HARMONY
SPATIAL & TRANSPORT PLANNING FOR A NEW MOBILITY ERA

Holistic Approach for Providing Spatial & Transport Planning Tools and Evidence to Metropolitan and Regional Authorities to Lead a Sustainable Transition to a New Mobility Era

D8.2 Assessment and transferability of the HARMONY MS

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SUMMARY SHEET

PROJECT

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
LUTI	Land-Use Transport Interaction model
DFM	Demographic Forecasting Model
EEM	Energy and Emissions Model
REM	Regional Economy Model
TPS	Tactical Passenger Simulator
TFS	Tactical Freight Simulator
OPS	Operational Passenger Simulator
OFS	Operational Freight Simulator
MS	Model Suite
CAV [AV]	Connected Autonomous Vehicles

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EXECUTIVE SUMMARY

This deliverable, as a part of WP8, presents an assessment of the HARMONY Model Suite (MS) as a platform and discusses in-depth the transferability of its individual modules, i.e., the models developed and integrated in its simulators. The transferability of transport and land-use models is important because it allows for the application of models developed for one location or context to another location or context. This is particularly significant because the development of transport and land-use models is costly and time-consuming. If models can be transferred from one location to another, it can save resources and time, and enable planners and policymakers to make more informed decisions about transportation and land-use policies. Additionally, transferability, when done correctly, can ensure consistency and improve comparability between regions, streamlining policy recommendations and highlighting best practices.

For the assessment part of the deliverable, we utilize an internal interview with consortium members and the RIAB members along with external interviews with potential users. The summary of the results, highlighting advantages and challenging features of the MS are presented in Chapter 2, and the more detailed version of the assessment can be found in D1.4. Overall, the MS is assessed as an important tool, with demonstrated capabilities, which could be challenging to navigate for some users and a significant part of the interviewed people said they would require a manual or other guide for using the platform.

Regarding the transferability part of the deliverable, we relied on the experts of the consortium, who were responsible for collecting the data, estimating the models and integrating the workflow in the HARMONY MS to evaluate their transferability, focusing on the transferability of key parameters in the models. For some models, such as the mode choice model of the TPS, there is sufficient literature to suggest which parameters could be transferable, using which techniques but for other models, including a number of innovative models developed in the context of HARMONY, there is no relevant literature.

For this reason, and for reasons of consistency, we conducted an internal survey of the key parameters of the models, their transferability, and their criticality in the model estimation. Chapter 3 presents the results for the models across all simulators. In general, for some models, the critical parameters can be transferred, especially if the data sources used to estimate them are well-established datasets (such as census or time surveys) which can be usually found across Europe. However, for some models it is more difficult to transfer parameters, especially for models which rely on data which is particular (or idiosyncratic) for the specific location for which the model is estimated. This is especially evident when discussing city-specific variables such as the number of jobs in an area, the travel times and distances or the cost elasticities. However, we try to identify alternative sources of data which could assist in the transferability of the models.

A final contribution of this deliverable is the presentation of an alternative or accompanying product to the MS, the MS-Lite. The MS-Lite idea was conceived exactly because of the difficulties of transferring a complex and data-dependent system as the HARMONY MS to other cities. While the HARMONY MS architecture is scalable and modular, facilitating flexible deployments of the platform, the MS-Lite addresses key issues in transferability, especially for the data-hungry TPS.

Overall, in terms of transferability, this deliverable identifies the key variables that influence travel behaviour and land-use in the HARMONY MS simulators, provides alternative data sources when available, highlights critical paths and acknowledging the limitations, presents an alternative to the MS, the MS-Lite.

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1. Introduction

HARMONY's main vision is to develop a new generation of harmonised spatial and multimodal transport planning tools, which comprehensively model spatial organization and the transport sector's dynamics, enabling regional and urban planning organizations to lead the transition to a low carbon new mobility era in a sustainable manner. However, HARMONY goes beyond the design of just a model suite in many ways. Stakeholders from both the public and private sector are actively engaged in both regional and cross-metropolitan co-creation labs to share their requirements with regards to integration of traditional and new transport modes, utilization of new technologies and sustainable regional developments. Subsequently, a co-creation philosophy is adopted, where project developments and processes are based on stakeholder's needs. The facilitation of the co-creation labs has been enabled through activities taking place in six EU metropolitan areas (HARMONY pilots) on six TEN-T corridors, i.e., Rotterdam (NL), Oxfordshire (UK), Turin (IT), Athens (GR), Trikala (GR) and Upper Silesian-Zaglebie Metropolis (PL).

Furthermore, new mobility technologies and concepts, such as electric autonomous vehicles (AVs), electric vehicles, self-driving robots and unmanned aerial vehicles (UAVs) are demonstrated in three of HARMONY's pilots and are integrated with the traditional transport modes to derive real-world challenges, social acceptance and policy requirements (see D9.5[1] for a detailed description).

HARMONY uses the results of the model suite (MS) applications from the pilots and the co-creation labs to offer a complete solution including recommendations for a new generation of SUMPs (Sustainable Urban Mobility Plans) ready to tackle the challenges of the new mobility era and regional planning. In addition, urban and regional multi-stakeholder partnerships, business models and cases required for attracting sustainable investments are proposed. HARMONY's outputs act as an enabler of the innovation process and its introduction in harmony with the needs and requirements of agglomerations.

Additionally, HARMONY's objective is to assist metropolitan areas with evidence-based decision making, by providing a state-of-the-art model suite that quantifies the multidimensional impact of various policies, investments and mobility concept applications, while simultaneously identifying the most appropriate solutions and recommending ways to exploit the disruptive mobility innovations.

1.1 The Harmony Model Suite

HARMONY MS (Model Suite) is one of the key outcomes of the HARMONY project and is a multiscale, integrated software platform which hosts, connects, and enables the development and interaction of a series of models developed in the HARMONY context in a user-friendly way, allowing for intuitive connection of models, uploading of new components, running of scenarios and visualizing the results.

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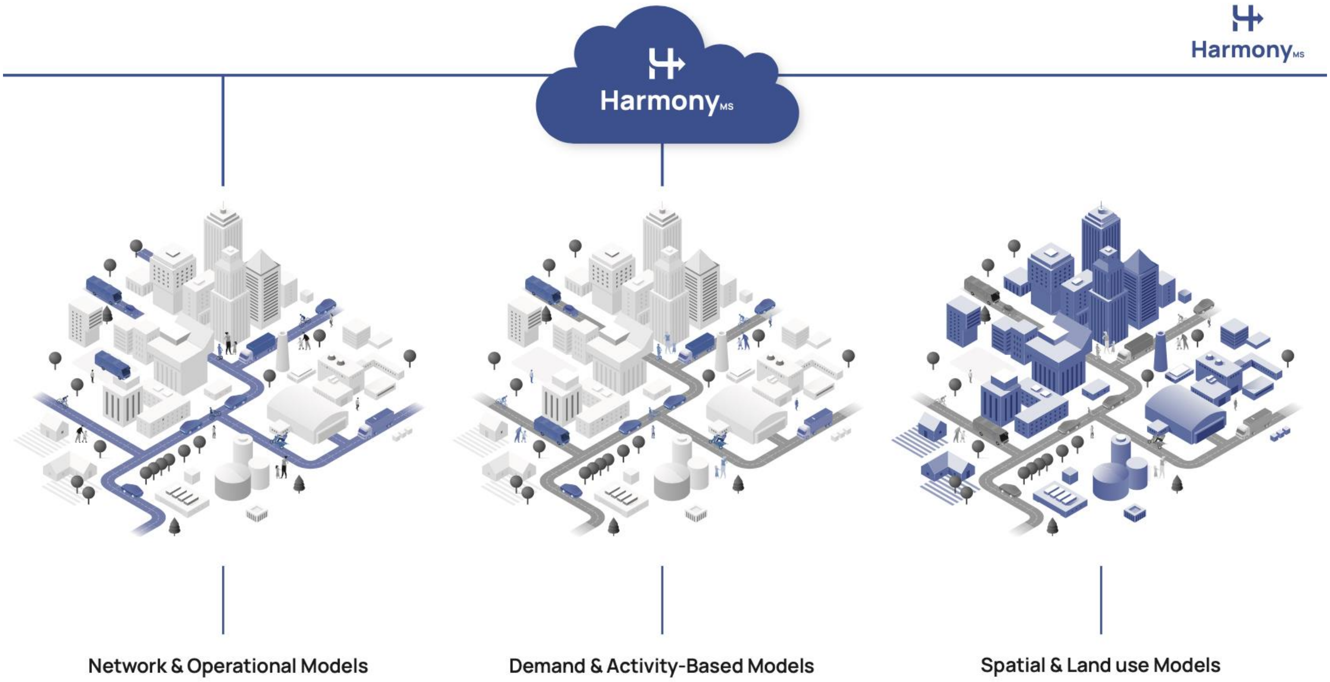

Figure 1 HARMONY-MS

The MS hosts a series of transport and spatial models, described in detail in D2.4[2] and deliverables of WPs related to the MS development and application (WP4, WP5, WP6 and WP7). The platform is built as a software agnostic component with demonstrated capability and connectivity to existing software platforms. The MS hosts models estimated for and applied to all the pilot areas of the project.

1.2 Objectives of the deliverable

Transport and spatial models have been widely used in the study of human mobility and land use patterns These models are designed to capture the interactions between people, places, and transportation systems, and to predict how these interactions will change over time. However, the transferability of transport and spatial models is a complex issue, as the validity of a model developed for one region or context may not hold for another. One of the main challenges in the transferability of transport and spatial models is the difficulty in capturing the nuances of different regions and contexts For example, a model developed for a dense urban area may not be appropriate for a rural region, as the factors that influence mobility and land use patterns are likely to be very different. In addition, transport and spatial models are often based on a specific set of assumptions about human behaviour and decision-making, which may not hold true in all contexts (Koppelman, 1982).

To overcome these challenges, researchers have proposed various strategies for improving the transferability of transport and spatial models. One approach is to use a flexible and modular model structure which can be easily adapted to different regions and contexts (Ziemke et al., 2015). This can be achieved by using a combination of generic and context-specific model components, and by allowing for the calibration and validation of the model using local data. Another approach is to use a multi-scale modelling approach which allows for the simultaneous consideration of different levels of spatial and temporal resolution (Fox and Hess, 2010). This can help to capture the interactions between different land use and transportation systems, and to account for the different factors that influence mobility and land use patterns at different scales. A third approach is to use machine learning techniques (Koushik, et al., 2020) to improve the model's ability to capture the nuances of different regions and contexts.

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Machine learning models can be trained on large amounts of data and can learn complex patterns and relationships that may not be captured by traditional transport and spatial models.

This deliverable discusses transferability in-depth by presenting detailed tables of models and their parameters, which include the transferability level, as indicated by experts and developers of the models, their criticality to the model estimation and any existing alternative data sources.

1.3 Structure of the deliverable

The deliverable is structured as follows: after this short introduction, chapter 2 briefly discusses the assessment of the HARMONY MS and links to D1.4[3] where detailed presentation of the assessment is available, chapter 3 presents the detailed transferability tables for most of the models developed in HARMONY MS, while chapter 4 presents an alternative to the MS with high transferability: the MS-Lite. Chapter 5 concludes the deliverable.

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2. Assessment of the HARMONY MS

This chapter shortly discusses the assessment of the HARMONY MS. An in-depth assessment of the MS as a whole, including functional and non-functional requirements and reaction of pilot users within the HARMONY consortium can be found in D1.4[4]. However, we summarize the results of the user-acceptance questionnaire distributed to the pilot users of the MS in this chapter.

To understand the user-acceptance of the HARMONY MS, a survey was conducted among potential users and Research and Innovation Advisory Board members. The purpose of the survey was to gather insights and opinions about the HARMONY MS and the HARMONY Dashboard. The results of the survey provide crucial information for the future of the project as it gives an understanding of what the main stakeholders think of the platform. 10 participants were surveyed to assess the MS.

The results of the user-acceptance questionnaire for the HARMONY MS platform showed an average response of 3.6 out of 5, indicating that the platform is well perceived but nevertheless needs improvement to fully meet the needs of potential users. The most important features for the platform are the ability to analyse and define scenarios, visualize KPIs, and have an easy-to-use and flexible interface. Respondents also highlighted the importance of robust modelling frameworks, clear descriptions of models and simulations, and user-friendly presentation of results.

However, survey results showed mixed opinions on the usefulness and ease of use of the platform. 46.7% of respondents agreed that the platform will increase efficiency and save time, while 46.7% are still undecided on their level of usage. 40% agreed that the platform has a clear and understandable interface, but 40% also do not know if they will use the platform after the project. Some respondents agreed that the platform may require some effort to properly use, and that training and technical help would be beneficial. The complexity of the platform was also a concern for some respondents, as was the interoperability between transport programs and the platform.

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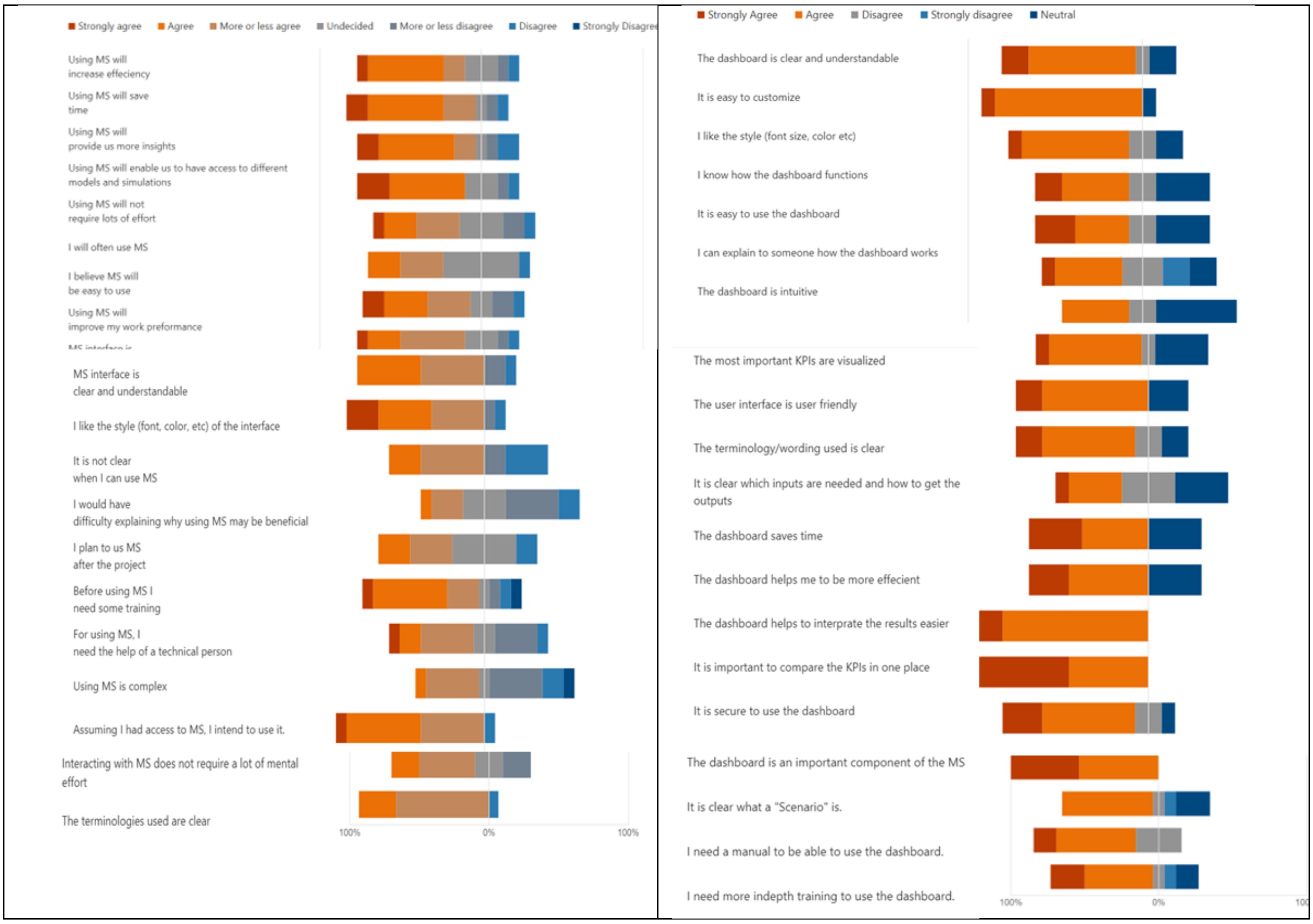

Figure 2 HARMONY MS assessment

The survey conducted to assess the requirements of the HARMONY project also included an evaluation of the HARMONY Dashboard. 11 respondents provided their ratings of the dashboard on a scale of 1 to 5, yielding an average score of 3.45, indicating that the dashboard is well received but has room for improvement.

The survey also collected opinions on various aspects of the dashboard, with respondents indicating their level of agreement on specific characteristics. With regards to ease of use, 61.5% agreed that the dashboard was clear and understandable, and 84.6% agreed that it was easy to customize. Around 30.8% strongly agree that the dashboard easy to use, while 38% strongly agree that they understood how it functioned and 38.5% considered it to be intuitive. Despite these positive perceptions, 30.8% of respondents were not sure on which inputs were needed and how to obtain outputs, but an equal percentage agreed with the opposite statement.

In terms of its impact on work, around 70% of respondents agreed that the dashboard would save time and increase efficiency in their tasks by making it easier to interpret results. However, like the HARMONY MS, training and manual support were seen as beneficial features to be added.

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3. Transferability of the HARMONY MS

In this chapter, we present the results of the internal review and study on the transferability and criticality of various parameters used in the simulators within the HARMONY MS. Model transferability generally refers to the ability of a transportation model developed and calibrated for a specific geographical context to be transferred to another geographical location or to be applied to a different context. A highly transferable model would have the ability to correctly model travel behaviour when transferred to another location, while if the model or the parameter is considered not to be transferable the modeller estimates that the model would perform poorly if transferred to a new region.

The parameters have been estimated for all cities in HARMONY, and their transferability and criticality have been evaluated based on the expert opinion of the transport modellers and developers in the consortium. The evaluation was conducted by at least one researcher/expert for each family of models, adding up to more than 10 evaluators, all of which had significant roles for developing the original models in the HARMONY context.

These results provide a comprehensive understanding of the various parameters used in the simulators, and the level of transferability and criticality associated with each parameter. This information will be useful for future applications of the HARMONY MS platform, as it will help to identify the key parameters that need to be considered for a successful transfer of the platform to a new city or region.

In the chapter, transferability tables are provided for each one of the following simulators:

- Strategic models:
  - Demographic Forecasting Model (DFM)
  - Regional Economy Model (REM)
  - Land-Use Transport Interaction model (LUTI)
  - Energy and Emissions Model (EEM)
  - Strategic Freight Simulators (SFS and FS)
- Tactical models:
  - Tactical Passenger Simulator (TPS)
  - Tactical Passenger Model (TPM) – Operational Passenger Model (OPM)
  - Tactical Freight Simulator (TFS)
- Operational models:
  - Operational Passenger Simulator (OPS)
  - Operational Freight Simulator (OFS)

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3.1 Strategic models

Table 1 DFM Lite transferability

Model: Demographic Forecasting Model LITE	**Simulator: DFM Lite**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Households	TUR, ATH	Mid to high	Census data / Statistical office and projections	-	Important	No
Households' yearly growth Rate	TUR, ATH	Mid to high	Census data / Statistical office and projections	-	Important	No
Macro Zone	TUR, ATH	Mid to high	Official urban zoning system, or custom	User elaboration	Critical	Must be the same used in all the other MS models
Population	TUR, ATH	Mid to high	Census data / Statistical office and projections	-	Important	No
Population yearly growth Rate	TUR, ATH	Mid to high	Census data / Statistical office and projections	-	Important	No
University Housing	TUR, ATH	Mid to high	Census data / Statistical office and projections	-	Mid	No
University Share	TUR, ATH	Mid to high	Census data / Statistical	-	Mid	No

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Model: Demographic Forecasting Model LITE	**Simulator: DFM Lite**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
			office and projections			
Years	TUR, ATH	Mid to high	Census data / Statistical office and projections	-	Important	No

The Demographic Forecasting Model LITE (DFM Lite) simulator assesses the transferability of its parameters using data from two cities: TUR and ATH. The results indicate that the households, households' yearly growth rate, population, and population yearly growth rate parameters have a mid to high transferability. This is because these parameters are estimated using census data and projections from statistical offices, which are considered reliable sources.

On the other hand, the macro zone parameter is considered critical for the model, and its transferability is also mid to high. The macro zone must be the same used in all the other models, as its dependence on other models is critical. The university housing and university share parameters have a mid-transferability, as they are also estimated using census data and projections from statistical offices.

Table 2 REM transferability

Model: Regional Economy model	**Simulator: REM**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Income	TUR, OXF, ATH, ROT	Mid to high	Census data / Statistical office and projections	-	Important	No

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Model: Regional Economy model	Simulator: REM					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Jobs by economic sector	TUR, OXF, ATH, ROT	Mid to high	Census data / Statistical office	-	Critical	No
Population	TUR, OXF, ATH, ROT	Mid to high	Census data / Statistical office and EU projections	-	Critical	DFM and DFM Lite (optional)
GDP	TUR, OXF, ATH, ROT	Mid to high	Census data / Statistical office and EU projections	-	Critical	No
Beta coefficients	TUR, OXF, ATH, ROT	High	Calibrated data (econometric estimation – EU NUTS3)	-	Critical	No
Beta multipliers	TUR, OXF, ATH, ROT	Low	Calibrated data (regional)	-	Critical	No

The Regional Economy Model (REM) simulator is applied in four cities: TUR, OXF, ATH, and ROT. The results indicate that the income, jobs by economic sector, population, and GDP parameters have a mid to high transferability. This is because these parameters are estimated using census data, projections from statistical offices, and EU projections, which are considered reliable sources.

The beta coefficients and beta multipliers parameters have a critical importance for the model, with high and low transferability, respectively. The beta coefficients are estimated using calibrated data from econometric estimation at the EU NUTS3 level, while the beta multipliers are calibrated at the regional level. The population parameter is also critical for the model, and its transferability is mid to high. The model's dependence on other models is optional, with the DFM and DFM Lite being used if needed.

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Table 3 LUTI transferability

Model: Land-Use Transport-Interaction model	**Simulator: LUTI**				
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Employment distribution	OXF, TUR, ATH	Mid to low	Jobs floorspace	Critical	Yes (REM)
Residential floorspace	OXF, TUR	Mid to low	Volume/number of buildings	Critical	No
Number of buildings	ATH	High	Estimation of residential capacity from population distribution	Important	
Retail centres' floorspace	OXF	Low	Retail centres'/economic activities revenues	Important	No
Schools capacities	OXF, TUR	Mid to low	Number of schools per area	Important	No
Hospitals capacities	OXF, TUR	Mid to low	Number of hospitals per area	Important	No
Road network	OXF, TUR, ATH	High	Euclidean distances	Critical	No
Rail network with timetables	OXF	Mid to low	Euclidean distances + travel time assumptions	Important	
Metro network with timetables	TUR	Mid to low	Euclidean distances + travel time assumptions	Important	
Bus timetables	OXF, TUR, ATH,	Mid to low	Euclidean distances + travel time assumptions	Important	

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The Land-Use Transport-Interaction model (LUTI) is applied in three cities: OXF, TUR, and ATH. The results indicate that the employment distribution and residential floorspace parameters have a mid to low transferability. This is because these parameters are estimated using the number of job floorspaces and the volume/number of buildings, respectively, which can vary greatly between cities. The employment distribution parameter is considered critical for the model, and its dependence on the Regional Economy Model (REM) is noted.

The number of buildings parameter in ATH is considered high transferable, as it is estimated using the residential capacity from the population distribution. The retail centres' floorspace in OXF has a low transferability, as it is estimated using retail centres and economic activities revenues. The schools' capacities and hospitals capacities parameters in OXF and TUR have a mid to low transferability, as they are estimated using the number of schools and hospitals per area, respectively.

The road network, rail network with timetables, metro network with timetables, and bus timetables parameters all have a mid to low transferability, as they are estimated using Euclidean distances and travel time assumptions. The rail and metro network with timetables are considered important, while the road network and bus timetables are considered critical for the model.

Table 4 EEM transferability

Model: Energy and Emissions		**Simulator: EEM**			
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Simulated drive cycle data	OXF	Low	If drive cycle data is not available, use link-level model	Mid (alternative methodology available)	Network models
Simulated Link level flows	OXF, TUR	Low	Scale historical vehicle flows with growth rates or evaluate on dummy network	Mid	Network models
Emissions indices by EURO standard	Europe	High	Freely available for European cities. Can be used for other cities where vehicle type by EURO standard known.	High	No

The Energy and Emissions model (EEM) is applied in two cities: OXF and TUR. The results indicate that the simulated drive cycle data and simulated link level flows parameters have a low transferability. This is because these parameters are estimated using specific data from OXF and TUR, respectively, and may not be applicable to other cities.

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However, an alternative methodology is available if drive cycle data is not available, which uses a link-level model. This alternative methodology is considered mid-critical for the model. The emissions indices by EURO standard parameter[5] have a high transferability, as it is based on freely available data for European cities and can be used for other cities if the vehicle type by EURO standard is known. This parameter is considered high critical for the model. The model's dependence on network models is noted.

Table 5 SFS and FS transferability

Model: Strategic Simulator	**Simulator: Strategic Freight Simulators (SFS and FS)**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Zones	ROT	Low	Local traffic model	Local traffic model or open data	Critical	No
Socio-economic data	ROT	Low	Local traffic model	Local traffic model or census data / statistical office	Critical	No
Commodity matrix	ROT	LOW	External interregional forecast	EU model TRUST	Critical	No
Distribution centers (DCs)	ROT	Low	OpenStreet Map API Google Maps API	Same open sources	Important	No
Surface of DCs (m2) per NUTS3-region.	ROT	Low	RWS database	Local database	Important	No
SIF PA parameters	ROT	Medium	Regression models freight production attraction	Estimate models on local data	Important	No

[5] Daskalakis, G., Psychoyios, D., & Markellos, R. N. (2009). Modeling CO2 emission allowance prices and derivatives: Evidence from the European trading scheme. *Journal of Banking & Finance*, *33*(7), 1230-1241.

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Model: Strategic Simulator	**Simulator: Strategic Freight Simulators (SFS and FS)**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Firm size distribution FS model	ROT	Medium	National Statistics Center (CBS)	National Statistics center	Important	No

The Strategic Simulator, which includes the Strategic Freight Simulators (SFS and FS) models, assesses the transferability of its parameters using data from the city of ROT. The results indicate that the zones, socio-economic data, commodity matrix, distribution centres (DCs), surface of DCs per NUTS3-region, SIF PA parameters, and firm size distribution FS model parameters have a low to medium transferability. This is because these parameters are estimated using local traffic models, openStreetMap API and Google Maps API, external interregional forecasts, regression models, and national statistics centres, respectively.

These sources may not be applicable or available for other cities. The zones and socio-economic data parameters are considered critical for the model, as alternative sources such as local traffic models and census data/statistical offices are available. The commodity matrix parameter is also considered critical, with the EU model TRUST being an alternative source. The distribution centres, surface of DCs per NUTS3-region, SIF PA parameters, and firm size distribution FS model parameters are considered important for the model but have low transferability. The model does not have a dependence on other models.

3.2 Tactical models

Table 6 TPS mode choice transferability

Model: Mode choice	**Simulator: Tactical Passenger Simulator**				
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Travel time (per mode)	TUR,OXS	Mid to low	Skim matrices or open travel data	Critical	No
Travel cost (per mode)	TUR,OXS	Mid to low	Skim matrices or open travel data	Critical	No

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Model: Mode choice		**Simulator: Tactical Passenger Simulator**			
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Age	TUR,OXS	Acceptable	Census or sample for application area	Important	No
Car ownership	TUR,OXS	Acceptable	Census or sample for application area	Important	No
Income	TUR,OXS	Acceptable	Census or sample for application area	Important	No
Student (Dummy)	TUR,OXS	Acceptable	Census or sample for application area	Important	No
Employment type	TUR,OXS	Acceptable	Census or sample for application area	Important	No
Distance to nearest PT station	TUR,OXS	Low	OSM other open data	Mid	No

The Mode Choice model, which is part of the TPS simulator, discusses the transferability of the parameters using the model applications in TUR and OXF. The results indicate that the travel time and travel cost parameters per mode have a mid to low transferability. This is because these parameters are estimated using travel surveys, skim matrices or open travel data, which may not be applicable or available for other cities. These parameters are considered critical for the model.

The age, car ownership, income, student (dummy), and employment type parameters are considered acceptable in transferability, as they can be estimated using census or sample data for the application area. These parameters are considered important for the model. The distance to the nearest PT station parameter has a low transferability, as it is estimated using OSM or other open data. This parameter is considered mid-critical for the model. The model does not have a dependence on other models.

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Table 7 TPS MDCEV(activity participation and duration) transferability

Model: Activity participation and duration		**Simulator: Tactical Passenger Simulator**			
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Employment type	TUR, OXS	Acceptable	Skim matrices or open travel data	Important	No
Income	TUR, OXS	Acceptable	Skim matrices or open travel data	Important	No
Age	TUR, OXS	Acceptable	Census or sample for application area	Important	No
Distance to nearest grocery	TUR, OXS	Low	OSM other open data	Important	No
Distance to nearest public space	TUR, OXS	Low	OSM other open data	Important	No
Student (Dummy)	TUR, OXS	Acceptable	Census or sample for application area	Important	No
Number of children	TUR, OXS	Acceptable	Census or sample for application area	Important	No
Remote work	TUR, OXS	Low	Census or sample for application area	Important	No

The results suggest that the parameters of the Activity Participation and Duration Simulator (TPS) have varying levels of transferability from the cities of TUR and OXS to other cities. For example, the Employment Type and Income parameters are estimated to be "Acceptable" in terms of transferability. This means that these parameters can be used for other cities with reasonable accuracy, and alternative data sources such as Skim Matrices or Open Travel Data can be used to estimate them. On the other hand, the Distance to nearest Grocery and Distance to nearest Public Space parameters are estimated to be "Low" in terms of transferability, meaning that they may not be applicable to other cities without modification.

Alternative data sources such as OSM or other open data can be used to estimate these parameters. Additionally, the parameters of the model are dependent on the availability of census or sample data

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for the area of application. The criticality of the model is largely dependent on the accuracy of the parameters, making it important to ensure that the right data sources are used to estimate them.

Table 8 TPS Destination choice transferability

Model: Destination choice		**Simulator: Tactical Passenger Simulator**			
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Distance matrix	TUR,OXS	Low	Skim matrices or open travel data	Critical	No
Travel time matrix	TUR,OXS	Low	Skim matrices or open travel data	Critical	No
Number of jobs	TUR,OXS	Low	Osm or other open data	Important	No
Number of points of interest	TUR,OXS	Low	Osm or other open data	Important	No
Land-use densities	TUR,OXS	Low	Osm or other open data	Important	No

The Destination choice model uses several key parameters to predict the choice of a destination for a trip. The transferability of these parameters is moderate to low, meaning that the data and results from the model estimated for TUR and OXS cities may not be directly applicable to other cities. The criticality for the model is high, as the accuracy of the results relies heavily on the accuracy of the input data.

The model uses a distance and travel time matrix, which can be obtained from skim matrices or open travel data, as well as the number of jobs, points of interest, and land-use densities, which can be obtained from OSM or other open data sources.

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Table 9 TPS Start times transferability

Model: Activity start time	**Simulator: Tactical Passenger Simulator**				
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Age	TUR, OXS	Mid to low	Census or time-survey data	Important	No
Number of persons employed in a household	TUR, OXS	Mid to low	Census or time-survey data	Important	No
Income	TUR, OXS	Acceptable	Census or time-survey data	Important	No
Education	TUR, OXS	Acceptable	Census or time-survey data	Important	No
Activity duration	TUR, OXS	Low	Time-survey	Critical	MDCEV
Employment type	TUR, OXS	Acceptable	Census or time-survey data	Important	No
Number of children	TUR, OXS	Acceptable	Census or time-survey data	Important	No

The transferability of the activity start time model estimated for a specific city using the TPS simulator is evaluated for various parameters. The model's transferability is considered mid to low for age, number of persons employed in a household, education, and employment type, and acceptable for income and number of children. Activity duration has low transferability and is critical to the model, requiring the use of time-survey data and dependence on the MDCEV model.

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Table 10 TPM-OPM transferability

Model: Dynamic Demand Shift/Re-evaluation	**Simulator: Tactical Passenger Model – Operational Passenger Model**				
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Network travel time	TUR	Low	If stated adaptation experiment is infeasible to apply, suggest constants' calibration using RP market shares	High (exogenous constraints/delays are translated in travel time variation)	Network models
Dynamic factors (alternative frequency)	TUR	Mid	Hard to transfer without panel data (scarce/expensive) or applying the experiment	Mid	No
Trip/activity attributes	TUR	Mid	RP panel diary data or constants' calibration using market shares	Mid	ABM
Number of opportunities (e.g., modes, routes, activity locations)	TUR	Mid to low	Network dependent, suggest applying the experiment on a small sample and/or evaluate region similarity	Mid	ABM
Sociodemographic characteristics (age, gender,	TUR, OXF	Mid to high	Structural equation results were found	Low	Synthetic population

Model: Dynamic Demand Shift/Re-evaluation	Simulator: Tactical Passenger Model – Operational Passenger Model				
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
education, mobility tool ownership)			relatively stable across regions.		

The transferability of the dynamic demand shift/re-evaluation model estimated for a specific city using the TPS-OPS simulators is evaluated for various parameters. The model's transferability is considered low for network travel time, mid for dynamic factors and trip/activity attributes, and mid to low for the number of opportunities and sociodemographic characteristics.

The criticality of the model parameters is considered high for network travel time, mid for dynamic factors, trip/activity attributes, and number of opportunities, and low for sociodemographic characteristics. The model depends on network models for network travel time, ABM for trip/activity attributes and number of opportunities, and synthetic population for sociodemographic characteristics.

Table 11 Mobility tool ownership transferability

Model: Household mobility tool ownership	Simulator: Tactical Passenger Simulator				
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Vehicle price	OXF, TUR	Low	Use values based on revealed purchasing behaviour regarding vehicle prices	Critical	No
Fuel price	OXF, TUR	Low	Use values based on revealed purchase g behaviour in relation to fuel prices	Important	No

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Model: Household mobility tool ownership	**Simulator: Tactical Passenger Simulator**				
Parameter	**Estimated for (city)**	**Transferability**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Current vehicle age	OXF, TUR	Low	Use values based on revealed purchase g behaviour in relation to current vehicle age (e.g., national data on vehicle stock replacement)	Critical	No
Household size	OXF, TUR	Low	Use values based on census data in relation to vehicles owned and household size	Important	No

The Household Mobility Tool Ownership model, part of the TPS simulator, is applied in two cities: OXF and TUR. The results indicate that the vehicle price, fuel price, current vehicle age, and household size parameters have a low transferability. This is because these parameters are estimated using data specific to OXF and TUR and may not be applicable to other cities.

The alternative approach is to use values based on revealed purchasing behavior in relation to these parameters. These parameters are not considered critical for the model and do not have a dependence on other models.

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Table 12 TFS transferability

Model: Tactical freight Simulator	**Simulator: Tactical Freight Simulator**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Road network	ROT	Low	Local traffic model	Local traffic model or open data	Critical	No
Zones	ROT	Low	Local traffic model	Local traffic model or open data	Critical	No
Socio-economic data	ROT	Low	Local traffic model	Local traffic model or census data / statistical office	Critical	No
Commodity matrix SFS	ROT	n.a.	Harmony Strategic Simulator	n.a.	Important	SFS module in strategic simulator
Firm population	ROT	n.a.	Harmony Strategic Simulator	n.a.	Important	FS module in strategic simulator
Distribution centers (DCs)	ROT	Low	OpenStreet Map API Google Maps API		Important	
CEP shares	ROT	Low	CEP market report NL	Local CEP market report		
Departure time parameters	ROT	Medium	CBS truck traffic data	Local data	Important	
Emission factors	ROT	High	EN16258 (tank-to-		Important	

Model: Tactical freight Simulator	**Simulator: Tactical Freight Simulator**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
			wheel) standard			
Cost factors per vehicle	ROT	Medium	Cost factor reports for NL	Local cost reports	Important	
Logistic choice parameters	ROT	Medium	CBS truck traffic data	Local data	Important	
Share of distribution channels (flowtypes)	ROT	Medium	CBS truck traffic data	Local data	Important	

The Tactical Freight Simulator is applied in the city of ROT. The results indicate that the road network and zones parameters have a low transferability. These parameters are estimated using local traffic models and may not be applicable to other cities. Alternative sources of data for new applications could be local traffic models or open data. These parameters are considered critical for the model and do not have a dependence on other models.

The socio-economic data parameter also has a low transferability and is estimated using local traffic models. Alternative sources of data for new applications could be census data or statistical office data. This parameter is considered critical for the model and does not have a dependence on other models. The commodity matrix SFS and firm population parameters are not available for transferability as they are part of the Harmony Strategic Simulator. These parameters are considered important for the model and have a dependence on the SFS and FS modules in the strategic simulator.

The distribution centres (DCs) parameter has a low transferability, as it is estimated using OpenStreetMap API or Google Maps API. This parameter is considered important for the model and does not have a dependence on other models. The departure time parameters, emission factors, cost factors per vehicle, logistic choice parameters, and share of distribution channels (flow types) parameters have a medium transferability, as they are estimated using CBS truck traffic data or local data. These parameters are considered important for the model and do not have a dependence on other models. The CEP shares parameter has a low transferability and is estimated using a CEP market report for the Netherlands. Alternative sources of data for new applications could be local CEP market reports.

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3.3 Operational models

Table 13 OFS transferability

Model: Operational Freight Simulator	**Simulator: Operational Freight Simulator**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Road network geometry	ROT	Very Low (Location specific)	Network geometry used by the simulation model	Any application that can generate the network geometry in various formats	Critical	No
Zones	ROT	Low	Input from TFS	To be generated by a tactical level component as it is linked to the demand.	Critical	TFS
Freight demand	ROT	Low	Input from TFS (Freight Tours)	N/A	Critical	TFS
Parcel demand	ROT	Low	Input from TFS, O/D pairs for each parcel based on Zones	N/A	Critical	TFS

The Operational Freight Simulator is applied in the city of ROT. The results indicate that the road network geometry parameter has a very low transferability, as it is location-specific and estimated using the network geometry used by the simulation model. Alternative sources of data for new applications

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could be any application that can generate the network geometry in various formats. This parameter is considered critical for the model and does not have a dependence on other models.

The zones parameter has a low transferability and is estimated using input from the Tactical Freight Simulator (TFS). Alternative sources of data for new applications could be generated by a tactical level component as it is linked to the demand. This parameter is considered critical for the model and has a dependence on the TFS. The freight demand and parcel demand parameters also have a low transferability and are estimated using input from the TFS. These parameters are considered critical for the model and have a dependence on the TFS.

Table 14 OPS transferability

Model: Network Model	**Simulator: Aimsun Ride (Operational Passenger Simulator)**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Multiple paramaters in network model's submodels	OXF, ROT	High	Multiple	-	Critical	No

Table 15 Traffic nowcasting transferability

Model: Nowcasting Module	**Simulator: Traffic Nowcasting Module**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
Traffic data (e.g. speed)	OXF	Low	HERE Traffic API	Any traffic data source to build the module for	Critical	No

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Model: Nowcasting Module	**Simulator: Traffic Nowcasting Module**					
Parameter	**Estimated for (city)**	**Transferability**	**Source**	**Alternative approaches to transferability (other sources of data for new application)**	**Criticality for the model**	**Dependence on other models (Which)**
				the targeted city		
Road event data (e.g. accident, congestion, road work)	OXF	Low	HERE traffic API and WebTRIS Traffic Flow API	Any source of road event data to build the module for the targeted city	Critical	No
Road network geometry	OXF	Low	Network geometry used by the simulation model	Any application that can generate the network geometry in various formats	Critical	No
Projected road event attributes	OXF	Low	The main input to the built module	N/A	Critical	No

The Nowcasting Module of the Traffic Nowcasting Module simulator has two critical parameters, traffic data and road event data, with low transferability. The traffic data, such as speed, is estimated for the city of OXF and obtained from the HERE Traffic API. However, any traffic data source can be used to build the module for a targeted city. Similarly, the road event data, such as accidents, congestion, and road work, is also obtained from the HERE traffic API and WebTRIS Traffic Flow API, but any source of road event data can be used to build the module.

The road network geometry is also critical and has low transferability, obtained from the network geometry used by the simulation model, but any application that can generate the network geometry in various formats can be used. The projected road event attributes are the main input to the built module and are critical, but there is no alternative approach to transferability.

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4. MS-Lite as a facilitator of transferability

MS Lite is envisioned as a flexible and scalable Software as a Service (SaaS) offering, accessed via subscription, which harnesses the power of open data and models (or proprietary data, available with license) to create a comprehensive, user-friendly platform, which is optimized for transferability.

The main characteristics of the Lite version are: a) the scalability, meaning that the sub-models are interchangeable and can be used to fit the user needs; b) the need for less data and c) the ability to integrate existing models and to estimate new models based on a set of existing parameters and models.

In the environment of the MS-Lite, users can select and use datasets and models that are available to them.

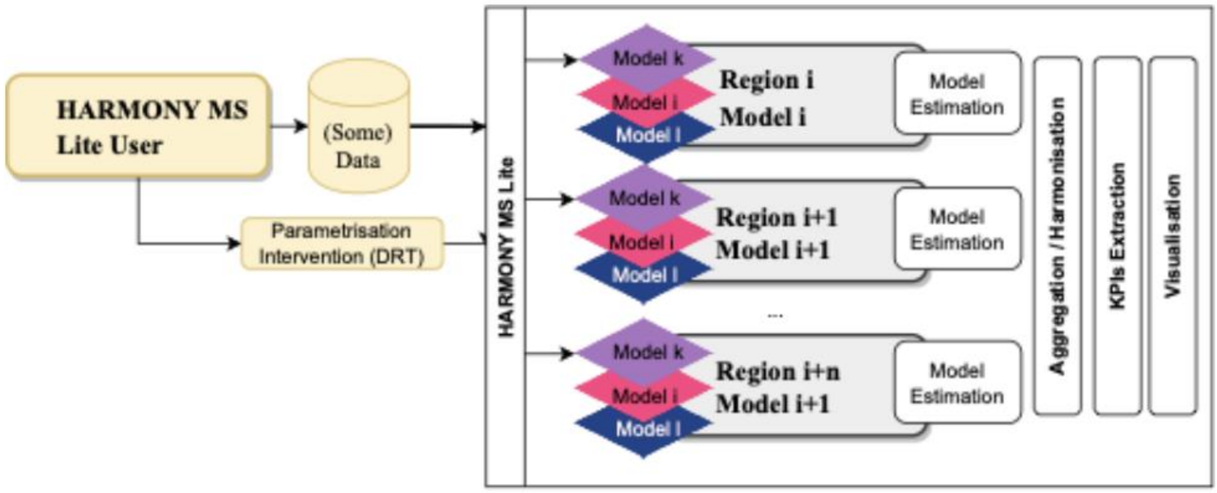

Figure 3 HARMONY MS-Lite architecture

In cases where users require access to proprietary data or models, they can purchase these through the platform's marketplace, which will be implemented in future iterations.

The platform boasts three key functional requirements that are essential to the MS Lite experience:

- Definition of Users and Regional Specification: to define and segment users based on their location and other relevant criteria.
- Classification-based Models Selection and Estimation: to enable users to select models that best suit their requirements and help them estimate results.
- Application of Corresponding Models: to apply the chosen models to the relevant data.

While the structure of MS Lite is similar to that of the HMS, it offers a host of additional components to meet the above requirements. The platform will use existing concepts such as modelling components, templates, projects, and scenarios, and will leverage the impressive visualization capabilities of the HMS, including its Dashboard and KPIs. The platform will also contain innovative new components and functionalities, designed to meet the needs of its users.

In short, MS Lite is a cutting-edge SaaS platform that empowers users to harness the power of open data and models, and provides the tools and functionalities necessary to make informed decisions. More details on MS-Lite, architecture and components can be found in D2.4[6].

6

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This section provides insight into a version of the MS-Lite Tactical level deployment, which uses classifications algorithms and machine learning to generate agent schedules and more specifically predicts time of day, activity type and destination.

For the current problem, we used a machine learning approach to tackle both regression and classification tasks in a supervised learning setting. In supervised learning, the target variable is labelled, and our dataset includes both features and targets. The data is in tabular form and includes information about a user's previous activity, such as position, trip duration, transport vehicle, and start and end times. In addition to this, socio-economic data was also provided.

To work with the dataset, we used Jupyter Notebook and Python v3.9. After importing the dataset, we split it into three categories: training, validation, and test sets. The training set consisted of 65% of the data, the validation set 15%, and the test set 20%. We took the time series structure into consideration in each split to avoid any look-ahead bias. Next, we removed users from the training set who had completed fewer than three trips to remove noisy observations. We also removed columns that had constant values among all observations. We performed these steps for all problems we tried to solve.

Based on our experience, tabular data is usually solved using random forest and gradient boosting techniques. Although deep learning models are considered superior in vision, text, and language models, they have consistently failed to beat gradient boosting models in tabular problems. For this reason, we decided to use gradient boosting methods, specifically the CatBoost library.

The first problem we tackled was a classification task (Activity type), where we predicted the next activity of each user. We created several features that we believed would help the model increase its accuracy, and lags were the most important feature that affected the model. Lags refer to previous activities, such as the duration of the previous trip or the previous trip itself, for each user. We avoided leakage between different users for each data point. We trained the model on the training set and used the validation set to optimize and find the necessary hyperparameters. We used the hyperopt library to optimize hyperparameters, and we did not find any overfitting. We optimized the model against the area under the curve. However, the model was better at predicting certain categories than others. For example, it was easier to predict that a user's first activity in the morning would be going to the office than to predict their activity after work. We used shapley values to understand the model and the impact of each feature. We observed that the features we created increased model performance and had a major impact on model prediction, whereas socio-economic data had a minor impact.

The second problem we tackled was a regression task to predict the average duration of a trip in the future. We used the CatBoost library and created similar features to the previous problem. We also used the hyperopt library to find the optimal hyperparameters. We aimed to minimize the mean absolute error, and we did not observe any overfitting. The model had higher accuracy in predicting a user's first activity in the morning because other parameters could affect trip duration during the day.

The last problem we tackled was destination choice, which was also a classification problem with 270 unique categories. We created several features by hand, but they had a minimal impact. Although we did not observe any overfitting, the model's performance was poor due to noisy data.

In all problems, we used CatBoost (Gradient Boosting) to make our predictions. Although we found some patterns and built some decent models, we strongly believe that there is room for improvement. Therefore, we propose the following steps to significantly improve performance: a) Clean the data to ensure each data point is 100% accurate; b) Focus on a smaller, cleaner dataset and use diffusion to create additional data points to help the model find more generalized patterns.

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5. Conclusions

This deliverable provides a discussion of the evaluation of the HARMONY MS and a detailed review of the transferability of most models developed within the HARMONY MS simulators. Additionally, the deliverable introduces an alternative to the full transfer/deployment of the HARMONY MS, the HARMONY MS-Lite, which is a more flexible and transferable alternative.

Regarding the evaluation of the HARMONY MS, the general assessment of the usability of the HARMONY MS is positive, with specific points regarding easiness to use, complexity and need for supporting material raised during the evaluation. It should be noted that the final version of the MS includes adjustments and developments made in the direction of addressing the comments made by partners during the evaluation.

The transferability of transport models is a complex issue as the validity of a model developed for one region or context may not hold for another. Researchers face a significant challenge in capturing the particularities of different regions and contexts. For example, a model developed for a dense urban area may not be appropriate for a rural region as the factors that influence mobility and land use patterns are likely to be very different. In addition, transport and spatial models are often based on a specific set of assumptions about human behaviour and decision-making, which may not hold true in all contexts.

To overcome these challenges, the HARMONY MS-Lite is proposed as a more flexible and transferable alternative to the HARMONY MS. The HARMONY MS-Lite allows for a more modular model structure and multi-scale modelling approach, enabling the model to be adapted to different regions and contexts. This can be achieved by using a combination of generic and context-specific model components and by allowing for the calibration and validation of the model using local data. Additionally, the HARMONY MS-Lite allows for the use of machine learning techniques to improve the model's flexibility and transferability. Machine learning models can be trained on large amounts of data and can learn complex patterns and relationships that may not be captured by traditional transport and spatial models.

The deliverable analysed numerous model parameters and assessed their transferability. Parameters include travel time, travel cost, age, car ownership, income, student status, employment type, distance to the nearest public transport station, dynamic factors, trip/activity attributes, household mobility tool ownership, road network, zones, socio-economic data, commodity matrix, firm population, distribution centres, departure time parameters, emission factors, and more. The general assessment of the transferability of these parameters showed that the transferability varies from low to acceptable, depending on the parameter and the city it was estimated for. The criticality of these parameters for the models was also evaluated, with some parameters being deemed critical for the model performance.

It is evident that the transferability of the MS is heavily dependent on the specific component of the MS, the use case, the data availability, and the context in which the model or simulator was originally estimated. Therefore, the HARMONY MS-Lite offers a more transferable and flexible alternative to the HARMONY MS, making it more adaptable to different regions and contexts. The use of a flexible and modular model structure, multi-scale modelling approach, and machine learning techniques can help capture the nuances of different regions and contexts, improving the accuracy of the predictions.

Overall, the HARMONY MS-Lite provides a more practical and efficient approach to the transfer and deployment of transport and spatial models, enabling researchers to create more accurate and transferable models. With the continued development of transport and spatial models, it is essential to consider the transferability of these models, enabling them to be used in a variety of contexts, making it a more valuable tool for the transportation industry.

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References

HARMONY D9.5 Evaluation of the HARMONY metropolitan areas engagement and demonstration activities – Final

Koppelman, F. S., & Wilmot, C. G. (1982). Transferability analysis of disaggregate choice models. *Transportation Research Record*, *895*, 18-24.

Ziemke, D., Nagel, K., & Moeckel, R. (2016). Towards an agent-based, integrated land-use transport modeling system. *Procedia computer science*, *83*, 958-963.

Fox, J., & Hess, S. (2010). Review of evidence for temporal transferability of mode-destination models. *Transportation Research Record*, *2175*(1), 74-83.

Koushik, A. N., Manoj, M., & Nezamuddin, N. (2020). Machine learning applications in activity-travel behaviour research: a review. *Transport reviews*, *40*(3), 288-311.

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