



Deliverable D 6.2

TOOL FOR PERFORMANCE ASSESSMENT

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Disclaimer

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1 Executive Summary

Since the main aim of the IP4MaaS project (S2R-OC-IP4-01-2020, GA 101015492) is to design, execute, monitor, and assess the Shift2Rail IP4 demonstrations by liaising between CFMs, TSPs, and users, it will be necessary to determine the indicators that will allow evaluating if the Tool adds value to the already existing webs and other services TSPs provide to the travellers.

Deliverable 6.2 “Tool for performance assessment” (WP6) will prepare a Toolbox with the data collected in the Athens phase I demonstration site. Moreover, this deliverable will assess the final list of operational KPIs of the users’ satisfaction with Transport Service Providers (TSPs) and travellers with the new approach. Furthermore, the methodology of this deliverable will focus on the effectiveness calculation for the functionalities assessed in the IP4MaaS project.

Additionally, the definition of “impact and performance assessment” will be discussed in D6.1 “Assessment methodology” (WP6). This performance assessment will be conceptually based on data collection, the definition of a hierarchical model, local weighted hierarchy of IP4 functionalities in level 1, local weighted hierarchy of IP4 functionalities in level 2, and the purpose of a global weighted hierarchy. These concepts will be introduced in detail in this document.

The operational KPIs assessed in this deliverable are extracted from deliverable D3.2, “List of operational KPIs, analysis of the users’ satisfaction and methodology as a whole, F-REL” (WP3). In addition, the data of specific operational KPIs assessed in the Athens demo site phase I are collected from CFMs and IP4MaaS partners involved in this project.

This deliverable provides an analysis and assessment based on IP4MaaS functionalities, relevant benefits, and expectations for both Transport Service Providers (TSPs) and Travellers through the list of operational Key Performance Indicators (KPIs) and (User Satisfaction Index) USI surveys.

The methodology which is used in D6.2, “Tool for performance assessment” (WP6), is based on AHP (Analytic Hierarchy Process) for measuring “Benefit clusters” regression analysis, Bayesian Networks to weight “operational KPIs and USI surveys” and ANOVA test.

2 Abbreviations and acronyms

Abbreviation / Acronym	Description
AHP	Analytic Hierarchy Process
ANOVA	Analysis of Variance
API	Application Programming Interface
BN	Bayesian Network
CFM	Calls for Members
CL	Criteria Level
DAG	Directed Acyclic Graph
EU	European Union
GA	Grant Agreement
H2020	Horizon 2020
IP4	Innovation Programme 4
IT	Information Technology
JP	Journey Planner
KPI	Key Performance Indicator
LBE	Location Based Experiences
MAAP	Multi-Annual Action Plan
MaaS	Mobility as a Service
MCA	Multicriteria Analysis
PI	Polyhedral Individual
PTO	Public Transport Operator
S2R JU	Shift2Rail Joint Undertaking
TC	Travel Companion
TSP	Transport Service Providers
USI	User Satisfaction Index
WP	Work Package
WPL	Work package leader

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5 Background

The present document constitutes the Deliverable D6.2 “Tool for performance assessment” in the framework of the WP6, Task 6.2 IP4MaaS project (S2R-OC-IP4-01-2020, GA 101015492).

This deliverable will set the terminology list used in this project as a starting point, summarizing the concepts from the previous IP4 projects. Those new concepts introduced by the IP4MaaS project will be differentiated, and special attention will be paid to those topics with a different meaning than the other IP4 projects (COHESIVE, CONNECTIVE, ExtenSive, RIDE2RAIL).

This deliverable, as a tool for performance assessment, will focus on the analysis and assessment of specific Key Performance Indicators (KPIs) and User Satisfaction Index (USI survey) based on the methodological framework which has been discussed in D3.2 “List of operational KPIs, analysis of the users’ satisfaction and methodology as a whole, F-REL” (WP3) to obtain the final weight of benefits cluster and IP4MaaS functionalities in Athens demo site phase I.

After explaining the methodology and the concept of the effectiveness formula, this deliverable indicates how this methodology can calculate the final weight of IP4 functionalities through operational Key Performance Indicators (KIPs) and the User Satisfaction Index (USI). Furthermore, it will evaluate user satisfaction with the IP4 solution¹ and illustrate how the Effectiveness will be calculated for each user profile and the technological innovation.

¹ IP4 solution refers to the Information technology solution, which includes different modules or functionalities, that is being developed by previous projects in Shift2Rail Innovation Program 4 (IP4), which include ATTRACKTIVE, CO-ACTIVE, MaaSive, and CONNECTIVE projects.

6 Objective/Aim

IP4MaaS WP6 has prepared this document to provide a Toolbox with the capability to establish correlations between variables and a hierarchy of their relevance, in order to allow CFMs to make decisions regarding the improvement of the Travel Companion application. The data regarding operational KPIs are saved in several databases of Travel Companion that are managed by CFMs. The toolbox in this deliverable has been developed for the specific needs of the assessment of the IP4MaaS project but it could be generalized and applied to assess other demo sites for future projects. It should be considered that in order to use the scripts introduced in this deliverable for other demo sites and future projects, the toolbox and its scripts need customization and adaptation for new variables and ranges of these new variables per each demo site.

This document has the following objectives:

- Defining data collection process: The list of operational KPIs feasible from the Travel Companion and Satisfaction index gathered through USI surveys.
- Definition of a hierarchical model of IP4 functionalities in 2 levels which is validated by the expert panel
- Introducing pairwise comparison matrices to analyze the importance of each criterion that is filled out by the expert panel
- Applying the AHP (Analytic Hierarchy Process) module to get a LOCAL weighted hierarchy of IP4 functionalities in level 1.
- Applying regression analysis to the collected data and operational KPIs
- Application of Bayesian Networks to get a LOCAL weighted hierarchy of IP4 functionalities in level 2.
- Definition of a GLOBAL weighted hierarchy (multiplication of weights level 1 and 2) for the IP4 functionalities to report CFMs what functionalities need to be urgently improved according to mentioned data and analysis.
- Implementing the ANOVA test in data analysis

The approach of this deliverable will be as follows:

- Classifying IP4MaaS functionalities per the benefits provided to Travellers, such as Time-saving, Cost saving, and comfort, can be defined as "Benefit clusters."
- These "Benefit clusters" will be weighted according to the AHP methodology (level 1 weights). Multidisciplinary expert panel for this approach will be defined, consisting of CFMs, IP4MaaS partners, and TSPs (Transport Service Providers) representatives.
- IP4MaaS functionalities will be weighted through operational Key Performance Indicators (KPIs) and User Satisfaction Index (USI) following Bayesian Networks (level 2 weights).
- The final weight will be calculated by multiplying the weight level 1 (Benefits cluster) per the weight level 2 (IP4MaaS functionalities).

The methodological framework of this deliverable aims to measure and weigh both operational KPIs and user satisfaction levels for TSPs and Travellers through USI surveys. Moreover, after defining the concept of methodology, the calculation of the Effectiveness of each profile based on IP4 functionalities and technological innovation will be studied in this document.

7 IP4MaaS assessment Tool architecture

Regarding GA, the performance assessment will be executed through the development of a tool in Excel with scripts on MATLAB to run the modules and Algorithm defined in T6.1 (assessment methodology). In this deliverable, the MATLAB software has been replaced by JULIA software (V 1.7.0). This replacement is because the JULIA programming language is free and open-source software, whereas MATLAB is private language software. Furthermore, JULIA is quicker than MATLAB in terms of data calculation.

The performance assessment methodology will be based on several mathematical data analysis tools as detailed in the following subsections, which will be a Toolbox with separate modules executed sequentially with the aim of achieving relevant results about the performance of the Travel Companion APP in each Demo site. See Figure 1 as a conceptual overview of the Toolbox, which is developed in Task 6.2:

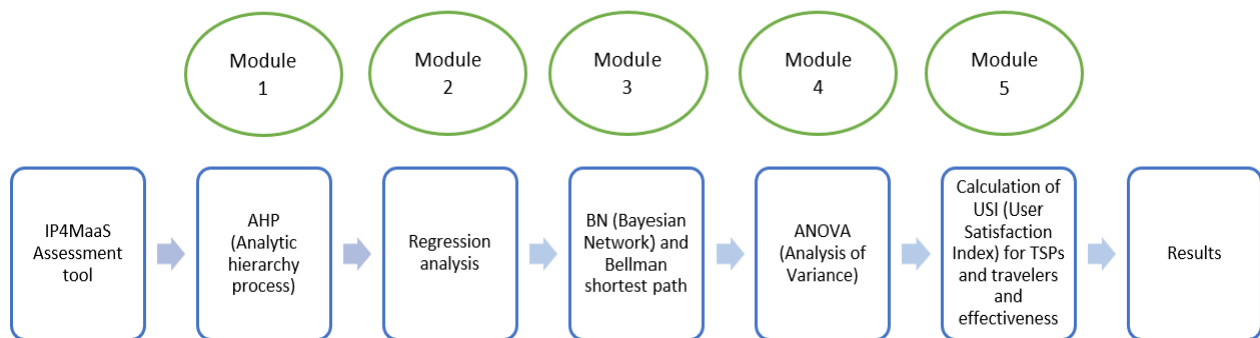


Figure 1. IP4MaaS assessment tools and modules

The performance assessment toolbox will work with data collected from Pairwise comparison matrixes filled by an expert panel, Operational KPIs, and USIs surveys in the WP5 during the execution of the demo.

The regression and BN analysis (modules 2 and 3) of the IP4MaaS assessment toolbox will be applied only to travellers. Furthermore, only modules 1 (AHP) and 4 (USIs and Effectiveness) are applied to the collected data from TSPs. The main reason for this decision is insufficient data from TSPs to be applied to regression and BN analysis.

The following table identifies which module in these data analysis is applied to which IP4MaaS assessment toolbox:

Table 1. Identifying the application of each data analysis modules on travellers and TSPs

Modules	Travellers	TSPs
Module 1: AHP (Analytic Hierarchy Process)	✓	✓
Module 2: Regression analysis	✓	✗
Module 3: Bayesian network analysis	✓	✗
Module 4: ANOVA test	✓	✗
Module 5: Calculation of USIs and effectiveness	✓	✓

Due to the fact that the task 6.2 responsible did not have access to the Cloud Wallet of Travel Companion (TC) APP, the operational KPIs of the Athens demo site phase I have been received through an Excel file from CFMs (Call For Members) who are the software developers in IP4MaaS project.

Regarding GA (Grant Agreement) on the description of WP5, manage the development and deployment of a small-scale API to be used by PTOs and TSPs that have no suitable one for the integration of IP4 Ecosystem IT tools and for the integration of the monitoring Tool described in Task 6.2, if necessary. Concerning the building of API connections, an alternative and more effective way was found instead of API connection. The data regarding operational KPIs was received in the format of an Excel file from CFMs after finishing the assessment of the demo site. Considering the abovementioned fact, as illustrated in Figure 2, API connections have been replaced by the shared file, including operational KPIs collected through the demo site.

The following figure will illustrate how the data exchange has been implemented instead of API connections:

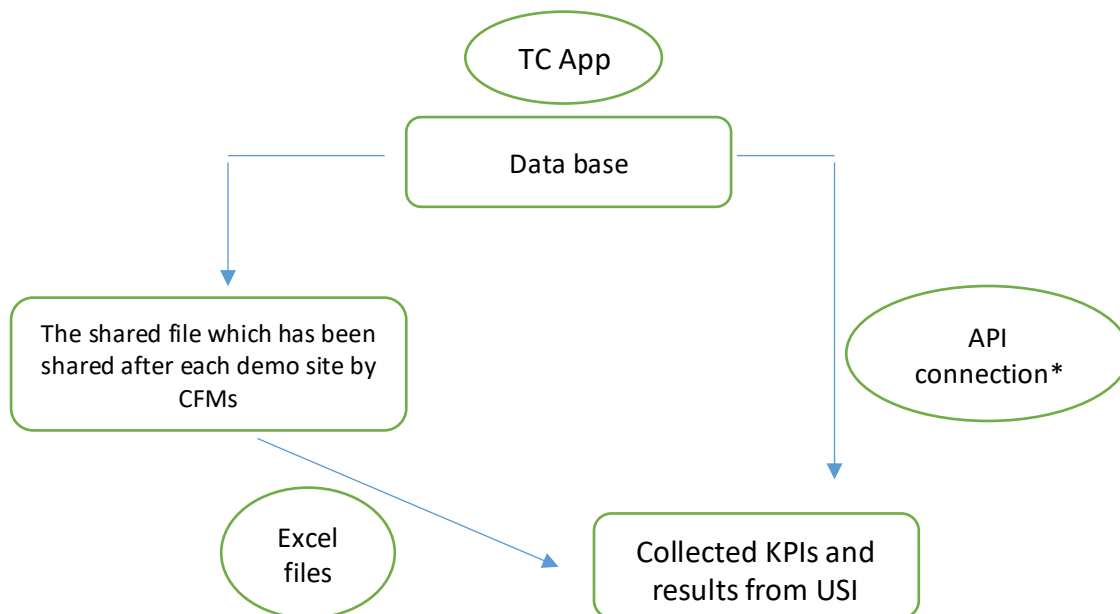


Figure 2. Data exchange from cloud wallet

*This API connection has been replaced by a file transferred from the Cloud Wallet.

8 Data on which IP4MaaS Tool is working

The IP4MaaS Tool works based on four types of data. Module 1 is working with Data 1, while Modules 2 to 5 are working with Data 2 to 4:

Data 1: Data collected from an expert panel comparing the importance of functionalities provided by the Travel Companion (TC) APP. This is done through pairwise comparison matrixes and Module 1 about AHP analysis is working on this data. This data must be collected per each demo site for which a different expert panel will be set. In *Annex 1*, filled pairwise comparison matrixes can be consulted.

Data 2: Operational KPIs gathered directly from the performance of the TC APP through a backup of the Cloud Wallet database after each demo. Operational KPIs considered in Modules 2 to 4 of the IP4MaaS Tool are detailed in D3.2. (IP4MaaS project (2022). Deliverable D 3.2 List of operational KPIs, analysis of the users' satisfaction and methodology as a whole, F-REL n.d.) The operational KPIs considered specifically in the phase 1 Athens demo site on which the IP4MaaS Tool has been applied for the first time were the next:

Table 2. List of operational KPIs that are assessed in Athens demo site phase I

Number	Innovative Technology (IP4)	Operational KPI	Responsible partner
1	Location-Based Experience	Number of entertainment services offered during the demo	CS Group
1	Location-Based Experience	Number of experiences launched during the demo	CS Group
1	Location-Based Experience	Average time per connection (in seconds) during the demo	CS Group
1	Location-Based Experience	Total number of connections in the morning	CS Group
1	Location-Based Experience	Total number of connections in the evening	CS Group
2	Asset manager	Number of services integrated with the pilot	POLIMI
3	Journey Planning	Average Number of modes involved in the journey	Extracted through USI surveys
3	Journey Planning	Average number of shopped offers	THALES group
4	Booking	Average number of booked offers	THALES group
5	Issuing	Average number of issued offers	THALES group

Data 3: Data collected from surveys about USI (User Satisfaction Index) for Travellers as detailed in D3.2 (IP4MaaS project (2022). Deliverable D 3.2 List of operational KPIs, analysis of the users' satisfaction and methodology as a whole, F-REL n.d.). In *Annex 2*, the specific USI survey for travellers in the phase 1 Athens demo can be consulted. The maximum amount of travellers was

involved through a user engagement strategy as defined in D4.4 (IP4MaaS project (2022). Deliverable D 4.4 IP4MaaS project (2022). User engagement strategy per each demonstrator n.d.) in a real experience of testing the TC APP while traveling. Then all of them were asked to complete a survey scoring their satisfaction regarding the benefits provided by this APP during the journey. A random sample of travellers was involved in the first experience (first phase of the Athens demo), independently of their socio-demographic profile. In phase 2 of the Athens demo and the following demos, it was found that out that will encourage the participation of those underrepresented socio-demographic profiles.

The TRAVELLERS sample was tried to be plural regarding age, job position, gender, professional status, disability, and familiarity with technology. Below, an analysis of this sample is detailed:

All profiles regarding aggregated analysis (r=1): Seventeen

Disabled or impaired people-people with physical or mental illnesses, person in a wheelchair, person with reduced mobility, person with visual impairment, person with hearing impairment (r=3): Zero

Elderly- People over 65 years old: Zero

Women (r=5): Four

All these profile vectors (r) are underrepresented in it was found out that the current database for data analysis after the Athens Demo phase 1. It was found that out that will encourage collecting data about these underrepresented profiles in the phase 2 demo of Athens and the other Demo sites (Barcelona, Warsaw, Osijek, Padua, Liberec).

Data 4: Data collected from surveys about USI for TSPs (Travel Service Providers) as defined in D3.2. (IP4MaaS project (2022). Deliverable D 3.2 List of operational KPIs, analysis of the users' satisfaction and methodology as a whole, F-REL n.d.) In *Annex 3*, the specific USI survey for TSPs used in the phase 1 Athens demo can be consulted. One person per each TSP involved in the demo was asked to fill out a survey regarding their satisfaction with the functionalities used by them in the TC addressed to TSPs, for instance, the Asset Manager functionality.

The sample of TSP's REPRESENTATIVES was tried to be plural regarding age, job position, and gender. Below, an analysis of this sample is detailed:

By age

Regarding the age distribution of TSPs respondents (Figure 1), about 57% of testers are from 25 to 44 years old. Furthermore, regarding the data, 43% of the tester are between 45 to 64 years old.

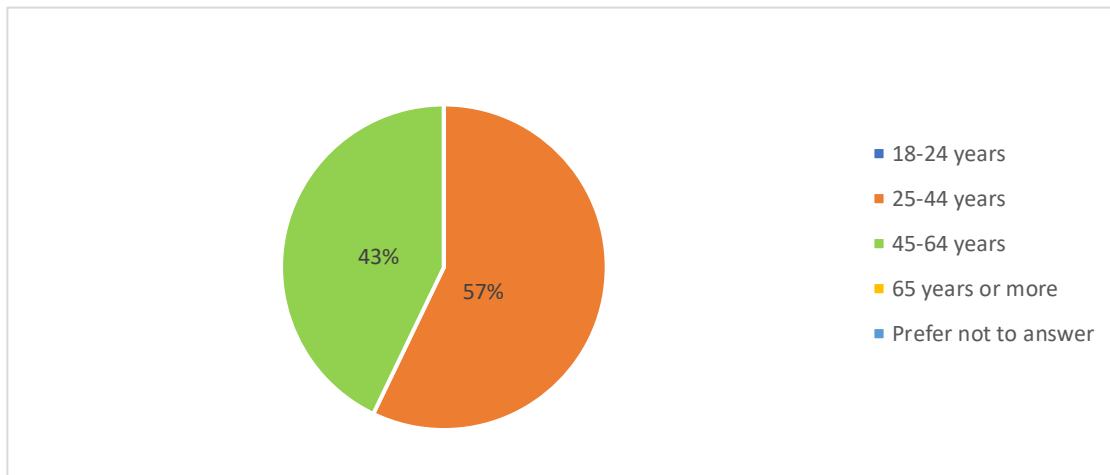


Figure 3. Age distribution of the TSPs respondents

By gender

Regarding responses executed from TSPs respondents about gender distribution, around 57% of testers were Female, and 43% were Male.

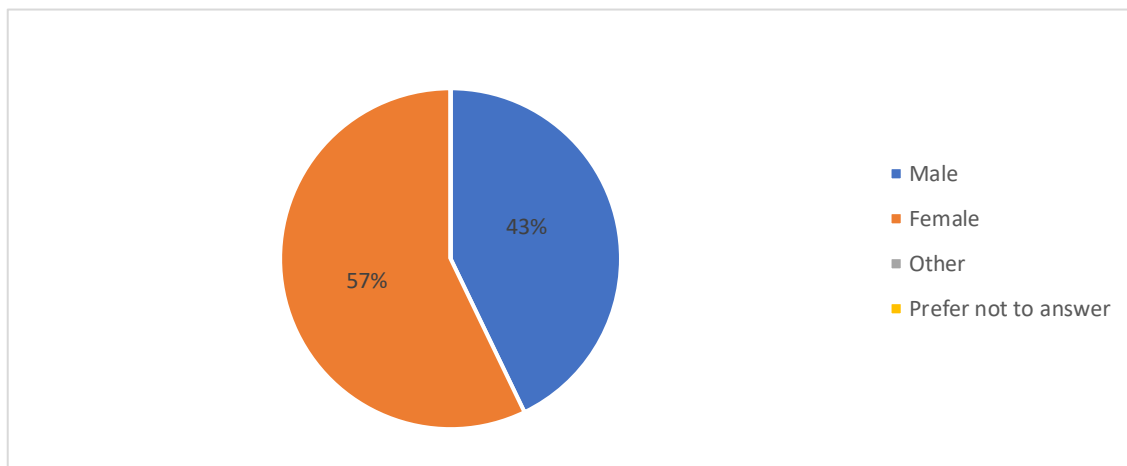


Figure 4. Gender distribution of the TSPs respondents

By residential area

Based on the statistics about TSP respondents' residential areas of TSPs respondents, all testers live in an urban environment.

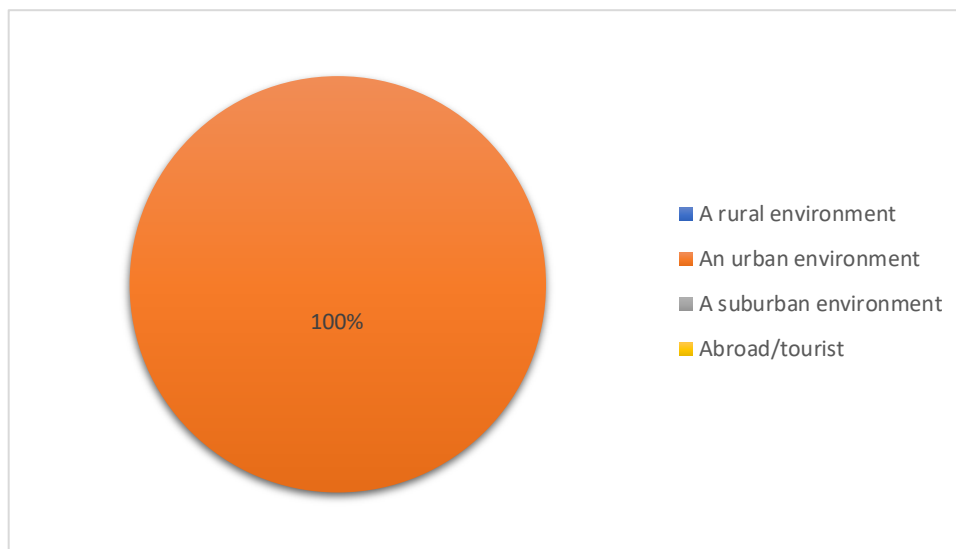


Figure 5. Residential area distribution of the TSPs respondents

By Profession status

Based on the statistics about the professional status of TSPs respondents, all testers are working in paid work.

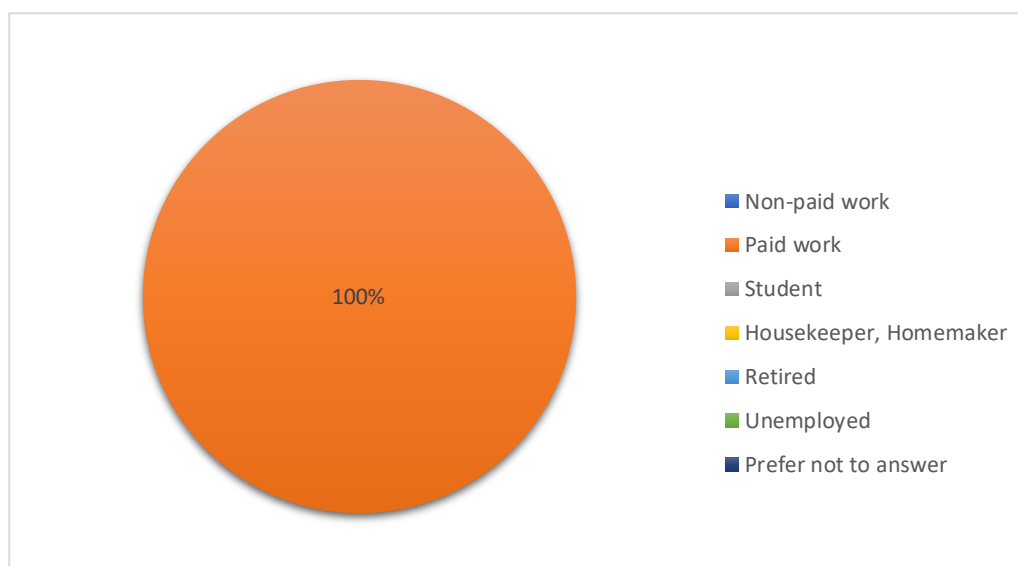


Figure 6. Profession status distribution of the TSPs respondents

Familiarity with technology and mobile application

Regarding the statistics about the level of Familiarity of TSPs respondents with technology and mobile application, all testers selected the Expert option in the survey.

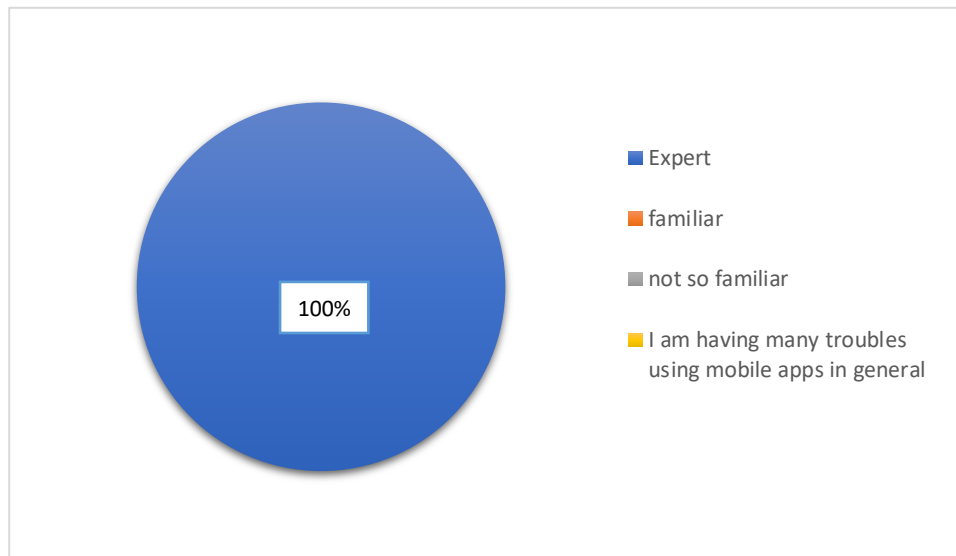


Figure 7. Familiarity with technology and mobile application distribution of the TSPs respondents

9 Methodology

9.1 Module 1: AHP (Analytical Hierarchy Process) analysis

The AHP is the first module in this deliverable data analysis applied to get a weighted hierarchy of factors with an influence on the two following goals defined for users of the Travel Companion APP:

- I. For Travellers: To increase the number of Travellers on public transport, especially railways.
- II. For TSPs: To increase the acceptability of the Travel Companion APP by TSPs.

The mathematical approach of this AHP analysis was detailed in D6.1. (IP4MaaS project (2022). Deliverable D 6.1 Assessment methodology n.d.)

The regression analysis in T6.2 has been developed in Julia's programming language. All the codes and scripts for the toolbox assessment can be found in Annex 4.

The AHP module has been done in the Julia programming language. The scripts and codes of this module can be found in *Annex 4*. These scripts can be divided into fit was found out that calculations:

Value AHP converts data into Saaty numbers to prepare a pairwise comparison matrix.

Consistency AHP: calculates the consistency of each pairwise matrix.

Consistent: filter out all inconsistent matrixes.

Apply AHP: primary AHP function to calculate the local and global weight.

9.1.1 Definition of the expert panel

The expert panel has been created to make a pairwise comparison between all level 1 and level 2 criteria. The expert panel is composed of the following members:

- 1 representant from each TSPs integrated with Athens's demo site phase I:
 - I. OASA: Katerina Antaraki
 - II. MIRAKLIO: Marina Tampakidi
 - III. TAXIWAY: Thodoros Stavridis
 - IV. BRAINBOX: George Keikoglou
- 1 CFMs (software developer)
 - I. Marco Ferreira, Thales group
- 2 Associations partners of the consortium
 - II. Giuseppe Rizzi, UITP
 - III. Stefanos Gogos, UNIFE

Criteria prioritization process:

Table 3. Scale of Saaty

Value	definition
1	Similar. Both elements are equally preferred.
3	The element in the row is slightly preferred.
5	The element in the row is strongly preferred.
7	The element in the row is very strongly
9	Extreme. The element in the row is extremely preferred.

If, on the other hand, the expert prefers the criterion in the column, the values to assign would be the reciprocals of those previously indicated, i.e., $1/3$, $1/5$, $1/7$, or $1/9$.

Finally, the global weight of each criterion or factor influencing the goal will be calculated. This final global weight (Roy and Słowiński 2013) will be calculated by multiplying the local weight of level 1 criteria and level 2 criteria calculated by applying AHP (T. Saaty 2013).

After this expert panel validates hierarchical models, pairwise comparison matrixes will be introduced. This means one pairwise comparison matrix per each criterion level 1. This comparison matrix will pairwise compare all criteria level 2 inside this criterion level 1.

The aim of preparing this matrix is to compare the importance between criteria levels 1 and 2. This matrix aims to assess the expert panel's technical opinion to determine which criteria are more important in achieving the main goal and how much this ratio is. (according to the scale of Saaty). The expert panel for the validation of the hierarchical models and the pairwise comparison between criteria influencing this goal is built in the following way (Reynolds, Schultz and Hekman 2006):

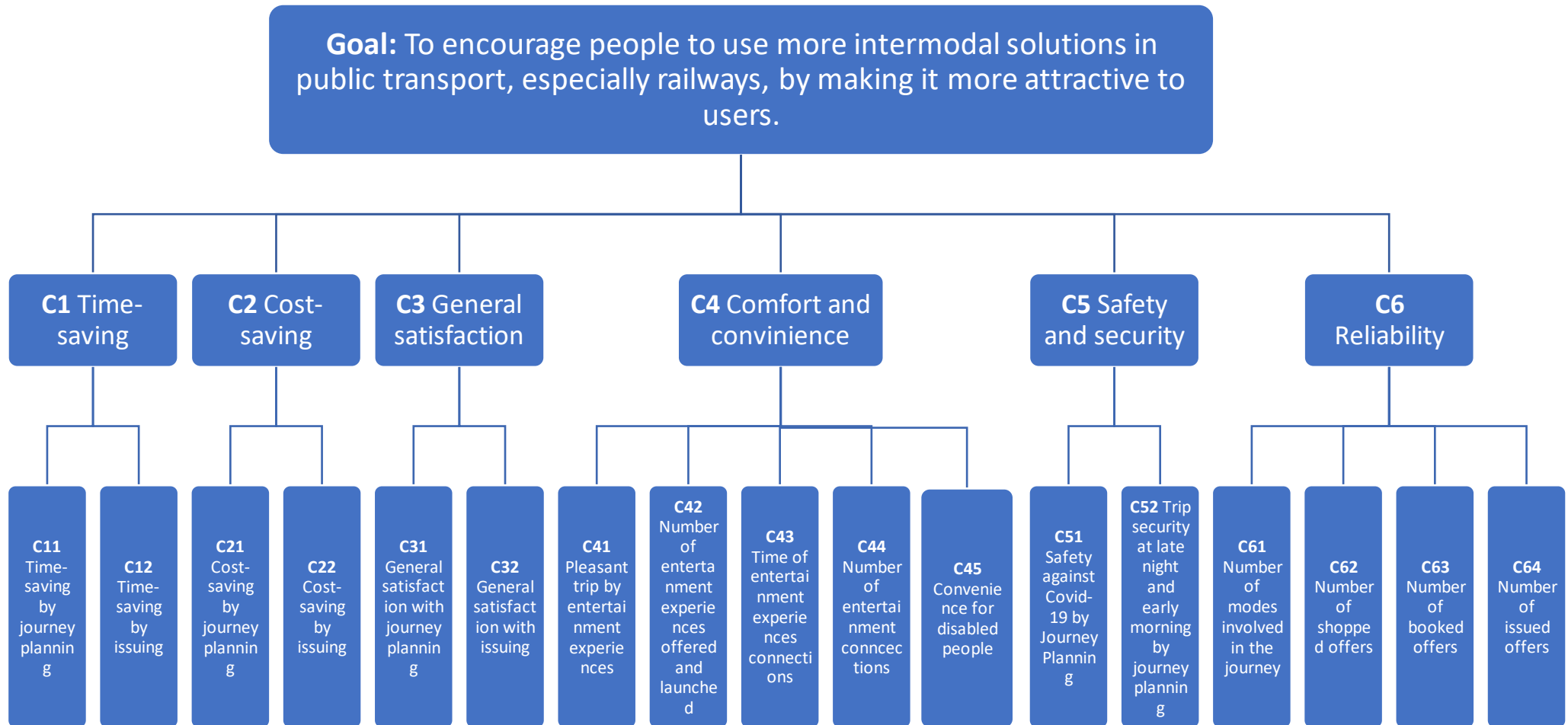


Figure 8. Hierarchical model for Travellers

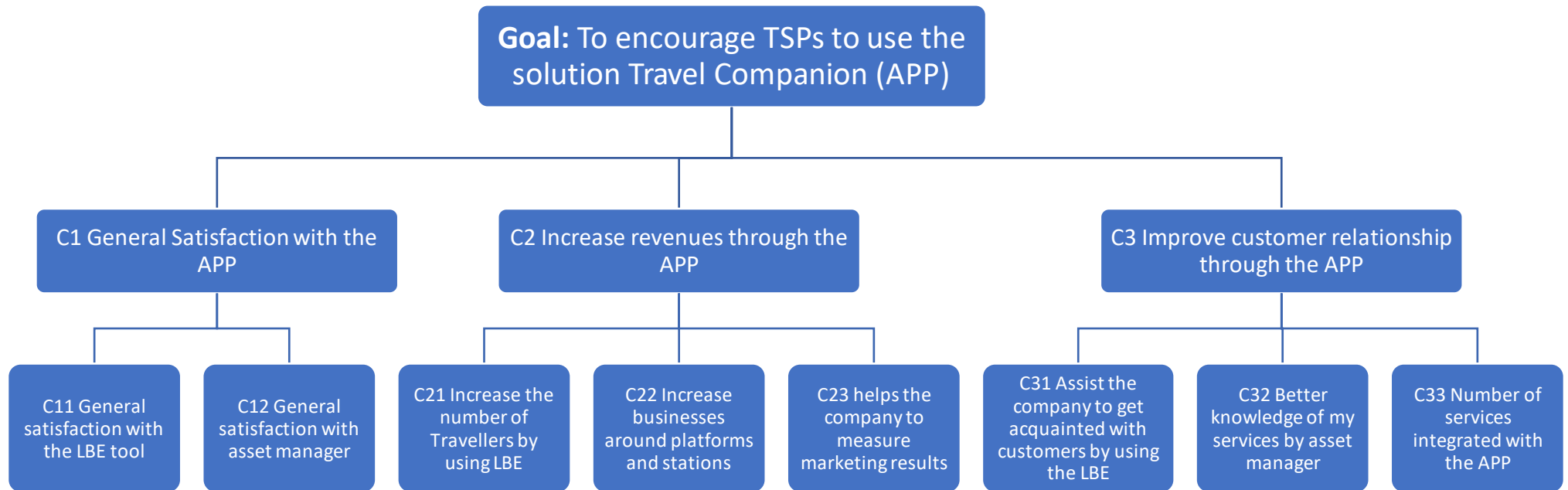


Figure 9. Hierarchical model for TSPs

9.1.2 Defining pairwise comparison matrix

After validation of the hierarchical model for Travellers and TSPs (abovementioned figures) by the expert panel, a pairwise comparison matrix was introduced. These matrices aim to identify the importance level of criteria levels 1 and 2 from the expert panel point of view considering the Saaty table (T. Saaty 1990). All of the feedback received by the expert panel can be found in Annex 1.

Any inconsistencies can usually occur when several pairwise comparisons are conducted. Let's take an example, assume that three criteria are taken into account, and the decision-maker assesses that the first criterion is slightly more important than the second criterion while the second criterion is slightly more important than the third. An obvious inconsistency arises when, by mistake, the decision-maker assesses that the third criterion is equally or more important than the first. On the other hand, when the decision-maker assesses that the first criterion is also slightly more important than the third criterion, a slight incoherence arises. For instance, a consistent analysis would be that the first criterion is more important than the third criterion. The AHP introduces an effective technique to test the consistency of the decisions taken by the decision-maker when constructing each of the matrices involved in the process. The consistency ratio (Eq.1) will be applied to the matrices received from the expert panel. This ratio will give the ability to remove the matrices and values which are not consistent with the final results:

$$CR = \frac{(\lambda_{\max} - n) / (n - 1)}{RI} \quad (\text{Eq.1})$$

Where:

n = number of criteria compared in the pairwise comparison matrix.

λ_{\max} = is the maximum eigenvector of the pairwise comparison matrix.

"RI" = is a value calculated according to Table 4.

A perfectly consistent decision-maker should always obtain $CR=0$; however, small values of inconsistency may be tolerated ($CR<0.1$). For the matrices that compare two criteria, since the value of $n=2$, the denominator in the consistency formula will become 0. As a result, the consistency ratio is not calculated for these criteria.

Table 4. Values of Random Index (RI) for up to 10 different criteria

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

9.1.3 Results of pairwise comparison matrix

The following charts and tables illustrate the weighted hierarchy of factors and the local and global weight obtained from the pairwise comparison matrixes filled by consistent experts (pairwise comparison matrixes with $CR > 0.1$ were not considered), as detailed in Annex 1.

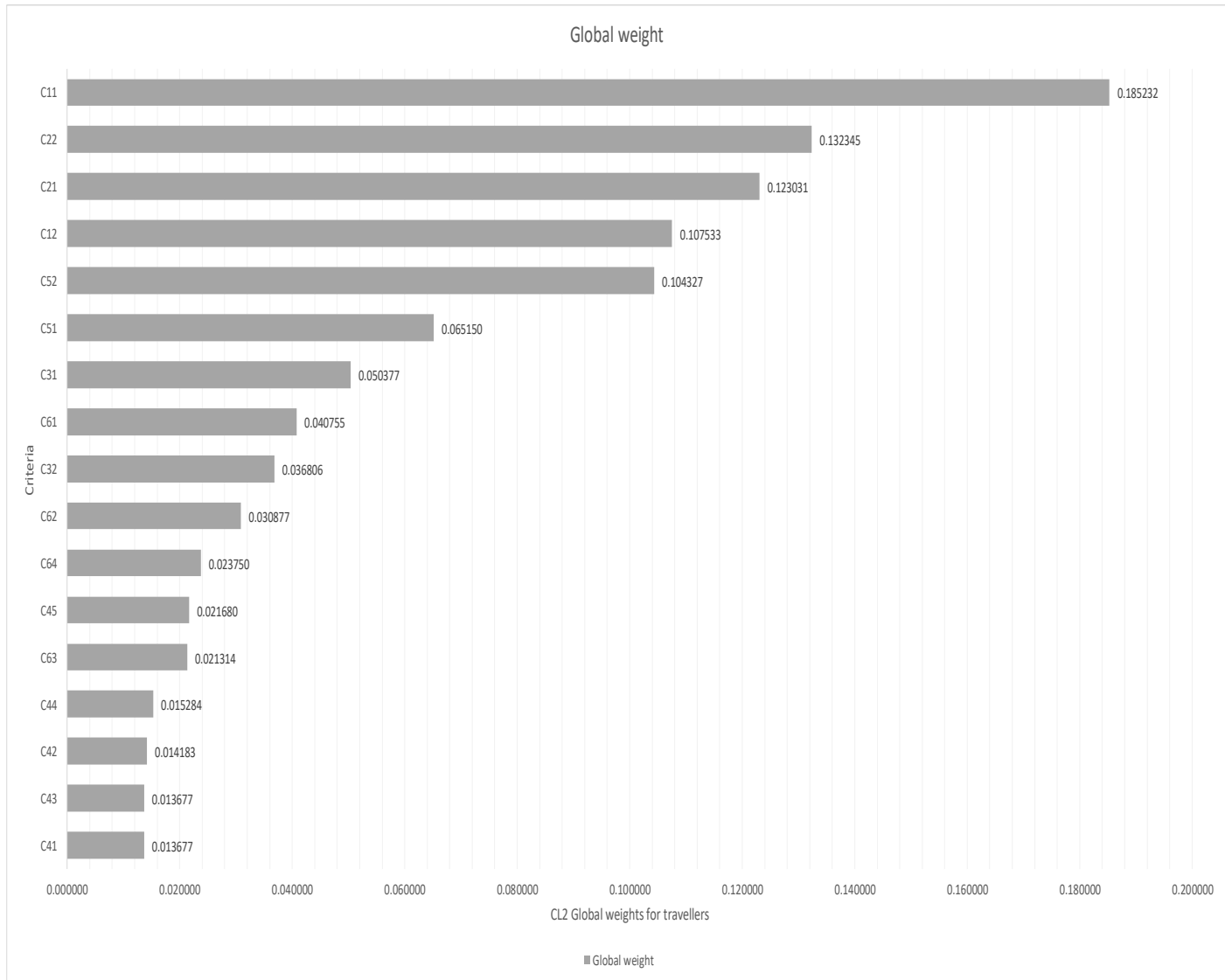


Figure 10. Calculation of global weights for Criteria Level 2 (travellers)

Table 5. Results of Level 1 and 2 Criteria for travellers

CL1	Description	Weight	Rank	CL2	Description	Local Weight	Local Rank	Global weight	Global rank
C1	Time-saving	0.292765036	1	C11	Time-saving by journey planning	0.632698026	1	0.185231861	1
				C12	Time-saving by issuing	0.367301974	2	0.107533176	4
C2	Cost-saving	0.255376593	2	C21	Cost-saving by journey planning	0.48176432	2	0.123031331	3
				C22	Cost-saving by issuing	0.51823568	1	0.132345262	2
C3	General satisfaction	0.087182748	5	C31	General satisfaction with journey planning	0.577834292	1	0.050377182	7
				C32	General satisfaction with issuing	0.422165708	2	0.036805567	9
C4	Comfort and Convenience	0.078502056	6	C41	Pleasant trip by entertainment experiences	0.174229658	4	0.013677386	16
				C42	Number of entertainment experiences offered and launched	0.180672453	3	0.014183159	15
				C43	Time of entertainment experiences connections	0.174229658	5	0.013677386	17
				C44	Number of entertainment connections	0.194700713	2	0.015284406	14
				C45	Convenience for disabled people	0.276167519	1	0.021679718	12
C5	Safety and security	0.169476707	3	C51	Safety against Covid-19 by Journey Planning	0.384418904	2	0.06515005	6
				C52	Trip security at late night and early morning by journey planning	0.615581096	1	0.104326657	5
C6	Reliability	0.11669686	4	C61	Number of modes involved in the journey	0.349237754	1	0.040754949	8
				C62	Number of shopped offers	0.264593727	2	0.030877257	10
				C63	Number of booked offers	0.18264783	4	0.021314428	13
				C64	Number of issued offers	0.203520688	3	0.023750225	11

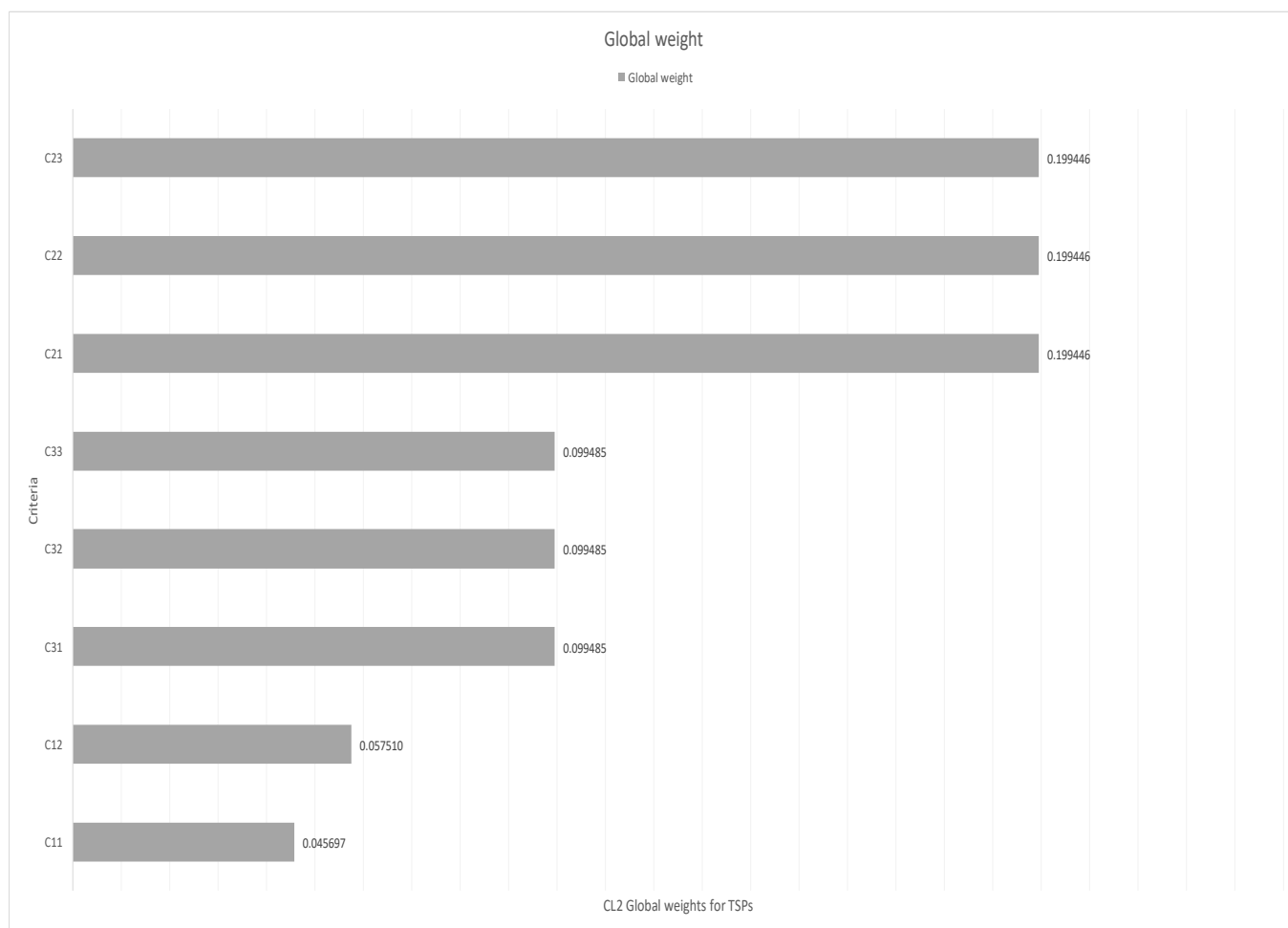


Figure 11. Calculation of global weights for Criteria Level 2 (TSPs)

Table 6. Results of Level 1 and 2 Criteria for TSPs

CL1	Description	Weight	Rank	CL2	Description	Local Weight	Local Rank	Global weight	Global rank
C1	General satisfaction with the APP	0.103207128	3	C11	General satisfaction with the LBE tool	0.442771957	2	0.045697222	8
				C12	General satisfaction with asset manager	0.557228043	1	0.057509906	7
C2	Increase revenues through the APP	0.598337753	1	C21	Increase the number of travelers by using LBE	0.333333333	1	0.199445918	1
				C22	Increase businesses around platforms and stations	0.333333333	2	0.199445918	2
				C23	helps the company to measure marketing results	0.333333333	3	0.199445918	3
C3	Improve customers relationship through the APP	0.29845512	2	C31	Assist the company to get acquainted with customers by using the LBE	0.333333333	1	0.09948504	4
				C32	Better knowledge of my services by asset manager	0.333333333	2	0.09948504	5
				C33	Number of services integrated with the APP	0.333333333	3	0.09948504	6

9.2 Module 2: Regression analysis

While Bayesian Network analysis aims to reach a correlation among all variables in a network that will allow us to conduct statistical predictions, the Regression analysis seeks to identify pairwise correlations between these variables. These pairwise correlations between couples of variables will let us define fixed connections in the Bayesian Network analysis to get more accurate results. Scores for variables were collected through USI questionnaires launched through an online survey in Greek and English versions. A total of 21 questionnaires were collected (9 in the Greek version of the online survey and 12 in the English version).

The mathematical approach of Regression analysis is detailed in D6.1. (IP4MaaS project (2022). Deliverable D 6.1 Assessment methodology n.d.)

The regression analysis in T6.2 has been developed in Julia's programming language. All the codes and scripts regarding Module 2 (Regression analysis) for the toolbox assessment can be found in *Annex 5*.

To identify each variable more accessible in data analysis, a unique code has been applied to each of them (Table 7). The code “J” identifies the “functionality,” the code “K” specifies the name of “TSPs,” and the code “q” introduces the associated question to each functionality.

In the following table, the definition of each code of variables has been introduced:

Table 7. Definition of variables codes

Variable name	Definition of variable name
J8K2KPI4	Total number of connections in the evening regarding Location-based experience for MIRAKLIO
J1K2KPI4	Average number of modes involved in the journey regarding journey planning for MIRAKLIO
J13K1KPI3	Number of services integrated with the pilot regarding asset manager for OASA
J8K1KPI1	Number of experiences launched during the demo regarding Location-based experience for OASA
J2K1KPI8	Average number of booked offers regarding booking for OASA
J8K2KPI0	Number of entertainment services offered during the demo regarding Location-based experience for MIRAKLIO
J8K2KPI3	Total number of connections in the morning regarding Location-based experience for MIRAKLIO
J8K2KPI2	Average time of connection (in seconds) regarding Location-based experience for MIRAKLIO
J1K2KPI7	Average number of shopped offers regarding journey planning for MIRAKLIO
J8K2KPI1	Number of experiences launched during the demo regarding Location-based experience for MIRAKLIO
J1K3KPI4	Average number of modes involved in the journey regarding journey planning for Taxiway
J1K4KPI4	Average number of modes involved in the journey regarding journey planning for Brainbox
J1K3KPI7	Average number of shopped offers regarding journey planning for Taxiway
J2K2KPI8	Average number of booked offers regarding booking for MIRAKLIO
J8K1KPI3	Total number of connections in the morning regarding Location-based experience for OASA
J3K4KPI10	Average Number of issued offers regarding issuing for Brainbox
J8K1KPI0	Number of entertainment services offered during the demo regarding Location-based experience for OASA
J3K1KPI10	Average Number of issued offers regarding issuing for OASA
J1K1KPI7	Average number of shopped offers regarding journey planning for OASA
J3K2KPI10	Average Number of issued offers regarding issuing for MIRAKLIO
J2K3KPI8	Average number of booked offers regarding booking for Taxiway
J8K1KPI2	Average time of connection (in seconds) regarding Location-based experience for OASA
J2K4KPI8	Average number of booked offers regarding booking for Brainbox
J8K1KPI4	Total number of connections in the evening regarding Location-based experience for OASA
J3K3KPI10	Average Number of issued offers regarding issuing for MIRAKLIO
J13K3KPI3	Number of services integrated with the pilot regarding asset manager for Taxiway
J1K1KPI4	Average number of modes involved in the journey regarding journey planning for OASA
J1K4KPI7	Average number of shopped offers regarding journey planning for Brainbox
J13K4KPI3	Number of services integrated with the pilot regarding asset manager for Brainbox
J13K2KPI3	Number of services integrated with the pilot regarding asset manager for MIRAKLIO
J1K1q4	question about safe trip from Covid-19 perspective regarding journey planning provided by OASA
J1K1q5	question about finding more secure routes in off-peak hours regarding journey planning provided by OASA
J8K1q1	question about general satisfaction regarding Location-based experience provided by OASA
J1K1q3	question about cost-saving regarding journey planning provided by OASA
J8K1q2	question about time-saving regarding Location-based experience provided by OASA
J8K1q3	question about cost-saving regarding location-based experience provided by OASA
J1K1q2	question about time-saving regarding journey planning provided by OASA
J1K1q1	question about general satisfaction regarding journey planning provided by OASA

The following table's red colour indicates that the variable is highly correlated (the value is less than or equal to 0.05, which means more than a 95% confidence level). On the other hand, the green colour means that the variable is not correlated or not highly correlated (low correlated), and this value is more than 0.05. As a result, the confidence level is less than 95%

The p-values in regression help determine whether the relationships observed in it were found out that the sample also exists in the larger population. The linear regression p-value for each independent variable tests the null hypothesis that the variable has no correlation with the dependent variable.

NaN or Not a Numbers are particular values in Data Frame arrays that represent the missing value in a cell. It is a special floating-point value and cannot be converted to any other type than float.

Results from the regression analysis of the correlation level between each pair of variables are shown in the following table:

Table 8. Analysis of the correlation level between each pair of variables

	J1K1q1	J1K1q2	J1K1q3	J8K1q1	J8K1q2	J8K1q3	J8K1KPI0	J8K2KPI0	J8K1KPI1	J8K2KPI1	J8K1KPI2	J8K2KPI2	J8K1KPI3	J8K2KPI3	J8K1KPI4	J8K2KPI4	J13K1KPI3	J13K2KPI3	J13K3KPI3	J13K4KPI3	J1K1KPI4	J1K1KPI7	J2K3KPI8
J1K1q1	0	0.1875	1.00E-13	0.7184	0.7184	1.00E-13	0.5722	0.5722	0.5722	0.5722	0.9874	0.9874	0.5719	0.5719	0.5719	0.5719	0.5719	0.9884	0.5719	0.9884	0.9884	0.6039	0.9884
J1K1q2	0.6823	0	0.5944	1	1	0.5016	0.5092	0.5092	0.5092	0.5092	1	1	0.5082	0.5082	0.5082	0.5082	0.5082	1	0.5082	1	1	0.5433	1
J1K1q3	1.00E-14	0.125	0	0.9316	0.9316	1.00E-13	0.538	0.538	0.538	0.538	0.9245	0.9245	0.5408	0.5408	0.5408	0.5408	0.5408	0.9307	0.5408	0.9307	0.9307	0.5652	0.9307
J8K1q1	1.00E-14	0.0769	NaN	0	1.00E-13	1.00E-13	0.552	0.552	0.552	0.552	0.865	0.865	0.5498	0.5498	0.5498	0.5498	0.5498	0.8607	0.5498	0.8607	0.8607	0.6105	0.8607
J8K1q2	NaN	NaN	1.00E-13	1.00E-13	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J8K1q3	1.00E-13	NaN	1.00E-13	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J8K1KPI0	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J8K2KPI0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J8K1KPI1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J8K2KPI1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J8K1KPI2	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	1.00E-13	NaN
J8K2KPI2	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J8K1KPI3	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J8K2KPI3	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J8K1KPI4	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J8K2KPI4	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN
J13K1KPI3	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN
J13K2KPI3	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN
J13K3KPI3	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN
J13K4KPI3	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN
J1K1KPI4	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0	NaN	NaN
J1K1KPI7	0.9985	0.95	0.7676	0.7098	0.7098	0.9683	1.00E-13	1.00E-13	1.00E-13	1.00E-13	1.00E-14	1.00E-14	1.00E-13	1.00E-13	1.00E-13	1.00E-13	1.00E-13	1.00E-14	1.00E-13	1.00E-14	1.00E-14	0	1.00E-14
J2K3KPI8	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0

It is important to note that the sample size was small, and some of those considerations may change if the sample size was to be increased, as the number of respondents was 17 in the Athens demos site phase 1.

9.3 Module 3: BN (Bayesian Network) and Bellman Shortest Path

The computational methods employed for the data analysis include Bayesian network analysis to obtain a weighted hierarchy based on USI questionnaires and operational KPIs.

This method is applied for three reasons:

- I. Assess correlations between factors level 2 (see the hierarchical model Figure 8 and 9), encouraging people to use more intermodal solutions in public transport, especially railways, by making it more attractive to users (T. Saaty 1990)
- II. Calculate a weighted hierarchy of these factors level 2 through the Bellman shortest pathway (see the following method) given the correlations defined in a). According to the hierarchical model, this weighted hierarchy of criteria level 2 will be compared with the weighted hierarchy obtained by applying only the AHP to validate results through these two methods: All AHP vs. AHP+BN. (Awad-Núñez, et al. 2016)
- III. To conduct predictions about how other variables change when it was found that an increase or decrease in the USI score or the KPI value in a specific variable.

The mathematical approach of BN analysis and Bellman shortest path is detailed in D6.1 (IP4MaaS project (2022). Deliverable D 6.1 Assessment methodology n.d.)

All the codes and scripts for module 3 of the toolbox assessment can be found in *Annex 6*.

Results concerning Travellers about correlations among factors and the weighted hierarchy of these factors through a BN analysis and Bellman shortest path considering the average of 5 tests with 1500 iterations each one are shown below after introducing the definition of each variable code:

Table 9. Results about the weighted hierarchy of these factors through a BN analysis and Bellman shortest path (test 1)

Variables	J8K2KP4	J1K2KP4	J1K1KP3	J8K1KP1	J2K1KP8	J8K2KP0	J8K2KP3	J8K2KP2	J1K2KP7	J8K2KP1	J1K3KP4	J1K4KP4	J1K3KP7	J2K2KP8	J8K1KP3	J3K4KP10	J8K1KP0	J3K1KP10	J1K1KP7	J3K2KP10	J2K3KP8	J8K1KP2	J2K4KP8	J8K1KP4	J3K3KP10	J1K3KP3	J1K1KP4	J1K4KP7	J1K4KP3	J1K3KP3	J1K1q4	J1K1q5	J8K1q1	J1K1q3	J8K1q2	J8K1q3	J1K1q2	J1K1q1
K2 Score	0.1	6.135565	0.1	0.1	0.1	0.1	0.1	0.1	3.73767	0.1	11.57364	4.382027	4.382027	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	8.542861	3.73767	0.1	0.1	0.1	14.67843	18.62202	33.03653	14.93314	30.43457	32.61696	30.17857
Path distance	0	6.135565	6.235565	6.335565	6.435565	6.535565	6.635565	6.735565	9.873235	9.973235	11.57364	15.95567	15.95567	16.05567	16.15567	16.25567	16.35567	16.45567	16.55567	16.65567	16.75567	16.85567	16.95567	17.05567	17.15567	17.25567	18.4161	19.69334	19.79334	19.89334	19.99334	24.55166	28.49525	39.17209	43.4284	69.60666	71.78905	101.9676
score	10	9.458455	9.449628	9.440802	9.431976	9.423149	9.414323	9.405497	9.128556	9.119729	8.978472	8.5917	8.5917	8.582873	8.574047	8.565221	8.556394	8.547568	8.538742	8.529915	8.521089	8.512263	8.503436	8.49461	8.485784	8.476957	8.374534	8.261801	8.252974	8.244148	8.235322	7.832989	7.484914	6.542541	6.166866	3.856286	3.663661	1
Cumulative Weights	0.032337	0.030586	0.030558	0.030529	0.030501	0.030472	0.030444	0.030415	0.029519	0.029491	0.029034	0.027783	0.027783	0.027755	0.027726	0.027698	0.027669	0.027641	0.027612	0.027584	0.027555	0.027526	0.027498	0.027469	0.027441	0.027412	0.027081	0.026717	0.026688	0.026659	0.026631	0.02553	0.024204	0.021157	0.019942	0.01247	0.011847	0.003248

Table 10. Results about the weighted hierarchy of these factors through a BN analysis and Bellman shortest path (test 2)

Variables	J1K4KP7	J3K1KP10	J8K1KP0	J8K1KP1	J3K2KP10	J1K4KP4	J2K3KP8	J8K2KP0	J1K2KP7	J1K3KP7	J2K2KP8	J8K2KP2	J1K3KP4	J1K3KP3	J2K4KP8	J3K4KP10	J1K1KP4	J8K1KP2	J1K3KP3	J1K4KP3	J8K1KP4	J1K2KP4	J8K2KP4	J1K1q4	J1K1KP7	J1K1q5	J8K1q1	J8K1q3	J1K1q3	J1K1q2	J1K3KP3	J8K1q2	J8K1KP3	J8K2KP3	J2K1KP8	J8K2KP1	J3K3KP10	J1K1q1
K2 Score	0.1	0.1	0.1	0.1	0.1	3.73767	0.1	0.1	6.135565	6.733402	0.1	0.1	7.544332	0.1	0.1	0.1	8.542861	0.1	0.1	0.1	0.1	3.73767	0.1	0.1	0.1	14.67843	26.4265	22.99275	27.02767	38.19174	0.1	14.93314	0.1	0.1	0.1	0.1	0.1	30.17857
Path distance	0	0.1	0.2	0.3	0.4	3.73767	3.83767	3.93767	6.535565	6.733402	6.833402	6.933402	7.544332	7.644332	7.744332	7.844332	8.542861	8.642861	8.742861	8.842861	8.942861	10.27323	10.37323	10.47323	10.57323	24.95166	32.96207	33.26599	37.30091	45.12515	45.22515	47.89521	47.99521	48.09521	48.19521	48.29521	48.39521	75.30372
score	10	9.980048	9.976097	9.964145	9.952194	9.553289	9.541337	9.529385	9.218895	9.195251	9.183299	9.171347	9.098332	9.08638	9.074428	9.062477	8.978991	8.96704	8.955088	8.943137	8.931185	8.772184	8.760232	8.748281	8.736329	7.017877	6.060505	6.024182	5.541944	4.606823	4.594871	4.275756	4.263804	4.251852	4.239901	4.227949	4.215998	1
Cumulative Weights	0.034281	0.03424	0.034199	0.034158	0.034117	0.032749	0.032708	0.032667	0.031603	0.031522	0.031481	0.03144	0.03119	0.031149	0.031108	0.031067	0.030781	0.03074	0.030699	0.030658	0.030617	0.030072	0.030031	0.02999	0.029949	0.024058	0.020776	0.020651	0.018998	0.015793	0.014658	0.014617	0.014576	0.014535	0.014494	0.014453	0.003428	

Table 11. Results about the weighted hierarchy of these factors through a BN analysis and Bellman shortest path (test 3)

Variables	J8K2KP2	J1K1q4	J1K2KP3	J1K4KP7	J8K2KP4	J3K2KP10	J2K2KP8	J3K3KP10	J1K4KP4	J3K4KP10	J8K1KP0	J8K1KP1	J8K2KP3	J8K1KP1	J3K1KP10	J8K2KP1	J1K3KP4	J1K1KP4	J8K1KP4	J1K1KP7	J1K3KP3	J2K4KP8	J1K3KP7	J1K2KP4	J8K1KP3	J8K2KP0	J1K3KP3	J1K2KP7	J2K1KP8	J8K1q2	J1K1q5	J1K4KP3	J2K3KP8	J8K1q1	J8K1q3	J1K1q1	J1K1q3	J1K1q2
K2 Score	0.1	0.1	0.1	6.135565	0.1	0.1	0.1	0.1	3.73767	0.1	0.1	0.1	0.1	0.1	0.1	0.1	7.544332	11.78805	0.1	0.1	0.1	0.1	5.023881	5.429346	0.1	0.1	0.1	3.73767	0.1	27.52512	14.67843	0.1	0.1	14.93314	22.99275	31.89622	31.87274	30.5463
Path distance	0	0.1	0.2	6.335565	6.435565	6.535565	6.635565	6.735565	10.07323	10.17323	10.27323	10.37323	10.47323	10.57323	10.67323	10.77323	17.61757	18.12362	18.22362	18.32362	18.42362	18.52362	23.1475	23.55296	23.65296	23.75296	23.85296	27.29063	27.39063	27.72512	38.23139	38.33139	38.43139	42.65826	46.54572	70.12761	78.41845	100.6739
score	10	9.99106	9.98212	9.433616	9.424676	9.415737	9.406797	9.397857	9.099478	9.090538	9.081598	9.072658	9.063719	9.054779	9.045839	9.036899	8.425033	8.379793	8.370853	8.361914	8.352974	8.344034	7.93067	7.894423	7.885483	7.876543	7.867604	7.560284	7.551345	7.521443	6.582208	6.573268	6.564328	6.186457	5.838927	3.730764	2.989583	1
Cumulative Weights	0.03318	0.03315	0.033121	0.031301	0.031271	0.031242	0.031212	0.031182	0.030192	0.030163	0.030133	0.030103	0.030074	0.030044	0.030014	0.029985	0.027954	0.027804	0.027775	0.027745	0.027715	0.027686	0.026314	0.026194	0.026164	0.026134	0.026105	0.025085	0.025055	0.024956	0.02184	0.02181	0.021781	0.020527	0.019374	0.012379	0.009919	0.003318

Table 12. Results about correlations among factors and the weighted hierarchy of these factors through a BN analysis and Bellman shortest path (test 4)

Variables	J8K1KP2	J8K2KP3	J13K2KP3	J1K1KP7	J1K2KP4	J8K2KP2	J13K3KP3	J1K2KP7	J2K3KP8	J2K4KP8	J1K4KP7	J8K1KP4	J1K4KP4	J1K1KP4	J8K1KP3	J8K1KP0	J8K1KP1	J1K3KP4	J1K1q5	J1K3KP7	J8K2KP0	J8K1q3	J8K1q2	J1K1q3	J1K1q1	J8K1q1	J1K1q2	J13K4KP3	J3K4KP10	J2K2KP8	J3K1KP10	J1K1q4	J3K3KP10	J8K2KP4	J13K1KP3	J8K2KP1	J3K2KP10	J2K1KP8	
K2 Score	0.1	0.1	0.1	0.1	6.135565	0.1	0.1	3.73767	0.1	0.1	6.135565	0.1	3.73767	8.542861	0.1	0.1	0.1	9.536762	14.67843	4.382027	0.1	22.99275	26.4265	28.50928	37.4986	14.93314	30.5463	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Path distance	0	0.1	0.2	0.3	6.435565	6.535565	6.635565	10.17323	10.27323	10.37323	12.77113	12.87113	16.5088	18.7161	18.8161	18.9161	19.0161	22.30789	24.85166	26.68992	26.78992	33.16599	36.59974	38.68251	47.87183	51.53288	78.41813	78.51813	78.61813	78.71813	78.81813	78.91813	79.01813	79.11813	79.21813	79.31813	79.41813	79.51813	
score	10	9.988682	9.977364	9.966045	9.271612	9.260293	9.248975	8.848576	8.837257	8.825939	8.554541	8.543223	8.131505	7.88168	7.870362	7.859043	7.847725	7.475154	7.187246	6.979189	6.96787	6.246216	5.857578	5.621846	4.581783	4.167419	1.1245	1.113182	1.101864	1.090545	1.079227	1.067909	1.056591	1.045273	1.033955	1.022636	1.011318	1	
Cumulative Weights	0.045716	0.045664	0.045612	0.04556	0.042386	0.042334	0.042282	0.040452	0.0404	0.040348	0.039108	0.039056	0.037174	0.036032	0.03598	0.035928	0.035876	0.034173	0.032857	0.031906	0.031854	0.028555	0.026778	0.025701	0.020946	0.019052	0.005141	0.005089	0.005037	0.004985	0.004934	0.004882	0.00483	0.004779	0.004727	0.004675	0.004623	0.004572	

Table 13. Results about the weighted hierarchy of these factors through a BN analysis and Bellman shortest path (test 5)

Variables	J1K4KP7	J1K4KP4	J1K2KP7	J1K3KP7	J8K2KP4	J13K4KP3	J1K1KP7	J2K1KP8	J8K1KP1	J3K2KP10	J2K3KP8	J1K3KP4	J8K1KP3	J3K3KP10	J2K4KP8	J8K1KP4	J8K2KP3	J3K4KP10	J13K1KP3	J1K1KP4	J13K2KP3	J1K2KP4	J3K1KP10	J8K2KP1	J1K1q4	J8K2KP0	J8K1KP0	J8K2KP2	J13K3KP3	J2K2KP8	J1K1q5	J8K1KP2	J8K1q1	J8K1q3	J8K1q2	J1K1q3	J1K1q1	J1K1q2
K2 Score	0.1	3.73767	6.733402	6.733402	0.1	0.1	0.1	0.1	0.1	0.1	0.1	7.544332	0.1	0.1	0.1	0.1	0.1	0.1	8.542861	0.1	3.73767	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	14.67843	0.1	28.13125	22.99275	14.93314	33.03653	32.27352	30.5463
Path distance	0	3.73767	6.733402	6.733402	6.833402	6.833402	6.933402	6.933402	7.033402	7.133402	7.233402	7.544332	7.644332	7.744332	7.844332	7.944332	8.044332	8.144332	8.244332	8.542861	8.642861	10.47107	10.57107	10.67107	10.77107	10.87107	10.97107	11.07107	11.17107	11.27107	25.1495	25.2495	28.13125	33.46382	43.06439	43.5076	75.78112	106.3274
score	10	9.683628	9.430057	9.430057	9.421592	9.421592	9.413128	9.413128	9.404663	9.396199	9.387734	9.361416	9.352952	9.344487	9.336023	9.327558	9.319094	9.310629	9.302165	9.276896	9.268432	9.113684	9.10522	9.096756	9.088291	9.079827	9.071362	9.062898	9.054433	9.045969	7.871241	7.862776	7.618852	7.167481	6.354848	6.317334	3.585567	1
Cumulative Weights	0.030572	0.029605	0.028829	0.028829	0.028804	0.028804	0.028778	0.028778	0.028752	0.028726	0.0287	0.02862	0.028594	0.028568	0.028542	0.028516	0.02849	0.028464	0.028438	0.028361	0.028335	0.027862	0.027836	0.02781	0.027785	0.027759	0.027733	0.027707	0.027681	0.027655	0.024064	0.024038	0.023292	0.021912	0.019428	0.019313	0.010962	0.003057

9.3.1 Results about the correlation between factors

The relevant graph of the abovementioned tests (Results about the weighted hierarchy of these factors through a BN analysis and Bellman shortest path) showing correlations among factors is demonstrated as follows:

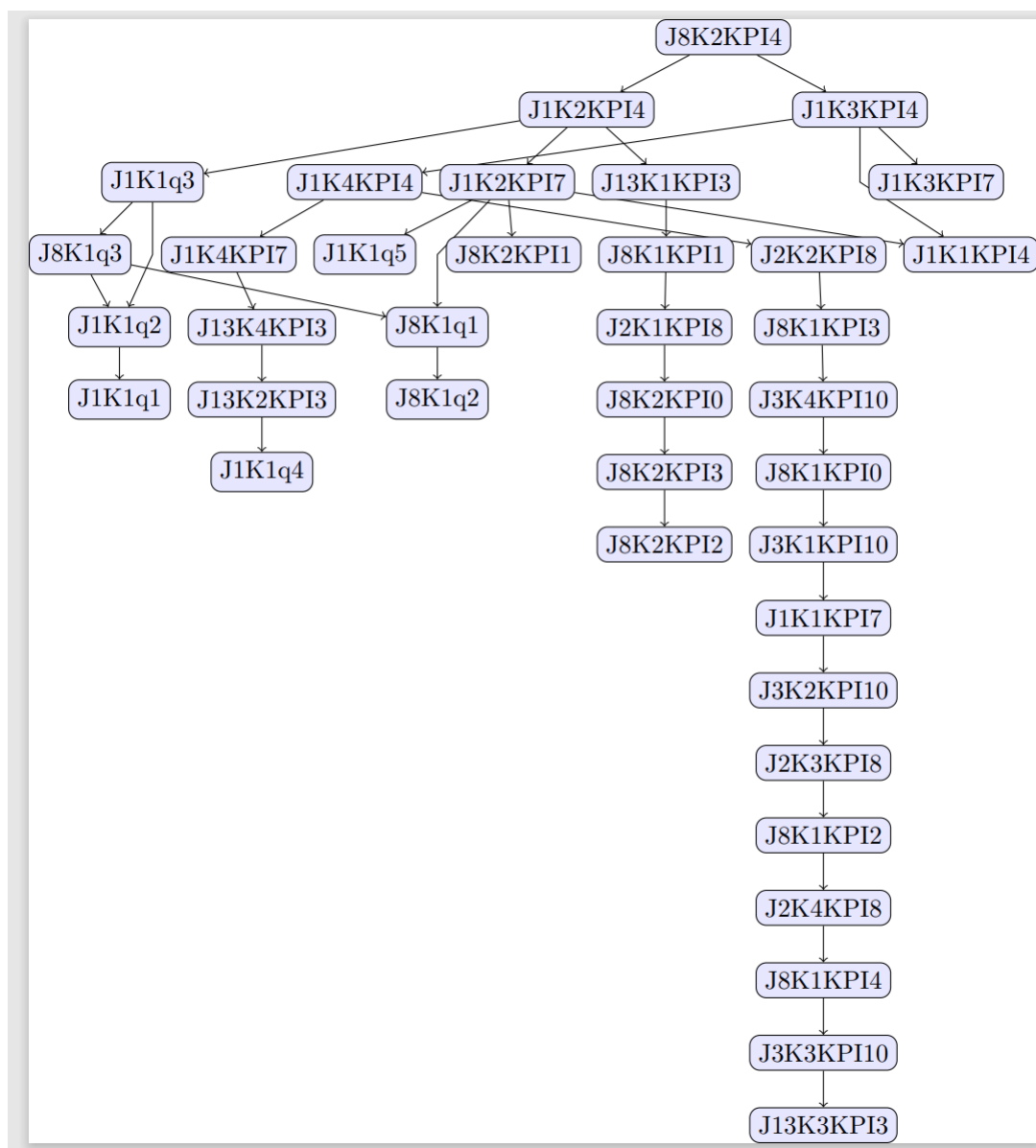


Figure 12. Graph of correlations among factors and the weighted hierarchy (test 1)

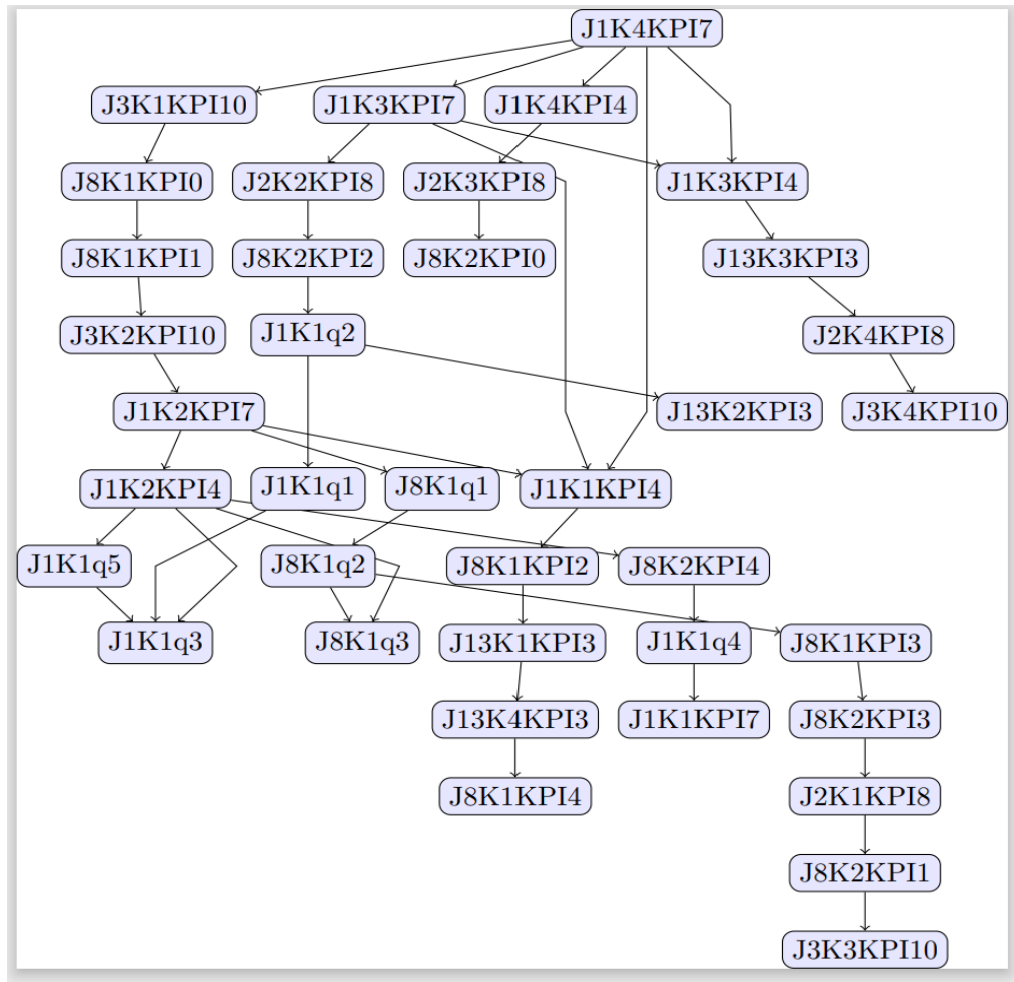


Figure 13. Graph of correlations among factors and the weighted hierarchy (test 2)

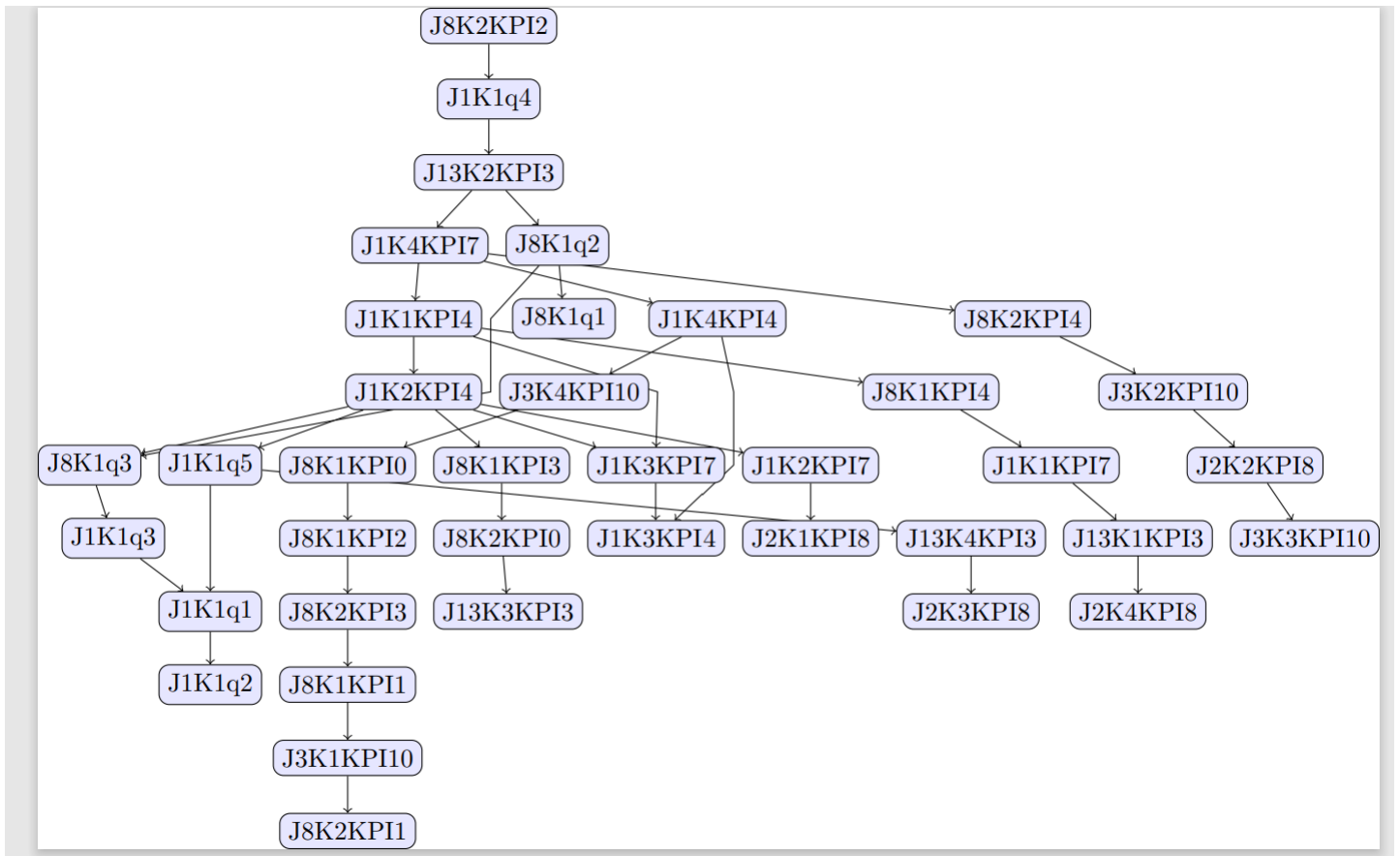


Figure 14. Graph of correlations among factors and the weighted hierarchy (test 3)

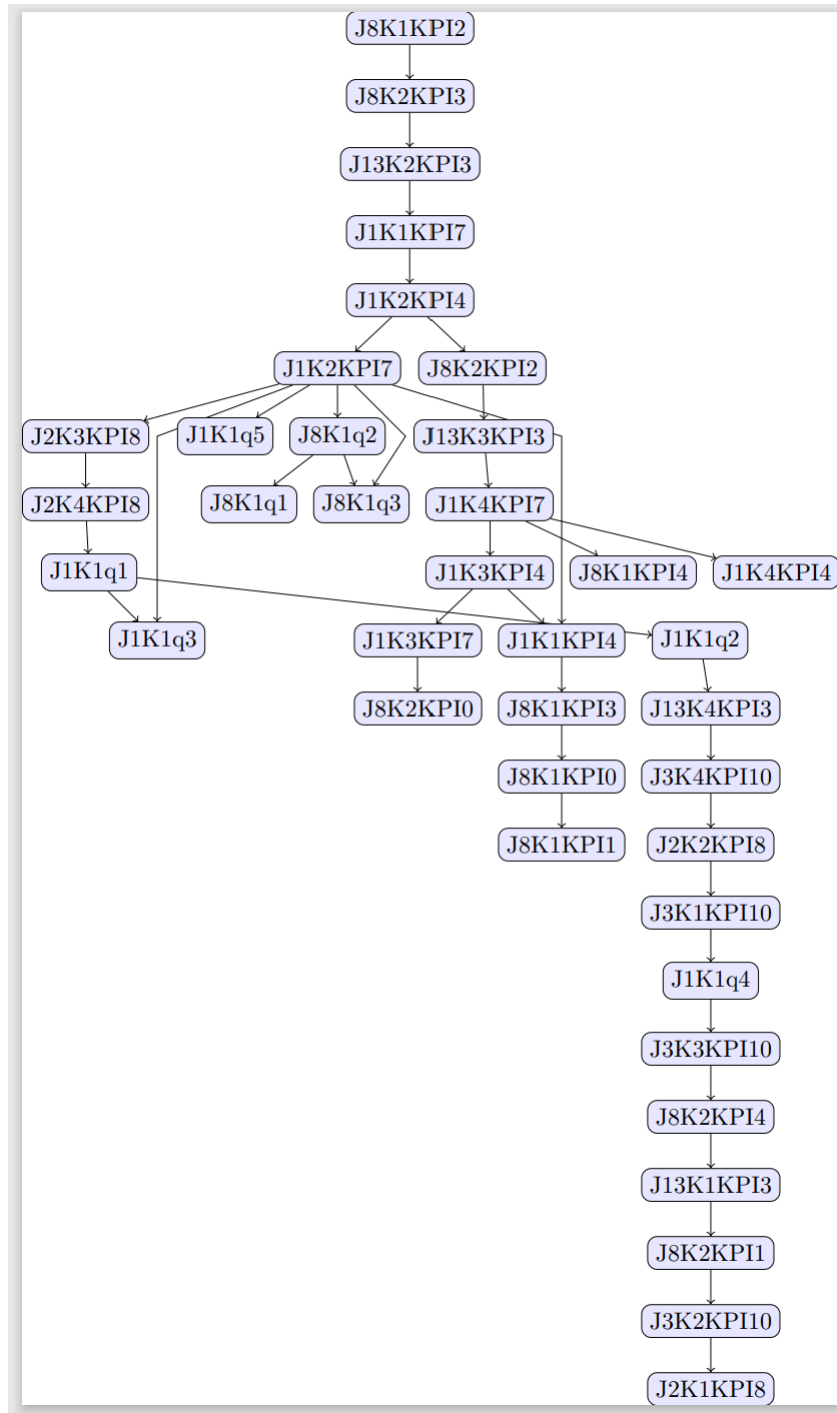


Figure 15. Graph of correlations among factors and the weighted hierarchy (test 4)

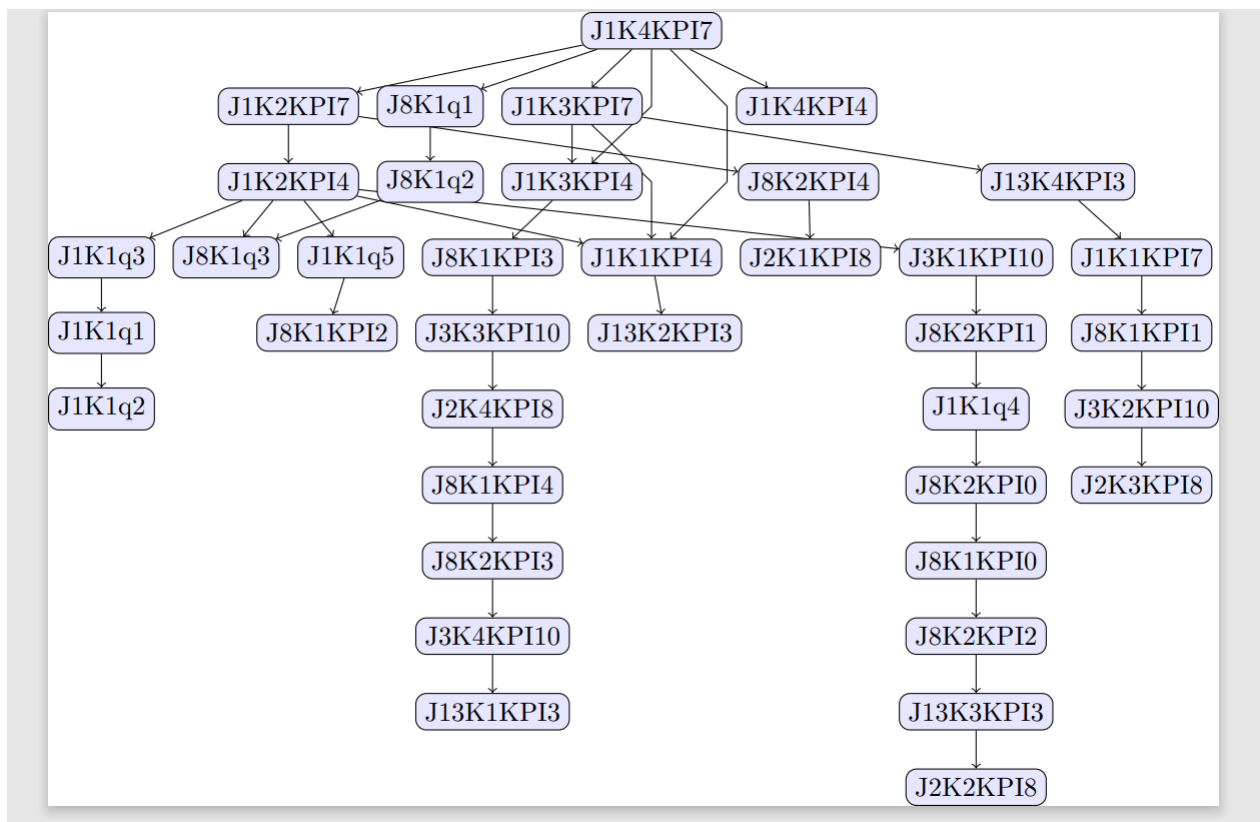


Figure 16. Graph of correlations among factors and the weighted hierarchy (test 5)

9.3.2 Results about the weighted hierarchy of factors

The results of the weighted hierarchy of these factors through a BN analysis and Bellman shortest path considering the average of 5 tests with 1500 iterations each one are shown below:

Table 14. Results of weighted hierarchy

Variables	Average of Cumulative weights
J8K2KPI2	0.033015
J1K4KPI7	0.032396
J1K1KPI7	0.031929
J8K1KPI1	0.031872
J8K1KPI2	0.031625
J1K4KPI4	0.031501
J1K2KPI4	0.031420
J8K1KPI0	0.031132
J1K2KPI7	0.031098
J2K4KPI8	0.031036
J13K3KPI3	0.030926
J8K1KPI4	0.030687
J2K3KPI8	0.030229
J1K3KPI4	0.030194
J1K1KPI4	0.030012
J13K2KPI3	0.029896
J8K2KPI3	0.029849
J8K2KPI0	0.029777
J1K3KPI7	0.029271
J8K1KPI3	0.026616
J1K1q5	0.025630
J8K2KPI4	0.025444
J3K2KPI10	0.025258
J3K1KPI10	0.024933
J2K2KPI8	0.024618
J1K1q4	0.024488
J3K4KPI10	0.024486
J13K1KPI3	0.024427
J13K4KPI3	0.022610
J8K1q1	0.021570
J3K3KPI10	0.021295
J8K2KPI1	0.021291
J8K1q2	0.021152
J2K1KPI8	0.020688
J8K1q3	0.020592
J1K1q3	0.019018
J1K1q1	0.010190
J1K1q2	0.007831

9.3.3 Results about predictions

The main reason for identifying and analyzing correlations between factors is to make the ability to assess predictions (probability of variables). As a result, correlations are studied to make predictions. These predictions aim to understand what will happen to other variables if it was found to increase the value of one variable.

Suppose that it was found out that have a statistical model of some data. Let k be the number of estimated parameters in the model, and let Lik_{max} be the maximum value of the likelihood function for the model. Then the AIC value of the model is expressed by the following Equation:

$$AIC = 2k - 2 \ln (Lik_{max}) \quad (Eq.2)$$

Given a set of candidate models for the data, the preferred model is the one with the minimum AIC value. AIC rewards goodness of fit (as assessed by the likelihood function) and, at the same time, provides a penalty that is an increasing function of the number of estimated parameters. The penalty discourages overfitting, which is desired because increasing the number of parameters in the model almost always improves the goodness of the fit. As a result, the lowest AIC scores have been chosen for this study (Molero, Poveda-Reyes, et al. 2021).

Choosing the Bayes Network from 9.3.1 with the lowest AIC parameter, some predictions can be made to assess the impact of improvements on some variables by the TSPs.

(Table 15) shows, as an example, the probability of finding any particular value for variable J1K1q1 in the current data (the data obtained from the survey) and the probability of finding any particular value for variable J1K1q1 assuming that **J1K1q3=5** (maximum possible satisfaction score by the traveller to this variable): For example, the probability of finding value 4 for J1K1q1 considering the condition applied to this prediction is equal to 0, while the probability of finding value 4 for J1K1q1 in the current data (without applying the prediction conditions) is equal to 0.38.

As J1K1q1 can take a satisfaction score from 1 to 5 too (for those questions not assessed by travellers, the arbitrary value 8 was assigned, so the probability shown in table 15 for J1K1q1=8 means the probability to skip this question by the traveller. On the other hand, satisfaction scores

6 and 7 are never possible, which is why the probability for J1K1q1=6 or 7 is zero). It has been obtained that define (Eq.3):

$$\begin{aligned}
 & \text{Gradient Low (GL)} \\
 &= \sum_{i=1}^4 \text{Probability (J1K1q1} \\
 &= i) \text{ (Before applying conditions defined in the prediction)} \\
 &- \sum_{i=1}^4 \text{Probability (J1K1q1} \\
 &= i) \text{ (After applying conditions defined in the prediction)}
 \end{aligned}$$

This GL represents the gradient in the probability that J1K1q1 takes a low satisfaction score from 1 to 4 before applying the prediction conditions and after applying them, and (Eq.4):

$$\begin{aligned}
 & \text{Gradient Max (GM)} \\
 &= \sum_{i=5}^8 \text{Probability (j1k1q1} \\
 &= i) \text{ (Before applying conditions defined in the prediction)} \\
 &- \sum_{i=5}^8 \text{Probability (j1k1q1} \\
 &= i) \text{ (After applying conditions defined in the prediction)}
 \end{aligned}$$

GM would represent the gradient in the probability that J1K1q1 takes the maximum satisfaction score (value=5) or it has not been assessed by the traveller (value=8) before applying the prediction conditions and after applying them. In this assumption, the study considers that “not assessing” is a “good assessment” (under the approach “no new, good news”).

So, if GL is negative and GM is positive, then the conditions defined in the prediction (the fact that J1K1q3=5) will be good for travelers' satisfaction. Conversely, the simulated change will not be good for travellers if GL is positive and GM is negative.

A good KPI about how impactful the change of J1K1q3 is regarding J1K1q1 is:

$$KPI \text{ simulation} = \text{Absolute value (GL)} + \text{Absolute value (GM)} \text{ (Eq.5)}$$

Coming back to Table 15, **GL=-0.71428** and **GM=+0.71428**, so the fact to change **J1K1q3** (Cost-saving by Location-Based experience provided by OASA) to **5** (maximum possible value for this

variable) are positive for the satisfaction of the traveller regarding J8K1q1 (General satisfaction of Location-based experience provided by OASA). The KPI about the impact would be 1.42857.

This value is useful to compare the impact on J1K1q1 when it has been obtained that change several variables (others than J8K1q1).

The results of the abovementioned predictions are demonstrated in the following tables:

Table 15. The results of prediction J1K1q1 with the evidence of J1K1q3

8x2 DataFrame					
Row	Values	Probability			
	Int64	Float64			
1	1	0.047619			
2	2	0.142857			
3	3	0.142857			
4	4	0.380952			
5	5	0.047619			
6	6	0.0			
7	7	0.0			
8	8	0.238095			
			8x4 DataFrame		
Row	Values	Probability	potential	Difference	
	Int64	Float64	Float64	Float64	
1	1	0.047619	0.0	-0.047619	
2	2	0.142857	0.0	-0.142857	
3	3	0.142857	0.0	-0.142857	
4	4	0.380952	0.0	-0.380952	
5	5	0.047619	1.0	0.952381	
6	6	0.0	0.0	0.0	
7	7	0.0	0.0	0.0	
8	8	0.238095	0.0	-0.238095	

1 rows × 7 columns

	Lb	La	Gradient_L	Mb	Ma	Gradient_M	KPI
	Float64	Float64	Float64	Float64	Float64	Float64	Float64
1	0.714286	0.0	-0.714286	0.285714	1.0	0.714286	1.42857

Regarding sample size for the Bayesian Network analysis:

Population size will be selected to obtain enough data to develop the analysis using machine learning techniques. Previous studies indicate that a population size of ten or fewer (e.g., stations, picking up points, hubs) is enough to obtain relationships and influence factors in Bayesian networks (Núñez, 2016) (Molero et al., 2018). The population size should be the one that i) makes the network converge and ii) the weight of the influence values obtained for each variable of the obtained network reaches the Wardrop equilibria (Haurie, 1985). If the convergence of the network is not obtained or it is not reached the Wardrop equilibria, additional data per each use case will be collected to obtain the stability of both, the network defining how criteria are connected and the influence values or weights among these criteria.

9.4 Module 4: ANOVA test (Analysis of Variance) for Travellers

To determine if some socio-demographic profiles are relevant for specific criteria, an ANOVA analysis was performed as a statistical way to compare different groups.

The ANOVA test for this case study will be done through the collected data from the USI questionnaire for Travellers, and TSPs USI surveys will not be considered as they do not depend on socio-demographic profiles. Moreover, the ANOVA test will identify the significant differences in the satisfaction level per each socio-demographic characteristic, and it will be developed in Excel.

The USI survey was administered online to Travellers who use different modes of transport from TSPs in the Athens demo site via an email containing a link to the survey via Google Forms. A socio-demographic survey was part of this USI questionnaire for Travellers.

The mathematical approach of the ANOVA analysis is detailed in D6.1. (IP4MaaS project (2022). Deliverable D 6.1 Assessment methodology n.d.)

All the codes and scripts for the toolbox assessment can be found in *Annex 7*. In ANOVA test scripts for the Toolbox, the scripts of socio-demographic variables will remain the same. Only the name of each variable of “Age, gender, income, profession status, residential area, travelling with the dependent person, disability or impairment and familiarity with technology” will be changed considering the range of each variable.

The results of the ANOVA test, which has been developed in Excel, are as follows:

If the p-value is less than or equal to 0.05, it means it is significant (green colour); otherwise, if the value is higher than 0.05, it is not significant (red colour).

Table 16. Results of ANOVA test regarding journey planning function question number 1

J1K1q1				
	<i>F</i>	<i>P-value</i>	<i>F crit</i>	<i>Significant</i>
Age	1.955876	0.165718	3.259167	No
Gender	0.38177	0.767847	3.410534	No
Residential area	2.305255	0.136329	3.738892	No
Income	1.211078	0.344758	3.410534	No
Travel with dependent	1.474692	0.262312	3.738892	No
Professional Status	0.214322	0.949177	3.203874	No
Disability	0.460625	0.507669	4.543077	No
Familiarity with tech	1.222075	0.28637	4.543077	No

Table 17. Results of the ANOVA test regarding journey planning function question number 2

J1K1q2				
	<i>F</i>	<i>P-value</i>	<i>F crit</i>	<i>Significant</i>
Age	2.067306	0.14846	3.259167	No
Gender	0.333359	0.801455	3.410534	No
Residential area	1.424246	0.273507	3.738892	No
Income	1.180013	0.355351	3.410534	No
Travel with dependent	1.223324	0.323858	3.738892	No
Professional Status	0.142711	0.978246	3.203874	No
Disability	0.542986	0.472567	4.543077	No
Familiarity with tech	0.589108	0.454677	4.543077	No

Table 18. Results of the ANOVA test regarding journey planning function question number 3

J1K1q3				
	<i>F</i>	<i>P-value</i>	<i>F crit</i>	<i>Significant</i>
Age	2.493964	0.098715	3.259167	No
Gender	0.553544	0.654758	3.410534	No
Residential area	1.582043	0.240188	3.738892	No
Income	1.411935	0.2839	3.410534	No
Travel with dependent	2.809689	0.094211	3.738892	No
Professional Status	0.116542	0.986036	3.203874	No
Disability	0.005335	0.942805	4.60011	No
Familiarity with tech	1.036551	0.324766	4.543077	No

Table 19. Results of ANOVA test regarding Location-based experience function question number

1

J8K1q1				
	<i>F</i>	<i>P-value</i>	<i>F crit</i>	<i>Significant</i>
Age	0.797189	0.549536	3.259167	No
Gender	0.069222	0.975349	3.410534	No
Residential area	0.693393	0.516251	3.738892	No
Income	0.662999	0.589405	3.410534	No
Travel with dependent	1.118237	0.354368	3.738892	No
Professional Status	1.034265	0.444432	3.203874	No
Disability	1.361736	0.262729	4.60011	No
Familiarity with tech	1.95113	0.18279	4.543077	No

Table 20. Results of ANOVA test regarding Location-based experience function question number 2

J8K1q2				
	<i>F</i>	<i>P-value</i>	<i>F crit</i>	<i>Significant</i>
Age	0.075518	0.988337	3.259167	No
Gender	1.330354	0.307102	3.410534	No
Residential area	0.693393	0.516251	3.738892	No
Income	0.12887	0.941245	3.410534	No
Travel with dependent	1.118237	0.354368	3.738892	No
Professional Status	0.057883	0.997194	3.203874	No
Disability	6.681818	0.021602	4.60011	Yes
Familiarity with tech	1.95113	0.18279	4.543077	No

Table 21. Results of ANOVA test regarding Location-based experience function question number 3

J8K1q3				
	<i>F</i>	<i>P-value</i>	<i>F crit</i>	<i>Significant</i>
Age	0.489531	0.743613	3.259167	No
Gender	0.248792	0.860753	3.410534	No
Residential area	4.936956	0.023847	3.738892	Yes
Income	0.3798	0.769205	3.410534	No
Travel with dependent	2.326885	0.134131	3.738892	No
Professional Status	0.733768	0.613227	3.203874	No
Disability	1.227181	0.285404	4.543077	No
Familiarity with tech	0.054363	0.81879	4.543077	No

Where “F” and “ $F_{\text{critical}} (F_0)$ ” are:

The F-value in an ANOVA is calculated as the variation between sample means/variation within the samples. The higher the F-value in an ANOVA, the higher the variation between sample means relative to the variation within the samples. The higher the F-value, the lower the corresponding p-value.

Critical F is the value of the F-statistic at the threshold probability α of mistakenly rejecting a true null hypothesis.

And the p-value is the probability of obtaining an F-ratio as large or more significant than the one observed, assuming that the null hypothesis of no difference amongst group means is true.

A more detailed explanation of the mathematical approach can be found in D6.1 (IP4MaaS project (2022). Deliverable D 6.1 Assessment methodology n.d.).

Not all these results are 95% confident regarding the statistical significance of differences among ranges for all socio-demographic variables. This is due to the sample size. According to the sample size calculator: <http://psychstat.org/anova>, the required sample size per each socio-demographic variable was calculated. The following table shows the required sample size and the sample that was found out that obtained during the Athens demo phase 1:

Table 22. Calculation of sample size using sample size calculator tool

	Ranges	N needed (formula)	N achieved	95% confidence achieved
Gender	4	13	17	YES
Age	5	15	17	YES
Living environment	4	13	17	YES
Income	4	13	17	YES
Travel with dependents person	6	17	17	Yes
Professional status	7	19	17	NO
Disability	7	19	17	NO
Familiarity with technology	4	13	17	YES

One-way ANOVA

Parameters (Help)	
Number of groups	<input type="text" value="7"/>
Sample size	<input type="text"/>
Effect size (Calculator)	<input type="text" value="0.5"/>
Significance level	<input type="text" value="0.05"/>
Power	<input type="text" value="0.2"/>
Type of analysis	<input type="text" value="Overall"/> ▼
Power curve	<input type="text" value="No power curve"/> ▼
Note	<input type="text" value="One-way ANOVA"/>

[Calculate](#)

Output

Power for One-way ANOVA

k	n	f	alpha	power
7	18.56	0.5	0.05	0.2

NOTE: n is the total sample size (overall)

URL: <http://psychstat.org/anova>

Figure 17. An example to illustrate how a sample size calculator works in the ANOVA test

9.5 Module 5: Calculation of USI (User Satisfaction Index) for TSPs and Travellers and Effectiveness

The satisfaction index for travellers belonging to a profile vector "r" with the functionality "j" offered by the TSP "k" is calculated as:

$$USI_{Traveller_{rjk}} = \frac{\sum_{w=1}^{m_{rjk}} \sum_{v=1}^{n_{1jk}+n_{2jk}^r} Score_{question_{wv}}}{m_{rjk} \cdot (n_{1jk} + n_{2jk}^r) \cdot 5} \quad (Eq. 6)$$

Being:

$Score_{question_{wv}}$ = the score to the question "v" by the respondent "w".

n_{1jk} = number of questions applicable to all the profiles measuring the satisfaction with the functionality "j" offered by the TSP "k".

n_{2jk}^r = number of questions applicable only to the profile "r" measuring the satisfaction with the functionality "j" offered by the TSP "k".

m_{rjk} = number of respondents to the USI questionnaire belonging to the profile "r" measuring the satisfaction with the functionality "j" offered by the TSP "k".

The satisfaction index for a TSP "k" regarding a functionality "j" is calculated as:

$$USI_{TSP_{jk}} = \frac{\sum_{v=1}^{n_j} Score_{question_v}}{n_j \cdot 5} \quad (Eq. 7)$$

Being, $Score_{question_v}$ the score to the question number "v" and " n_j " The number of questions in the USI questionnaire belonging to a specific functionality "j" offered by the TSP "k".

In both equations, a 5 appears to divide to normalize and obtain a value between 0.2 and 1 because the answer to each question has a value between 1 (representing the minimum satisfaction) to 5 (representing the maximum satisfaction).

All this quantitative data (operational KPIs and USIs) is managed together within the concept of "Effectiveness".

The Effectiveness of a functionality "j" offered by a TSP "k" for a specific profile "r" in a demonstration scenario "D" is calculated through the following Equation. To avoid producing several equations for effectiveness per each group identified in section 9.5.3, a unique formula (Eq.8) has been prepared and it can be implemented for all the groups in this study:

$$Effectiveness_{rjk} = \frac{\sum_{n=1}^N KPI_{njk} + USI_{Traveler_{rjk}} + USI_{TSP_{jk}}}{N + \delta_{Traveller} + \delta_{TSP}} \quad (Eq. 8)$$

Being:

$$\left\{ \begin{array}{l} \delta_{Traveller} = 0 \text{ if } USI_{Traveler_{rjk}} = 0 \\ \delta_{Traveller} = 1 \text{ if } USI_{Traveler_{rjk}} \neq 0 \end{array} \right.$$

$$\left\{ \begin{array}{l} \delta_{TSP} = 0 \text{ if } USI_{TSP_{jk}} = 0 \\ \delta_{TSP} = 1 \text{ if } USI_{TSP_{jk}} \neq 0 \end{array} \right.$$

"N" is the Number of operational dimensionless KPIs linked to the functionality "j" offered by the TSP "k" (N can be zero for some functionalities),

$KPI_{n_{jk}}$ the value of the KPI "n" belonging to the functionality "j" offered by the TSP "k",

$USI_{Traveler_{rjk}}$ the value calculated in Eq. 6, and

$USI_{TSP_{jk}}$ The value is calculated in Eq. 7.

Given that the Effectiveness is dimensionless with a value between 0 and 1, the higher, the better, and different demonstration scenarios "D" can be compared to analyze how the needs of travellers in other locations or demo sites are matched by the same innovative technology "j" offered by different TSPs.

The three elements in the numerator are summed in a linear way and with an equal weight because an innovative technology with no good operational KPIs, no good acceptance level by travellers, or no good acceptance level by the TSP would not be implemented in practice or would not remain in use for a long time, as it would therefore not be answering users' needs.

All these formulations have been prepared in Julia's programming language. The scripts and codes of this module can be found in *Annex 8*.

9.5.1 Results of USI travellers

The following table will introduce the definition of each code appearing in the results of USI Travellers: For the case of USI_Travellers_r4_J1_k1, since no data has been received the value of this variable is indeterminate (undefined), as expected, given that the numerator and denominator are both equal to zero.

Table 23. Definition of each code for the results of USI travellers

Code	Definition
USI_Traveller_r1_J1_K1	Calculation of USI traveller regarding journey planning considering OASA as TSP for all profile vectors
USI_Traveller_r4_J1_K1	Calculation of USI traveller regarding journey planning considering OASA as TSP for elderly people
USI_Traveller_r5_J1_K1	Calculation of USI traveller regarding journey planning considering OASA as TSP for Women
USI_Traveller_r1_J8_K1	Calculation of USI traveller regarding Location-Based Experience considering OASA as TSP for all profile vectors

Table 24. Results of USI travellers

USI_traveler_r1_j1_k1	0.633333
USI_traveler_r4_j1_k1	Undefined due to lack of data
USI_traveler_r5_j1_k1	0.65
USI_traveler_r1_j8_k1	0.753333

9.5.2 Results of USI TSPs

The table below will illustrate the definition of each code appearing in the results of USI TSPs:

Table 25. Definition of each code for the results of USI TSPs

Code	Definition
USI_TSP_8_1_8	Calculation of USI TSP regarding Location-Based Experience for OASA
USI_TSP_8_1_13	Calculation of USI TSP regarding asset manager for OASA
USI_TSP_8_2_8	Calculation of USI TSP regarding Location-Based Experience for MIRAKLIO
USI_TSP_8_2_13	Calculation of USI TSP regarding asset manager for MIRAKLIO
USI_TSP_8_3_8	Calculation of USI TSP regarding Location-Based Experience for Taxiway
USI_TSP_8_3_13	Calculation of USI TSP regarding asset manager for Taxiway

Table 26. Results of USI TSPs

USI_TSP_8_1_8	0.72
USI_TSP_8_1_13	0
USI_TSP_8_2_8	0.76
USI_TSP_8_2_13	0
USI_TSP_8_3_8	0
USI_TSP_8_3_13	0.9

9.5.3 The results of Effectiveness

In the following table, the results of implementing the effectiveness formula considering the USI TSPs, USI Travellers, and KPIs value are illustrated:

In this table, NaN and zero mean regarding the effectiveness formula of the numerator for the value of TSP or traveller are 0, and from the mathematical point of view, it is not acceptable. Regarding the effectiveness formula, there are three components in the numerator. These values are the value of specific operational KPI, the value of USI traveller, and the value of USI TSP. There is a possibility that the value of USI TSP and Travellers will become zero. Moreover, for some variables, only the value of KPI is defined, and the value of USI TSP and USI travellers is zero. As a result of including these three components, the effectiveness value will become zero, or it may go to infinity.

In other words, the effectiveness formula has three components: USI Travellers, USI TSP, and operational KPI value. Each component value is derived from the abovementioned formula (see Eq.6 and Eq.7). As per the formula above, if the value in the numerator (Value of TSP or Traveller) becomes zero, the value of the component become infinity. As a result, In this way, even if one of the components is to become infinite in value, the entire Equation will tend to infinity as any addition made to infinity becomes infinity. Hence, it may be considered as not a number NaN.

Since three elements are involved in the effectiveness formula, if the value of USI Travellers and USI TSP goes to zero, only the value of KPI will be considered in the numerator. As a result, the value of Effectiveness will decrease significantly. Since the value of operational KPIs for some variables equals zero, the value shown in Table 29 will also become zero. Moreover, for that effectiveness that the value is equal to zero, the value of operational KPIs, USI travellers, and USI TSPs in the numerator is equal to zero.

The effectiveness comparison can only be done after grouping based on what parameters are considered in the Effectiveness formula: KPIs, USI Travellers, USI TSPs, or combinations among them. For example, in the demo of Athens's first phase, the Effectiveness can be grouped in the following way:

Group 1: KPIs

- Calculating Effectiveness for functionalities (J) considering only the value of operational KPIs. In this case, the value of “Effectiveness” can be between 0 and 1.

Group 2: KPIs + Travellers

- Calculating Effectiveness for functionalities (J) considering the value of operational KPIs and USI travellers. In this case, the value of “Effectiveness” can get a value between 0 and 1.

Group 3: KPIs + travellers + TSPs

- Calculating Effectiveness for functionalities (J) considering all values of operational KPIs, USI travellers, and USI TSPs. In this case, the value of “Effectiveness” can get a value between 0 and 1.

In addition to the abovementioned groups, four more groups for the calculation of effectiveness can be considered. These groups can be implemented into the demonstration sites in the second phase of the IP4MaaS project.

Group 4: KPIs + TSPs

- Calculating Effectiveness for functionalities (J) considering the value of operational KPIs and USI TSPs. In this case, the value of “Effectiveness” can get a value between 0 and 1.

Group 5: Travellers

- Calculating Effectiveness for functionalities (J) considering only the value of USI travellers. In this case, the value of “Effectiveness” can get a value between 0.2 and 1.

Group 6: Travellers + TSPs

- Calculating Effectiveness for functionalities (J) considering the value of USI travellers and USI TSPs. In this case, the value of “Effectiveness” can get a value between 0.2 and 1.

Group 7: TSPs

- Calculating Effectiveness for functionalities (J) considering only the USI TSPs. In this case, the value of “Effectiveness” can get a value between 0.2 and 1.

Table 27. Calculating Effectiveness for functionalities (J) considering the value of operational KPIs and USI TSPs.

Name of Variable	Definition of variable	Value	Group (s)
Effectiveness_r1_J1_K2	Effectiveness value for all profiles vectors considering Journey planning functionality provided by MIRAKLIO	0.024509804	KPIs
Effectiveness_r4_J1_K2	Effectiveness value for profiles vectors "Women" considering Journey planning functionality provided by MIRAKLIO	0.024509804	KPIs
Effectiveness_r1_J1_K3	Effectiveness value for all profiles vectors considering Journey planning functionality provided by Taxiway	0.053921569	KPIs
Effectiveness_r4_J1_K3	Effectiveness value for profiles vectors "Women" considering Journey planning functionality provided by Taxiway	0.053921569	KPIs
Effectiveness_r1_J1_K4	Effectiveness value for all profiles vectors considering Journey planning functionality provided by BrainBox	0.029411765	KPIs
Effectiveness_r4_J1_K4	Effectiveness value for profiles vectors "Women" considering Journey planning functionality provided by BrainBox	0.029411765	KPIs
Effectiveness_r1_J2_K3	Effectiveness value for all profiles vectors considering booking functionality provided by Taxiway	0.333333333	KPIs
Effectiveness_r4_J2_K3	Effectiveness value for profiles vectors "Women" considering booking functionality provided by Taxiway	0.333333333	KPIs
Effectiveness_r1_J13_K1	Effectiveness value for all profiles vectors considering asset manager functionality provided by OASA	0.333333333	KPIs
Effectiveness_r4_J13_K1	Effectiveness value for profiles vectors "Women" considering asset manager functionality provided by OASA	0.333333333	KPIs
Effectiveness_r1_J13_K2	Effectiveness value for all profiles vectors considering asset manager functionality provided by MIRAKLIO	0.111111111	KPIs
Effectiveness_r4_J13_K2	Effectiveness value for profiles vectors "Women" considering asset manager functionality provided by MIRAKLIO	0.111111111	KPIs
Effectiveness_r1_J13_K3	Effectiveness value for all profiles vectors considering asset manager functionality provided by Taxiway	0.333333333	KPIs
Effectiveness_r4_J13_K3	Effectiveness value for profiles vectors "Women" considering asset manager functionality provided by Taxiway	0.333333333	KPIs
Effectiveness_r1_J13_K4	Effectiveness value for all profiles vectors considering asset manager functionality provided by BrainBox	0.222222222	KPIs
Effectiveness_r4_J13_K4	Effectiveness value for profiles vectors "Women" considering asset manager functionality provided by BrainBox	0.222222222	KPIs

Name of Variable	Definition of variable	Value	Group (s)
Effectiveness_r1_J1_K1	Effectiveness value for all profiles vectors considering Journey planning functionality provided by OASA	0.51127451	KPIs+travellers
Effectiveness_r4_J1_K1	Effectiveness value for profiles vectors "Women" considering Journey planning functionality provided by OASA	0.51127451	KPIs+travellers

Name of Variable	Definition of variable	Value	Group (s)
Effectiveness_r1_J8_K1	Effectiveness value for all profiles vectors considering Location-Based Experience functionality provided by OASA	0.924761905	KPIs+Travellers+TSPs

Name of Variable	Definition of variable	Value	Group (s)
Effectiveness_r4_J8_K1	Effectiveness value for profiles vectors "Women" considering Location-Based Experience functionality provided by OASA	0.817142857	KPIs+TSPs
Effectiveness_r1_J8_K2	Effectiveness value for all profiles vectors considering Location-Based Experience functionality provided by MIRAKLIO	0.822857143	KPIs+TSPs
Effectiveness_r4_J8_K2	Effectiveness value for profiles vectors "Women" considering Location-Based Experience functionality provided by MIRAKLIO	0.822857143	KPIs+TSPs

Table 28. Results of Effectiveness

Name of Variable	Value
Effectiveness_r1_j1_k1	0.511275
Effectiveness_r4_j1_k1	0.511275
Effectiveness_r1_j1_k2	0.024510
Effectiveness_r4_j1_k2	0.024510
Effectiveness_r1_j1_k3	0.053922
Effectiveness_r4_j1_k3	0.053922
Effectiveness_r1_j1_k4	0.029412
Effectiveness_r4_j1_k4	0.029412
Effectiveness_r1_j2_k3	0.333333
Effectiveness_r4_j2_k3	0.333333
Effectiveness_r1_j8_k1	0.924762
Effectiveness_r4_j8_k1	0.817143
Effectiveness_r1_j8_k2	0.822857
Effectiveness_r4_j8_k2	0.822857
Effectiveness_r1_j13_k1	0.333333
Effectiveness_r4_j13_k1	0.333333
Effectiveness_r1_j13_k2	0.111111
Effectiveness_r4_j13_k2	0.111111
Effectiveness_r1_j13_k3	0.333333
Effectiveness_r4_j13_k3	0.333333
Effectiveness_r1_j13_k4	0.222222
Effectiveness_r4_j13_k4	0.222222

10 Conclusions

This research provides Deliverable 6.2. The performance assessment will be executed through developing a tool on Excel with scripts in Julia to run algorithms defined in T6.1. The Effectiveness rate will be calculated and assessed in an automatic way, and unfair conditions for some specific groups of travellers, classified by socio-demographic profiles, will be identified continuously by the Tool.

The Tool will apply the algorithms developed in Task 6.1 to carry out a Business Intelligence analysis of trends capable of predicting future users' needs and expectations.

Deliverable 6.2 provides five modules (AHP method, Regression analysis, BN analysis, ANOVA test, USI TSPs, and Travellers and Effectiveness) in terms of data analysis considering the collected data in USI surveys and operational KPIs integrated with Athens demo site phase I. A capable toolbox has been prepared for this data analysis on Excel and Julia programming language software, and this Toolbox will be implemented in all other IP4MaaS demo sites (Barcelona, Padua, Liberec, Osijek, and Warsaw).

In this deliverable 6.2 tool for performance assessment, the following results have been achieved :

- I. Weights in AHP: Top 8 criteria/variables according to the weights calculated through AHP are listed below:

Table 29. Top 8 criteria in AHP weights

	Criteria/variable	Global weight
1	C11 Time-saving by journey planning	0.185231861
2	C22 Cost-saving by issuing	0.132345262
3	C21 Cost-saving by journey planning	0.123031331
4	C12 Time-saving by issuing	0.107533176
5	C52 Trip security at late night and early morning by journey planning	0.104326657
6	C51 Safety against Covid-19 by Journey Planning	0.06515005
7	C31 General satisfaction with journey planning	0.050377182
8	C61 Number of modes involved in the journey	0.040754949

- II. Weights in BN: Top 8 criteria/variables according to the weights calculated through BN are listed as follows:

Table 30. Top 8 criteria in BN analysis

	Variable name	Weights
1	J1K1q5 (question about finding more secure routes in off-peak hours regarding journey planning)	0.025630
2	J1K1q4 (question about safe trip from Covid-19 perspective regarding journey planning)	0.024488
3	J8K1q1 (question about general satisfaction regarding Location-based experience)	0.021570
4	J8K1q2 (question about time-saving regarding Location-based experience)	0.021152
5	J8K1q3 (question about cost-saving regarding location-based experience)	0.020592
6	J1K1q3 (question about cost-saving regarding journey planning)	0.019018
7	J1K1q1 (question about general satisfaction regarding journey planning)	0.010190
8	J1K1q2 (question about time-saving regarding journey planning)	0.007831

- III. Differences and comparison between weights from AHP and BN network

Regarding comparisons between AHP analysis and BN analysis, five factors out of 8 are the same. These factors are the same in the top 8 from two different methods and are significantly relevant, boosting and improving TC (Travel Companion) APP. The list of these top 5 crucial factors is illustrated below:

Table 31. Top 5 criteria and Variables in AHP and BN analysis

	Criteria in AHP	Variable in BN
1	C11 (Time-saving by journey planning)	J1K1q2 (Time-saving by journey planning)
2	C21 (Cost-saving by journey planning)	J1K1q3 (Cost-saving by journey planning)
3	C52 (Trip security at late night and early morning by journey planning)	J1K1q5 (finding more secure routes in peak-off hours regarding journey planning)
4	C51 (Safety against Covid-19 by journey planning)	J1K1q4 (Safe trip from Covid-19 perspective regarding journey planning)
5	C31 (General satisfaction with journey planning)	J1K1q1 (General satisfaction regarding journey planning)

- IV. Correlation between variables

Regarding the results of the correlation between factors, five graphs are created among factors and the weighted hierarchy considering BN analysis and Bellman's shortest path. These graphs must be well organized and feasible to identify and recognize which variable is linked to which other variables. It would be worth noting that among these five graphs and tests, graph and test number five have the highest Bayes score(highest belief). Regarding the regression analysis, as defined above, red colours identify that the studied variable is highly correlated and their value is less than or equal to 0.05 (more than 95% confidence level). In contrast, the green colours illustrate that variables are not correlated

or highly correlated, and their value is less than 0.05. As a result, the confidence level is inferior to 95%. This result was considered by the consortium and expected.

V. Results about prediction and probability

After identifying and analyzing the correlation between factors, the ability to assess and evaluate predictions and probability becomes feasible. In this methodology, it was found out that have chosen two variables to predict and two variables to instantiate. It was found out that this study aimed to discover how the maximum value of a variable will change if it was found out that it changes the value of one variable.

According to what has been discussed in this report, the toolbox in this study has been developed for the specific needs for the assessment of the IP4MaaS project but it has the capability to be implemented to assess other demo sites for future projects. To achieve this, the scripts and codes introduced in this document should be customized and adapted to the new variables and ranges of variables regarding each new demo site.

References

- Awad-Núñez, N., F. González-Cancelas, A. Soler-Flores, and A. Camarero-Orive. "Methodology for Measuring Sustainability of Dry Ports Location Based on Bayesian Networks and Multi-criteria Decision Analysis." *Procedia*. 13 , 2016: 124–133.
- Cheng, C. H., K. L. Yang, and C. L. Hwang. "Evaluating attack helicopters by AHP based on linguistic variable weight. *European Journal of Operational Research*." 1999: 423–435.
- Cooper, G. F., and E. Herskovits. "A Bayesian Method for the Induction of Probabilistic Networks from Data. *Machine Learning*." 1992: 309–347.
- Ekpanyapong, M., T. Waterwai, and Lim. Sung Kyu. "Statistical bellman-ford algorithm with an application to retiming. ." *Asia and South Pacific Conference on Design Automation, 2006*, 2006: 959–964.
- Gámez, J. A., J. L. Mateo, and J. M. Puerta. "Learning Bayesian networks by hill climbing: Efficient methods based on progressive restriction of the neighborhood. ." *Data Mining and Knowledge Discovery*, 22(1–2), 2011: 106–148.
- García, Elena, et al. "Diamond Project, D4.3 Computational analysis report." 2021.
- "IP4MaaS project (2022). Deliverable D 3.2 List of operational KPIs, analysis of the users' satisfaction and methodology as a whole, F-REL." n.d.
- "IP4MaaS project (2022). Deliverable D 4.4 IP4MaaS project (2022). User engagement strategy per each demonstrator." n.d.
- "IP4MaaS project (2022). Deliverable D 6.1 Assessment methodology." n.d.
- Lerner, B., and R. Malka. "Investigation of the K2 algorithm in learning bayesian network classifiers. *Applied Artificial Intelligence*." 25(1) (2011): 74–96.
- Lerner, B., and R. Malka. "Investigation of the K2 algorithm in learning bayesian network classifiers. *Applied Artificial Intelligence*, 25(1)." 2011: 74–96.
- Molero, Gemma Dolores, Francisco Enrique Santarremigia, Pablo Aragonés-Beltrán, and Juan-Pascual Pastor-Ferrando. "Total safety by design: Increased safety and operability of supply chain of inland terminals for containers with dangerous goods." *ELSEVIER*, 2016.
- Molero, Gemma Dolores, Sara Poveda-Reyes, Ashwani Kumar Malviya, Elena García-Jiménez, Maria Chiara Leva, and Francisco Enrique Santarremigia. "Computational Solutions Based on Bayesian Networks to Hierarchize and to Predict Factors Influencing Gender Fairness in the Transport System: Four Use Cases." *MDPI*, 2021.
- Reynolds, S.J., F.C Schultz, and D.R. Hekman. "Stakeholder Theory and Managerial Decision-Making: Constraints and Implications of Balancing Stakeholder Interests. *J Bus Ethics* 64." 2006: 285-301.
- Roy, B., and R. Słowiński. "Questions guiding the choice of a multicriteria decision aiding method. *EURO J. Decis. Process*. 1." 2013: 69–97.
- Saaty, T.L. "The analytic network process. *Decis. Mak. Anal. Netw. Process* 195." 2013: 1-40.
- Saaty, Thomas. "Multicriteria decision making: the analytic hierarchy process: planning, priority setting resource allocation." 1990.
- Sulaiman, O. K., A. M. Siregar, K. Nasution, and T. Haramaini. "Bellman Ford algorithm - in Routing Information Protocol (RIP). ." *Journal of Physics: Conference Series*, 1007(1), 012009., 2018.

11 ANNEXES

Annex 1: Calculations of AHP

Excel files from the AHP analysis are available at: [AHP Data analysis Excels](#)

Annex 2: TSPs USI survey

1. The tool that allows building Location-Based Experiences for the user:
(LBE tool)

1.a.- In general terms, I am satisfied with this Function

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1.b. - I am willing to pay for this functionality

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1.c.- It has the potential to increase the number of travellers using railways services.

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1.d.- It has the potential to increase the business around platforms and stations.

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1.e.-It has the potential to assist the company in getting acquainted with the customers based on the comments and reviews on the application

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1. f. It has the potential to help the company to measure marketing results.

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. The platform to provide and describe the services, and facilities in the IP4 platform and identify the integration of these services on the IP4 ecosystem: (Asset manager)

2.a.- In general terms, I am satisfied with this platform

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2.b. - I am willing to pay for this functionality

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2.c.- It has allowed me to know better my services offer and technology level

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Socio-demographic questionnaire for travellers USI surveys

1. Do you consider yourself to live in:

- a. A rural environment ☐
- b. An urban environment ☐
- c. A suburban environment ☐

d. Abroad/tourist ☐

2. Please choose your age group.

- a. 18-24 years ☐
- b. 25-44 years ☐
- c. 45-64 years ☐
- d. 65 years or more ☐
- e. Prefer not to answer ☐

3. What is your average yearly income?

- a. Less than 11,999 € ☐
- b. 12,000-40,999 € ☐
- c. More than 41,000 € ☐
- d. Prefer not to answer ☐

4. Do you travel weekly with a dependent person?

- a. No ☐
- b. Preschool age children (under 5 years) ☐
- c. School age children (5-16 years) ☐
- d. Elderly relative ☐
- e. Disabled person ☐
- f. Prefer not to answer ☐

5. What is your professional status?

- a. Non-paid work ☐
- b. Paid work ☐
- c. Student ☐
- d. Housekeeper, Homemaker ☐
- e. Retired ☐
- f. Unemployed ☐
- g. Prefer not to answer ☐

6. Do you currently have a problem, disability, or impairment that affects how you travel?

- a. No ☐
- b. Person in a wheelchair ☐
- c. Person with reduced mobility ☐
- d. Person with visual impairment ☐
- e. hearing impaired ☐
- f. Other ☐

g. Prefer not to answer

☐

7. Do you identify yourself as:

a. Male

☐

b. Female

☐

c. Other

☐

d. Prefer not to answer

☐

8. How familiar are you with technology, specifically mobile applications?

a. Expert

☐

b. familiar

☐

c. not so familiar

☐

d. I am having many troubles using mobile apps in general

☐

Annex 3: Travellers USI survey

J=1 The function to find routes involving different modes of transport (metro, rail, bus...) in a journey from an origin to a destination: (Journey planning function)

q=1 - In general terms, I am satisfied with this function

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=2 - I am willing to pay for this functionality

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=3 - It has saved me time

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=4 - It has saved me money

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

J=2 The function for booking both a specific ticket for a trip and tickets that allow you to travel on multiple forms of transport such as metro, buses, and trains: (Booking function)

q=1 - In general terms, I am satisfied with this function

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=2 - I am willing to pay for this functionality

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=3 - It will urge me to use the buses, trains, and public transport systems more frequently

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

J=3 The function that allows you to purchase tickets that can be used, validated, and inspected through the mobile application: (Issuing function)

q=1 - In general terms, I am satisfied with this function

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=2 - I am willing to pay for this functionality

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=3 - It will urge me to use the train, buses, and generally public transport systems more frequently

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=4 - It has saved me time, from my point of view

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=5 - It has saved me money, from my point of view

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

J=8 The function for providing you entertainment services, such as quiz games or mini-games, or commercial offers during your trip on specific stations: (Location-based experience function)

q=1 - In general terms, I am satisfied with this function

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=2 - I am willing to pay for this functionality

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=3 - It has made my trip more pleasant

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

q=4 - It will urge me to use different modes of transportation more frequently

1. Strongly disagree	2. Disagree	3. Neither agree nor disagree	4. Agree	5. Strongly agree	N/A	No opinion
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Socio-demographic questionnaire for travellers USI surveys

1. Do you consider yourself to live in:

- a. A rural environment ☐
- b. An urban environment ☐
- c. A suburban environment ☐
- d. Abroad/tourist ☐

2. Please choose your age group.

- a. 18-24 years ☐
- b. 25-44 years ☐
- c. 45-64 years ☐
- d. 65 years or more ☐
- e. Prefer not to answer ☐

3. What is your average yearly income?

- a. Less than 11,999 € ☐
- b. 12,000-40,999 € ☐
- c. More than 41,000 € ☐
- d. Prefer not to answer ☐

4. Do you travel weekly with a dependent person?

- a. No ☐
- b. Preschool age children (under 5 years) ☐
- c. School age children (5-16 years) ☐
- d. Elderly relative ☐

- e. Disabled person ☐
- f. Prefer not to answer ☐

5. What is your professional status?

- a. Non-paid work ☐
- b. Paid work ☐
- c. Student ☐
- d. Housekeeper, Homemaker ☐
- e. Retired ☐
- f. Unemployed ☐
- g. Prefer not to answer ☐

6. Do you currently have a problem, disability, or impairment that affects how you travel?

- a. No ☐
- b. Person in a wheelchair ☐
- c. Person with reduced mobility ☐
- d. Person with visual impairment ☐
- e. hearing impaired ☐
- f. Other ☐
- g. Prefer not to answer ☐

7. Do you identify yourself as:

- a. Male ☐
- b. Female ☐
- c. Other ☐
- d. Prefer not to answer ☐

8. How familiar are you with technology, specifically mobile applications?

- a. Expert ☐
- b. familiar ☐
- c. not so familiar ☐
- d. I am having many troubles using mobile apps in general ☐

Annex 4: Scripts and codes of JULIA regarding MODULE 1- AHP method

Scripts and codes of Julia about MODULE 1 are available at: [AHP method](#)

Annex 5: Codes and scripts in Julia regarding MODULE 2 about Regression analysis

Scripts and codes of Julia about MODULE 2 are available at: [Regression analysis](#)

Annex 6: Scripts and codes of JULIA regarding MODULE 3 about BN network and Bellman shortest path

Scripts and codes of Julia about MODULE 3 are available at: [BN network and Bellman shortest path analysis](#)

Annex 7: Scripts and codes regarding MODULE 4 about the ANOVA test

Scripts and codes of Julia about MODULE 4 are available at: [Anova Test analysis](#)

Annex 8: Scripts and codes regarding MODULE 5 about USI Travellers, USI TSPs, and Effectiveness calculation:

Scripts and codes of Julia about MODULE 5 are available at: [USI Travellers, USI TSPs and Effectiveness](#)