Progress towards Federated Logistics through the Integration of TEN-T into A Global Trade Network

D2.12 Multi-Actor Multi-Criteria Analysis final version

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
AI	Artificial Intelligence
EPCIS	Electronic Product Code Information Services
H-M interface	Human Machine interface
IoT	Internet of Things
KPI	Key Performance Indicator
LSP	Logistics Service Provider
MAMCA	Multi Actor Multi Criteria Analysis
MCDA	Multi Criteria Decision Analysis
PoR	Port of Rotterdam
TEN-T	Trans-European Transport Network
T&L	Transport and Logistics

1 Executive Summary

This report addresses the challenges associated to multi-stakeholder decision making in the context of Transport and Logistics (T&L). A Multi-actor multi-criteria analysis is undertaken considering the unique supply chain contexts of intercontinental corridors, warehouse and hinterland transport and last mile delivery. Operators with activity in all three supply chain sectors are found to have unique operational criteria and priorities, that indicate the need for separate instantiations of MACMA in each context.

A preliminary stakeholder analysis was undertaken, and a workshop was organized for undertaking the first three steps of the MACMA. The MAMCA Workshop undertaken during the project's GA meeting in Poznan, Poland in October 2022, enabled the identification of significant stakeholders and criteria and their ranking, that enabled the development of questionnaires for the collection of criteria weights.

The questionnaire outputs, data processing and analysis are discussed, that form a database for the EGTN MAMCA service instantiation. Furthermore, the service features allowing customization are presented, that enable future Living Lab users to adjust the stakeholders and criteria considered in specific analytic contexts, increasing the functionality and usability of the model.

Implementation and MAMCA operationalisation examples are presented covering strategic level disruption analysis that can impact infrastructural investments.Finally, based on the MAMCA analysis, a multi operator context is considered that enables a criterion filtering mechanism. This feature is significant for enabling operator criteria driven collaborative opportunities identification that can lead to more efficient operations.

2 Introduction

Performance of freight transportation is one of the crucial elements for the sustainability of logistics and supply chain. The costs for the freight transportation can reach up to 50% of the total logistics costs for shippers [1], and inefficiencies in transportation costs can be characterized by economic, social, and environmental inefficiencies and unsustainability. Despite efforts by transport companies, the frequency of empty trips remains high and average truck fill-rate is low. Overall, at total transport level, a fifth of road freight kilometers are associated to empty vehicles [2]. Moreover, freight transportation (in developed countries) is responsible for nearly 15% of greenhouse gas emissions. This ratio has been increasing despite ambitious reduction targets. Improved transportation efficiency is therefore an important objective of the Physical Internet.

Establishing an efficient system for moving goods, is an essential milestone for commerce while at the same time extracting higher capacity from legacy infrastructure such as railways, riverways and motorways. Furthermore, with sustainability becoming an increasing concern, logistical solutions in transport became more relevant, aiming to satisfy transportation demand in an environmentally friendly manner. Although methods and technologies for planning and executing transport and logistics have improved with time, the main principles and inefficiencies still apply today. Furthermore, as specialisation increases with agglomeration economy, supply chains tend to get longer, involving more stages and partners. At the same time, the products themselves are becoming increasingly varied and complex following the ever-increasing societal needs.

The Physical Internet is proposed as a more efficient paradigm for Transport and Logistics (T&L) operations, that can improve utilization rates and reduce emissions. This report investigates the application of Multi-Actor Multi-Criteria Analysis (MAMCA) in various supply chain contexts in order to accommodate unique stakeholder perspectives into the strategic and operational decision making process. As steps are taken towards integrating the Physical Internet principles, accommodating individual perspectives is an increasingly significant feature of the PI.

In the context of the PLANET project and its Living Labs, multiple alternative technologies, infrastructures, and policies are considered. The aim of all alternatives is to drive operational efficiency in a Physical Internet enabled supply chain. The planning impact horizon of the decisions' considered in PLANET project living labs ranges from operational to strategic levels. The three PLANET Living Labs investigate three unique aspects of technological and infrastructural development. Focusing on the connectivity of the TEN-T network to global trade corridors:

- LL1 examines how new technologies (IoT, AI and blockchain) and concepts (such as Physical Internet) can improve processes, operations and efficiency along the door-to-door transport chains linking the Maritime Silk Road with EU internal corridors.
- LL2 examines how synchro-modal dynamic management of TEN-T & intercontinental flows promoting rail transport and utilizing the Port of Rotterdam (PoR) as the principal smart EGTN Node coordinating the rail focused transport chains linking China through Rotterdam to/from USA, and Rhine-Alpine Corridor destinations, and
- LL3 examines streamlining logistic processes in flows from China to Europe along the Silk Road by implementing IoT technologies (based on the EPCIS platform) and GS1 standards that facilitate transmission of data between the partners involved in the e-commerce operations.

2.1 Mapping PLANET Outputs

Purpose of this section is to map PLANET's Grant Agreement commitments, both within the formal Deliverable and Task description, against the project's respective outputs and work performed.

Table 2.1: Adherence to PLANET's GA Deliverable & Tasks Descriptions

PLANET GA Component Title	PLANET GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D2.12 Multi-Actor Multi-Criteria Analysis DSS final version	Final version of D2.11. (D2.11 description: Definition of the MAMCA model and DSS and interfaces to support customized versions of D2.11 for LLs)	Sections 3,4,5	Section 3 presents the development work undertaken for undertaking the MACMA. Section 4 presents the instantiation of MAMCA in the EGTN platform as a DSS. Section 5 presents examples of MAMCA operationalisation.
TASKS			
T2.4 Group multi criteria DSS for transport and PI Networks	This Task develops multi-user and multi-criteria models that will allow stakeholders to analyse and assess the effect of new T&L developments (e.g. new trans-continental freight routes) that cross or neighbour their regions.	Section 3, 4	Three separate instantiations of the MAMCA model are undertaken, considering the contexts of intercontinental corridors, warehouse and hinterland transport and last mile delivery
ST2.4.1 Multi-Actor Multi-Criteria Analysis (MAMCA) DSS	Multi-Criteria Analysis (MCA) will be used to enhance policy analysis by explicitly considering the opinions of various stakeholders regarding investment scenarios that maximize for economic impacts from new corridors and routes. Stakeholder groups will identify a specific set of criteria and allocate weights to each distinct criterion. Depending on the weights that the	Sections 3,4,5	Section 3 presents the development work undertaken for undertaking the MACMA and Section 4 presents the instantiation of MAMCA in the EGTN platform as a DSS. Three separate instantiations of the MAMCA model are undertaken, considering the contexts of intercontinental corridors, warehouse and hinterland transport and last mile delivery. In each context unique stakeholders and criteria are identified through a workshop and weights information are collected through a questionnaire. Section 5 presents examples of MAMCA operationalisation in assessing

	stakeholders give to each criterion, distinct weighting methods will subsequently be adopted as direct weights, direct allocation, and so on. The resulting DSS models will be incrementally calibrated and will be made available to the Project's Living Labs to be applied across specific transport and corridor decision challenges.		disruptions and link criticality leading to strategic investment decisions, as well as at an operational collaboration level leading to more efficient T&L operations.

2.2 Deliverable Overview and Report Structure

The MAMCA model presented in this report focuses on the interconnection of the European Transport network to global trade corridors and the technological implementation of the Physical Internet. Due to the unique characteristics of the T&L sector, the EGTN service is developed to accommodate three separate instantiations of the MAMCA, as three unique contexts are identified.

The MACMA instantiations consider the contexts of intercontinental corridors, warehouse and hinterland transport and last mile delivery. Section 3 presents the development work undertaken for instantiating the MACMA. In each context, unique stakeholders and criteria are identified through a workshop and weights information is collected through a questionnaire. Section 4 presents the instantiation of MAMCA in the EGTN platform as a DSS. The EGTN service functionality and connectivity to weights databases is discussed and user features are presented. Section 5 presents examples of MAMCA operationalisation in assessing disruptions and link criticality leading to strategic investment decisions, as well as at an operational collaboration level leading to more efficient T&L operations.

3 Multi-Actor Logistics Collaboration Applications

The Physical Internet (PI) promises to revolutionise how transport and logistics is practiced, and to improve on critical variables such as cost, utilisation rates, and emissions through improved multi-modal integration and open accessibility to static and mobile infrastructure. The core constraints, objectives and business processes involved in planning, coordinating, and executing the transport of goods from origin to destination remain largely unaltered in a PI approach. What changes under the PI is the standardisation and interoperability of transport, logistics systems and processes. For these features of the PI to materialise, several information and decision support systems as well as standardisation and integration services need to be introduced.

T&L involves the coordinating effort of several organizations, each of them focusing on a different part of the supply chain process. A supply chain includes not only the customers and the manufactures, but also transporters, warehouses, retailers, and suppliers. It may also include organization with an indirect role such as for example banks and insurance companies. Although such organizations do not directly influence operational efficiency in the transport and logistics process their perspectives can be significant at a strategic level. in the transport and logistics processes can be due to them owning the goods that are transported (initially or ultimately- i.e., as sellers and buyers), the equipment and other resources by which the goods will be processed and transported, or because they are integrators of the different processes and activities involved.

3.1 MAMCA in the Physical Internet Context

Supply chain stakeholders' perception of performance varies with the stakeholder role, operational context and function in the supply chain. For example, in the context of last mile delivery, receivers who are active participants are interested in low delivery cost, quick delivery and reliable delivery times, while citizens who are passive participants are interested in low emissions and road congestion. The performance metrics each stakeholder utilises to measure operational efficiency do not always match and in cases are contradicting.

Through interactive discussions with stakeholders, several studies [3] establish criteria and their associated weights per stakeholder. Due to this variability, collected information and decision processes vary greatly in each T&L stakeholder setting, hindering the motivation for standardization and integration of processes that PI promotes.

The MACMA is typically broken down into seven steps [3,4], that are:

1. the identification of the problem or the alternatives. They can be different technological solutions, different policy measures, long term strategic options, etc.
2. identify stakeholders and people/groups who have interests in this decision.
3. identify the key objectives of the stakeholders and give each a relative importance or priority (weights).

The first three steps are conducted interactively in a circular way. They are followed by the solution methodology steps that are:

4. each criterion, one or more indicators are constructed (e.g., direct quantitative indicators such as money spent, number of lives saved, reductions in CO2 emissions achieved, etc. or scores on an ordinal indicator such as high/medium/low for criteria with values that are difficult to express in quantitative terms, etc.). The measurement method for each indicator is also made explicit (for instance willingness to pay, quantitative scores based on macroscopic computer simulation,

etc.). This allows to measure each alternative performance in terms of its contribution to the objectives of specific stakeholder groups.

5. construction of the evaluation matrix. The alternatives are further described and translated into scenarios which also describe the contexts in which the policy options will be implemented.
6. The different scenarios are then scored on the objectives of each stakeholder group. For each stakeholder group an MCDA is performed. The different points of view are brought together in a multi actor view. This yields a ranking of the various alternatives and reveals their strengths and weaknesses. Afterwards, the stability of the ranking can be assessed through sensitivity analyses.
7. The actual implementation. Based on the insights of the analysis, an implementation can be developed, taking the wishes of the different actors into account.

As illustrated in Figure 3.1, the MAMCA starts by populating the alternatives and conducting a stakeholder analysis. Then, performance criteria are agreed upon by the stakeholders, and weights are defined, and measurement methods and scales are provided. Then the components from the first three steps are integrated into an MCA overall analysis, that yields the results in a stakeholder neutral way.

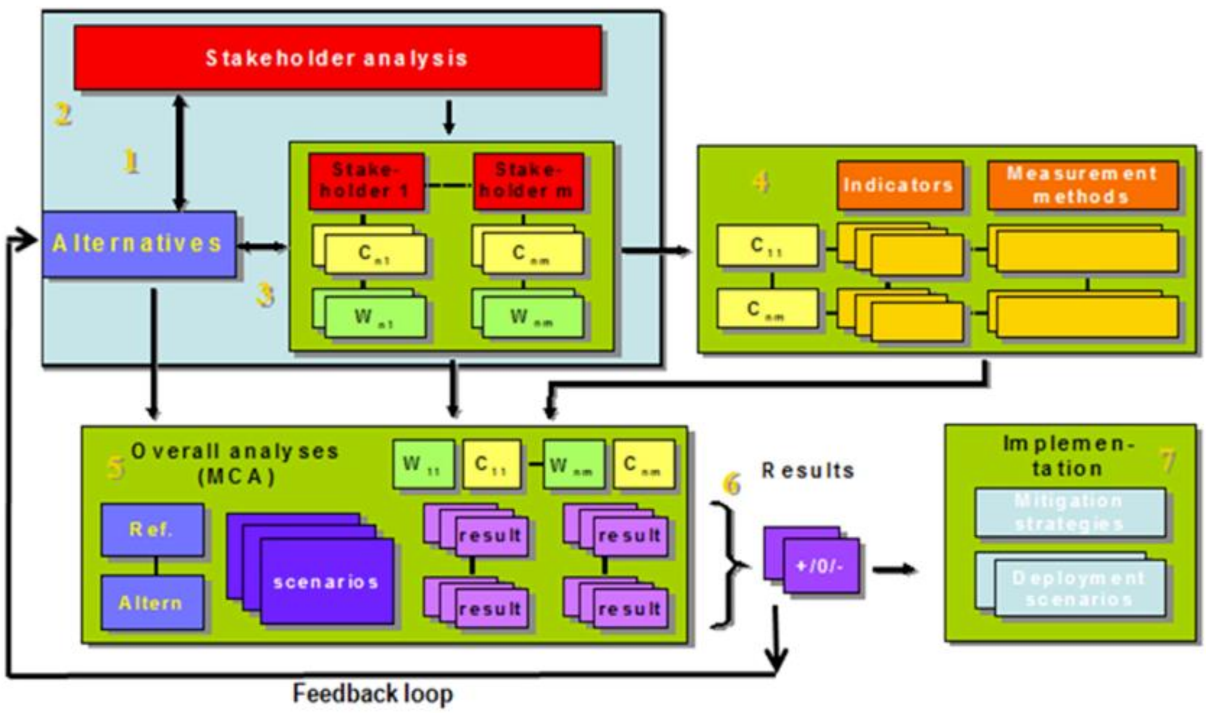

Figure 3.1 Representation of the MAMCA steps [5]

3.2 Unique T&L Contexts

All PLANET Living Labs investigate the integration of TEN-T operations as hinterland to global corridors. As part of this exercise, three types of use cases are defined. As illustrated in Figure 3.2, the first concerns the sea-side collaboration, between ocean liner operators, and port operators. In a more generic sense, this represents the operators of a global corridor, irrespective of the mode. The second concerns long-haul hinterland connections, between port and terminal operators, LSPs and warehouse operators. The third concerns urban distribution and the collaboration between regional warehouse operators and last mile logistics companies.

In the first version of the deliverable (D2.11) a generalized MAMCA framework was proposed, that treated all supply chain components simultaneously. In this final version of the deliverable, this has been refined into three unique supply chain sub-contexts. The division to intercontinental corridors, hinterland transport and last mile delivery, was made after liaising with PLANET project partners who are industry experts. They have indicated that for operators there are significantly different goals in each context, and frequently different legal entities in the form of subsidiary companies are assigned the operational task in each context, partially due to handling these uniquely different operational goals. For example focusing on DHL's operations, there are three different businesses for:

- the intercontinental corridors and points of entry are handled by DHL Global Forwarding division (Air and maritime freight)
- warehouses and hinterland transport and handled by DHL Supply Chain
- while last mile delivery is handled by DHL Express.

Each context has very specific KPIs, that can be further divided into micro-KPIs and macro-KPIs. Micro-KPIs are for example when in last mile distribution the missing/wrong deliveries are considered as a critical KPI (as a single driver manages on average 60-70 deliveries per day). Obviously, for maritime or hinterland transportation such a KPI is not relevant. In maritime context, other KPIs such as waiting times at the port, total of containers/ship, etc. are more relevant. In a warehouse context, KPIs are typically related to receiving performance, putaway, storage, pick&pack, etc. For hinterland transportation KPIs typically include cost/km, truck utilization (%), time windows accuracy in collections/deliveries, etc.

So, depending on the activity, the customer and the sector, KPIs can be very different and specific. It's not the same to transport refrigerated material, fresh food or just wood and bricks as transport conditions and lead times are very different in each case. Furthermore, industry sector also have unique characteristics and KPIs. For example, medicine or automotive have very short delivery times, so it would be more interesting to know collection/deliveries on time rather than other indicators.

On the other side, macro-KPIs, can be more standard and similar across sectors, customers and contexts. In DHL such KPIs include costs, CO_2 emissions, accidents, etc. Such KPIs are significant across the business and all its subdivisions, and do not depent on the customer or sector. Such macro-KPIs cover high level company features such as the company's social responsibility, profitability, etc. For example, on CO2, DHL has the commitment of "Zero emissions by 2050"[2]. This target will apply to all the DHL group so every business in DHL has to measure and reduce CO2 emissions.

[2] https://www.dhl.com/global-en/delivered/sustainability/zero-emissions-by-2050.html

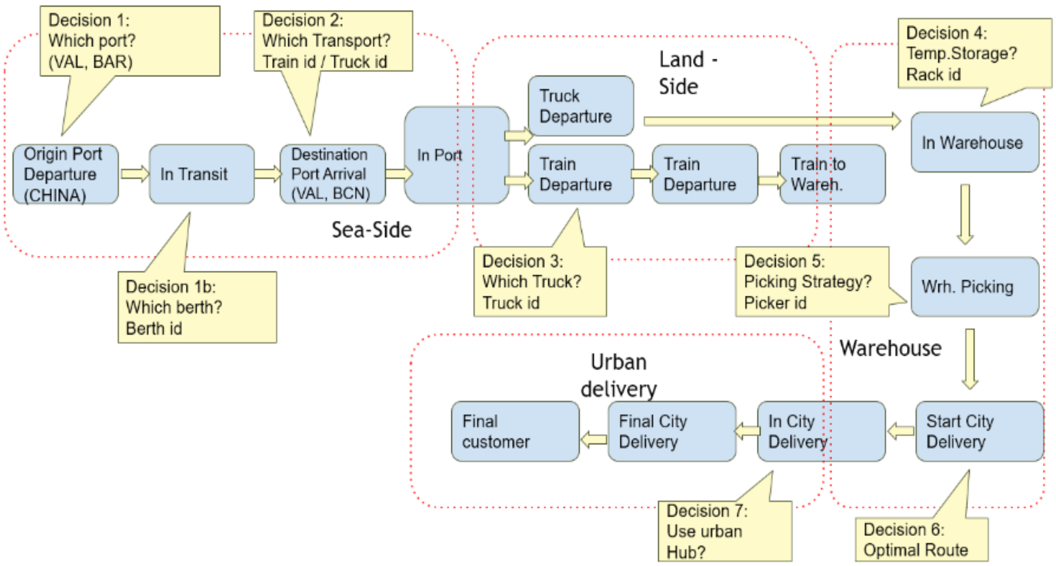

Figure 3.2 Living Lab 1 collaboration sequence map [6]

3.3 Stakeholders and Performance Indicators Analysis – Workshop

To process the first three steps of the MAMCA model, for all three unique contexts identified in PLANET project, a one hour workshop was conducted in order to identify the core stakeholders and the criteria stakeholders consider significant. The workshop was conducted as part of the PLANET General Assembly meeting in Poznan, Poland on 4-5 October 2022. The workshop was attended by the entire consortium and a preliminary classification of the attendees was made in order to identify any stakeholder gaps. The preliminary mapping of project partners, advisory board members, and other PLANET affiliations is illustrated in Table 3.1.

Table 3.1 Preliminary mapping of partners for MAMCA workshop

Intercontinental corridors and Points of Entry	Warehouses/ hubs and hinterland transportation	Last mile delivery
RSUUS	Citylogin	Citylogin
Polish Post	DHL	DHL
Port of Valencia	ILiM (also representing Małaszewicze terminal)	ILiM
Rhine-Alpine EGTC	Duisport	RSUUS
ILiM (also representing Małaszewicze terminal)	CSP Iberian Zaragoza Rail Terminal	
PKP cargo	Hyperloop	
COSSP	Port of Sines	
UIRR	Port of Rotterdam	
UTLC ERA	UIRR	
Port of Sines		
Port of Rotterdam		

As illustrated in Table 3.1, the intercontinental corridors and PoE, and the warehouse and hinterland transportation contexts are well represented from stakeholder. The representation in the last mile logistics, is less complete, however, additionally to the relevant partners list, receivers, citizens and local authorities perspectives could be captured from the workshop participants as individuals rather than as legal entities. An initial list of stakeholder and criteria was drafted to initiate discussion for each of the categories based on the literature review conducted and presented in the previous deliverable [4].

The workshop was structured into three twenty-minute sections. The first section involved identifying the all relevant stakeholders in each supply chain context. The second section focused on each workshop participant self-identifying a matching stakeholder, while the later section focused on the identification of relevant criteria for each supply chain context.

In "Section One" of the workshop, attendees were initially asked to make amendments or subtractions from the three stakeholders lists. In the intercontinental corridor context, stakeholder amendments included LSPs, customs, and EU governance. Then utilizing a robust online voting functionality, the attendees were asked to vote on who of the stakeholders are more significant in each context. The aim of this step of the workshop was to offer the ability to narrow down the list of stakeholders, considering the criteria weights data collection questionnaires that followed the workshop. The aim of limiting the stakeholder options available was to ensure all categories are represented. The stakeholder significance voting result is illustrated in the left panel of Figure 3.3. The most significant stakeholders were therefore found to be rail/ vessel operators, which are the PI movers equivalent in the Physical Internet context.

In the hinterland transportation context, stakeholder amendments included LSPs, infrastructure managers and national government. The stakeholder significance voting result is illustrated in the middle panel of Figure 3.3. The most significant stakeholders in this context are found to be warehouse operators, followed by hinterland transport providers and LSPs.

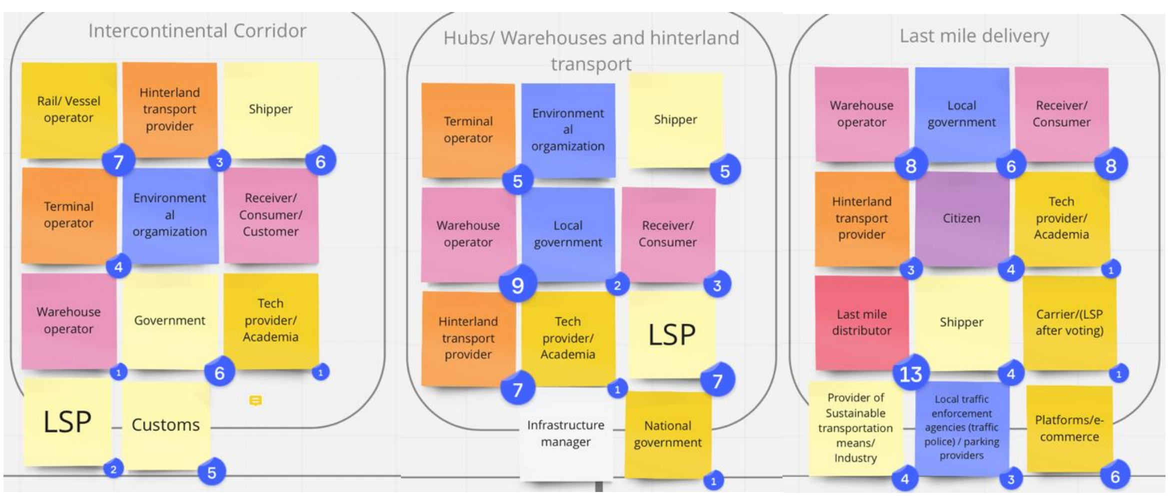

Figure 3.3 Stakeholder significance voting for intercontinental corridor

In the last mile delivery context, stakeholder amendments included LSPs, sustainable vehicle manufacturers, local traffic enforcement and e-commerce platforms. The stakeholder significance voting result is illustrated in the right panel of Figure 3.3. The most significant stakeholders in this context are found to be last mile distributors, receivers/ consumers and warehouse operators.

The voting results were briefly summarized, making evident the unique nature of each individual context both in terms of relevant as well as most significant stakeholders. In "Section Two" of the workshop, attendees were asked to indicate which stakeholder they would feel most comfortable in representing in each supply chain context, as well as indicate secondary preferences, which may be applicable. The aim of this step was to establish accountability, in identifying and voting for significant criteria in "Section Three" of the workshop, as well as for populating and responding to the subsequent criteria weight questionnaires.

Table 3.2 Stakeholder categories representation

representation	*intercontinental*	*hinterland*	*last mile*
COSCO	Rail/Vessel operator		
UIRR	Rail/Vessel operator Terminal operator Hinterland transport provider	Terminal operator Hinterland transport provider	
ESC	Shipper	Shipper	
Wupertal Institute	Government		Local government
Valencia	Terminal operator	Terminal operator	
RSUUS	Hinterland transport provider	LSP Warehouse operator	Last mile distributor Warehouse operator Platform/ e-Commerce
DHL		Warehouse operator	Warehouse operator
CityLogin			Last mile distributor Warehouse operator

As illustrated in Figure 3.4, representation and ownership was achieved for most stakeholder categories, and more importantly for all significant stakeholders categories identified in "Section One". A preliminary matching of key stakeholder categories and representation is illustrated in Table 3.2.

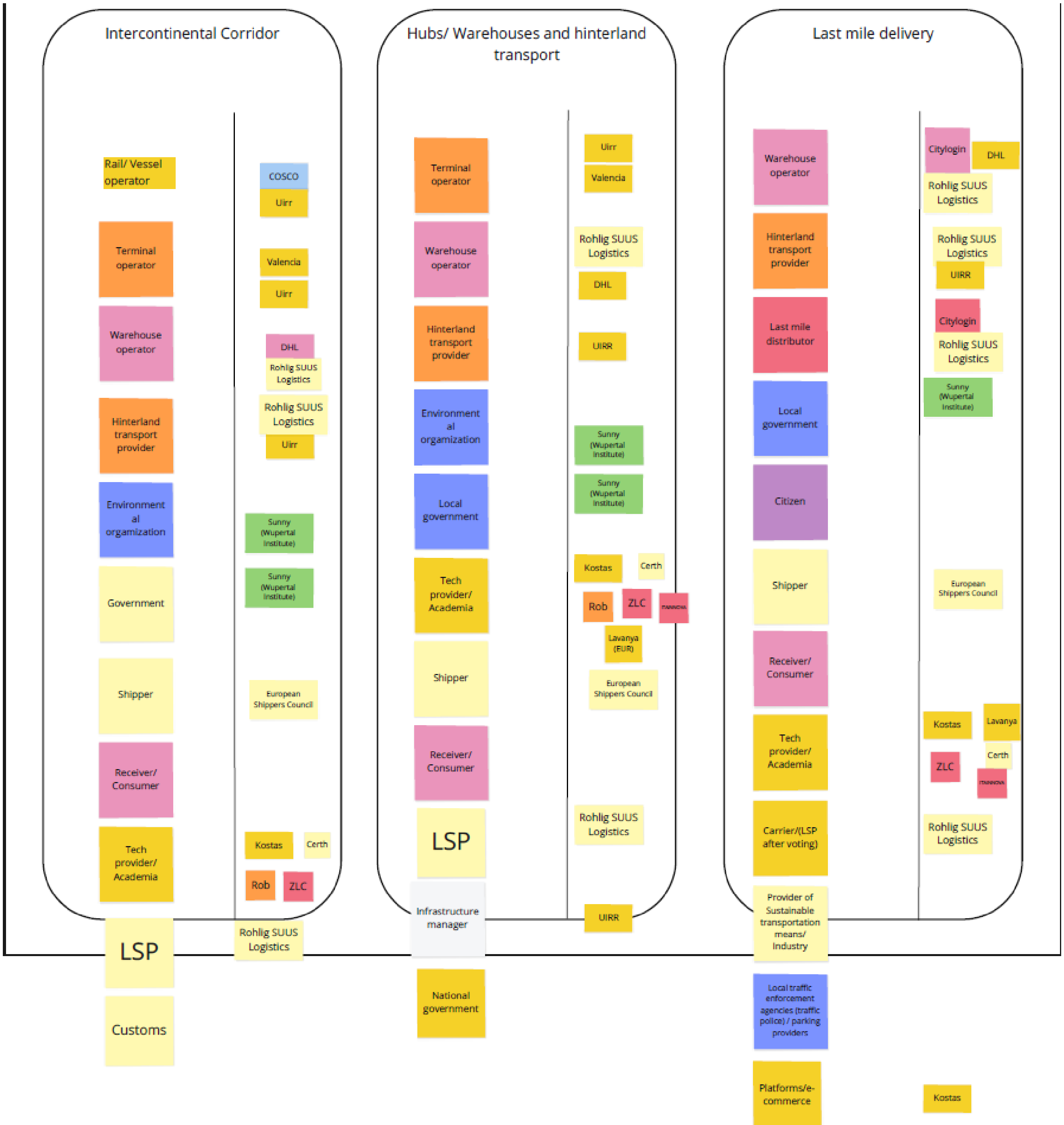

Figure 3.4 Workshop "Section Two" - stakeholder matching exercise

In "Section Three", attendees were then finally asked to assume their primary stakeholder role and propose amendments and changes to the criteria list. After undertaking this task, the online voting functionality was utilized to vote on the most significant criteria in each context. As illustrated in Figure 3.5, the most significant criteria were identified based on the voting exercise for each of context.

Figure 3.5 Criteria significance voting result for each context

3.4 Stakeholder Criteria Weights – Questionnaire

Determining the criteria of the stakeholder groups for each context as undertaken in the MAMCA workshop, is not sufficient to enable the evaluation of PI relevant freight measures and initiatives, because not every criterion is equally important for a given stakeholder. Therefore, it is necessary to measure the stakeholders' relative preferences which is done by asking them to allocate weights to each criterion by pairwise comparisons. The Analytic Hierarchy Process (AHP) [7] is a frequently used multi-criteria analysis for this purpose and it is used in the context of PLANET to determine the weights of the criteria of the various stakeholder groups. The pairwise comparison measurement is based on the law of comparative judgement (Thurston, 1927). The most effective way to evaluate a certain property is to take a pair of elements and compare them with regards to that property only. This is done by using the following matrix equation:

$$Aw = nw$$

A is the pairwise matrix, n the dimension of the matrix A (in our case the number of criteria) and w the eigenvector of A (which gives the weight vector):

$$\begin{bmatrix} \frac{w1}{w1} & \frac{w1}{w2} & \cdots & \frac{w1}{wn} \\ \frac{w2}{w1} & \frac{w2}{w2} & \cdots & \frac{w2}{wn} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{wn}{w1} & \frac{wn}{w2} & \cdots & \frac{wn}{wn} \end{bmatrix} \begin{bmatrix} w1 \\ w2 \\ \vdots \\ wn \end{bmatrix} = n \begin{bmatrix} w1 \\ w2 \\ \vdots \\ wn \end{bmatrix}$$

Due to the fact, that populating the criteria weights requires a pairwise comparison and to maintain the questionnaires reasonably short, the most significant criteria were identified. This was achieved by utilizing the discussion and voting undertaken during the MAMCA workshop. Therefore, for each context the six most significant stakeholders and criteria were identified as illustrated in Table 3.3 and Table 3.4 respectively.

Table 3.3 Stakeholders considered for each PI context

intercontinental	hinterland	last mile
Rail/vessel operator	Warehouser operator	Last mile distributori
Shipper	Hinterland transport provider	Warehouse operator
Customs	Shipper	Receiver/ Customer
Terminal operator	LSP	Local government
Hinterland transport provider	Terminal operator	Platforms/ e-Commerce
LSP	Local/ regional government	Citizen
Technology provider	Receiver/ Customer	Sustainable vehicle manufacturer
Government	Technology provider	Local traffic enforcement
	Academia	Technology provider

Table 3.4 Criteria considered for each PI context

intercontinental	hinterland	last mile
Transport cost	Profitability	Sustainability

Time	Delivery time	Transport cost
Profitability	Operational throughput	Congestion
Fill rate	Transport cost	Service quality
Emissions	Service quality	Emissions
Congestion	Emissions and sustainability	Driver availability (HR)
Service quality	Operational punctuality	Delivery time
	Information availability	Profitability

The questionnaires were made available to PLANET project partners in late October 2022, and remained available through November 2022. The templates used can be found in the Appendix section. A sufficient number of responses was collected, with Figure 3.6 illustrating that a good distribution of stakeholder representation was achieved.

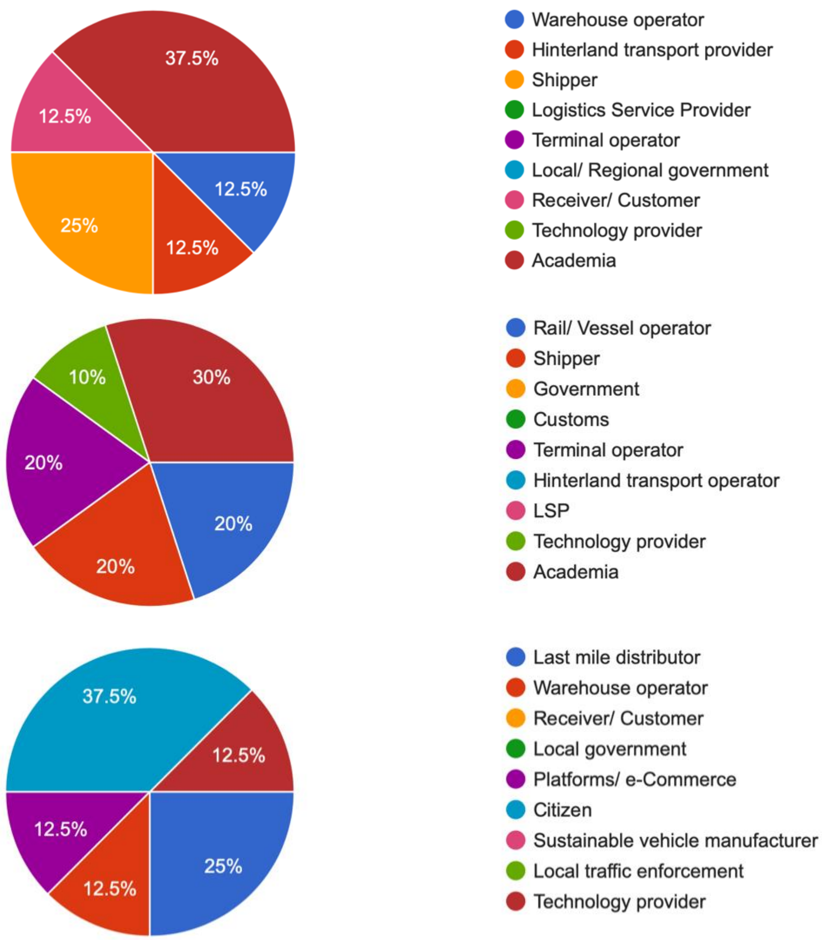

Figure 3.6 Participant stakeholder proportions (top: intercontinental; middle: hinterland; bottom: last mile)

For each pairwise comparison, respondents were asked to rate the significance using a range from zero to ten, where zero indicated extreme significance of one criterion, ten indicated extreme significance of the other criterion and five was balanced significance of both criteria. The results were found to vary depending on the criteria being accessed and the stakeholder in each context. Furthermore, varying levels of dispersion were observed as illustrated in Figure 3.7 and Figure 3.8.

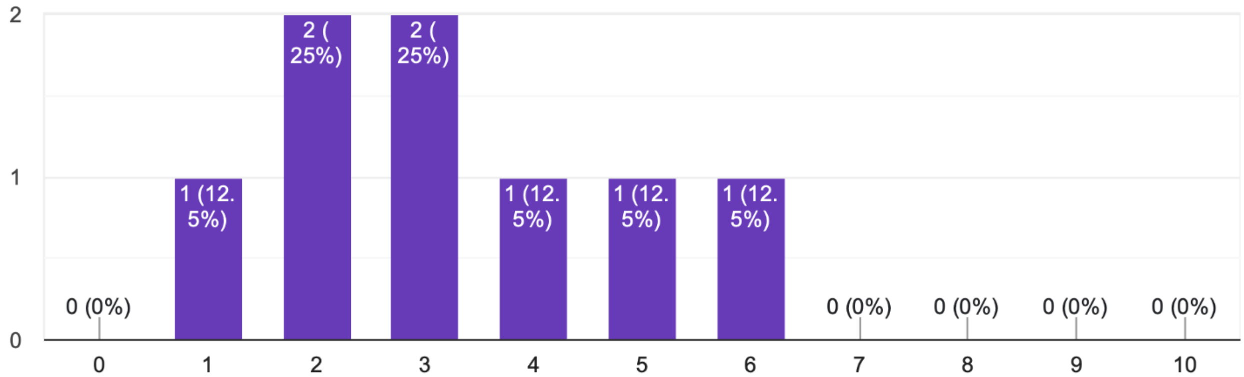

Figure 3.7 Comparison of profitability (zero) to operational throughput (ten) in the hinterland transport context

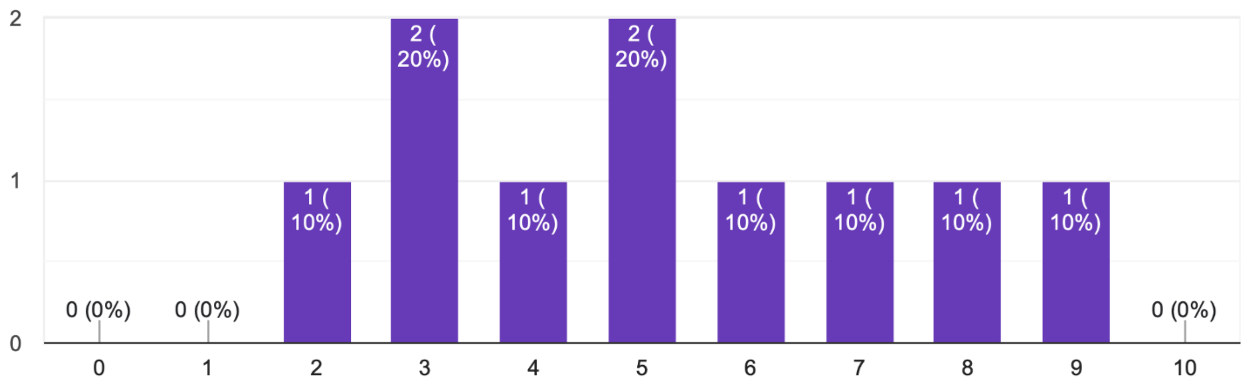

Figure 3.8 Comparison of delivery time (zero) to fill rate (ten) in the intercontinental corridor context

The criteria weights have been calculated using the pairwise comparisons from the questionnaire responses converted into weight vectors. For cases were multiple responses are provided for a single stakeholder the each stakeholders appropriateness is considered, and then the average value of all responses is considered.

4 MAMCA DSS EGTN Deployment

The MAMCA model presented in this report focuses on the interconnection of the European Transport network to global trade corridors and the technological implementation of the Physical Internet. Due to the unique characteristics of the T&L sector, the EGTN service is developed to accommodate three separate instantiations of the MAMCA, as three unique contexts are identified.

4.1 Stakeholder-Criteria Weights Database

The output of the questionnaire is a pairwise comparison table as the one illustrated in Table 4.1, for the warehouse, terminal and hinterland transport context, for hinterland transport providers. The table describes the pairwise relationship in terms of significance for the specific stakeholders between each pair of criteria. A similar table is obtained for all stakeholders and contexts considered. The outputs are stored in a database in MongoDB from where the EGTN service can retrieve them and analyse them upon request.

Table 4.1 Hinterland transport provider pairwise comparison output

	profitability	delivery time	operational throughput	transport cost	service quality	emissions and sustainability	operational punctuality	information availability
profitability	-	5	1	1	4	4	6	6
delivery time	5	-	1	4	5	4	9	7
operational throughput	9	9	-	8	8	7	8	7
transport cost	9	6	2	-	5	5	8	8
service quality	6	5	2	5	-	5	7	7
emissions and sustainability	6	6	3	5	5	-	5	5
operational punctuality	4	1	2	2	3	5	-	5
information availability	4	3	3	2	3	5	5	-
weight	0.15	0.12	0.05	0.09	0.12	0.12	0.17	0.16

The analysis involves the development of weights based on the pairwise comparison for a specific stakeholder. Considering the questionnaire scale ranges from zero to ten and depending on the number of criteria considered in each context, the impact is summed up for each criterion and a common scale adjustment is applied. The weight estimates (illustrated in the last row of Table 4.1) indicate that for hinterland transport providers the most significant criterion is punctuality with weight 0.17, followed by information availability with weight 0.16, followed by profitability with weight 0.15. Beyond that delivery time, service quality and emissions and sustainability are found to be weighted evenly. Operational throughput is found to be the less significant weight for this stakeholder.

Figure 4.1 summarizes the criteria weights for several hinterland transport stakeholders including hinterland transport providers. It is observed that delivery time weight is 0.12 for both warehouse operators and hinterland transport providers, while it is 0.16 for receivers/ customers. Transport cost weight is 0.08 for warehouse operators, 0.09 for hinterland transport providers and 0.12 for receivers/ customers. Operational throughput that is found to have limited significance for hinterland transport providers, has higher significance for warehouse operators and receivers. Information availability that was found to be significant for hinterland transport providers, is found to have limited significance for warehouse operators and receivers.

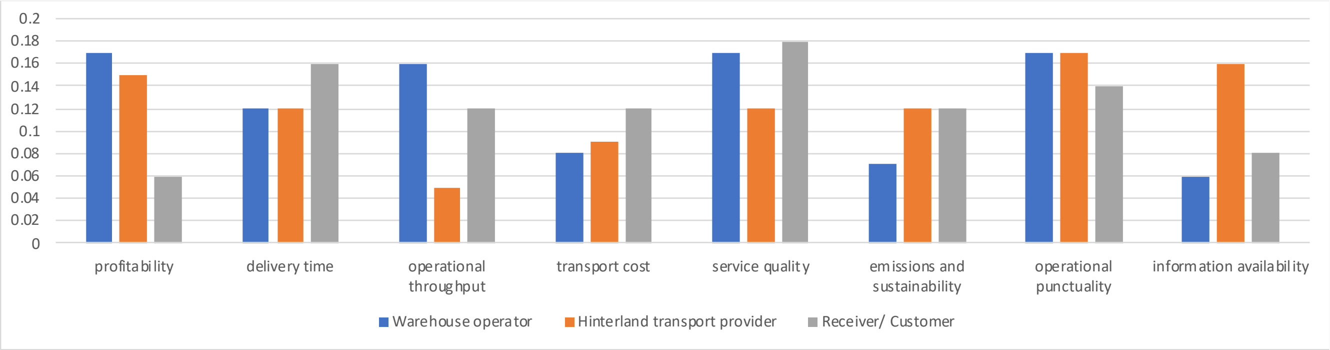

Figure 4.1 Criteria weights for selected hinterland transport stakeholders

Weights tables are developed for all three contexts considered in PLANET and for all significant stakeholders and criteria identified in each context. The weights tables for intercontinental corridors, warehouse and hinterland transport and last mile delivery can then be used to breakdown the analytic findings of transport studies to stakeholder preferences. The following section presents the service instantiation of PLANET project's MAMCA model for PI impact assessments.

4.2 Service and H-M Interface

The MAMCA service developed anticipates the parametrization of the MAMCA model for each unique T&L context. The aim of the tool, is to provide the user with customized information for specific analysis needs. In the PI context, an analysis might involve one or more stakeholders, and criteria. Customization of both parameters is important, but more so for criteria as their operationalization in an integrated model can be difficult to achieve. Therefore, depending on the user needs and the context of application, the service recalculates the criteria, using the raw questionnaire responses, and returns and customized table.

The H-M interface has been developed to incorporate a scenario builder with the following features:

- Contextualization of the MAMCA model is achieved using a drop-down menu, that offers the choices of intercontinental corridor, hinterland transport, and last mile delivery. Depending on the contextualization choice of the user the stakeholder and criteria list are updated in the background, to align with the relevant stakeholders and criteria in each context (see Table 3.3 and Table 3.4 for stakeholders and criteria respectively).
- Selection of Stakeholders is incorporated in the H-M interface using tick boxes. A context relevant list of stakeholders is populated, where the user is able to add or remove stakeholders to be considered in the criteria weights table.
- Selection of Criteria is incorporated in the H-W interface using tick boxes. A context relevant list of criteria is populated, where the user is able to add or remove criteria to be considered in the criteria weights table.
- An execute button collates all the scenario information in terms of context, stakeholders and criteria and communicates them to the service.

- A table visualization panel. The service returns a customized criteria weights table, that is illustrated in the visualization panel, while the user is also provided with the option to download the table output in an Excel format.

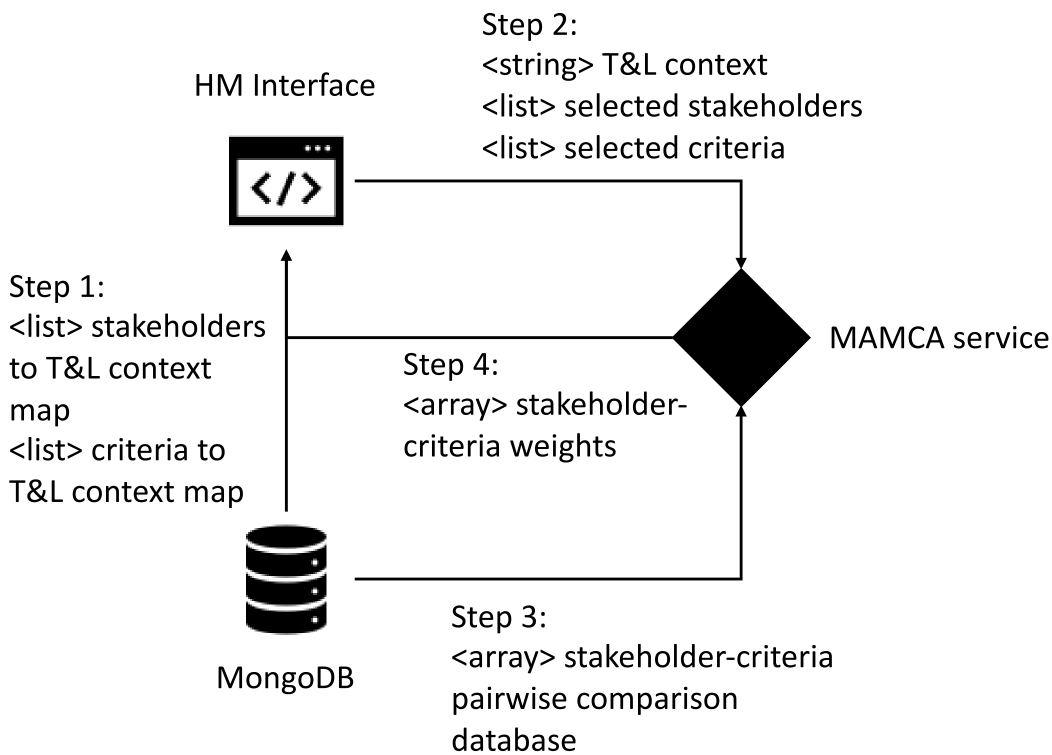

Figure 4.2 HM interface-MongoDB-EGTN MAMCA service communication process

The MAMCA service has been developed as a dockerized service made available through the EGTN platform. As a context is selected in the HM interface through the contextualization drop-down, then HM interface communicates with the MongoDB to collect the lists of relevant stakeholders and relevant criteria for the chosen T&L context. Two lists for each context, one for stakeholders and one for criteria are maintained in MongoDB to enable dynamically updating them as more data and more responses are being collected.

In the HM interface, the user is then presented with the relevant stakeholder and criteria information for the context selected. For ease of use, initially the tick boxes for all relevant to the selected context, stakeholders and criteria are ticked and therefore included. The user is able to select a subset of the stakeholders and criteria presented by unticking some of the boxes. As lost as at least two criteria and two stakeholders are selected, the user is able to click the execute button.

Upon pressing the execute button, the HM interface communicates the selected by the user T&L context, stakeholders list and criteria list, to the EGTN MAMCA service. Once the MAMCA service receives a request, it initially checks the information provided to conform a viable dataset. If so, it then retrieves the pairwise comparison database for the selected context, and processes the data, to identify the appropriate stakeholder-criteria weights.

Finally, the service communicates the table of weights to the HM interface where it is presented in the table visualization panel. The context, stakeholder, and criteria information required for the customization of the output, are provided to the service via an API, and the EGTN service returns a .json output, that can be processed by the HM interface. The service is available to PLANET Living Lab users for analysing operational and tactical decisions for the development of the transport network based on the PI principles.

5 MAMCA Operationalization and Implementation

The MAMCA model considers multiple stakeholders and criteria, that require to be operationalized through an analytic model. In the context of the PLANET project multiple models have been considered, capable of operationalizing some of the MAMCA criteria parameters, which is why the capability of customizing the MAMCA output is considered in its as-a-service manifestation available in EGTN platform and presented in Section 4.2. As discussed in D2.11 the findings of the MAMCA model can add value both at strategic and operational levels.

5.1 Strategic level: PI Network Criticality Assessment

5.1.1 EU flow model

The EU flow model is a macro-level model that captures aggregate cargo movements within the European Union, and considers Physical Internet infrastructure availability. The model sets-up a single commodity network with predefined source and sink nodes and their associated supply and demand capacities respectively. Sources are then linked optimally to sink nodes considering the capacitated links available between various PI Nodes in the network. Links are associated to costs that arise form a generalized cost function and travel times.

The model considers links connecting European cities for road, rail, sea and river modes. The PI enabled nodes are represented as transshipment locations where multimodal terminals are available. The PI nodes are also associated to normalized trade inflow or outflow volumes, that represent the export and import flows between at least two network nodes. It then calculates the optimal routes based on distance, travel time, or other parameters, while considering the throughput capacity for each node and link. It allows for the representation of the PI Hubs at a different aggregation level that accounts for terminals and other PI Hub functionalities as illustrated in Figure 5.1. Disaggregate PI representation, enables the accurate modelling of within the port cargo movement and transshipment costs, that have a significant impact on transshipment potential. The model can therefore be configured to quantify aggregate flows and how they are impacted by infrastructural and operational improvements in the network.

Each node is associated to a positive or negative trade-balance classifying them into source or sink nodes. A flow assignment algorithm is used to quantify the total cost to satisfy demand, which is used as a proxy for network performance. The multiple KPIs considered in the generalized cost function for the model, enable the integration of Multi-Actor Multi-Criteria Analysis and the per stakeholder criteria assessment.

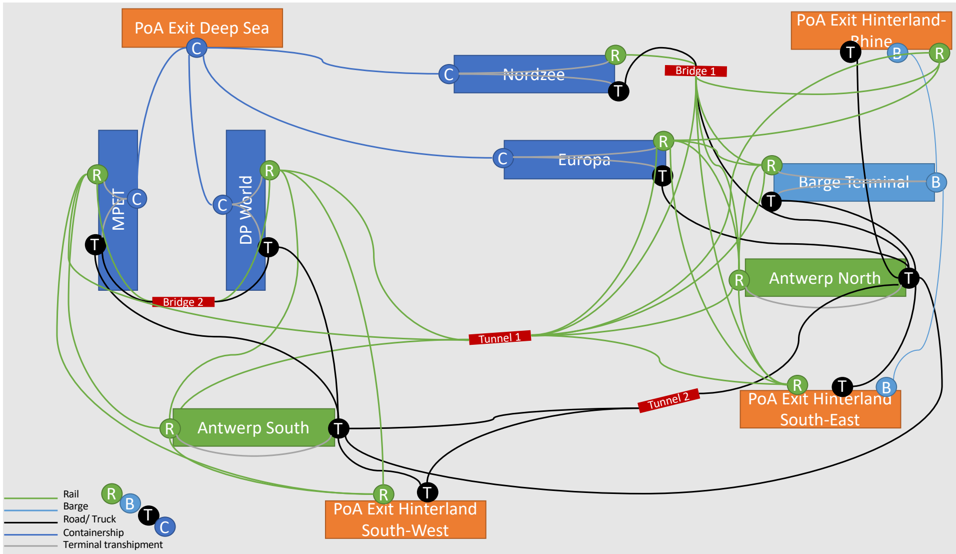

Figure 5.1 Example of PI Hub representation

5.1.2 PI Network link criticality assessment

The model can be operationalized to perform a stress test of the network, and quantifying the criticality of various components as it utilizes a flow assignment algorithm able to quantify network performance in terms of various KPIs. This insight becomes valuable when analyzing budgeted infrastructure investments, in terms of their impact to various stakeholders. Node or link characteristics can be altered to examine what-if scenario for investments, or disruptions. In the case of disruptions, each link is sequentially disrupted to zero throughput capacity, to quantify its overall significance to the whole network.

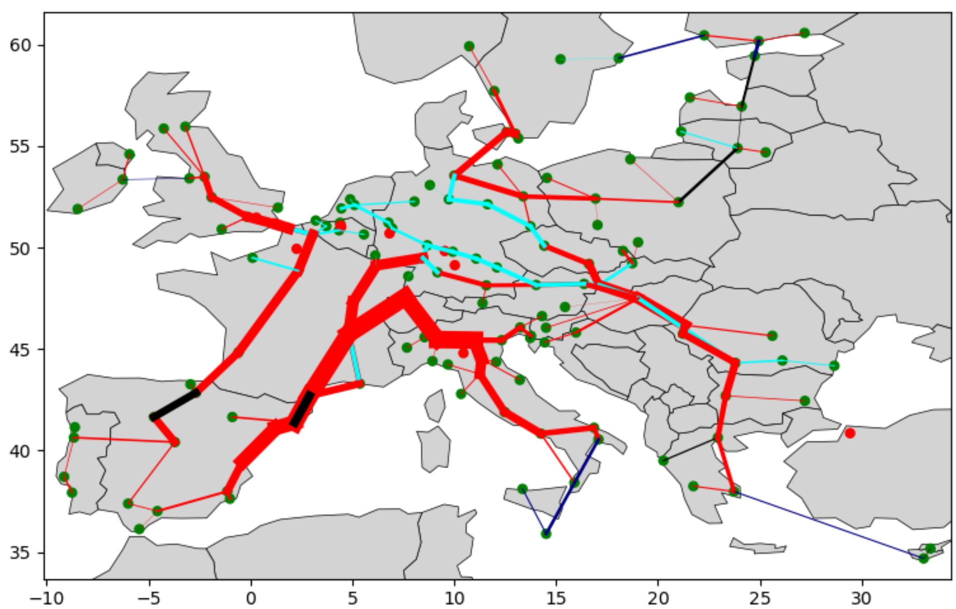

Figure 5.2 EU flow model baseline network for disruption criticality assessment

The baseline network performance is evaluated, and then the disrupted performance of the network is calculated for every link disruption. The analysis is undertaken separately for various KPIs, such as cost and time and link disruptions are ranked in terms of impact as illustrated in Figure 5.3 for operational cost, and in Figure 5.6 in terms of operational time.

linkid	linkorigin	ıkdestinatid	linkmode	costeuro	distkm	aveltimemi	pacity_low	crit_cost	%_increase	rank
216	Basel	Milan	Rail	78	341	255	0	4897395	12.6	1
155	Barcelona	Perpignan	Rail	44	193	144	0	4890767	12.5	2
30	Arad	Budapest	Rail	60	265	198	0	4790413	10.2	3
222	Milan	Verona	Rail	36	160	120	0	4760393	9.5	4
218	Lyon	Basel	Rail	94	409	306	0	4746620	9.2	5
146	Valencia	Tarragona	Rail	59	259	194	0	4714450	8.4	6
157	Rome	Florence	Rail	64	279	209	0	4657447	7.1	7
5	Athens	Thessalonik	Rail	115	501	375	0	4653119	7	8

Figure 5.3 EU PI Network critical links in terms of cost

linkid	linkorigin	ıkdestinatid	linkmode	costeuro	distkm	aveltimemi	crit_time	% increase	rank
154	Barcelona	Perpignan	Road	293	193	130	10899606	8.31	1
210	Lyon	Turin	Road	474	312	219	10813342	6.66	2
136	Valladolid	Vitoria	Road	364	240	153	10722480	4.93	3
182	Kaunas	Warsaw	Road	653	430	303	10715935	4.8	4
172	Perpignan	Lyon	Road	685	451	253	10694203	4.39	5
54	Tallinn	Riga	Road	468	308	246	10688563	4.28	6
221	Milan	Verona	Road	243	160	119	10668927	3.9	7
177	Bordeaux	Paris	Road	890	586	342	10584015	2.28	8
155	Barcelona	Perpignan	Rail	44	193	144	10546263	1.56	9
7	Igoumenits	Thessalonik	Road	489	322	204	10533509	1.32	10
211	Turin	Novara	Road	145	96	76	10531152	1.27	11
13	Sofia	Craiova	Rail	60	262	196	10523169	1.12	12

Figure 5.4 EU PI Network critical links in terms of travel time

The disruption assessment indicates that in a Physical Internet operated transport network the higher monetary costs are caused by rail link disruptions while the highest travel time costs are caused by road link disruptions. The proposed model considers transport cost and delivery time. Therefore, the two respective weights (from Figure 4.1) are considered for each stakeholder and adjusted to sum up to one. The cost weight is 0.4 for warehouse operators and 0.43 for hinterland transport operators and customers. The time weight is 0.6 for warehouse operators and 0.57 for hinterland transport operators and customers.

The weighted link disruption impact is illustrated in Figure 5.5. The MAMCA model indicates that the disruption of road link between Barcelona and Perpignan (link id: 154) is the most severe for all stakeholders. However, it is observed that the weighted impact for this specific disruption is more sever for warehouse managers rather than hinterland operators and receivers. The second most sever disruption is that of the rail link between Basel and Milan (link id: 216). This disruption has a more severe impact for hinterland operators and receivers rather than warehouse managers. The third most significant impact is that of . which has a higher impact for significant differentiation in terms of weighted impact is that of the road link between Tallinn and Riga (link id: 54). In this case the weighted disruption impact is found to be roughly similar for all stakeholders.

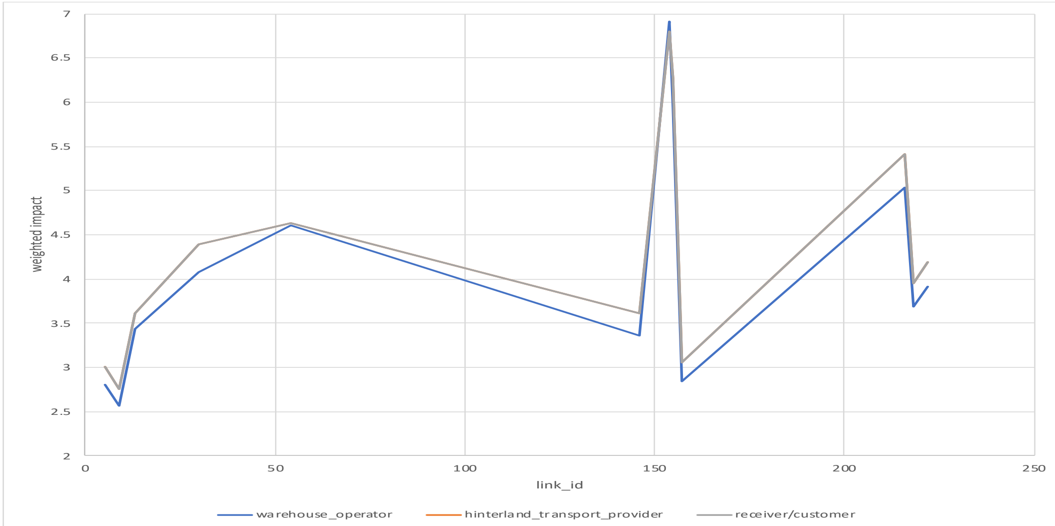

Figure 5.5 Weighted MAMCA output for link criticality

Therefore, considering the stakeholder weights and the percentile increase to the networks performance by each disruption, policy decisions can be made and a better understanding of disruption impact per stakeholder can be achieved.

5.2 Operational level: Last mile collaboration marketplace functionality

Collaboration in T&L can be performed in multiple contexts ranging from warehouse and consolidation location sharing to dynamic re-routing solutions and is applicable to all contexts considered in this report. T&L operators avoid horizontal collaboration, typically claiming fear of losing delivery volumes to competitors, poor service quality of other operators, as well as lack of brand recognition.

T&L operator collaboration leads to the identification of more efficient transport options and can significantly impact solution efficiency. PLANET's MAMCA Workshop enabled the establishment of the most significant stakeholders and performance criteria for each operational context, also ranking them in terms of significance. When asked specifically about last mile delivery, the most significant criteria identified were: sustainability, transport cost, congestion, service quality, emissions, driver availability (human resources), delivery time and profitability. Each of those criteria was weighted uniquely by various stakeholders.

To address operational collaboration challenges the principles of MAMCA can be adjusted instead of considering all relevant stakeholders to only incorporate operators. Using a standard scale for each of the criteria, a comprehensive characterization of each operator can be achieved. For example, Figure 5.6 presents a mapping of five last mile operators based on synthetic data, where Operators 1, 3 and 4 are conventional van operators while operators 2 and 5 and cargo bike operators, scoring higher in emissions and sustainability performance.

Figure 5.6 Multi-criteria mapping of last mile operators

Maintaining a comprehensive multi-criteria performance characterization for each operator as the one illustrated above, enables, a collaborative filtering process to take place. Each operator can pre-define acceptable performance criteria for collaboration. For example, a mainstream operator that uses vans, may specify emissions and sustainability performance for collaboration to be at least 7, in which case only the two cargo-bike operators would qualify. Then, after respecting operators preferences, a collaboration algorithm can be implemented to establish optimal operational conditions, considering only the last mile operators that qualify after applying the multi-criteria filtering process. Note that the collaborative filtering service is not yet implemented as part of the EGTN parcel MAMCA service due to the limited last mile operator data available.

6 Conclusions

The MAMCA model presented in this report focuses on the interconnection of the European Transport network to global trade corridors and the technological implementation of the Physical Internet. Due to the unique characteristics of the T&L sector, the EGTN service developed accommodates three separate instantiations of the MAMCA, for the contexts of:

- intercontinental corridors,
- warehouse and hinterland transport, and
- last mile delivery.

The MAMCA model exploits the identification of significant stakeholders and criteria for each context and the findings from the three questionnaires shared with project partners. The process followed for the implementation of the MAMCA, involved:

1. a preliminary stakeholder analysis undertaken in collaboration with Living Lab partners, and including the projects Advisory Board members as well as affiliations (e.g. ALICE network).
2. an interview with LL partners representing significant supply chain operators from various stages of the supply chain (intercontinental, warehouse, last mile), and a mix of organizations (e.g. transport and hub operators, government).
3. a set of significant stakeholders for each operational T&L context including a voting-based significance ranking.
4. a set of significant criteria for each operational T&L context including a voting-based significance ranking.
5. context specific questionnaires involving criteria pairwise comparison associated to a specific stakeholder category.
6. a service deployed in the EGTN platform exploiting the stakeholder-criteria weights and customizing them to specific user needs.

The preliminary stakeholder analysis indicated a significant amount of relevant stakeholders being part of PLANET project, enabling a holistic representation of the significant stakeholders in T&L.

The interview stage indicated the need for breaking down the analysis into three separate contexts, due to the significantly different performance criteria used in each context. The interview process indicated the existence of macro-criteria that apply across contexts as well as context specific criteria. It was also observed that transport operators typically assign context specific operations to different entities (usually in the form of subsidiaries).

Significant stakeholders and criteria were ranked for each operational T&L context. This stage validated the findings of the interview stage, as significantly different stakeholder and criteria were identified in each context. Some stakeholders were found to be relevant in multiple contexts, such as warehouse operators who are relevant both in hinterland operations and last mile delivery. Some sort of government stakeholder ranging from national government to local authority was identified as a stakeholder in all contexts. At the same time, several stakeholders relevant to only one context were identified, such as last mile operators and e-commerce platforms in the last mile and LSP in hinterland transport. Differences across contexts were also observed in terms of criteria. Transport cost, sustainability and time were found to be relevant across all contexts, while other criteria were found to be context specific. For example, throughput was found to be relevant in a hinterland transport context, while staffing and human resources aspects were found to be significant in the last mile.

The questionnaire responses enabled the determination of dynamic stakeholder-criteria specific weights that are made available through a EGTN deployed service. The service is made available for use by the Living Lab partners. Specific customization features were considered in the service's EGTN platform interface, enabling potential Living Lab users to adjust the tables to the needs of specific case studies.

The operationalisation of the MACMA models' indicated the versatility of the tool to identify associate multi-criteria performance to specific stakeholders at both tactical and operational levels. The tool is shown to produce valuable findings in analysing network performance and assessing network disruptions and link criticality. The same functionality involving the analysis of network performance, can be utilized to assess strategic investment decisions for new infrastructures and technology and indicate how various stakeholders reflect on its impact. At an operational level, the tool can be utilized as an operational collaboration feature enabling collaborative filtering and to efficient T&L operations.

7 References

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Annex I: Criteria Weights Pairwise Comparison Questionnaires

Questionnaire 1 - Intercontinental Corridors and Points of Entry

Link: https://forms.gle/aVbrQN9U5FWcwrTL6

Questionnaire 2 - Warehouse/ Terminal and Hinterland Transportation

Link: https://forms.gle/8toDwk9nWZs5dJq46

Questionnaire 3 - Last Mile Delivery

Link: https://forms.gle/K4W6s3SdDU3FBMkH6