data
	3	Network load		Network Data
	4	Facilities		Demand data
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Zero-emission zones	Policy	No
	2	Vehicle type restrictions	Policy	No
	3	Speed restrictions	Policy	No
	4	Mobility hubs, distribution centres	Infrastructure	No
	5			

Software					
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Java			
	2				
	3				
	4				
	5				
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**
	X			GPL	

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	- Further development of freight movements - Generalized library of common freight policy use cases and respective metrics - in the coming months
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	- As shown above, it is difficult to fit MATSim into this template, as it is merely a framework. We currently have a passenger transport model of Lyon, in which we can add freight movements and then measure the impact of those freight movements on congestion, emissions etc. But which metrics exactly to measure depends on the specific use case. For Lyon, we will generate freight movements separately based on the data available in the area, and based on the MASS-GT model. We need to explore how this methodology translates to other use cases. - One potential way to go forward discussed with TU Delft is to provide a framework, based on generally available data, for instance OpenStreetMap, to create basic simulation environments for MASS-GT and MATSim for any city and region, which then can be enriched with local and more specific data sets
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	- It is possible to visualize the movements of all the vehicles dynamically (e.g. like in a movie second by second), to follow specific agents to demonstrate the working of a scheduling or tour planning algorithm; it is possible to show the utilisation of roads by (freight) vehicles by time of day, the amount of emissions in certain zones, ... - MATSim can be used in the Digital Twin to provide the bridge to passenger transport and a global

	view of the city, and to understand how existing and new freight movements effect the overall functioning of the transport system of a city.

Documentation

Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Title**	**URL**
	1	MATSIm Website	http://www.matsim.org
	2	MATSim book	https://www.matsim.org/the-book
	3	Thesis chapter 2	https://www.research-collection.ethz.ch/handle/20.500.11850/419837
	4		
	5		

Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**File name**
	1	
	2	
	3	
	4	
	5	

8.15 IRTX2

Model Description	
Model Name	Synthetic population
Author/Owner (please state the name of the developer and the owner of the model)	IRT SystemX / ETH Zurich
Year	2019 – 2020
Version	1
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	For agent-based passenger transport simulation (e.g. MATSim) it is usually necessary to have a detailed digital representation of the population with sociodemographic and socioprofessional attributes and daily plans of activities (where do they live, where do they go to work/school, where do they do shopping, and at which times and in which order). We provide a framework to create synthetic populations of cities and regions, with households, persons and daily activity chains. The framework is mainly developed for France, but is quite versatile, and has been adapted for Los Angeles / San Francisco, Jakarta, Sao Paulo and other places around the world.
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model,	Demand model

emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	
Model Summary (please provide us with a brief description of the model in max 3 lines)	We provide a model to create synthetic populations based on open data with households, persons and daily activity chains to represent the daily mobility and activity patterns of regions and cities.

Modelling approach

Model structure, methods and techniques	Currently, the framework makes use of rather simple algorithms, which create a synthetic population from open and publicly available data. It consists of multiple sub-models for the assignment of home locations, work/education locations, and secondary locations and the assignment of activity chains based on sociodemographic attributes of the agents. An overview of the steps can be seen here [1] in Figure 1. [1] https://www.researchgate.net/publication/341131284_Reproducible_scenarios_for_agent-based_transport_simulation_A_case_study_for_Paris_and_Ile-de-France

Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment)

	Name	Description	Subtype	Type
1	Population sampling	Generating households and persons based on census data	Population	Demand
2	Statistical matching	Attaching activity chains to persons based on household travel survey data	Generation pax trips	Demand
3	Income imputation	Adding income to households based on tax data	Generation pax trips	Demand
4	Primary destinations	Based on work/education OD matrices	Generation pax trips	Demand

PLEASE FEEL FREE TO ADD MORE LINES	***5***	Secondary destinations	Based on service and facility census	Generation pax trips	Demand
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***	Consumers			
	2				
	3				
	4				
	5				
Dependence of other external models					
Interactions (Please describe possible interactions with other models)	The generated population is simulated in MATSim to derive detailed mobility metrics for the city. We could use demand models for deliveries to estimate how many deliveries certain households with certain characteristics produce. Those could then be used in the subsequent simulation.				

Model Inputs

		Short description	Subtype	Type
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Census data	Population	External to Freight
	2	Household Travel Survey	Population	External to Freight
	3	OD data	Pax trip demand	External to Freight
	4	Service / enterprise census	City	External to Freight
	5	Tax data	City	External to Freight
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	Planning information for residences and business districts, to create future scenarios			

Model Outputs			
		Short description (KPIs in red)	**Type**
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Number of passengers	Demand data
	2	Number of trips	Demand data
	3	People being potential customers / users of a logistics solution	Demand data
	4	Shops / restaurants in an area / potential customers	Demand data
	-	Households	External to Freight
	-	Persons	External to Freight

	-	Trips		External to Freight
	5	People living in an area affected by a new logistics solution		Externality
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Given a solution (and simulated in a simulator like MATSim), how does the impact change if patterns of population or employment change?	Planning and infrastructure	no
	2	What is the impact of home office on deliveries?	Planning and infrastructure	no
	3	What is the impact of changes in population structure (ageing,) on logistics solutions?	Planning and infrastructure	no
	4	What is the impact of seasons (winter vs. summer) or weather (sunny vs. rain) on certain solutions / the delivery demand?	Planning and infrastructure	no
	5			

Software						
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	1	Python				
	2					
	3					
	4					
	5					
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**	
	X			GPL		

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	- Currently implementing home office scenarios based on surveys during Covid with IFPen in France - Including models to estimate the demand for deliveries based on the population
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	- Data hungry, may not be easy adaptable to other cases, but we have found that in many countries sufficient data is available (Jakarta, Sao Paulo, USA, ...)
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	- Providing a synthetic population for transport simulation to test the impact of policies and transport solutions on the population - Providing a more dynamic and detailed demand for deliveries

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Title**	**URL**
	1	Github repository + Documentation / Usage / Data sources / …	https://github.com/eqasim-org/ile-de-france
	2	Preprint describing methodology	https://www.researchgate.net/publication/341131284_Reproducible_scenarios_for_agent-based_transport_simulation_A_case_study_for_Paris_and_Ile-de-France
	3		

	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**File name**	
	1		
	2		
	3		
	4		
	5		

8.16 TUDELFT1

Model Description	
Model Name	MASS-GT
Author/Owner (please state the name of the developer and the owner of the model)	TU Delft-Significance
Year	2020

Version	2.0
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Urban freight demand
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	ABM (modelling of agents using simulation and choice models)
Model Summary (please provide us with a brief description of the model in max 3 lines)	MASS-GT is a multi-agent simulation model of the logistics decisions in the urban freight context. MASS-GT models urban freight demand in a long term and short term tactical level.

Modelling approach	
Model structure, methods and techniques	MASS-GT consist of two core modules:1) the shipment synthesizer that simulates decisions in the long term; 2) and the scheduling module that simulates decisions on a more short-term tactical level. Specifically the shipment synthesizer uses an event based simulation to create a set of shipments and models the following a set of shipments that are transported in the study area. To create this set of shipments, an event-based simulation is used for the following logistic processes: 1) sourcing; 2) distribution channel choices; and 3) shipment size & vehicle type. The scheduling module simulates the formation of tours, chooses the time for each trip and optimizes the vehicle type choice. A parcel module runs in parallel

Modelling approach					
	to the shipment modules, integrates two parcel modules: 1) The parcel demand module that simulates the demand for parcels and creates a synthetic set of parcels, with origin (DC) and receiver (hh); 2) The parcel scheduling module simulates the allocation of parcels to vehicles, and creates delivery tours.				
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Name**	**Description**	**Subtype**	**Type**
	1	Shipment synthesizer module	The shipment synthesizer uses an event based simulation to create a set of shipments that are transported in the study area. To create this set of shipments, the following logistics process are modelled: 1) sourcing using a probabilistic decay function; 2) distribution channel choices via observed market shares and 3) shipment size & vehicle type by applying a choice model	Generation Freight trips	Demand
	2	Scheduling module	The scheduling module simulates the formation of tours, chooses the time for each trip and optimizes the vehicle type choice.	Scheduling	Optimization
	3	Parcel module	The parcel demand module that simulates the demand for parcels and creates a synthetic set of parcels, with origin (distribution centre) and receiver (household) The parcel demand module that simulates the demand for parcels and creates a synthetic set of parcels, with origin (distribution centre) and receiver (household) The parcel demand module that simulates the demand for parcels and creates a synthetic set of parcels, with origin (distribution centre) and receiver (household)	Parcels	Demand
	4	Parcel scheduling module	The parcel scheduling module simulates the allocation of parcels to vehicles, and creates parcel delivery tours.	Scheduling	Optimization
	5	Indicator module	The indicator module calculates the KPIs. The main KPIs used are GHG emissions, vehicle kms (per vehicle type), average load factor per vehicle type), number of trips (per vehicle type)	KPI measurement	Assessment
	6	Network module	The network module assigns parcel and shipment tours to the network	Traffic assignment	Network

Modelling approach		
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***	Producers
	2	Consumers
	3	3PLs
	4	Carriers
	5	Shippers with own account transport
Dependence of other external models	n.a.	
Interactions (Please describe possible interactions with other models)	The MASS-GT will be part of the HARMONY suite where it will interact with the HARMONY strategic and operational simulators.	

Model Inputs				
Data Inputs (Please describe the data input of the mode, such as:	-	**Short description**	**Subtype**	**Type**
	1	Firm population	Product demand	Demand data

Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	***2***	Observed market shares to calculate transport flows (direct, via DC, etc.)	Logistic service demand	Demand data
	3	Trips (trip diaries)	Product demand	Demand data
	4	Weight (trip diaries)	Product demand	Demand data
	5	Departure time (trip diaries)	Pax trips	External to Freight
	6	Duration (trip diaries)	Pax trips	External to Freight
	7	Households	Population	External to Freight
	8	Location of distribution centres	Logistical infrastructure	Logistical infrastructure
	9	Shipment size distributions per logistics flow	Shipment	Logistical service
	#	Vehicle type (trip diaries)	Fleet	Logistical service
	#	Network data	Network structure	Network
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	One of the main data sources is a large dataset of truck travel diaries collected by the Netherlands Statistics Bureau (CBS). CBS applies an innovative XML-interface to automatically extract microdata from the Transport Management Systems (TMS) of transport companies. Therefore, trip dairies are necessary for the update of the model. Statistics such as firm population, network data, households, location of terminals and DCs, market shares should be collected from the physical twin.			

Model Outputs			
Descriptors (Please describe the output generated by the model. For example: Freight generation,		**Short description** **(KPIs in red)**	**Type**

commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Matrix of parcel tours	Demand data
	2	Matrix of parcels created by the parcel synthesizer	Demand data
	3	Matrix of shipments created by the shipment synthesizer	Demand data
	4	Matrix of tours	Demand data
	5	Matrix of trips	Demand data
	6	Number of trips	Demand data
	7	GHG emissions	Externality
	8	Average Loads	Logistical service
	9	Network flow	Network Data
	#	Transported tonnes	Network Data
	#	Vehicle kms	Network Data

	-	Description	Category	Already analysed in the model? (Yes/No)
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Test different policies scenarios in the study area	Policy	Yes
	2	Test the development of new infrastructure	Planning and Infrastructure	No
	3	Test the implementation of new technologies such as Avs	Technology	No
	4			
	5			

Software

Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Python				
	2	R (for some choice models)				
	3					
	4					
	5					
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**	
	Python, R					

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	Improve the choice models that represent the behaviour of the agents especially time of day choice and sourcing models. At the moment MASS-GT is applied for the city of Rotterdam. In LEAD it will be applied for the Hague.
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	In general it is a data thirsty model and needs a substantial amount of data to be calibrated for other cities. Differentiation between the amount of
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Model the urban freight demand in the city of The Hague. Model the effect of new on demand services and mobility hubs in the Hague.

Documentation

		Title	URL
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	**1**		
	2		
	3		
	4		
	5		

		File name
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	**1**	MASS_GT_WCTR-Tavasszy et al.
	2	Tour_formation_TRE_Thoen et al.
	3	
	4	
	5	

8.17 TUDELFT2

Model Description	
Model Name	Bi-level Acceptance model
Author/Owner (please state the name of the developer and the owner of the model)	Wicaksono
Year	2018
Version	
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Knowledge
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Choice modelling
Model Summary (please provide us with a brief description of the model in max 3 lines)	The model combines a demand model for crowdshipping services together with a willingness to be crowdshipper model in order to obtain an equilibrium price.

Modelling approach					
Model structure, methods and techniques	The model is based on two choice models				
		Name	**Description**	**Subtype**	**Type**
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Commute flows	OD matrix generation	Generation pax trips	Demand
	2	Parcel demand	Parcel demand per household	Choice model	Demand
	3	Transport model	Model of parcel delivery method	Choice model	Demand
	4	Supply model	Model of commuters willing to offer crowdshipping	Crowdshipping supply	Other
	5	Equilibrium model	Supply demand equilibrium	Supply/Demand equilibrium	Demand
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***	Consumers			
	2	Transport service providers			
	3				
	4				
	5				
Dependence of other external models	None				
Interactions (Please describe possible interactions with other models)	The internal model can be used as input for ABMs				

Model Inputs				
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Short description**	**Subtype**	**Type**
	1	Parcel data	Product demand	Demand data
	2	Preference data	Preference data	Demand data
	3	OD data	Pax trip demand	External to Freight
	4	Transport service data	Shipment	Logistical service
	5			
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)	Transport providers market shares, bike market shares			

Model Outputs

		Short description (KPIs in red)	Type
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) PLEASE FEEL FREE TO ADD MORE LINES	1	Amount of parcels delivered by crowdshipping	Demand data
	2	Modal split	Demand data
	3	Equilibrium price	Logistical service
	4	Equilibrium profits	Logistical service
	5		

	-	Description	Category	Already analysed in the model? (Yes/No)
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) PLEASE FEEL FREE TO ADD MORE LINES	1			
	2			
	3			
	4			
	5			

Software

Software (please describe in which software programming languages the model has been developed for the different parts of the model) PLEASE FEEL FREE TO ADD MORE LINES	1	Biogeme
	2	
	3	
	4	
	5	

	Open source	Public domain	Permissive	Copyleft	Commercial
Type of Access (which type and name)					

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	

Documentation			
	_	**Title**	**URL**
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***		_
	2		
	3		
	4		
	5		
	_	**File name**	
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Thesis_Satrio Wicaksono_Bicycle Crowdshipping_Online - PostGL (1).pdf	
	2		
	3		
	4		
	5		

8.18 BKK1

Model Description	
Model Name	The Macroscopic Transport Model of Budapest (MTM)
Author/Owner (please state the name of the developer and the owner of the model)	Centre for Budapest Transport
Year	2019 (last update). The first version created in 2014-2015.
Version	SV05
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Urban model
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Multimodal, macroscopic, strategic 4-step transport model
Model Summary (please provide us with a brief description of the model in max 3 lines)	MTM is a multimodal, macroscopic strategy transport model of Budapest. It represents the current situation and it can also be used for modelling future scenarios. The transport model enables to select and prioritise development suggestions, alternatives and technical versions within the project proposal during the decision-preparatory studies.

Deliverable 1.2

Modelling approach

Model structure, methods and techniques	The MTM consists of three elements: area model, transport supply model and transport demand model. The most commonly used passenger transport demand model is four-step model which is also the basis for the MTM. The modelling process can be divided into four main phases: traffic generation, distribution, division and assignment.

Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment)
PLEASE FEEL FREE TO ADD MORE LINES

	Name	Description	Subtype	Type
1	Transport supply model	the appropriate description of transport networks and services as well as their features and the terms of use which enable the calculation of the choice of routes of the modal transport demands, the network loads and their typical circumstances.	Delivery network	Network
2	Area model	the geographical framework serving the mapping of the places of emergence (traffic zones) and the spatial relations (networks) of transport demands	Delivery network	Network
3	Transport demand model	the inter-zone quantitative, model and temporal description of passenger transport and freight traffic demands arising from daily economic and social process, taking into account to the factors influencing demand	Generation	Demand
4				
5				

Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)

1	Facilities, shops
2	
3	
4	
5	

Dependence of other external models: no dependence

Interactions (Please describe possible interactions with other models)	

Model Inputs

	-	**Short description**	**Subtype**	**Type**
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	*1*	Household surveys, SP	Population	External to Freight
	2	Land use and demographic statistics	City	External to Freight
	3	Traffic volumes and passenger volumes	Pax trip demand	External to Freight
	4	Infrastructure data and timetables	Logistical infrastructure	Logistical infrastructure
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)				

Model Outputs

		Short description **(KPIs in red)**		**Type**
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***	*1*	Modal split		Demand data
	2	OD matrix		Demand data
	3	Loaded transport network		Network Data
	4	Travel distance		Network Data
	5	Travel time		Network Data
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	Test the development of new infrastructure	Planning and Infrastructure	

	2			
	3			
	4			
	5			

Software						
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	PTV Visum				
	2					
	3					
	4					
	5					
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**	
			PTV Visum			

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	Improve the agglomeration area, create hourly model with dynamic assignment, and further improve the freight model.
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	As a macroscopic, it can be used for large scale, long-term strategy investigation, and multimodal infrastructure intervention.
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	Model the urban freight demand in the city of Budapest. Model the effect of new on demand services and mobility hubs in Budapest.

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Title**	**URL**
	1		-
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**File name**	
	1		
	2		
	3		
	4		
	5		

8.19 ARGUSI1

Model Description	
Model Name	NDG Network Design | City Logistics
Author/Owner (please state the name of the developer and the owner of the model)	Marlies de Keizer, Argusi b.v
Year	2020
Version	Version 4.3
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Design of the City Logistics Last-Mile delivery network in game setup. Trade-off between 1) Packages delivered at home using vans or bikes, 2) Packages to be picked-up at collection point >75% delivered at home Around 10.000 collection points in The Netherlands Up to 52% of households is within walking distance of a collection point If collection point delivery can be increased to 50%, CO2 emissions will decrease by around 17%
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Heuristic optimization and scenario based analysis.
Model Summary (please provide us with a brief description of the model in max 3 lines)	NDG Network Design | City Logistics is a design game that illustrates the trade-off between different KPI's in a realistic e-city environment. The players can implement their own scenarios and solutions and get direct feed-back on their decisions in terms of costs, emissions, kilometres and performance.

<table>
<tr><th colspan="6"><u>Modelling approach</u></th></tr>
<tr><td><u>Model structure, methods and techniques</u></td><td colspan="5">evaluation / scenario turn-based model</td></tr>
<tr><td rowspan="6"><u>Submodels</u> (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment)
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td></td><td>Name</td><td>Description</td><td>Subtype</td><td>Type</td></tr>
<tr><td><u>1</u></td><td>vrp - model</td><td>cloud based vrp model to determine the shortest route paths</td><td>Routing</td><td>Optimization</td></tr>
<tr><td><u>2</u></td><td>cost model</td><td>simple costing structure on last-mile delivery</td><td>Overall cost</td><td>Cost model</td></tr>
<tr><td><u>3</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td><u>4</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td><u>5</u></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="5">Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)</td><td><u>1</u></td><td colspan="4">consumers</td></tr>
<tr><td><u>2</u></td><td colspan="4">shippers</td></tr>
<tr><td><u>3</u></td><td colspan="4">service providers</td></tr>
<tr><td><u>4</u></td><td colspan="4"></td></tr>
<tr><td><u>5</u></td><td colspan="4"></td></tr>
<tr><td><u>Dependence of other external models</u></td><td colspan="5">none</td></tr>
<tr><td><u>Interactions</u> (Please describe possible interactions with other models)</td><td colspan="5">there is a possibility to include congestion and vehicle routing</td></tr>
</table>

<table>
<tr><th colspan="5"><u>Model Inputs</u></th></tr>
<tr><td rowspan="6"><u>Data Inputs (</u>Please describe the data input of the mode, such as:

Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.)
<u>PLEASE FEEL FREE TO ADD MORE LINES</u></td><td>_</td><td>Short description</td><td>Subtype</td><td>Type</td></tr>
<tr><td><u>1</u></td><td>costs components</td><td>Cost structure</td><td>Cost Data</td></tr>
<tr><td><u>2</u></td><td>delivery points</td><td>Logistical infrastructure</td><td>Logistical infrastructure</td></tr>
<tr><td><u>3</u></td><td>potential transfer points</td><td>Logistical infrastructure</td><td>Logistical infrastructure</td></tr>
<tr><td><u>4</u></td><td>infrastructure (road)</td><td>Network structure</td><td>Network</td></tr>
<tr><td><u>5</u></td><td></td><td></td><td></td></tr>
<tr><td><u>Feedback from Physical twin (</u>What type of measurements are needed from the city in order to keep the model updated)</td><td colspan="4">possible feedback road utilization</td></tr>
</table>

Model Outputs			
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description (KPIs in red)**	**Type**
	1	Facility costs	Cost Data
	2	inbound costs	Cost Data
	3	outbound costs	Cost Data
	4	total costs	Cost Data
	5	orders	Demand data
	6	emissions	Externality
	7	handling	Logistical service
	8	kilometres	Logistical service
	9	service percentage, cover of demand	Logistical service

Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	heuristic approach (no optimization)		
	2			
	3			
	4			
	5			

Software						
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Flask framework (Python)				
	2	Argusi Azure portal				
	3	SQL Alchemy				
	4	HTML				
	5					
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**	

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	Extension on Breda and Den Haag example is developed
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	model is more game than a part of Digital twin as such
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	

Documentation			
	-	**Title**	**URL**
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	1	Network design game	www.argusi.org/ndg
	2		
	3		
	4		
	5		
	-	**File name**	
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	1	Supply Chain Network modelling for city distribution (1).pdf	
	2		
	3		
	4		
	5		

8.20 ARGUSI2

Model Description	
Model Name	City Logistics Game
Author/Owner (please state the name of the developer and the owner of the model)	Frans Cruijssen, Argusi b.v / TNT
Year	2011
Version	Version 2.4
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	City Logistics game (board game, supported by simulation) with the perspective of different stakeholders. The game is played in the City of Innoville. A medium size, growing city. Small historic centre and quickly growing office area surrounding it 250.000 inhabitants and growing. The game is played on the game board and is supported with an interactive interface (displayed on the beamer)
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Heuristic optimization and turn-based analysis supported by simulation.
Model Summary (please provide us with a brief description of the model in max 3 lines)	City Logistics game (board game, supported by simulation) with the perspective of different stakeholders. The game is played in the City of Innoville. The game is played on the game board and is supported with an interactive interface, trading-off Quality of life, Economy, Accessibility, Health&Safety.

Modelling approach					
Model structure, methods and techniques	evaluation / scenario turn-based model				
		Name	**Description**	**Subtype**	**Type**
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	vrp -model	cloud based vrp model to determine the shortest route paths	Routing	Optimization
	2	cost model	cost structure	Overall cost	Cost model
	3	system dynamics model		System Dynamics	Other
	4				
	5				
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	***1***	consumers			
	2	shippers			
	3	service providers (local carrier, international carrier)			
	4	municipality Environmental department, Economic department			
	5				
Dependence of other external models	none				
Interactions (Please describe possible interactions with other models)					

Model Inputs				
	-	**Short description**	**Subtype**	**Type**
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Economy	City	External to Freight
	2	Health and safety	Population	External to Freight
	3	Price per m2	Population	External to Freight
	4	Quality of Life	Population	External to Freight
	5			
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)				

Model Outputs

Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) ***PLEASE FEEL FREE TO ADD MORE LINES***		**Short description (KPIs in red)**		**Type**
	1	costs / drop		Cost Data
	2	Price per m2		Cost Data
	3	Profit per shop		Cost Data
	4	Economy		External to Freight
	-	Health and safety		External to Freight
	-	Quality of Life		External to Freight
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Description**	**Category**	**Already analysed in the model? (Yes/No)**
	1	heuristic approach (no optimization)		
	2			
	3			
	4			
	5			

Software

Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	SQL				
	2	Excel / Macros				
	3					
	4					
	5					
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**	

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	none
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**Title**	**URL**
	1		-
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	-	**File name**	
	1		
	2		
	3		
	4		
	5		

8.21 POLIS1

Model Description	
Model Name	Noveleg evaluation tool
Author/Owner (please state the name of the developer and the owner of the model)	Novelog project
Year	2019
Version	
Scope (please describe the scope of the model and which issue of UFT/transport modelling the model solves; For example: Economic, efficiency, safety, environmental, Infrastructure and Management, Urban structure, Knowledge, etc.)	Impact assessment
Model Type (optimisation, demand model (freight generation, choice modelling), empirical model, emissions/noise {externalities model}, ABM, simulation, network, impact assessment)	Externalities model
Model Summary (please provide us with a brief description of the model in max 3 lines)	The model takes several inputs from the cities in order to estimate the impact of different policies

Modelling approach					
Model structure, methods and techniques					
		Name	**Description**	**Subtype**	**Type**
Submodels (Non exhaustive list of examples: Inventory, shipment size, delivery frequency, type of vehicle/Mode choice, Route choice, Time of Day, Warehouse/Consolidation centres location, traffic assignment) ***PLEASE FEEL FREE TO ADD MORE LINES***	1	Impact assessment		KPI measurement	Assessment
	2	Social cost benefit analysis		Economic	Assessment
	3	Transferability and adaptability		Transferability	Assessment
	4	Risk Analysis		Risk	Assessment
	5	Behavioural modelling		Choice model	Demand
Urban Freight Agents involved in the model (Consumers, Shops, Shipper, Transport Service Providers, Public Authorities, outside UF or aggregated model)	1	Public authority			
	2				
	3				
	4				
	5				
Dependence of other external models					
Interactions (Please describe possible interactions with other models)					

Model Inputs				
	-	**Short description**	**Subtype**	**Type**
	1	Project details	Cost structure	Cost Data
	2	Macroeconomic vars	City	External to Freight
	3	Energy and Fuel consumption	Externality ponderations	Externalities data
Data Inputs (Please describe the data input of the mode, such as: Cost data, network data, preference data, Demand data, sensor data, traffic data, etc.) ***PLEASE FEEL FREE TO ADD MORE LINES***	4	Indicators preference (weights	Externality ponderations	Externalities data
	5	Risks (impact and prob)	Externality ponderations	Externalities data
	6	WTP	Externality ponderations	Externalities data
	7	Actor relationships, preferences and attitudes	Agent relationship	Logistic system
	8			
	9			
	#			
Feedback from Physical twin (What type of measurements are needed from the city in order to keep the model updated)				

Model Outputs			
		Short description (KPIs in red)	**Type**
Descriptors (Please describe the output generated by the model. For example: Freight generation, commodities flow, Willingness to Pay, Modal split, Warehouse location, Traffic flows, Inventory policy, cost-benefit, etc) *PLEASE FEEL FREE TO ADD MORE LINES*	1	Costs of projects	Cost Data
	2	Shifting to eco alternatives propensity of agents	Demand data
	3	Benefits of projects	Externality
	4	Logistic sustainability Index	Externality
	-	Risk severity	Externality
	-	Risk	Policy
	5	SCBA	Policy

		Description	**Category**	**Already analysed in the model? (Yes/No)**
Solution approach (Which type of city logistic problem could be analysed by the model. Possible categories: Policy, Planning and Infrastructure, Technology, n.a.) *PLEASE FEEL FREE TO ADD MORE LINES*	1			
	2			
	3			
	4			
	5			

Software						
Software (please describe in which software programming languages the model has been developed for the different parts of the model) ***PLEASE FEEL FREE TO ADD MORE LINES***	***1***	Online tool				
	2					
	3					
	4					
	5					
Type of Access (which type and name)	**Open source**	**Public domain**	**Permissive**	**Copyleft**	**Commercial**	

Future Model Developments	
Next planned extensions and updates (expected date of release and content)	
Model Limitations for use as part of digital twin for LEAD (Please describe possible limitations of the model)	
Expected role/function of model in a digital twin of a city (how do I visualize this model to be used as part of a DT)	

Documentation			
Online documentation: For documentation available online ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**Title**	**URL**
	1	Manual	http://evalog.civ.uth.gr/docs/Manual.pdf
	2		
	3		
	4		
	5		
Attached documentation: For attached documentation in an email ***PLEASE FEEL FREE TO ADD MORE LINES***	_	**File name**	
	1		
	2		
	3		
	4		
	5		

9 Annex III – Input and Output table

			ZLC1	ZLC2	ZLC4	ZLC5	UPM3	SZE1	UPM1	UPM2	UPM4	UPM5	Polis1	ZLC3	MOLDE1	IRTX1	TUDELFT1	BKK1	IRTX2	TUDELFT2	ARGUSI1	ARGUSI2	MOLDE2
Inputs	Cost Data	Cost structure											X								X		
		Infrastructure cost		X								X											
		Salary cost		X																			
		Storage cost	X																				
		Transport cost	X	X								X		X									
	Demand data	Geographical location	X	X																			
		Logistic service demand												X			X						
		Preference data													X	X				X			
		Product demand	X	X	X	X		X						X			X			X			
	External to Freight	City								X		X	X					X	X			X	
		Pax trip demand																X	X	X			
		Pax trips														X	X						
		Population		X												X	X	X	X			X	
	Externalities	Externalities value							X		X	X											
		Externality weights							X	X	X	X	X	X									
	Supply Chain	Agent relationship											X		X								
		Logistic market																					X
	Logistical infrastructure	Logistical infrastructure		X	X	X											X	X			X		
	Logistic	Fleet		X	X	X		X						X			X						

		Shipment		X	X									X			X			X			
	Network	Network LoS		X	X				X	X	X	X		X		X							
		Network structure					X									X	X				X		
Output	Cost Data		X	X	X	X		X			X		X	X							X	X	
	Demand data												X		X	X	X	X	X	X	X		X
	External to Freight																		X			X	
	Externality						X		X	X	X	X	X	X	X		X		X		X		X
	Logistical infrastructure					X																	
	Logistical service		X		X			X						X			X			X	X		
	Network Data		X			X	X									X	X	X					
	Policy												X		X								

10 Annex IV – List of outputs

Model	Output category	Detail (KPI)	Model Type
ARGUSI1	Cost Data	Facility costs	Data collection
ARGUSI1	Cost Data	inbound costs	Data collection
ARGUSI1	Cost Data	outbound costs	Data collection
ARGUSI1	Cost Data	total costs	Data collection
ARGUSI1	Demand data	orders	Data collection
ARGUSI1	Externality	emissions	Data collection
ARGUSI1	Logistical service	handling	Data collection
ARGUSI1	Logistical service	kilometres	Data collection
ARGUSI1	Logistical service	service percentage, cover of demand	Data collection
ARGUSI2	Cost Data	costs / drop	Data collection
ARGUSI2	Cost Data	Price per m2	Data collection
ARGUSI2	Cost Data	Profit per shop	Data collection
ARGUSI2	External to Freight	Economy	Data collection
ARGUSI2	External to Freight	Health and safety	Data collection
ARGUSI2	External to Freight	Quality of Life	Data collection
BKK1	Demand data	Modal split	Demand models
BKK1	Demand data	OD matrix	Demand models
BKK1	Network Data	Loaded transport network	Demand models
BKK1	Network Data	Travel distance	Demand models
BKK1	Network Data	Travel time	Demand models
IRTX1	Demand data	Events file with detailed activities, movements and interactions of the agents	ABM
IRTX1	Demand data	OD matrix	ABM
IRTX1	Network Data	Network load	ABM
IRTX2	Demand data	Facilities	Demand models
IRTX2	Demand data	Number of passengers	Demand models
IRTX2	Demand data	Number of trips	Demand models
IRTX2	Demand data	People being potential customers / users of a logistics solution	Demand models

Model	Output category	Detail (KPI)	Model Type
IRTX2	Demand data	Shops / restaurants in an area / potential customers	Demand models
IRTX2	External to Freight	Households	Demand models
IRTX2	External to Freight	Persons	Demand models
IRTX2	External to Freight	Trips	Demand models
IRTX2	Externality	People living in an area affected by a new logistics solution	Demand models
MOLDE1	Demand data	Decisions process insights	ABM
MOLDE1	Demand data	Market shares	ABM
MOLDE1	Externality	WTP	ABM
MOLDE1	Policy	Global satisfaction	ABM
MOLDE1	Policy	Overall Policy acceptance	ABM
MOLDE1	Policy	stakeholder-specific policy acceptance	ABM
MOLDE2	Demand data	Preference data	Data collection
MOLDE2	Demand data	WTP	Data collection
POLIS1	Cost Data	Costs of projects	Externalities Model
POLIS1	Demand data	Shifting to eco alternatives propensity of agents	Externalities Model
POLIS1	Externality	Benefits of projects	Externalities Model
POLIS1	Externality	Logistic sustainability Index	Externalities Model
POLIS1	Externality	Risk severity	Externalities Model
POLIS1	Policy	Risk	Externalities Model
POLIS1	Policy	SCBA	Externalities Model
SZE1	Cost Data	Distribution Costs	Network model
SZE1	Cost Data	Number of vehicles/drivers	Network model
SZE1	Logistical service	Distribution Time	Network model
TUDELFT1	Demand data	Matrix of parcel tours	ABM
TUDELFT1	Demand data	Matrix of parcels created by the parcel synthesizer	ABM

Model	Output category	Detail (KPI)	Model Type
TUDELFT1	Demand data	Matrix of shipments created by the shipment synthesizer	ABM
TUDELFT1	Demand data	Matrix of tours	ABM
TUDELFT1	Demand data	Matrix of trips	ABM
TUDELFT1	Demand data	Number of trips	ABM
TUDELFT1	Externality	GHG emissions	ABM
TUDELFT1	Logistical service	Average Loads	ABM
TUDELFT1	Network Data	Network flow	ABM
TUDELFT1	Network Data	Transported tonnes	ABM
TUDELFT1	Network Data	Vehicle kms	ABM
TUDELFT2	Demand data	Amount of parcels delivered by crowdshipping	Demand models
TUDELFT2	Demand data	Modal split	Demand models
TUDELFT2	Logistical service	Equilibrium price	Demand models
TUDELFT2	Logistical service	Equilibrium profits	Demand models
UPM1	Externality	emissions	Externalities Model
UPM1	Externality	GHG emissions	Externalities Model
UPM2	Externality	Emission factors	Externalities Model
UPM2	Externality	GHG emissions	Externalities Model
UPM2	Externality	Total emissions	Externalities Model
UPM3	Externality	emissions	Network model
UPM3	Externality	GHG emissions	Network model
UPM3	Network Data	Network usage	Network model
UPM3	Network Data	Traffic flows	Network model
UPM4	Cost Data	Cost per externality	Externalities Model
UPM4	Externality	GHG emissions	Externalities Model
UPM4	Externality	Transport externalities	Externalities Model
UPM5	Externality	Alternatives sustainable performance	Externalities Model

Model	Output category	Detail (KPI)	Model Type
UPM5	Externality	Overall sustainability performance	Externalities Model
ZLC1	Cost Data	Total inventory cost	Optimization
ZLC1	Logistical service	Inventory policy	Optimization
ZLC1	Logistical service	Shipment size	Optimization
ZLC1	Network Data	Commodity flows	Optimization
ZLC2	Cost Data	Driver wages	Optimization
ZLC2	Cost Data	Logistics space costs	Optimization
ZLC2	Cost Data	Transport distance costs	Optimization
ZLC2	Cost Data	Transport time costs	Optimization
ZLC3	Cost Data	Operating costs	Externalities Model
ZLC3	Externality	GHG emissions	Externalities Model
ZLC3	Externality	PM, CO, Nox, NMHC	Externalities Model
ZLC3	Logistical service	service level (image on the right)	Externalities Model
ZLC4	Cost Data	Total Costs	Optimization
ZLC4	Logistical service	number of vehicles (Urban trucks, city freighters)	Optimization
ZLC5	Cost Data	Total Costs	Optimization
ZLC5	Logistical infrastructure	facilities location	Optimization
ZLC5	Network Data	Commodity flows	Optimization

11 Annex V – List of inputs

Model	Input Category	Sub Input category	Detail	Model Type
ARGUSI1	Cost Data	Cost structure	costs components	Data collection
ARGUSI1	Logistical infrastructure	Logistical infrastructure	delivery points	Data collection
ARGUSI1	Logistical infrastructure	Logistical infrastructure	potential transfer points	Data collection
ARGUSI1	Network	Network structure	infrastructure (road)	Data collection
ARGUSI2	External to Freight	City	Economy	Data collection
ARGUSI2	External to Freight	Population	Health and safety	Data collection
ARGUSI2	External to Freight	Population	Price per m2	Data collection
ARGUSI2	External to Freight	Population	Quality of Life	Data collection
BKK1	External to Freight	Population	Household surveys, SP	Demand models
BKK1	External to Freight	City	Land use and demographic statistics	Demand models
BKK1	External to Freight	Pax trip demand	Traffic volumes and passenger volumes	Demand models
BKK1	Logistical infrastructure	Logistical infrastructure	Infrastructure data and timetables	Demand models
IRTX1	Demand data	Preference data	Choice model	ABM
IRTX1	External to Freight	Population	Synthetic population	ABM
IRTX1	External to Freight	Pax trips	Transit schedule (GTFS)	ABM
IRTX1	Network	Network LoS	Flow / travel time data for validation	ABM
IRTX1	Network	Network structure	Network data	ABM
IRTX2	External to Freight	Population	Census data	Demand models
IRTX2	External to Freight	Population	Household Travel Survey	Demand models

Model	Input Category	Sub Input category	Detail	Model Type
IRTX2	External to Freight	Pax trip demand	OD data	Demand models
IRTX2	External to Freight	City	Service / enterprise census	Demand models
IRTX2	External to Freight	City	Tax data	Demand models
MOLDE1	Demand data	Preference data	Preference data	ABM
MOLDE1	Supply Chain	Agent relationship	Agents relationships	ABM
MOLDE2	Supply Chain	Logistic market	Alternatives	Data collection
MOLDE2	Supply Chain	Logistic market	Attribute levels	Data collection
MOLDE2	Supply Chain	Logistic market	Attributes characterising the alternatives	Data collection
POLIS1	Cost Data	Cost structure	Project details	Externalities Model
POLIS1	External to Freight	City	Macroeconomic vars	Externalities Model
POLIS1	Externalities data	Externality weights	Energy and Fuel consumption	Externalities Model
POLIS1	Externalities data	Externality weights	Indicators preference (weights	Externalities Model
POLIS1	Externalities data	Externality weights	Risks (impact and probability)	Externalities Model
POLIS1	Externalities data	Externality weights	WTP	Externalities Model
POLIS1	Supply Chain	Agent relationship	Actor relationships, preferences and attitudes	Externalities Model
SZE1	Demand data	Product demand	Demand	Network model
SZE1	Logistical service	Fleet	Fleet data	Network model
TUDELFT1	Demand data	Product demand	Firm population	ABM
TUDELFT1	Demand data	Logistic service demand	Observed market shares to calculate transport flows (direct, via DC, etc.)	ABM
TUDELFT1	Demand data	Product demand	Trips (trip diaries)	ABM
TUDELFT1	Demand data	Product demand	Weight (trip diaries)	ABM

Model	Input Category	Sub Input category	Detail	Model Type
TUDELFT1	External to Freight	Pax trips	Departure time (trip diaries)	ABM
TUDELFT1	External to Freight	Pax trips	Duration (trip diaries)	ABM
TUDELFT1	External to Freight	Population	Households	ABM
TUDELFT1	Logistical infrastructure	Logistical infrastructure	Location of distribution centres	ABM
TUDELFT1	Logistical service	Shipment	Shipment size distributions per logistics flow	ABM
TUDELFT1	Logistical service	Fleet	Vehicle type (trip diaries)	ABM
TUDELFT1	Network	Network structure	Network data	ABM
TUDELFT2	Demand data	Product demand	Parcel data	Demand models
TUDELFT2	Demand data	Preference data	Preference data	Demand models
TUDELFT2	External to Freight	Pax trip demand	OD data	Demand models
TUDELFT2	Logistical service	Shipment	Transport service data	Demand models
UPM1	Externalities data	Externalities value	Air quality receptors	Externalities Model
UPM1	Externalities data	Externality weights	Speed band emission factors	Externalities Model
UPM1	Network	Network LoS	Traffic flow	Externalities Model
UPM2	External to Freight	City	Activity data	Externalities Model
UPM2	Externalities data	Externality weights	Emission factors	Externalities Model
UPM2	Externalities data	Externality weights	Fuel variables	Externalities Model
UPM2	Externalities data	Externality weights	location-specific factors	Externalities Model
UPM2	Network	Network LoS	Driving conditions	Externalities Model
UPM3	Network	Network structure	Network Data	Network model

Model	Input Category	Sub Input category	Detail	Model Type
UPM4	Externalities data	Externalities value	Accident statistics	Externalities Model
UPM4	Externalities data	Externality weights	Emission factors	Externalities Model
UPM4	Externalities data	Externalities value	People/habitat exposed	Externalities Model
UPM4	Externalities data	Externality weights	WTP/cost valuations	Externalities Model
UPM4	Network	Network LoS	Network activity data	Externalities Model
UPM5	Cost Data	Infrastructure cost	Investment costs	Externalities Model
UPM5	Cost Data	Infrastructure cost	Maintenance costs	Externalities Model
UPM5	Cost Data	Transport cost	Road operation costs	Externalities Model
UPM5	Cost Data	Transport cost	Vehicle operation costs	Externalities Model
UPM5	External to Freight	City	Macroeconomic Effects	Externalities Model
UPM5	Externalities data	Externality weights	Accident costs	Externalities Model
UPM5	Externalities data	Externalities value	CO2 Emissions	Externalities Model
UPM5	Externalities data	Externalities value	Community disruption	Externalities Model
UPM5	Externalities data	Externalities value	Employment effects	Externalities Model
UPM5	Externalities data	Externalities value	Habitat fragmentation and negative effects on species	Externalities Model
UPM5	Externalities data	Externalities value	Impacts on businesses and community services	Externalities Model
UPM5	Externalities data	Externalities value	Landscape degradation/visual negative impacts	Externalities Model
UPM5	Externalities data	Externalities value	Noise Pollution	Externalities Model
UPM5	Network	Network LoS	Travel time	Externalities Model

Model	Input Category	Sub Input category	Detail	Model Type
ZLC1	Cost data	Storage cost	Cost per item	Optimization
ZLC1	Cost data	Storage cost	Setup costs	Optimization
ZLC1	Cost data	Storage cost	Storage costs	Optimization
ZLC1	Cost Data	Transport cost	Transport Costs	Optimization
ZLC1	Demand data	Product demand	Demand per item	Optimization
ZLC1	Demand data	Product demand	Number of items	Optimization
ZLC1	Demand data	Geographical location	Number of retailers	Optimization
ZLC1	Demand data	Product demand	weight per item	Optimization
ZLC2	Cost Data	Transport cost	Fuel consumption	Optimization
ZLC2	Cost Data	Transport cost	fuel price	Optimization
ZLC2	Cost Data	Infrastructure cost	Rent cost	Optimization
ZLC2	Cost data	Salary cost	Shift length	Optimization
ZLC2	Cost Data	Transport cost	Transport Costs	Optimization
ZLC2	Cost data	Salary cost	wage	Optimization
ZLC2	Demand data	Geographical location	Average distance between stops	Optimization
ZLC2	Demand data	Geographical location	Average distance depot to stop	Optimization
ZLC2	Demand data	Geographical location	Average stop	Optimization
ZLC2	Demand data	Product demand	Number of receivers	Optimization
ZLC2	Demand data	Product demand	Replenishment frequency	Optimization
ZLC2	Demand data	Geographical location	Size area	Optimization
ZLC2	Demand data	Geographical location	stop density	Optimization
ZLC2	Demand data	Product demand	Value per item	Optimization
ZLC2	Demand data	Product demand	Volume per item	Optimization
ZLC2	External to Freight	Population	Population	Optimization
ZLC2	Logistical infrastructure	Logistical infrastructure	Depot capacity	Optimization

Model	Input Category	Sub Input category	Detail	Model Type
ZLC2	Logistical infrastructure	Logistical infrastructure	Depot/UCC/warehouse capacity	Optimization
ZLC2	Logistical service	Fleet	Delivery vehicle capacity	Optimization
ZLC2	Logistical service	Shipment	Service time per customer	Optimization
ZLC2	Network	Network LoS	Average speeds	Optimization
ZLC2	Network	Network LoS	Congestion factor	Optimization
ZLC2	Network	Network LoS	Time restrictions	Optimization
ZLC2	Network	Network LoS	Vehicle restrictions	Optimization
ZLC3	Cost Data	Transport cost	Fixed cost truck	Externalities Model
ZLC3	Cost Data	Transport cost	Variable cost truck	Externalities Model
ZLC3	Demand data	Product demand	Consumer demand	Externalities Model
ZLC3	Demand data	Logistic service demand	Market share	Externalities Model
ZLC3	Demand data	Logistic service demand	Market Share	Externalities Model
ZLC3	Externalities data	Externality weights	Circuity multiplier	Externalities Model
ZLC3	Externalities data	Externality weights	Externalities weights	Externalities Model
ZLC3	Logistical service	Fleet	Average capacity utilization	Externalities Model
ZLC3	Logistical service	Fleet	Average capacity utilization (trycicle)	Externalities Model
ZLC3	Logistical service	Shipment	Service time truck (min/client)	Externalities Model
ZLC3	Network	Network LoS	Truck inner velocity	Externalities Model
ZLC4	Demand data	Product demand	Consumers demand	Optimization
ZLC4	Logistical infrastructure	Logistical infrastructure	Satellites capacity	Optimization
ZLC4	Logistical service	Shipment	Loading time	Optimization
ZLC4	Logistical service	Shipment	Unloading time	Optimization
ZLC4	**Logistical service**	Fleet	vehicles capacity	Optimization

Model	Input Category	Sub Input category	Detail	Model Type
ZLC4	Network	Network LoS	Travel time	Optimization
ZLC5	Demand data	Product demand	Demand data	Optimization
ZLC5	Logistical infrastructure	Logistical infrastructure	Facilities capacity	Optimization
ZLC5	**Logistical service**	Fleet	vehicles capacity	Optimization