



D5.4

Impact Assessment Report

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1 EXECUTIVE SUMMARY

FENIX stands for “A European **F**ederated **N**etwork of Information **eX**change in Logistics”. FENIX is an action 2018-EU-TM-0077-S under the Grant Agreement number INEA/CEF/TRAN/M2018/1793401. The project duration was 36 months, effective from 01 April 2019 until 31 March 2023, due to the pandemic later extended to end of March 2023.

Within FENIX, Activity 5 evaluated all eleven Pilot Sites in FENIX. Evaluation played an important role in the 'learning by doing' approach which FENIX applied. This approach was used to prepare the next phase for deployment of Logistics & Transport corridor information services across TEN-T corridors based on the federative architecture of platforms of networks.

Deliverable D5.4 (milestones M76-M77) describes the background, methodology, and calculations performed to assess the impact of the federated platforms within the overall FENIX Evaluation Methodology. It used a combination of Multi-Criteria Analysis (MCA) and Analytical Hierarchy Process (AHP) and described the application of this methodology to the FENIX Pilot Sites. It demonstrated the approach by using high-level results or exemplary calculations. Detailed results for each Pilot Site were made available in specific Pilot Site reports.

Multi-criteria analysis (MCA) and Analytical Hierarchy Process (AHP) are common techniques to assist in decision-making in complex systems such as transport. This deliverable has performed a brief literature review which identified a very diverse range of topics where both MCA and AHP have been used until to date. The wide applicability and transparency of the approaches make both methods useable for assessing the impact of federated platforms which is the aim of this study. The deliverable uses MCA for determining the impact of federated platforms based on different criteria (and units) and AHP for assessing the weights of the various criteria used in the MCA.

A specific methodology has been developed to determine the overall impact assessment indicator for each Pilot Site. Following the overall FENIX Evaluation Framework, seven steps were proposed and described in detail to perform the calculations for each Pilot Site. These calculations use a lot of data due to the high number of KPIs, Use Cases, Pilot Sites, and the performed KPI measurements. Due to the subjectivity of many parameters and assumptions, an uncertainty calculation approach based on a Monte-Carlo simulation has also been included in the overall approach.

The calculations performed within an Excel-based software FEMCAHP have been explained and demonstrated using exemplary calculations. The different input requirements to run the software have been discussed, including the user input, Pilot Site, Use Case, and KPI details. More detailed descriptions have been provided for the dependencies in between the aforementioned inputs, the KPI baseline and To-Be measurements, and the Single-Attribute Value Functions (SAVF) to transform the KPI measurements into a scaled and comparable indicator values.

The Monte-Carlo simulations for addressing the uncertainties in the methods and measurements have been applied to all Pilot Sites, using different variability of input parameters and numbers of

simulations. Example simulations were performed demonstrating how the software works and which type of results will principally be available. Conclusions can be drawn from these calculations regarding the importance of the parameters used for the calculations of the impact indicator in the various Pilot Sites.

The results for all Pilot Sites are summarised in Table 24 and show that the implementation of federated networks has a significant impact on the performance of a broad range of elements within the supply chains using very different transport modes. This has been demonstrated using the described impact assessment approach. Further details regarding the performance of specific KPIs and the associated costs can also be found in Deliverables D5.1, D5.2 and D5.3, respectively. The detailed results for each of the Pilot Sites, based on the methodology described in this deliverable are summarised in Annex B of this deliverable and have also been sent to the Pilot Sites.

The following more detailed results can be found from applying the developed methodology to all Pilot Sites:

- MCA and AHP approaches provide valuable methods to assess the ranking of stakeholder perspectives and hence calculate the impact assessment of the implementation of federated networks within the FENIX Pilot Sites.
- The impact indicators for all Pilot Sites are ranging from 0.515 to 0.986 (maximum values from Table 24), using a scale from '0' (bad performance) to '1' (best performance), hence showing that the use of federated networks has a significant impact on the (improved) performance of the logistics processes.
- The overall results are dependent (amongst other less influencing parameters) on the stakeholder profile influencing the weights of the KPI used for assessing the impacts in the Use Cases of the Pilot Sites. The variability has principally been in a range of 10% from the average results (with an exception for PS IT2 where a 30% deviation was observed).
- The uncertainty analysis has shown that impact assessment calculations are quite stable for most of the impact assessments. In some cases, however, due to limited KPIs in the Use Cases, a small number of Use Cases in the Pilot Site, and/or limited number of measurements, the variability can be larger. The latter did not show any impact on the overall assessment of the results.

2 INTRODUCTION

2.1 Purpose of the document

The overall objective of Deliverable D5.4 (this document) is to provide the background, methodology, and necessary calculations to assess the impact of federated platforms used in the Pilot Sites of FENIX. The approach has been applied to the various Pilot Sites in FENIX and demonstrated by using high-level results or exemplary calculations. Detailed results for each Pilot Site will be available in the Pilot Site reports.

This document is understood as a reference to explain the details of calculations performed and to enable users to adapt any of the calculations according to their preferences. Step-by-step descriptions are provided for the calculations of the results to allow for a transparent and adaptable impact assessment of what FENIX has achieved by setting up the federated platforms and applying this approach in its Pilot Sites.

2.2 Contractual references

FENIX stands for “A European **FE**derated **N**etwork of **I**nformation **eX**change in Logistics”. FENIX is an action 2018-EU-TM-0077-S under the Grant Agreement number INEA/CEF/TRAN/M2018/1793401 and the project duration is 36 months, effective from 01 April 2019 until 31 March 2022, later extended to 48 months until 31 March 2023. It was a contract with the European Climate Infrastructure and Environment Executive Agency (CINEA) under the powers delegated by the European Commission.

Communication details of the Agency:

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- European Climate Infrastructure and Environment Executive Agency (CINEA)
- Department C – Connecting Europe Facility (CEF)
- Unit C2 Transport
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2.3 Mapping deliverable against FENIX outputs

This section seeks to provide a justification of the work and results described in this deliverable against FENIX's respective outputs. Table 1 maps the deliverable against the objectives of the FENIX Grant Agreement (GA), Table 2 describes how the deliverable matches the relevant Activity (Act. 5) contents, and Table 3 maps the deliverable against the relevant task (T5.4) and its description in the Grant Agreement.

Table 1: Mapping of deliverable against relevant FENIX's GA descriptions

Deliverable	
GA Title:	D5.4 'Impact assessment report'
Outline:	<i>Deliverable D5.4 describes the background and methodology of the impact assessment of the federated platforms within the overall FENIX Evaluation Methodology. It uses a combination of Multi-Criteria Analysis (MCA) and Analytical Hierarchy Process (AHP). It describes the application of this methodology to the FENIX Pilot Sites, and reports the (high-level) results of this application. For detailed results for each of the Pilot Sites, the reader is referred to the Pilot Site reports.</i>
Deliverable chapters:	Chapters 3, 4, 5, and 6
Justification:	Chapter 4 summarises the methodology of the approach in a 7-step-methodology. It provides details for the individual steps and how the measurements of Key Performance Indicators (KPIs) within each Use Case of the Pilot Sites are used to assess an overall impact scale. Chapter 5 describes the calculations performed with the developed calculation tool, starting from the required inputs, the calculation of weights using AHP, and the overall results for each Pilot Site. It also discusses the calculation of uncertainties within these calculations. Chapter 6 describes the application of the methodology and the calculations to the 11 Pilot Sites of FENIX. Specific attention will be given to the calculation of weights for KPIs and Use Cases, and the Single-Attribute-Value Function (SAVF) which translates the various measurements (with different units) into a homogenous scale. Eventually, Chapter 6 provides a high-level overview of the results where details for each Pilot Site will be provided in the Pilot Site reports. Overall, the report provides all necessary details to assess the impact of using federated platforms within the Pilot Sites and suggests single 'values' to evaluate these impacts.

Table 2: Mapping of deliverable against FENIX's GA descriptions for Activity 5

Activity	
GA Title:	Activity 5 'Evaluation'
GA Outline:	<p><i>Act. 5. will evaluate all eleven Pilot Sites in FENIX. Evaluation plays an important role in the 'learning by doing' approach which FENIX applies. This approach is used to prepare the next phase for deployment of Logistics & Transport corridor information services across TEN-T corridors based on the federative architecture of platforms of networks.</i></p> <p><i>Act. 5 comprises four tasks dealing with different aspects of evaluation:</i></p> <ul style="list-style-type: none"> <i>T5.1: Evaluation Framework of the federated platforms</i> <i>T5.2: Technical and operational evaluation (KPIs included)</i> <i>T5.3: Cost-effectiveness analysis (CEA)</i> <i>T5.4: Experience and impact assessment (reported in this deliverable)</i>
Deliverable chapters:	Chapters 3, 4, 5, and 6
Justification:	<p>The focus of this deliverable is to find an overall assessment possibility for the impact of using federated platforms which have been set up, installed, and used within the Pilot Sites of FENIX. The methodology uses standard methods (MCA and AHP) to evaluate different criteria with different units (KPIs) and weights. The results will provide comparable scales for the impacts of the aforementioned platforms in the Pilot Sites and will allow a justifiable and transparent evaluation of these impacts. The deliverable therefore supports the overall objective of the Activity to provide a common overall Evaluation Framework and comparable results. The transferability of this approach to other Pilot Sites or cases is granted, the sensitivity of the evaluation approach is considered by using a probabilistic approach applying the methodology.</p>

Table 3: Mapping of deliverable against FENIX's GA descriptions for Task 5.4

Tasks	
GA Title:	T5.4 ' Experience and impact assessment '
GA Outline:	<i>Impact assessment will be based on Multi-Criteria Analysis (MCA) and especially the Analytical Hierarchy Process (AHP). MCA and especially the AHP will be used in case there is a need to prioritize a set of options in order to do an impact assessment. KPIs will be used from each of the aforementioned impact assessment methodologies and to assess the direct impact of solution by their quantifying 'before' and 'after' implementation status.</i>
Deliverable chapters:	Chapters 3, 4, 5, and 6
Justification:	MCA and AHP are used to evaluate the impact of using federated platforms in the Pilot Sites. The key focus of this deliverable is on bringing together different sets of options to evaluate the foreseen improvements. The KPIs used in the different Use Cases of the Pilot Sites are interpreted as options to evaluate the impact. The measurements of KPIs are processed and analysed within T5.2 of Activity 5 and are then used as input for this task. MCA and AHP will assist in developing a transparent assessment methodology which will lead to comparable results of the impacts of (different) federated platforms in the Pilot Sites. The approach is universally applicable to all Pilot Sites and will provide an easily understandable result for the overall impact of the federated platforms.

2.4 Deliverable structure

This deliverable is structured as follows:

- Chapter 3 provides a brief summary of the background of MCA and AHP, introducing the overall idea and methodology, and providing example(s) on how these methods work
- Chapter 4 develops the methodology on how these methods are used within Task 5.4 and introduces a 7-step-approach to assess the impact of the federated platforms. Each step will be explained using the background idea and linking it to the FENIX evaluation framework.
- Chapter 5 introduces the calculation tool and how this is set up and will be used. It describes the required input(s), the calculation of weights (especially focusing on AHP for the weights of the KPIs used in the Use Cases), the overall results for the Pilot Sites, and the calculation of the uncertainties for these results, applying uncertainties to the input parameters, but also the calculation parameters.

- Chapter 6 applies the methodology to the eleven pilot sites using the aforementioned calculation tools. The description does not go into details for each of the Pilot Sites (these details will be provided in the final Pilot Site reports) but provides either a high-level overview of results or, alternatively, using exemplary calculations to demonstrate the use of the software. It will also discuss the weights for KPIs and Use Cases, and the Single-Attribute-Value functions which 'translate' the measurements of KPIs in comparable scales. It demonstrates how an overall result can principally be achieved and how sensitive these results would be on the different input parameters for the used software.
- Chapter 7 eventually summarises the findings and provides concluding remarks on the use of the results.

3 BACKGROUND

This chapter seeks to provide a brief overview of the background of this investigation looking into scientific publications on Multi-Criteria Analysis (MCA) and Analytical Hierarchy Process (AHP). The findings of these investigations will be summarised and provide the solid background of why these methods have been selected to perform the impact assessment of the federated platforms as described in this report.

3.1 Introduction

In psychology, decision-making is regarded as the cognitive process resulting in the selection of a belief or a course of action among several possible alternative options. It could be either rational or irrational. The decision-making process is a reasoning process based on assumptions of values, preferences and beliefs of the decision-maker. Every decision-making process produces a final choice, which may or may not prompt action¹.

Wikipedia continues to state that *"Decision-making can be regarded as a problem-solving activity yielding a solution deemed to be optimal, or at least satisfactory. It is therefore a process which can be more or less rational or irrational and can be based on explicit or tacit knowledge and beliefs. Tacit knowledge is often used to fill the gaps in complex decision-making processes.[3] Usually, both of these types of knowledge, tacit and explicit, are used together in the decision-making process."*

Operations research (or Operational Research) is *a discipline that deals with the development and application of advanced analytical methods to improve decision-making²*. There are various analytical models to solve decision problems or to support decision-making such as modelling, statistics, or optimisation techniques. The key issue with many of the decision problems is that there are (too) many parameters involved which very often are controversial and therefore have to be weighted to come to an optimal or near-optimal solution.

Imagine a new car should be bought and it needs to be 1) safe, 2) fully equipped, and 3) cheap. You will know then immediately that compromises have to be made since 'cheap' means that very often safety features are reduced or the car is not fully equipped with all available features. The decision problem here is then where to prioritise or to how to fit the needs within the available budget. This might still be feasible within the aforementioned three parameters and one new owner but will be significantly more difficult when several tens or hundreds of parameters are involved and when more 'owners' or stakeholders are involved in the decision making process.

Both Multi-criteria analysis (MCA) and Analytical Hierarchy Process (AHP) are techniques to assist in decision-making in complex systems. The details of MCA are further detailed in section 3.2 below whereas more details on the background of the AHP can be found in section 3.3.

¹ <https://en.wikipedia.org/wiki/Decision-making>

² https://en.wikipedia.org/wiki/Operations_research

3.2 Multi-Criteria Analysis (MCA)

Multi-criteria analysis (or more accurately "Multiple-Criteria Decision-Making (MCDM)" or "Multiple-Criteria Decision Analysis (MCDA)") is a sub-discipline of Operational Research and has been developed in the 1970s. It has been applied to very different disciplines ever since and explicitly evaluates criteria (also conflicting) for decision-making purposes. "Conflicting criteria" occur typically in evaluating options. "Cost or price" is usually one of the main criteria, and some measure of "quality" is typically another criterion, easily in conflict with the cost. In daily life, people typically solve these decision problems by intuition and are comfortable with bearing the consequences of these decisions. However, if more complex decisions (many criteria) and various levels of consequences (people) are involved, a more structured approach is meaningful.

MCA has been widely used in the past and across various topics, for a historical overview see for example Köksalan et al. (2011)³. A recent literature review of the use of MCA in the transport sector has been provided by Yannis et al. (2020)⁴. The study investigated more than 50 papers and publications in between 1982 and 2019 and concluded that *"MCA analysis can be effectively used to evaluate transportation projects, alternative design solutions of an infrastructure transportation project, transport options and transport policies or transport policy measures and can result in ranking of examined options, identification of a single most preferred option, classification of options into categories, and optimization."*

Recent applications in transport cover emission reductions⁵, road infrastructure (in combination with cost-benefit analysis)⁶, route planners⁷, urban mobility⁸, or heritage buildings⁹, to just name a few. MCA is often used in combination with other methods, most commonly AHP (see below) but also cost-benefit analysis (CBA), Multi-Attribute Utility Theory (MAUT), Simple Additive Weighing (SAW), Geographical Information Systems (GIS, for spatial problems), and others. Methods differ depending

³ Köksalan, M.M., Wallenius, J., Zionts, S., Zionts, S. and Wallenius, J. (2011). Multiple criteria decision making: from early history to the 21st century, Singapore Hackensack, NJ World Scientific

⁴ Yannis, G., Kopsacheili, A., Dragomanovits, A. and Petraki, V. (2020). "State-of-the-art review on multi-criteria decision-making in the transport sector." Journal of Traffic and Transportation Engineering (English Edition), vol. 7, no. 4: pp. 413-431. doi: 10.1016/j.jtte.2020.05.005.

⁵ Hasan, M.A., Chapman, R. and Frame, D.J. (2020). "Acceptability of transport emissions reduction policies: A multi-criteria analysis." Renewable and Sustainable Energy Reviews, vol. 133: 12 pp. doi: 10.1016/j.rser.2020.110298.

⁶ Gühnemann, A., Laird, J.J. and Pearman, A.D. (2012). "Combining cost-benefit and multi-criteria analysis to prioritise a national road infrastructure programme." Transport Policy, vol. 23: pp. 15-24. doi: 10.1016/j.tranpol.2012.05.005.

⁷ Sarraf, R. and McGuire, M.P. (2020). "Integration and comparison of multi-criteria decision making methods in safe route planner." Expert Systems with Applications, vol. 154. doi: 10.1016/j.eswa.2020.113399.

⁸ Awasthi, A., Omrani, H. and Gerber, P. (2018). "Investigating ideal-solution based multicriteria decision making techniques for sustainability evaluation of urban mobility projects." Transportation Research Part A: Policy and Practice, vol. 116: pp. 247-259. doi: 10.1016/j.tra.2018.06.007.

⁹ Awasthi, A., Omrani, H. and Gerber, P. (2018). "Investigating ideal-solution based multicriteria decision making techniques for sustainability evaluation of urban mobility projects." Transportation Research Part A: Policy and Practice, vol. 116: pp. 247-259. doi: 10.1016/j.tra.2018.06.007.

on whether the alternative solutions are known at the beginning (MADM or MCA models) or not (MODM).

The review also shows that in a MCA very often a structured approach is used, starting with the definition of the (decision) problem, identification of the criteria, defining the alternative solutions (if known), assessing the weights of the alternatives, and so forth. It therefore makes sense in a MCA to clearly define the necessary steps to eventually propose a decision or outcome of the study. Additionally, due to its subjective character, MCA can be combined with uncertainty analyses to check the sensitivities of criteria or their weights and to better understand the variability of the obtained results.

3.3 Analytic Hierarchy Process (AHP)

There are several methods available for the determination of criterion weights, such as ranking, rating, pairwise comparison, and trade-off analysis method. In all methods, weights are usually normalized to a sum of 1 ($\sum w_j = 1$, where w_j is the weight of j^{th} criterion). Amongst these methods, the pairwise comparison method within the Analytical Hierarchy Process is briefly described in the following.

Analytical Hierarchy Process (AHP) is a structured technique for organizing and analysing complex decisions, based on mathematics and psychology¹⁰. It has been developed by Thomas L. Saaty¹¹ in 1970 and has been refined since then. AHP is an analytical method to evaluate the weights of decision criteria by pairwise comparison of the criteria and therefore reduces the decision problem to pairs of priorities or ranking them.

The pairwise comparison method takes each criterion and compares it to all the others where an importance scale of 1-9 (Table 4) is used.

¹⁰ https://en.wikipedia.org/wiki/Analytic_hierarchy_process

¹¹ https://en.wikipedia.org/wiki/Thomas_L._Saaty

Table 4: Importance scale of pairwise comparison (see e.g. Saaty & Sodenkamp, 2008¹²)

Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Equal to moderate importance	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate to strong importance	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong to very strong importance	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong importance	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

If activity i has one of the above non-zero numbers assigned to it when compared with activity j , then j has the reciprocal value when compared with i .

A step-by-step example for deriving weights using AHP is given in Table 5 until Table 8. In this example on buying a car, three factors are considered: cost, comfort, and safety (see Mu and Pereyra-Rojas, 2017¹³). It should be noted that AHP is only useful with a minimum of three parameters. For only two parameters, the comparison of these two parameters will directly lead to the weights and therefore does not need the pairwise comparison.

Table 5: AHP: pairwise comparison matrix with intensity judgements

Buying a car	Cost	Comfort	Safety
Cost	1	7	3
Comfort	1/7	1	1/3
Safety	1/3	3	1

Table 6: AHP: column addition

Buying a car	Cost	Comfort	Safety
Cost	1.000	7.000	3.000

¹² Saaty, T.L. and Sodenkamp, M. (2008). "Making decisions in hierarchic and network systems." International Journal Applied Decision Sciences vol. 1(no. 1): pp. 24-79.

¹³ Mu, E. and Pereyra-Rojas, M. (2017). "Understanding the Analytic Hierarchy Process". In: Practical decision making using super decisions: An introduction to the Analytical Hierarchy Process. Ed(s). Springer Briefs in Operations Research. version 3: pp. 7 - 23.

Comfort	0.143	1.000	0.333
Safety	0.333	3.000	1.000
Total	1.476	11.000	4.333

Table 7: AHP: normalized matrix

Buying a car	Cost	Comfort	Safety
Cost	0.677	0.636	0.692
Comfort	0.097	0.091	0.077
Safety	0.226	0.273	0.231

Table 8: AHP: calculation of weights as row averages

Buying a car	Cost	Comfort	Safety	Weights
Cost	0.677	0.636	0.692	0.669
Comfort	0.097	0.091	0.077	0.088
Safety	0.226	0.273	0.231	0.243

Table 5 provides the different importance for each of the three factors, e.g. cost is a lot more important than comfort (factor 7) whereas only slightly more important than safety (factor 3). The lower left part of Table 5 contains the reciprocal values of these factors. In Table 6, the columns are summed up and in Table 7 each cell is divided by the totals of the columns so that the totals result to 1.0 in Table 7. In Table 8, the weights are then achieved by averaging all values in each row showing that the costs is the most important factor (67%), over the safety (24%), and the comfort (9%).

Due to the pairwise comparison and subjective preferences of the input, a consistency check on the results is performed checking whether the pairwise input was is consistent. AHP calculates a consistency ratio (CR) comparing the consistency index (CI) of the matrix of judgements versus the consistency index of a random-like matrix (RI) (Mu and Pereyra-Rojas, 2017, see footnote 13). RI is the average CI of 500 randomly filled in matrices. Saaty & Sodenkamp (2008)¹⁴ provide the calculated RI value for matrices of different sizes. In AHP, the consistency ratio is defined as $CR = CI/RI$. Saaty & Sodenkamp (2008) have shown that a consistency ratio (CR) of 0.10 or less is acceptable to continue the AHP analysis.

The calculation works as follows: each column of the comparison matrix (Table 5) should be multiplied by the respective column weight. For example, each value of the cost column is multiplied by the calculated weight (0.669). The resulting table is shown in Table 9. Then then each row is summed up to obtain a set of values called weighted sum (Table 10).

¹⁴ Saaty, T.L. and Sodenkamp, M. (2008). "Making decisions in hierarchic and network systems." International Journal Applied Decision Sciences, vol. 1 (no. 1): pp. 24-79.

Table 9: Calculation of weighted columns

Buying a car	Cost	Comfort	Safety
Cost	0.669	0.617	0.729
Comfort	0.096	0.088	0.081
Safety	0.223	0.265	0.243

Table 10: Calculation of weighted sum

Buying a car	Cost	Comfort	Safety	Weighted sum
Cost	0.669	0.617	0.729	2.015
Comfort	0.096	0.088	0.081	0.265
Safety	0.223	0.265	0.243	0.731

In the last step, the weighted sum (last column in Table 10) is divided by the weights again and the average of the three values is calculated (denominated as λ_{\max}). The consistency index (CI) is then calculated by $CI = (\lambda_{\max} - n) / (n - 1)$, where n is the number of compared elements (i.e. 3 in this example). Therefore, here, CI is calculated as $CI = (3.007 - 3) / (3 - 1) = 0.004$.

Now the consistency ratio (CR) can be calculated as $CR = CI / RI$ which for $n=3$, $RI = 0.58$ and therefore, $CR = 0.004 / 0.58 = 0.006$. Since the calculated CR value of 0.006 is less than 0.10, the judgement matrix is assumed to be reasonably consistent so that the derived weights can be used for the decision-making process. If the consistency ratio is greater than 0.10, it is necessary to revise the judgments to locate the cause of the inconsistency and correct it.

The main advantage of the pairwise comparison approach is that it allows the decision makers to express their preference structure among several criteria but still focus on a direct (and easy) comparison between just two of them.

AHP has been used in thousands of applications, covering very diverse topics such as climate change¹⁵, university faculty selection¹⁶, offshore locations¹⁷, roadway bridges¹⁸, and many more. Despite its wide application range, relatively easy applicability, and broad impacts¹⁹, the method was also recently

¹⁵ Berrittella, M., Certa, A., Enea, M. and Zito, P. (2007). "An Analytic Hierarchy Process for the Evaluation of Transport Policies to Reduce Climate Change Impacts", Fondazione Eni Enrico Mattei (Milano)

¹⁶ Grandzol, J.R. (2005). "Improving the Faculty Selection Process in Higher Education: A Case for the Analytic Hierarchy Process." IR Applications, vol. 6: 13 pp.

¹⁷ Atthirawong, W. and McCarthy, B. (2002). "An Application of the Analytical Hierarchy Process to International Location Decision-Making". Proceedings of the 7th Annual Cambridge International Manufacturing Symposium: Restructuring Global Manufacturing, Cambridge, England, Gregory, M. (ed.), pp. 1-18.

¹⁸ Salem, O., Salman, B. and Ghorai, S. (2017). "Accelerating construction of roadway bridges using alternative techniques and procurement methods." Transport, vol. 33, no. 2: pp. 567-579.

¹⁹ https://en.wikipedia.org/wiki/Analytic_hierarchy_process

criticised (see e.g. Munier & Hontoria, 2021²⁰) where at least 30 flaws were found in the AHP and it was considered unsuitable for complex problems, and in certain situations even for small problems.

3.4 Summary

Multi-criteria analysis (MCA) and Analytical Hierarchy Process (AHP) are common techniques to assist in decision-making in complex systems such as transport. The brief literature review in this chapter has identified a diverse range of topics where both MCA and AHP have been used.

The wide applicability and transparency of the approaches make both methods useable for assessing the impact of federated platforms which is the aim of this study. The following approach is suggested here:

- use of MCA for determining the impact of federated platforms based on different criteria (and units);
- use of AHP for assessing the weights of the various criteria used in the MCA;
- a stepwise approach to determine the impact indicator for each Pilot Site of FENIX

The following seven steps are proposed for a structured analysis of the impact:

- 1. Decision problem:** provide an overall impact evaluation for implementing the FENIX federated network;
- 2. Define evaluation criteria:** the Key Performance Indicators (KPIs) used across all Pilot Sites in FENIX (within the various Use Cases) are evaluation criteria for a better performance after installation of the federated network(s);
- 3. Define alternatives:** the different use cases in the Pilot Sites are alternatives to quantify the decision problem;
- 4. Performance evaluation:** the performance is evaluated according to the change of KPIs in each UC. This could be a percentage (e.g. 50% higher) or a difference (e.g. 2h less waiting time);
- 5. Criterion weights:** AHP is used to calculate weights by pairwise comparison of KPIs for each UC in the Pilot Sites;
- 6. Decision rules:** transform a KPI performance in a standardised number (typically in between 0 and 1). This is necessary since many KPI measurements (even for identical KPIs) are provided in different units and therefore have to be harmonised;
- 7. Aggregation matrix:** bring all evaluation steps together by means of weights, determine an overall impact assessment indicator (IAI, in between '0' and '1') for each Pilot Site.

These steps have to be further refined in the following. Therefore, chapter 4 will continue to develop a detailed methodology for assessing the impact of the federated networks, and chapter 5 after that will explain the calculations needed and the software used for these calculations.

²⁰ Munier, N. and Hontoria, E. (2021). "Uses and Limitations of the AHP Method: A Non-Mathematical and Rational Analysis". Switzerland, Springer Nature. doi: 10.1007/978-3-030-60392-2, ISBN: 978-3-030-60392-2.

4 METHODOLOGY

Chapter 3 has summarised the background of MCA and AHP and defined the next steps to determine an overall impact assessment for the implementation of the federated networks in FENIX. This chapter will detail the methodology on how this is done using the measurements of KPIs in the various Use Cases within the Pilot Sites. The Pilot Sites and their Use Cases have been described in Deliverable D2.1.1 of FENIX²¹.

This chapter will first summarise the overall FENIX methodology developed within Activity 5 (Evaluation) of FENIX (section 4.1). In section 4.2, the aforementioned seven steps will be further elaborated to obtain the overall impact assessment indicator for each Pilot Site.

4.1 Overall evaluation methodology

An overall FENIX Evaluation Framework has been developed²². It develops a framework for the overall evaluation of the Pilot Sites, including evaluation criteria, adaptation of evaluation methods, and the refinement, and harmonization of data analyses methods and data management. The purpose of this document is to provide the FENIX Evaluation Framework to the Pilot Sites, coordinate the activities for the evaluation (Activity 5), align them with pilot preparation (Activity 2) and roll-out (Activity 4) from an evaluation perspective, and support the Pilot Sites in reporting their evaluation processes and outcomes (Deliverables 5.1.1 – 5.1.9).

The evaluation framework defines “what” needs to be evaluated, “how” it will be evaluated and “who” will perform the evaluation. It outlines the evaluation objectives, and the required key performance indicators and measurements from measurements within the Pilot Sites. In addition, it presents the impact categories that are used as a basis to identify the relevant performance indicators in each PS. The overall approach is illustrated in Figure 1.

²¹ Fantì, M.P., Ukovich, W., Di Pierro, B., Berardi, A. and Giansante, C. (2020). "Pilot Sites Description", A European FEDerated Network of Information eXchange in Logistics (FENIX). D2.1.1, POLIBA, 234 pp.

²² Parodos, L., Dais, S., Ayfantopoulou, G., Renzi, G. and Kortenhaus, A. (2022). "Evaluation framework", A European FEDerated Network of Information eXchange in Logistics (FENIX). D5.1, CERTH, 50 pp.

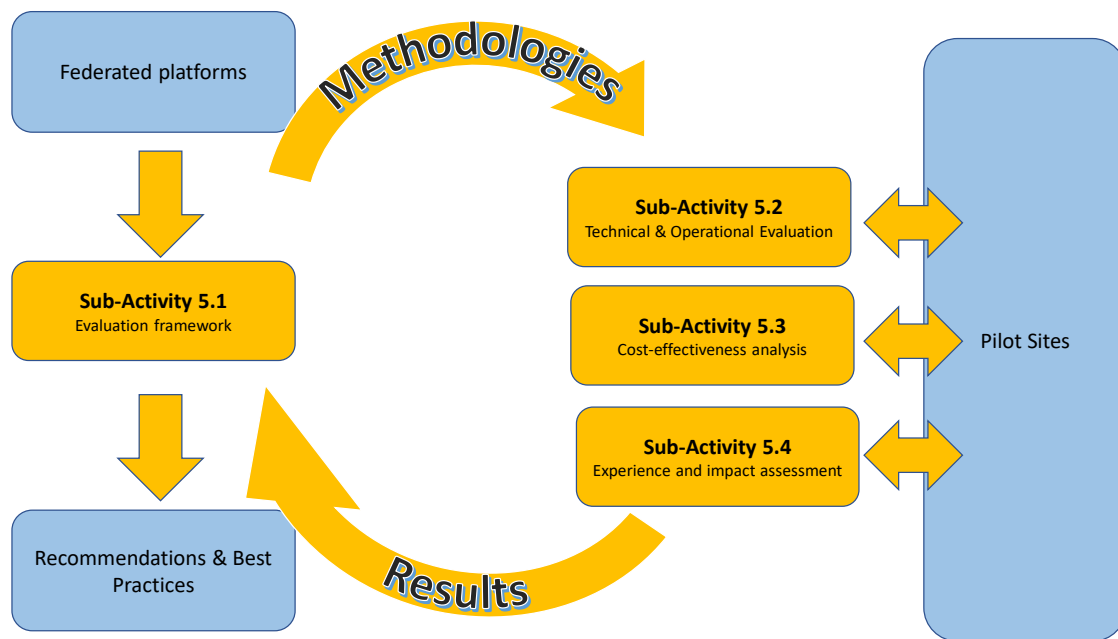


Figure 1: FENIX Evaluation Methodology overview (source: Parodos et al., 2022, see footnote 22)

Figure 1 shows that the overall framework has been developed in Sub-Activity 5.1, the technical and operational evaluation of the KPI measurements is performed in Sub-Activity 5.2, the cost-effectiveness analysis (CEA) in Sub-Activity 5.3, and the impact assessment in Sub-Activity 5.4. The latter activities receive data from the Use Cases of the Pilot Sites and deliver their results back to the Pilot Sites for inclusion in the specific Pilot Site reports.

A more detailed graphical presentation how Sub-Activity 5.4 is linked to the other Sub-Activities is shown in Figure 2.

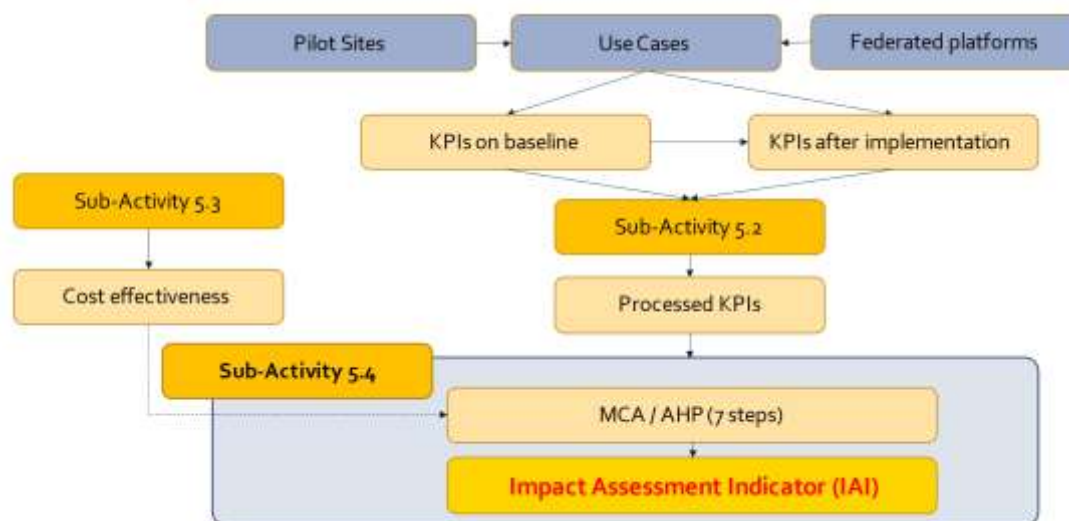


Figure 2: Integration and collaboration of Sub-Activity 5.4 with other sub-activities

Figure 2 shows that the measurements of KPIs within the Use Cases of the Pilot Sites are first processed and analysed within Sub-Activity 5.2. After this technical and operational evaluation the results are forwarded to Sub-Activity 5.4 to obtain the overall impact assessment indicator. The latter process will be detailed in the following. Sub-Activity 5.3 obtains additional data from the Pilot Sites by means of interviews which will then be processed and analysed to provide the cost effectiveness as an evaluation of the implementation of the federated networks with respect to costs.

4.2 7-step-methodology

Following the background analysis of MCA and AHP, seven steps were proposed to obtain the overall impact assessment. These steps will now be worked out in more detail to provide the basis for an analytical way to calculate an overall impact indicator for each of the Pilot Sites.

4.2.1 Step I: Decision problem

As previously mentioned, the first step is the identification of the decision problem. The key question linked to this decision is:

How can the implementation of the federated networks in the Pilot Sites of FENIX be evaluated using just one parameter?

There are eleven Pilot Sites in FENIX located in nine different European countries. Each of these Pilot Sites have a different number of Use Cases installed to test the implementation of (in most cases) different federated networks. In each Use Case, a different number of pre-defined Key Performance Indicators (KPIs) is used, sometimes using the same type of measurements, sometimes different ones.

The challenge is therefore not only to bring together different numbers of measurements (or even types of measurements) over various durations, but also to combine all those measurements to a

single parameter. The principal calculation flow and the key issues in each of these steps are summarised in Figure 3.

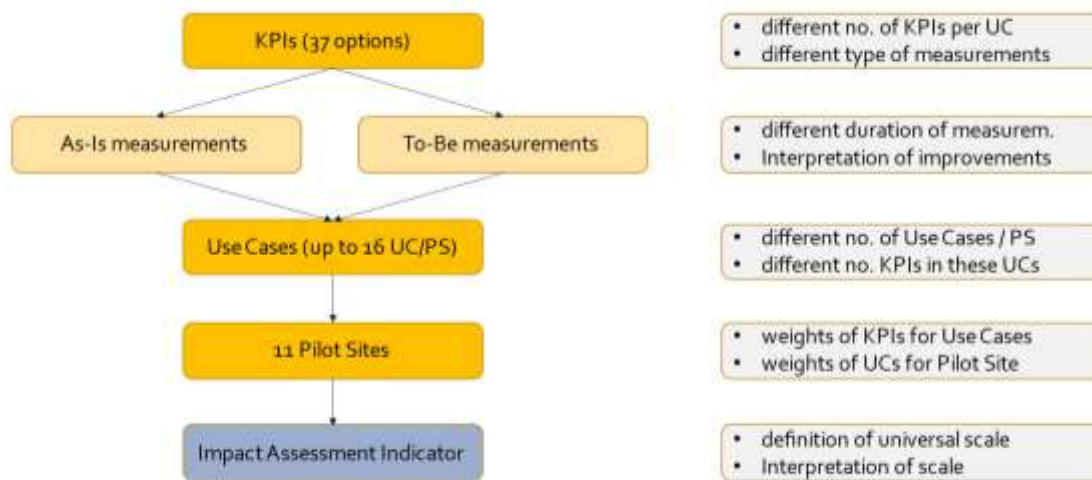


Figure 3: Principal steps in decision problem and key issues

Figure 3 shows that there are a couple of issues to address to eventually be able to provide an impact assessment indicator. These issues will be addressed in the following steps.

4.2.2 Step II: Define evaluation criteria

As already indicated for Step I (section 4.2.1), the KPIs will act as evaluation criteria. If well selected, a KPI (or better: the measurement of changes of this KPI) will indicate a change in performance of a key feature of the selected Use Case. If the waiting time of a truck reduces significantly due to the use of a federated platform, this reduction in waiting time is an indicator for a better performance of the Pilot Site in this specific aspect. The list of KPIs which have been agreed on within the Evaluation Framework of FENIX is provided in Table 11. The second but last column in Table 11 indicates whether the KPI is from a common set of KPIs ("Comm", each UC ideally uses at least one of these KPIs for better comparison) or Pilot Site specific ("Site"). The last column in Table 11 indicates whether the KPI has actually been used (considering all data collected by mid-January 2023).

Table 11: List of FENIX Key Performance Indicators

No.	KPI	Impact cat.	Comm/Site	Benchmark	In use
1	CO2 emissions	Emissions - externalities	Comm	-20%	X
9	NOx emissions	Emissions - externalities	Comm	-30%	X
3	Load factor	Load factor	Comm	30%	X
4	(Physical) document number exchar	Document exchange	Comm	-30%	X
5	Delivery reliability	Delivery/pick-up reliability and vis	Comm	20%	X
8	Product/shipment visibility	Delivery/pick-up reliability and vis	Comm	20%	X
37	Shipment status updates	Delivery/pick-up reliability and vis	Comm	50%	X
13	Interoperabilitiy	Interoperability	Comm	50%	
2	Waiting times	Transport optimization	Site	-30%	X
24	Routing efficiency	Transport optimization	Site	35%	
6	Order fulfillment cycle time	Responsiveness	Site	-50%	X
7	Custom Procedures	Customs	Site	-30%	X
29	Application downloading	Data visibility	Site	25%	X
28	Application use	Data visibility	Site	25%	
31	Data updating frequency	Data visibility	Site	30%	X
17	Digital services	Data visibility	Site	50%	X
18	Corridor indicators visualized	Data visibility	Site	30%	X
32	Dashboard tabs	Data visibility	Site	35%	
25	Delay on the estimated arrival time	Transit and travel times	Site	-20%	X
33	Overall corridor transit time	Transit and travel times	Site	-20%	X
35	Travel time to Port gate	Transit and travel times	Site	-10%	X
36	Time the driver spends on that drive	Transit and travel times	Site	-25%	X
10	Turnaround time	Terminal/Node efficiency (incl. p	Site	-20%	X
10a	Turnaround time	Terminal/Node efficiency (incl. p	Site	100%	X
10b	Turnaround time	Terminal/Node efficiency (incl. p	Site	50%	
10c	Turnaround time	Terminal/Node efficiency (incl. p	Site	50%	
10d	Turnaround time	Terminal/Node efficiency (incl. p	Site	50%	
10e	Turnaround time	Terminal/Node efficiency (incl. p	Site	50%	
19	Detention and demurrage	Terminal/Node efficiency (incl. p	Site	-25%	
20	Companies interested in logistics no	Terminal/Node efficiency (incl. p	Site	15%	X
16	Terminal saturation time	Terminal/Node efficiency (incl. p	Site	-40%	X
11	(Un)Loading time	Terminal/Node efficiency (incl. p	Site	-20%	X
26	Number of accidents	On-site security & safety	Site	-30%	X
27	Time to react	On-site security & safety	Site	-60%	
12	Modal shift	Modal shift	Site	20%	X
14	Workflow automation	Automation	Site	30%	X
14a	Workflow automation	Workflow time	Site	-30%	X
15	Administration work time	Administration	Site	-25%	X
23	Development & Maintenance	Costs and asset management	Site	-30%	
21	Terminal occupancy rate	Parking availability/efficiency	Site	-25%	
22	Parking search time	Parking availability/efficiency	Site	-30%	
30	Number of parking areas	Parking availability/efficiency	Site	20%	
34	Level of traffic service	Traffic efficiency	Site	20%	X

There are the following key issues with KPIs as evaluation criteria:

- the number of KPIs will differ from Use Case to Use Case. More KPIs are not necessarily better than fewer since all KPIs represent a certain performance. It will be up to the stakeholder in the process to define the weights of how 'representative' a KPI is for the performance of the Use Case;
- not each KPI is measured in the same way. For example, KPI 4 (document number exchange) could be measured as the number of documents for a specific process but also as a percentage to which documents have to be filled;
- KPIs were measured before the implementation of the federated networks and after implementation. These measurement phases are not always the same and the analysis of data therefore requires some interpretation which statistical data to use for the respective measurement period (minimum, maximum, average, etc.).

4.2.3 Step III: Define alternatives

The various Use Cases in the Pilot Sites are representing the respective Pilot Site and are testing in which way the Pilot Site's performance is increasing after implementation of the FENIX connector (= federated platforms). Each Use Case typically represents a specific aspect of the Pilot Site. The FENIX Use Cases are shown in Table 12 below, they are based on the Pilot Site presentations during the 6th General Assembly of FENIX on 10/11 May 2022 in Brussels.

Table 12: List of Use Cases in the Pilot Sites of FENIX

PS	UC	Name	PS	UC	Name
PS AT	1	Track & trace solutions	PS IT2	1	Expected Time of arrival – ETA (Milan)
	2	Customs corridor		2	Reduction of CO2 & NOx emission (Milan)
PS BE1	1	Reservation of time slot		3	Dangerous goods transportation monitoring (Milan)
	2	Real-time vehicle tracking		4	B2A/A2B services like Customs (Milan)
	3	Capacity management		5	Safety and eCustom (Milan)
PS BE2	1	On-time delivery		6	Digitalization of documental flows
	2	Track & trace		7	Machine-assisted replanning of operation in case of disruptions
	3	Dangerous goods service		8	Machine-assisted optimization of truck missions
	4	Digital document exchange		9	Machine-assisted planning of rail shunting maneuvers
	5	Sustainability (CO2-NOx transparency)			
PS FR	1	Dynamic status slot verification	PS NL	1	e-CMR
	2	Slot management		2	e-GATE
	3	Multimodal ETA for cargo optimization	PS SK	1	ERP -> ERP / ERP -> TMS
	4	Dangerous goods		2	ERP "WHS" -> TMS -> ERP "customer"
	5	CO2 reduction		3	ERP MDLZ -> TMS -> ERP "Customer"
	6	Customs optimisation	PS ES	1	Rail Planning
	7	C-ITS for logistics		2	B2A & A2B services with Customs
PS DE	1	Multimodal Freight Capacity		3	Dangerous Goods Authorization
	2	Intermodal Railway Capacity		4	Booking of slots for operations in Dry Port
	3	Intermodal Corridor Data Hub		5	Loading & Discharge lists management of cargo by train
	4	Mode Free Capacity Planning		6	Port2DryPort Track & Trace
PS GR	1	Digitalisation of port processes		7	Business Intelligence applied to intermodal operation
	2	Balanced use of modal availability along the corridor			
	3	Monitoring of status of transport operations			
	4	Traffic management & parking availability			
	5	Yellow Pages & KPI			
PS IT1	1a	Development app for truck arrivals			
	1b	Track & trace of vehicles			
	1c	ETA trucks			
	2a	CO2 & NOx emission reduction			
	2b	Carbon footprint			
	3	Multimodal route planning & re-routing			
	4a	Track & trace of trains (Trieste)			
	4b	Track & trace vehicle/shipment			
	4c	Vehicle movement track & trace between ports			
	4d	Track & trace of trucks entering the port of Trieste			
	5a	TM2.0 services across the TEN-T corridors			
	5b	TM2.0 services across the TEN-T corridors			
	6	Parking booking service			
	7a	Pre-gate operations			
	7b	B2A, A2B services such as Customs			
	7c	International Fast Trade Lane between Europe and Turkey			
	8	Dangerous goods/eCall EGNOS/Galileo			
	9	Carrier certification & eCMR testing in progress			

The potential issues with these alternatives (Use Cases) are:

- the number of Use Cases are different per Pilot Site. Similar for the representation of KPIs in the Use Cases, the representation of Use Cases for the Pilot Sites could be dealt with in a similar way by defining their weights and adding them up accordingly.
- the aforementioned weights are subjective and might be defined differently from stakeholder to stakeholder. This would lead to different results (impact assessment) but also raises the question whether a stakeholder dependent interpretation of the impact assessment should be performed (e.g. by specific stakeholder profiles when defining the weights)

4.2.4 Step IV: Performance evaluation

The performance evaluation is interpreted here as the change of a KPI measurement within a Use Case. This evaluation has to be performed for all KPIs in all Use Cases and then to be 'merged' to provide an overall value (impact assessment indicator). The list of KPIs (Table 11) has therefore to be evaluated regarding the performance of these measurements.

This evaluation often requires an interpretation of the KPI measurements performed (comparison of 'before' and 'after' the implementation). If, for example, the CO₂ emission is reduced due to the implementation of a federated network, then this is undoubtedly a positive result and can be easily assessed (e.g. as the percentage of reduction). If the number of exchanged documents have increased, the question will be whether this is positive (more documents could mean that there is more traffic) or negative (despite the federated network there is still the same or more documents to be exchanged).

This type of evaluation will essentially be performed within Sub-Activity 5.2 (technical and operational evaluation) and will therefore not be repeated within this Sub-Activity. The results of Sub-Activity 5.2 will directly be used to be consistent within the overall FENIX Evaluation Methodology.

Note: Due to the very late delivery of some of the Pilot Site data, the results of the aforementioned evaluation were not available at the time when this draft of Deliverable D5.4 was written. Therefore, an own interpretation of the Pilot Site data will be used in the following.

4.2.5 Step V: Criterion weights

Criterion weights are understood here as the relative importance of the KPIs within a Use Case. As discussed within chapter 3 and 4, AHP will be used to identify the weights of the different criteria. This is best illustrated using a case-specific example (here: UC2 of the Dutch Pilot Site). Please note that the numbers used below are examples only and not the real numbers. The approach is following the approach illustrated in section 3.3.

It is first assumed here that the Use Case uses the following five KPIs (see Table 11):

- KPI 2: Average truck waiting time
- KPI 5: Perfect order fulfilment
- KPI 10: Terminal efficiency
- KPI 14: Workflow automation
- KPI 15: Av. administration work time

Similar to Table 5, the pairwise comparison matrix for UC2 would like depicted in Table 13. Note that the importance values from Table 4 are used here as well. As before, the importance values are filling the top right part of the matrix, and the reciprocal values are calculated and populating the lower left

part of the matrix (indicated by the arrows). The totals at the bottom of the matrix were calculated as the sum of each column in Table 13, similar to Table 6 in section 3.3.

Table 13: Exemplary pairwise comparison matrix for UC2 of the Dutch Pilot Site

Criterion	KPI 2	KPI 14	KPI 10	KPI 15	KPI 5	Weights
KPI 2	1	2	2	8	9	
KPI 14	0.5	1	1	5	7	
KPI 10	0.5	1	1	2	4	
KPI 15	0.125	0.2	0.5	1	2	
KPI 5	0.111	0.143	0.25	0.5	1	
TOTAL	2.236	4.343	4.583	17.5	23.0	

Similar to Table 7 and Table 8 in section 3.3, the matrix is then normalized by using the calculated totals and the weights are determined by the averages of each row. The result is presented in Table 14.

Table 14: Normalised importance matrix and weights for UC2 of the Dutch Pilot Site

Criterion	KPI 2	KPI 14	KPI 10	KPI 15	KPI 5	Weights
KPI 2	0.447	0.461	0.436	0.457	0.391	0.439
KPI 14	0.224	0.23	0.218	0.286	0.304	0.252
KPI 10	0.224	0.23	0.218	0.171	0.174	0.203
KPI 15	0.056	0.046	0.073	0.057	0.087	0.064
KPI 5	0.05	0.033	0.055	0.029	0.043	0.042
TOTAL	1.0	1.0	1.0	1.0	1.0	

These results (last column of Table 14) would then be used to calculate the weighted performance of UC2 within the Dutch Pilot Site. It is clear from these results that KPI 5 and 15 would not play a significant role for the overall impact assessment due to their relatively low weights. This will also mean that under those conditions the measurements performed for these KPIs are not significantly relevant.

4.2.6 Step VI: Decision rules

Decision rules are used to transform the KPI measurements (more accurately: the changes of KPI measurements in between 'before' and 'after' implementation of the federated networks) into standardised numbers or a 'scale'. This scale is typically defined from '0' to '1', where '0' means no change in the measurements (worst possible performance) and '1' means the most optimal change (best possible performance), respectively. The definition of this scale and its interpretation are the issues which have to be defined for this step.

The aforementioned transformation from the KPI measurements to standardised numbers will be performed using so-called Single-Attribute Value Functions (SAVF) These functions translate the performance of KPIs into the performance relevant for a stakeholder or decision maker. There are numerous functions which fulfil these requirements some of which are explained in the following.

Let us consider that the desired performance lies in between '0' and '1' as indicated above. Typical functions can then be:

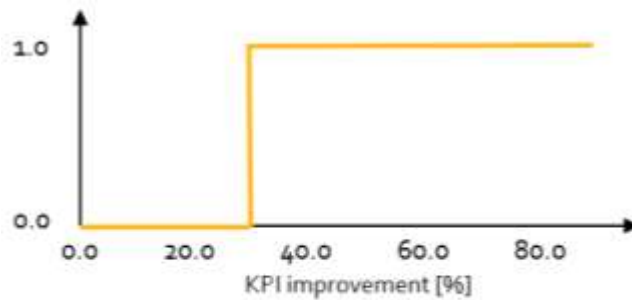
- a boolean function: as soon as value exceeds a trigger value, result is '1', otherwise '0'
- a linear function: increases linearly from '0' to '1' (at maximum or pre-defined value)
- a quadratic function: quadratic relation in between '0' and '1'
- an exponential function in between '0' and '1'

These functions are exemplarily shown in Figure 4 where the desired performance in between '0' and '1' is drawn on the y-axis, and the KPI improvement is expressed in percent and plotted at the x-axis, respectively. The KPI performance could, however, expressed differently here, for example as a difference in waiting time, or a change in the number of documents, or a reduction in the CO₂ emission, etc.

The key difference in between the functions are the threshold value when the desired performance reaches '1' and the type of function in between. Keeping these two parameters flexible means that they could easily be varied, for example in an uncertainty or sensitivity analysis.

Using the SAVF in Figure 4 will translate all KPI performances into the desired performance 'scale' in between '0' and '1' and will therefore allow to produce comparable results from all KPI measurements. It however requires the definition of these functions for each KPI and each type of measurement performed for this KPI. In case a KPI is measured in three different ways, three SAVF are required and have to be defined according to their threshold value and function type. If not further specified the default SAVF would be a linear function between '0' and '1' and a threshold value of 100%.

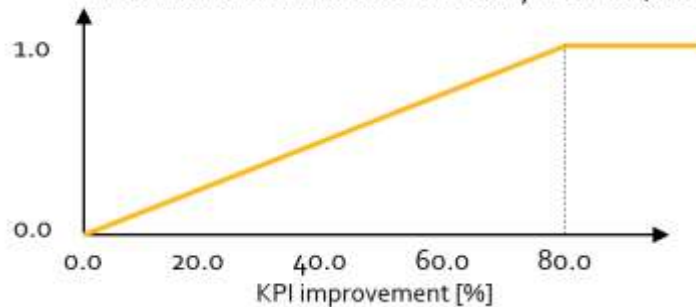
- Boolean function: as soon as value exceeds a trigger value, result is 1, otherwise 0



Example:

- KPI improvement expressed in %
- Trigger value assumed 30%

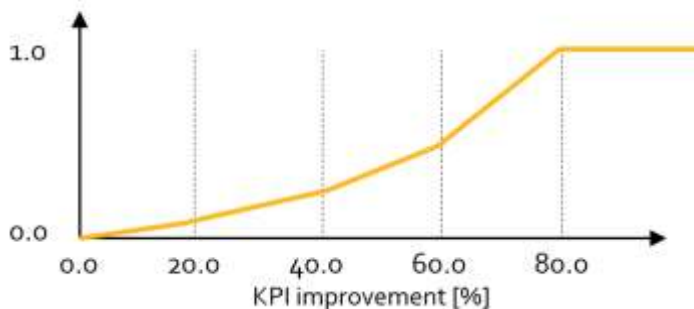
- Linear function: increases linearly from 0 (at 0) to 1 (at maximum value)



Example:

- KPI improvement expressed in %
- Max. value assumed 80%

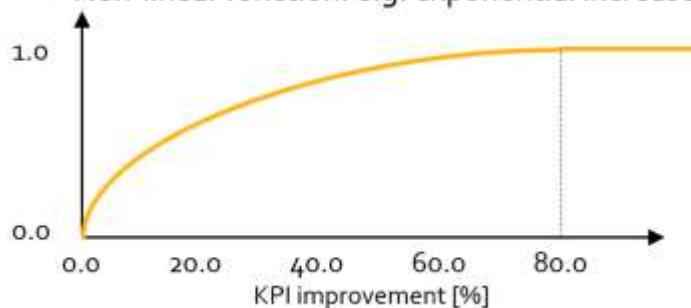
- Quadratic function: quadratic relation in between 0% and 80%



Example:

- KPI improvement expressed in %
- Max. value assumed 80%

- Non-linear function: e.g. exponential increase from 0 (at 0) to 1



Example:

- KPI improvement expressed in %
- Max. value assumed 80%

Figure 4: Different types of single-attribute value functions (SAVF)

4.2.7 Step VII: Aggregation matrix

Within the last step of the evaluation, all previously obtained results have to be brought together to determine the impact assessment indicator. This will first be done using all KPIs and all Use Cases for each Pilot Site. The approach is principally sketched in Figure 5 showing different matrices (results for KPIs in Use Cases) which will be aggregated using the calculated weights from Step V (section 4.2.5) using AHP.



Figure 5: Aggregation steps to achieve the Impact Assessment Indicator for a Use Case

The overall result can then be calculated by bringing together the results of the Use Cases for the Pilot Site in question. The necessary weights for doing so can again be assessed by using AHP (pairwise comparison of the importance of Use Cases) but can also be estimated by providing weights to Use Cases directly. The default calculation here would be based on an equal weight for all Use Cases within one Pilot Site. This means that if there are four Use Cases in one Pilot Site, the individual weights of these Use Cases would be 0.25, giving all Use Cases the same weight.

As per definition, the overall result (overall impact assessment indicator) can only vary in between '0' and '1' where '1' represents the best possible performance. The question remains how this can be interpreted and how meaningful this result will be. Therefore, the 'best possible' performance should be defined which can principally be done on a KPI level in several ways:

- **Comparative case:** the best possible performance is taken as the highest value achieved for the same KPI through all Pilot Sites. This highest value is defined as "1" which means that it will be reached at least once within all Pilot Sites. This approach will allow for a direct comparison in between all Pilot Sites (with respect to the KPI in question). The disadvantage of this method is that if one outstanding result is achieved in only one Pilot Site, this will set the standard for all other Pilot Sites. Furthermore, if there is a large difference in between results achieved (for the same KPI), the lowest result will reflect in a small performance indicator.

- **Benchmark case:** the best possible performance could be defined by a benchmark case. If for example the best possible waiting time for trucks at a terminal is defined as 10 min, all measurements will be compared to this desirable result and if reached, the indicator will be set to "1". The advantage of this case is that an indicator of "1" can always be compared to a known and defined benchmark case.
- **Expectation case:** the improved performance for a specific KPI is compared to the expected performance which was also provided during the measurement and implementation phases of the FENIX federation. As soon as the expected performance is reached or is exceeded the indicator will be set to "1". The disadvantage of this case is that the value for the expected performance is based on a 'subjective' evaluation in the Use Cases and that they will differ from Use Case to Use Case.

For this analysis, the default case will be defined as the 'Benchmark case' where the best possible performance is defined against the defined benchmark for each KPI. Details of this calculation will be discussed in Chapter 5.

4.3 Uncertainty analysis

The steps described before contain elements where either a subjective decision needs to be made or where rather uncertain values have to be entered (e.g. the threshold values in the SAVF). Furthermore, the results of the KPI measurements (before and after the implementation of the federated networks) will contain some uncertainties. It is therefore desirable to perform a sensitivity analysis or an uncertainty analysis of the results.

Uncertainty or sensitivity analysis aims at quantifying the variability of the output (here: the impact assessment indicator for each Pilot Site) under the condition that the input variables or (some of) the calculations are uncertain. It will also help understanding:

- the robustness of the results of the underlying calculations;
- understanding the relation in between input parameters and the impact assessment (output);
- the key input parameters which have most effect on the output;
- potential errors in the model by identifying unexpected results.

Sensitivity analysis are typically performed by variation of one (or several) input parameters and checking the variability of the output parameter. The variation of input parameter(s) are typically done in between (pre-defined) margins with equidistant steps. The disadvantage of this approach is often that the variation of the input parameter is more often distributed around the pre-defined value following a probabilistic density function rather than uniformly distributed (as assumed in this type of sensitivity analysis).

To overcome the aforementioned limitations, so-called Monte-Carlo simulations or Monte-Carlo methods²³ can be applied. In this approach all input parameters are varied at the same time and the 'variability' of the input parameters is assumed to follow a probabilistic density function (e.g. Normal, Weibull, Pareto, or any other distribution). Each parameter is then assumed to be a random realisation of this distribution and the model is run several (thousands of) times to provide the output (which is then also distributed, typically around the deterministic result which was achieved without running the Monte-Carlo simulation).

In 2014, Farrance & Frenkel²⁴ have performed a review on the use of this method to quantify uncertainties in biochemical measurements. They have used Excel as a basis spreadsheet calculation for this data analysis and concluded that Monte-Carlo simulations are a powerful tool to provide uncertainties of the outputs of these measurements.

McMurray et al. (2017)²⁵ have looked into uncertainties of forestry and greenhouse gas accounting following IPCC recommendations. They pointed out that Monte-Carlo simulations used only for the uncertainties of (input) parameters might lead to an underestimation of the output uncertainties so that it would be preferable to use it for the whole calculation process.

Due to the high number of simulations often required to achieve statistically stable results, Monte-Carlo Simulations can be quite time-consuming. A survey on Monte-Carlo Methods has recently been performed by Zhang (2020)²⁶ and shows that modern techniques are nowadays available to overcome the (time-consuming) large number of simulations often used.

The Monte-Carlo method will be used in this study and requires the following steps to be performed:

- identify the input parameters which are uncertain;
- determine or assume the type of probability distribution for each of these parameters (if measurements were performed, the statistical analysis of these measurements could be used as input);
- determine or assume the standard deviation of each of these parameters (either available from measurements or as an assumed percentage);
- calculate the required parameters of the probabilistic density function by Moment Estimator approach (or any other method of moments²⁷);
- install a random number generator providing numbers in between '0' and '1';

²³ https://en.wikipedia.org/wiki/Monte_Carlo_method

²⁴ Farrance, I. and Frenkel, R. (2014). "Uncertainty in Measurement: A Review of Monte Carlo Simulation Using Microsoft Excel for the Calculation of Uncertainties Through Functional Relationships, Including Uncertainties in Empirically Derived Constants." Clin Biochem Rev, vol. 35, no. 1: pp. 37-61

²⁵ McMurray, A., Pearson, T. and Casarim, F. (2017). "Guidance on applying the Monte-Carlo approach to uncertainty analyses in Forestry and Greenhouse Gas Accounting", WinRock International, 19 pp., 3 Annexes.

²⁶ Zhang, J. (2020). "Modern Monte Carlo Methods for Efficient Uncertainty Quantification and Propagation: A Survey", Oak Ridge National Laboratory, Computer Science and Mathematics Division, 42 pp.

²⁷ [https://en.wikipedia.org/wiki/Method_of_moments_\(statistics\)](https://en.wikipedia.org/wiki/Method_of_moments_(statistics))

- interpret the random number a cumulative density function output of the respective parameter and back-calculate the corresponding input parameter of the probability distribution;
- use these realisations of input parameters to calculate the output;
- perform this calculation sufficient times to provide a stable outcome;

Depending on the type of probabilistic density function, the output will be distributed similarly. For example, if all input parameters are normally distributed, the output will also be normally distributed. Assuming a uniform distribution for the input parameters is like performing the previously described sensitivity analysis but with randomly selected input realisations rather than pre-defined realisations. Other than a normal or extreme value distribution, a uniform or triangular distribution have clear lower and upper margins beyond which no data will be simulated. For example, in a uniform distribution with an average of 1.0, a lower margin of 0.5 and an upper margin of 1.5, no data will be simulated below 0.5, and above 1.5, respectively.

In this study, the default distribution is a normal distribution. The Gauss or Normal-distribution is shown in Figure 6 where the input values are shown on the x-axis (around the average value μ with a standard deviation σ) and the probabilistic density is shown on the y-axis. The Normal distribution is symmetrical around the average (so-called bell curve). Figure 6 also shows that 68% of all values lie within ± 1 standard deviation around the average, and 95% within ± 2 standard deviations.

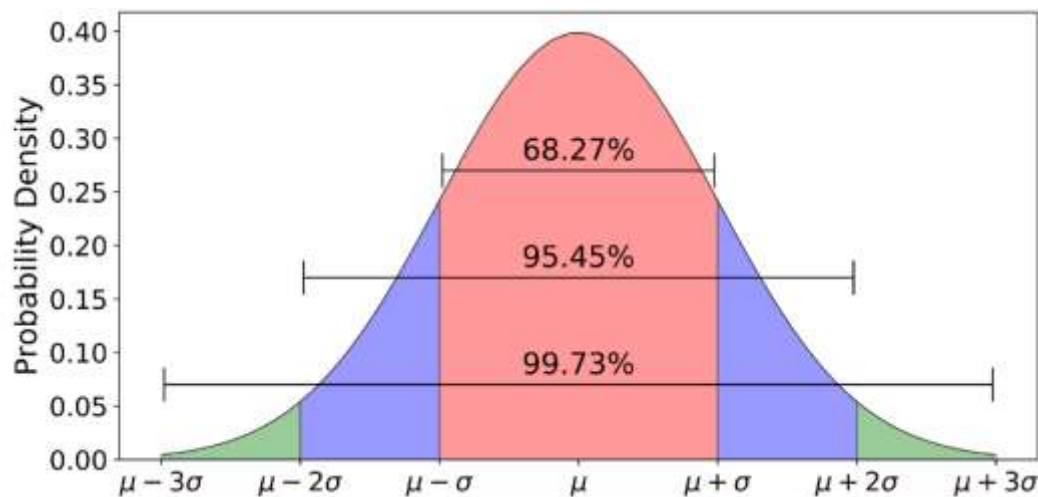


Figure 6: Probabilistic density function of a Normal distribution

The coefficient of variation CoV is defined as the standard deviation divided by the average and can therefore be expressed as a percentage of the average. If, for example, the average of an input parameter is 5 and the CoV is 10%, it means that the standard deviation is 0.5 and 68% of all values lie

within 4.5 and 5.5 (95% of all values within 4 and 6). This allows for a relatively simple input of parameters (providing the average or deterministic value, the CoV, and the type of distribution).

4.4 Summary

This chapter has discussed the methodology to be used to determine the overall impact assessment indicator for each Pilot Site. The work performed within this Sub-Activity was first embedded in the overall FENIX Evaluation Framework (section 4.1). In the following, the seven steps proposed in chapter 3 were further elaborated to perform the calculations for each Pilot Site (section 4.2). Open questions in these steps were discussed and default solutions were proposed.

The necessary calculations are not overly complex but use a lot of data due to the high number of KPIs, Use Cases, Pilot Sites, and the performed measurements. Due to the subjectivity of many parameters and assumptions, a uncertainty calculation approach has been included in the overall approach (section 4.3). This approach is based on a Monte-Carlo simulation assuming different statistical distributions (default: Normal distribution) for certain parameters. The statistical distributions, the parameters in question, and the basic principles of the Monte-Carlo simulation are discussed in section 4.3.

Chapter 5 will now discuss the calculations performed on the basis of the methodology described here and will present some exemplary results to illustrate the software used. Details of the results will be discussed in chapter 6 and are available in the reports of each Pilot Site.

5 CALCULATIONS

This chapter discusses the details of the calculations performed using the background in chapter 3 and the methodology in chapter 4. The chapter will first introduce the software which was used (section 5.1) and discusses the required input parameters (section 5.2). In section 5.3, the weights for the KPIs used in the Use Cases are calculated using AHP, before section 5.4 shows how the overall results of the Pilot Site are calculated. Eventually, in section 5.5 the uncertainty calculations are demonstrated.

5.1 Introduction

The calculations described under chapter 4 require a software with the following features:

- read data input provided in MS Excel (KPI measurements);
- adapt to a flexible number of KPIs, Use Cases, and Pilot Sites;
- provide understandable graphics and tables for input in Pilot Site reports;
- perform AHP (matrix) operations;
- apply SAVF to KPI measurements in a flexible way;
- perform impact assessment calculations for each Pilot Site;
- perform Monte-Carlo simulations for uncertainty analysis.

Based on these requirements, it was decided to use MS Excel 365 with macros scripted in the MS macro language (Visual Basic for Applications, or short: VBA). The software was named FEMCAHP (short for FENIX-Evaluation using MCA-AHP). The software will run on MS desktop computers with Office 365 installed, but not on Apple machines (even though there is MS Office 365 for Mac available) and not on the internet-based version of MS Excel 365. The user will have to allow macros to run and might need to adapt the security settings in this respect.

The advantage of the self-programmed modules in FEMCAHP are that any necessary modification can still be implemented and that it can be extended in case any additional request might come up.

Figure 7 shows the main screen of FEMCAHP. It is principally split in an 'Introduction' part, 'Input', 'Output', 'Uncertainty' and 'Info'. The principle is that all required steps to run FEMCAHP is done by buttons and pre-defined input fields which should be easy to work with. It is not required to change any of the Excel sheets or the underlying macros. However, this can be done (no cells nor macros are protected) but due to the number and complexity of (some of) the sheets and the background macros it is not recommended to do this without detailed knowledge of MS Excel and VBA.

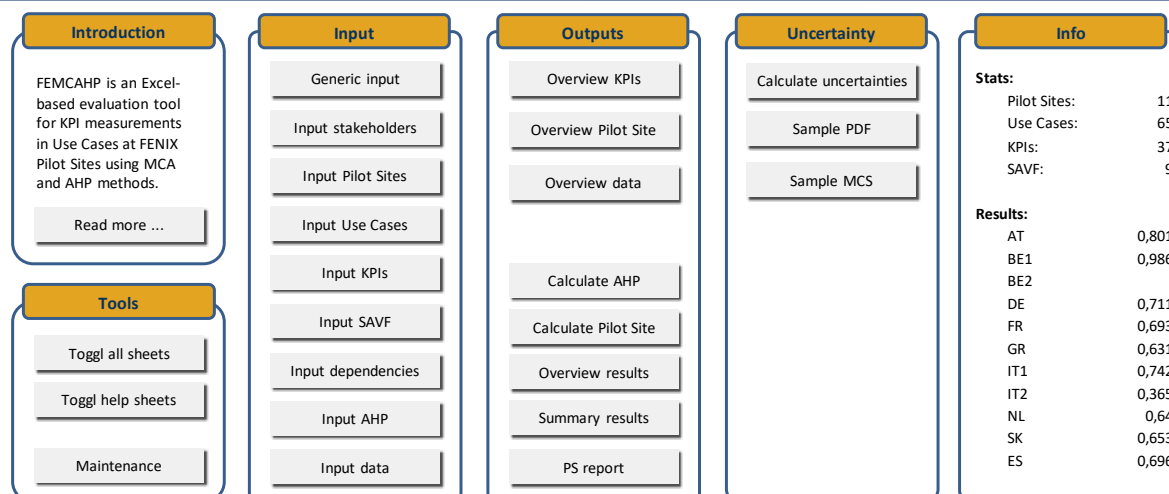


Figure 7: Main screen of developed software FEMCAHP for impact assessment

The following sections discuss the usage of FEMCAHP (input) and the details of calculations (if not already addressed within chapter 4).

5.2 Required input

Figure 7 shows that there is quite some input required to run the software. Much of that, however, is pre-defined input like the input for Pilot Sites (number, country, and names of the 11 FENIX Pilot Sites), the Use Cases (the corresponding Pilot Site, the number and the name of the 65 Use Cases (at the time this deliverable was written)), and the KPIs (number, category, and names of the 37 pre-defined KPIs of FENIX). However, all of these 'pre-defined' inputs are adaptable and FEMCAHP will consider any changes in those inputs. Some of these inputs will be further discussed later in this chapter. The remaining inputs are:

- General input
- Input of dependencies
- Input AHP (pairwise importance matrix)
- input of SAVF (name, type, threshold value, and parameters of the SAVF)
- Input data (KPI measurement data)

These inputs are discussed in more detail in the following.

5.2.1 General Input

The input sheet for 'General Input' is shown in Figure 8 below. All input sheets are structured in a similar way, comprising a header, an introduction (not always), and clearly structured sections with a

description of the required input or output. The coloured fields are input fields, all other fields should not be changed. All sheets are printable (for reporting purposes) and will print on either A4 landscape or orientation mode, depending on the columns used on the sheet.

Notes:

- The input parameter listed here are of generic type. More specific input parameter will be requested when working with the specific modules of FENeval.
- The general rule for inputs is that orange fields can be changed, all other fields (especially when marked grey) should only be changed by experienced users.
- NOTE: the uncertainties of specific parameters can be 'switched off' if the percentage is set to zero (0%)

INPUT

Project:	FENIX PS Evaluation
Analysis by:	ESC Andreas Kortenhaus

Pilot Site:	PS IT1
Stakeholder:	SHP: Shipper
Best perform.:	1

Note: explanation provided in section 3.2.7 of D5.4

select from dropdown list
 select from dropdown list
 0: pre-selected values acc. to 'Inp_SAVF'
 1: benchmark case (default)
 2: comparison case (comp. to other PS)
 3: expectation case (within PS)

Delimiter:	;
Mark low value:	0.2
Mark high value:	0.9
Data path:	X:\justASK!_Projects\ESC\Projects\FENI
Data file:	Operational Evaluation_Pilot Sites.xlsx
Print path:	x:\AKS\temp\

delimiter for listing KPIs for UCs
 value below which results are highlighted (low performance)
 value above which results are highlighted (high performance)
 path for input data
 file for input data, requires certain structure
 path for printing files

UNCERTAINTIES

Measurements:	10%	-	N
KPI weights:	5%	-	N
UC weights:	5%	-	N
SAVF perc.:	5%	-	N
SAVF type:	fixed		
No. simulat.:	10,000		
No. display:	2,000		
No. classes:	20		

data from As-Is and To-Be measurements
 weights of KPIs coming from AHP analysis
 weights of UC results for Pilot Site
 calculation of results using SAVF for KPIs
 type of SAVF: 'fixed' or 'random'
 no of Monte Carlo simulations
 how often results are displayed (0 = no display)
 classes of result histogram

Figure 8: General input screen of FEMCAHP

The general input comprises some general input parameters, for example the Pilot Site to be investigated (here: the Spanish Pilot Site), the stakeholder profile to be used (here: shippers), the type of best performance evaluation, and a delimiter which is later used for separation of input values.

In the 'Uncertainties' section, the CoV for some variable input parameter can be changed, together with the type of the probabilistic density function (here: 'N' stands for Normal distribution). The input for 'measurements' refer to the KPI measurements where both the baseline and To-Be measurements are treated with the same uncertainty. KPI weights and UC weights refer to the calculated weights of KPIs (using AHP) or the equally distributed weights of Use Cases in the Pilot Site, respectively. The 'SAVF perc.' refers to the threshold value of SAVF, see also section 5.2.4. If for all these parameters the CoV is set to 0%, the uncertainty calculation will not be performed for this specific parameter.

A special case is the SAVF type. This defines the type of function used to translate the KPI measurements into a scale of '0' to '1'. There are two input options for this parameter ('fixed' or 'random'). The latter input assumes a random type of SAVF and therefore changes from boolean to linear, quadratic, and logarithmic functions. This will lead to impact assessment indicators which are more widely spread in each calculation of the Monte-Carlo simulation (see section 4.3) than just by variation of the CoV.

At the end of the list, the simulation parameters can be changed (number of simulations: here 10,000, how often the results are displayed (here: every 2,000 simulations), and the number of classes used for the histogram figure (here: 20).

5.2.2 Input of dependencies

The inputs discussed so far are of general type or are only showing the lists of Pilot Sites, Use Cases, and KPIs, but the connections between them are not yet fully described. While the list of Use Case also contains the Pilot Sites where these Use Cases were defined, the relation between Use Cases and KPIs have not yet been defined. This happens on the input sheet for 'dependencies', depicted in Figure 9.

The input sheet contains the list of Use Cases (and the Pilot Sites they are located in), but also a column called 'Desired KPIs' which contains the KPIs as initially defined for this specific Use Case (separated by the delimiter which had to be entered on the 'General Input' sheet, see section 5.2.1). The next column simply counts the number of KPIs which were entered. The column 'KPI list' contains the list of actual deployed KPIs for the Use Cases (in the same format than the desired list), and can be updated from the list of actual measurements (button 'KPI from data' on top).

Pilot Sit	UC no.	UC description	Desired KPIs	NDesKl KPI list	Vo. KPI: Calc. weights	Fin. Weights
PS AT	1	Track & trace solutions	4; 13; 33; 20	4 4; 20; 33	3 0,342; 0,121; 0,537	
PS AT	2	Customs corridor	4; 13; 20	3 4; 20	2 0,778; 0,222	
PS BE1	1	Reservation of time slot	5; 6; 8; 14	4 5; 6; 14	3 0,675; 0,176; 0,149	
PS BE1	2	Real-time vehicle tracking	5; 6; 14	3 5; 6	2 0,875; 0,125	
PS BE1	3	Capacity management	8	1	0 1	
PS BE2	1	On-time delivery	13; 2	2	0 1	
PS BE2	2	Track & trace	5; 13; 6; 25; 19; 12; 14	7	0 1	
PS BE2	3	Dangerous goods service	8; 13; 14	3	0 1	
PS BE2	4	Digital document exchange	4; 5; 13; 6; 25; 14; 15	7	0 1	
PS BE2	5	Sustainability (CO2-NOx transparency)	4; 8; 13; 2; 6; 7; 14; 15	8	0 1	
PS FR	1	Dynamic status slot verification	1; 9; 13; 12	4 2; 8	2 0,389; 0,611	
PS FR	2	Slot management	8; 13; 2; 25; 21; 22	6 2; 8; 10	3 0,317; 0,454; 0,230	
PS FR	3	Multimodal ETA for cargo optimization	8; 13; 2; 10; 21; 22	6 1; 2; 8	3 0,204; 0,327; 0,469	
PS FR	4	Dangerous goods	1; 8; 13; 2; 21	5 4; 14a; 26	3 0,585; 0,251; 0,165	
PS FR	5	CO2 reduction	4; 13; 26; 27; 14; 15; 21	7 1; 8; 9	3 0,233; 0,535; 0,233	
PS FR	6	Customs optimisation	1; 9; 8; 13; 24	5 2; 6; 8	3 0,308; 0,251; 0,441	
PS FR	7	C-ITS for logistics	8; 13; 2; 6; 7	5 1; 2; 6; 8; 10	5 0,136; 0,218; 0,177; 0,312; 0,158	
PS DE	1	Multimodal Freight Capacity	1; 3; 8; 9	4 1; 3; 8; 9	4 0,130; 0,442; 0,298; 0,130	
PS DE	2	Intermodal Railway Capacity	13	1 8	1 1	
PS DE	3	Intermodal Corridor Data Hub	13; 37	2 37	1 1	
PS DE	4	Mode Free Capacity Planning	1; 3; 8; 9; 12	5 1; 3; 8; 9; 12	5 0,117; 0,398; 0,269; 0,117; 0,099	
PS GR	1	Digitalisation of port processes	1; 2; 4; 7; 8; 14a; 15	7 1; 2; 4; 7; 8; 14a; 15	7 0,088; 0,140; 0,226; 0,152; 0,201; 0,097; 0,097	
PS GR	2	Balanced use of modal availability along	13	1	0 1	
PS GR	3	Monitoring of status of transport operat	13	1 5; 37	2 0,800; 0,200	
PS GR	4	Traffic management & parking availabilit	13	1 2; 34; 35	3 0,413; 0,270; 0,317	
PS GR	5	Yellow Pages & KPI	13	1 8; 14; 17; 18; 31	5 0,317; 0,152; 0,206; 0,192; 0,132	
PS IT1	1a	Development app for truck arrivals	8; 13; 17; 18; 32; 14	6 2	1 1	

Figure 9: Extract of input of dependencies and calculation of weights of KPIs for Use Cases

The last two columns consider the weights of KPIs in the respective Use Case where the column 'Calc. weights' uses the input for the AHP method (discussed later in section 5.3) and performs the complete AHP calculation for all KPIs and each Use Case in case the number of KPIs is larger than 2. In case the input for the AHP calculation is not provided or the number of KPIs is smaller than 3, the weights are equally distributed over the KPIs. This calculation can be started by pressing the button 'Calc. weights' on top of the page.

In the last column 'Fin. weights', these calculations can be overwritten by manual input. Whenever there is an input available in this last column, all further calculations will use this input for the KPI weights. In case, there is no final weights defined, the calculated results will be taken.

5.2.3 AHP input

The input for the AHP calculations is provided on a separate input sheet. According to section 4.2.5, the pairwise importance matrix has to be filled for all Use Cases which are using more than 2 KPIs. At the moment of writing, there were about 40 Use Cases with more than 2 KPIs over all 11 Pilot Sites (in case of the desired list of KPIs). After analysis of the available data this number has reduced to 24 Use Cases. Since the number of KPIs is sometimes quite large, the corresponding matrices range from 3 KPIs to maximum 20 KPIs. A sample input matrix is provided (see Figure 10) which has been produced for all Use Cases with more than 2 KPIs.

Notes

- input matrices will be generated only for 3 or more KPIs per Use Case (input is taken from sheet 'Inp_dep')
- Fill by ranking' will use the ranking defined in 'Inp_KPI' and fill the sheets. Use 'Generate Input' first!
- use carefully! Existing numbers will be overwritten! Make a copy first!
- matrices are changed if the sample are changed and 'Generate input' is run again, size of matrix is fixed!

Sample

Crit.	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI	KPI
KPI	1																		
KPI		1																	
KPI			1																
KPI				1															
KPI					1														
KPI						1													
KPI							1												
KPI								1											
KPI									1										
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KPI													1						
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KPI																1			
KPI																	1		
KPI																		1	
KPI																			1
TOTAL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Figure 10: Sample input matrix for entering importance values for AHP

As soon as these matrixes have been filled, the input will be used in all calculations where the AHP method is used to calculate the weights of the KPIs in the Use Cases. If the input is missing, the weights will be similarly distributed over all KPIs in the specific Use Case (i.e. the weight will be 1/10 for each KPI for 10 KPIs).

The values for filling the matrix are described in Table 4, a calculation visualisation, including the calculation of the consistency, can be performed by checking the sheet 'Calc_AHP' in FEMCAHP. For space reasons, the latter visualisation is however limited to a maximum of 5 KPIs. Whenever more KPIs are used, the calculation will not be correct on this sheet, but the background calculation will of course always consider the complete number of KPIs.

Due to the high number of AHP matrices required for all Use Cases and KPIs used, and due to the very limited time available for the analysis after the delivery of data from Pilot Sites at the end of the project, a different approach was also developed. The principal idea is that all pairwise comparisons are based on a ranking of the KPIs in use. This 'KPI ranking' lists all KPIs in a certain order from 1 to the total number of KPIs where KPIs can also share a rank (and therefore would have the same importance). The difficulty remains that this ranking would be subjective to the stakeholder who has to rank the KPIs. It seems evident that e.g. a shipper would rank KPIs differently than a warehouse manager.

Therefore, the following steps were performed:

- an input of stakeholder was provided;
- depending on this input different stakeholder rankings are entered or can still be entered;
- the ranking was then 'condensed' from a complete list of KPIs to a virtual list from 1 to 9, matching the importance scale shown in Table 4;
- this scaled ranking was then used to enter the AHP matrices for pairwise comparisons automatically;
- with this input the same procedure was followed than before.

The latter approach allows for a lot less input than filling all AHP matrices individually. It also does not require a consistency check any more, since the input is consistently following an overall ranking. Furthermore, the approach provides identical inputs for all Use Cases in all Pilot Sites so that the results achieved in the Pilot Sites are better comparable. In addition, any dependency on the input on the stakeholder perspective is explicitly considered. For these reasons, the latter approach has been adopted for this study.

5.2.4 Input SAVF

The Single-Attribute Value Functions (SAVF) have been introduced in section 4.2.6 (Step VI: Decision rules). The sheet 'Inp_SAVF' in FEMCAHP provides the input for these functions by specifying a number, the name (boolean, linear, etc.), a type code, the threshold percentage, two parameters (a and b) to describe the underlying function, and the formula used (see Figure 11).

Additional SAVFs can still be added by following the same principle although it is believed that the available functions are already a good start for assigning a 'transformation' of KPI measurements to an output (impact assessment) scale in between '0' and '1'. The SAVFs have to be assigned to the KPIs in the Use Cases which will be briefly described in section 5.2.5 below and further explained in sections 5.4 and 7.

No.	Name	Type	MaxPerc	a	b	Comm.
1	Boolean	11	30			change perc. to be reached
2	Boolean	12	100			absolue value to be reached
3	Linear	21	80	1.25		$y = a * x$
4	Linear	22	100	1		$y = a * x$
5	Linear	23	-80	-1.25		$y = a * x$
6	Quadratic	31	80	1.5625		$y = a * x^2$
7	Quadratic	32	100	1		$y = a * x^2$
8	Exponential	41	80	1	1.8	$y = \log_b (x + a)$
9	Exponential	42	100	1	2	$y = \log_b (x + a)$

Note:

The 'MaxPerc' input for types '11', '21', '31', etc. will be overwritten in case the Best performance type is NOT set to '0' (see input). The maximum percentage will be adapted according to the selected method. Additionally, types '22' and '23' and all future type starting with '2' will also be overwritten. Type '21' is used as default.

Figure 11: Input sheet for entering SAVF in FEMCAHP

5.2.5 Input of KPI measurements

The sheet 'Inp_data' lists all available measurements of KPIs for all Pilot Sites, Use Cases, and KPIs. During the calculation, this sheet will be consulted to obtain the relevant measurements and use them for the calculation of the performance of the Use Case. Figure 12 shows the input sheet for these measurements.

Each row contains first the Pilot Site, the Use Case, and the KPI where the measurements have been performed (incl. a column with just the KPI number). The next two columns contain the values itself for the baseline measurements ('As-Is') and the 'To-Be' measurements. These values will be the average values over the measurement periods (if not agreed otherwise within the evaluation team and the Pilot Site) whereas the next column contains the unit in which these measurements were performed.

The column 'Result' calculates the changes between 'As-Is' and 'To-Be' in percent. This number is either positive if the 'To-Be' measurements are larger than the 'As-Is' measurements or negative if the number has decreased. The column 'Expect.' contains the expected value for each of these measurements which are also provided by the Pilot Sites. The column 'Unit' shows in which unit the measurements have been performed.

No.	Pilot Site	Use Case desc.	UC	KPI desc.	KPI	As-Is	To-Be	Result	Expect.	Unit	SAVF
1	PS AT	1: Track & trace solutions	1	4: (Physical) document number exchange	4	6	4.666667	-22.2%	-20,0%	-	23
2	PS AT	1: Track & trace solutions	1	20: Companies interested in logistics noc	20	56	62.333	11.3%	30,0%	-	22
3	PS AT	1: Track & trace solutions	1	33: Overall corridor transit time	33	6	5.25	-12.5%	-20,0%	h	23
4	PS AT	2: Customs corridor	2	4: (Physical) document number exchange	4	4	2	-50.0%	-100,0%	-	23
5	PS AT	2: Customs corridor	2	20: Companies interested in logistics noc	20	56	67.66667	20.8%	40,0%	-	22
6	PS BE1	1: Reservation of time slot	1	5: Delivery reliability	5	0	30	0	100,0%	%	21
7	PS BE1	1: Reservation of time slot	1	6: Order fulfillment cycle time	6	96	50	-47.9%	-20,0%	min	23
8	PS BE1	1: Reservation of time slot	1	14: Workflow automation	14	0	44.8	0	100,0%	%	21
9	PS BE1	2: Real-time vehicle tracking	2	5: Delivery reliability	5	0	11.1	0	100,0%	%	21
10	PS BE1	2: Real-time vehicle tracking	2	6: Order fulfillment cycle time	6	96	50	-47.9%	-20,0%	min	23
11	PS FR	1: Dynamic status slot verification	1	2: Waiting times	2	33.2	26.5	-20.2%	0,0%	%	23
12	PS FR	1: Dynamic status slot verification	1	8: Product/shipment visibility	8	66.7	82	22.9%	100,0%	%	21
13	PS FR	2: Slot management	2	2: Waiting times	2	33.2	26.5	-20.2%	0,0%	%	23
14	PS FR	2: Slot management	2	8: Product/shipment visibility	8	66	82	24.2%	100,0%	%	21
15	PS FR	2: Slot management	2	10: Turnaround time	10	27	93.435	246.1%	<20	?	23
16	PS FR	3: Multimodal ETA for cargo optimizati	3	1: CO2 emissions	1	5570.35367	5241.472	-5.9%	<1000	g/km	23
17	PS FR	3: Multimodal ETA for cargo optimizati	3	2: Waiting times	2	33.2	26.5	-20.2%	0,0%	%	23
18	PS FR	3: Multimodal ETA for cargo optimizati	3	8: Product/shipment visibility	8	66	82	24.2%	100,0%	%	21
19	PS FR	4: Dangerous goods	4	4: (Physical) document number exchange	4	6	14.88	148.0%	75,0%	-	23
20	PS FR	4: Dangerous goods	4	14a: Workflow automation	14a	5	2.603261	-47.9%	<2	min	23
21	PS FR	4: Dangerous goods	4	26: Number of accidents	26	130.666667	2	-98.5%	<20	-	23
22	PS FR	5: CO2 reduction	5	1: CO2 emissions	1	5570.35367	5241.472	-5.9%	<800	g/km	23
23	PS FR	5: CO2 reduction	5	8: Product/shipment visibility	8	66	82	24.2%	100,0%	%	21
24	PS FR	5: CO2 reduction	5	9: NOx emissions	9	1.95	2085.5	#####	<1.6	g/tkm	23
25	PS FR	6: Customs optimisation	6	2: Waiting times	2	33.2	26.5	-20.2%	0,0%	%	23
26	PS FR	6: Customs optimisation	6	6: Order fulfillment cycle time	6	9.69	6.535	-32.6%	<7	d	23
27	PS FR	6: Customs optimisation	6	8: Product/shipment visibility	8	66	82	24.2%	100,0%	%	21
28	PS FR	7: C-ITS for logistics	7	1: CO2 emissions	1	5570.35367	5241.472	-5.9%	<1000	g/km	23
29	PS FR	7: C-ITS for logistics	7	2: Waiting times	2	33.2	26.5	-20.2%	0,0%	%	23
30	PS FR	7: C-ITS for logistics	7	6: Order fulfillment cycle time	6	9.69	6.535	-32.6%	<7	d	23
31	PS FR	7: C-ITS for logistics	7	8: Product/shipment visibility	8	66	82	24.2%	100,0%	%	21
32	PS FR	7: C-ITS for logistics	7	10: Turnaround time	10	183.37	93.435	-49.0%		h	23

Figure 12: Extract of KPI measurements in FEMCAHP

The last column contains the type of the SAVF which can either be assigned via the software (by pressing the button 'Assign SAVF' on top) or added manually. The default value is '21' (see also Figure 11) which determines a linear relation between measurements and result scale and a threshold value of 80%. Details of these calculations will be discussed further in section 5.4 and 5.2.4.

5.3 Calculate weights for KPIs using AHP

As already discussed in section 3.3 and 4.2.5, AHP is used for calculating the weights of the KPIs used in the Use Cases. The FEMCAHP software follows the example calculation provided for the purchase of a car in section 3.3 but has been expanded to a maximum of 20 KPIs per Use Case. The visualisation of the procedure in sheet 'Calc_AHP' (see also section 5.2.3) uses maximum 5 KPIs to show how the calculation works.

In Figure 13 to Figure 15, the AHP calculation is shown for Use Case 2 of the Spanish Pilot Site with 3 KPIs (KPI 4, 7 and 15).

A step-wise calculation is shown (with five or fewer KPIs) on how to apply AHP pairwise comparison to weighing KPIs for each of the Use Cases (UC) in the Pilot Sites (PS).

Input:

Pilot Site: PS ES

Use Case: 2: B2A & A2B services with Customs

KPIs: 4; 7; 15

[Show input](#)
[Calculate](#)
Step 1. Enter comparison values and calculate reciprocals and totals

Crit.	4	7	15	Weights	
4	1	1.484848	2.333333		
7	0.67	1	1.571429		
15	0.43	0.64	1		
	0.00	0.00	0.00	1	
	0.00	0.00	0.00	0.00	1
TOTAL	2.102	3.121	4.905	1.000	1.000

Figure 13: Calculation example for AHP within FEMCAHP, step 1

After the input is provided on the top of the sheet, the 'Calculate' button searches for the AHP input on the respective input sheet and fills the importance matrix shown in Figure 13, including the reciprocal values in the lower left of the matrix, and the totals of each column at the bottom.

In the next step (Step 2 in Figure 14), the weights are calculated from the normalised matrix by averaging the rows, showing that for the selected input KPI 4 receive the highest weight.

In Step 3 of Figure 14, the weighted sum matrix is calculated as a prerequisite to obtain the consistency index later.

Due to the alternative approach discussed in section 5.2.3 the normalised matrix and the weighted sum matrix add all up to 1.0 for each KPI column which would not be the case if a pairwise comparison approach had been used. For the same reason, the consistency check of the matrix will succeed (CR = CI).

Step 4 in Figure 15 shows the calculation of the consistency ratio CR according to the steps discussed in section 3.3.

Step 2. Calculate relative importances and weights

Crit.	4	7	15	Weights
4	0.476	0.476	0.476	0.476
7	0.320	0.320	0.320	0.320
15	0.204	0.204	0.204	0.204
TOTAL	1.000	1.000	1.000	1.000

Step 3. Calculation of weighted sum matrix

Crit.	4	7	15	W. sums	norm. s.
4	0.476	0.476	0.476	1.427	3.000
7	0.320	0.320	0.320	0.961	3.000
15	0.204	0.204	0.204	0.612	3.000
TOTAL	1.000	1.000	1.000		3.000

Figure 14: Calculation example for AHP within FEMCAHP, step 2 and 3

Step 4. Check consistency of matrix

After Saaty & Bodenkamp (2008)

$$CR = CI/RI$$

				Saaty & Bodenkamp (2008)	
where	CR	=	Consistency Ratio	n	RI
	CI	=	Consistency Index	3	0.52
	RI	=	Consistency Index of a random matrix (Random Index)	4	0.89
				5	1.11
				6	1.25
here:	n	=	3	7	1.35
	RI	=	0.52	8	1.4
				9	1.45
				10	1.49
				11	1.52
				12	1.54
				13	1.56
				14	1.58
				15	1.59

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

where λ_{max} = principal eigenvalue of matrix

$$CI = 0$$

$$CR = 0 < 0.1$$

The result is consistent. The weights calculated under Step 2 can be used.

Figure 15: Calculation example for AHP within FEMCAHP, step 4

In this case, the consistency ratio is calculated to CR = 0.0 (as expected) so that the weights calculated here could be used for the following determination of the impact assessment.

5.4 Calculate Pilot Site results

The overall objective of FEMCAHP is to provide calculations of the impact assessment indicators for all Pilot Sites. Whilst the input sheets described before, together with the calculation of the weights using AHP and the assignments of SAVF to the KPI measurements are first steps in performing these calculations, FEMCAHP is designed to perform all these steps in one sheet.

FEMCAHP also provides a statistical overview of all KPIs in the Pilot Sites which might be useful to check before starting the calculation. In sheet 'Ovr_KPI' the table presented in Figure 16 is shown.

Pilot Sites

Acr.	No. UCs	No. KPIs	No. uniq. KPIs	Min.	Max.	Most	Data
PS AT	2	5	3	4	33	4	5
PS BE1	3	5	3	5	14	5	5
PS BE2	5	0	0				0
PS DE	4	10	6	1	37	8	13
PS ES	7	13	6	2	36	15	33
PS FR	7	22	9	1	26	8	22
PS GR	5	15	15	1	37	2	20
PS IT1	18	14	8	1	29	14a	14
PS IT2	9	21	13	1	36	2	27
PS NL	2	7	6	2	15	4	7
PS SK	3	9	4	4	14	4	9
ALL	65	43	73	1	37	2	155

Figure 16: Overview of Use Case and KPIs used in the FENIX Pilot Sites

Figure 16 displays the overall number of KPIs in the Pilot Sites, but also the number of unique KPIs. The latter is different from the first since some of the KPIs are used in different Use Cases. The table also shows the smallest and highest number of KPI used and the most often used KPI in the Pilot Sites. At the bottom of the table the same statistics is provided for all Pilot Sites, showing that from the overall 37 KPIs 26 KPIs are used where KPI 8 (Product/shipment visibility) is the most often used. The last column in Figure 16 shows the number of data available for each of the Pilot Sites. Note that the latter number might be misleading since each data row counted here actually comprises various measurements for As-Is and To-Be measurements (which are then averaged to be used for this analysis).

Once the input sheets for one Pilot Site are filled and the respective Pilot Site has been selected in the 'Input' sheet, the calculation for this specific Pilot Site can be performed. In this section, the calculation steps which will be performed for this analysis are briefly listed here:

- Initialise all Use Cases, including:
 - read number of Use Cases
 - read the number of unique KPIs in the Pilot Site
 - read the weights for each Use Case (no re-calculation here)
 - read the KPIs in use for each Use Case
 - read all measurements performed for all Use Cases
- read SAVF (no-reassignment, see section 5.2.5)
- calculate KPI weights using AHP (no re-calculation if final weights have been entered, see section 5.2.2)
- apply SAVF to measurements and get impact scale for KPI
- apply KPI weights and calculate result per Use Case
- apply UC weights and calculate result for Pilot Site

The intermediate and final results are shown in sheet 'Calc_PS', here exemplarily shown for the Slovakian Pilot Site (Figure 17) and a 'Best Performance' approach using a benchmark case (see section 4.2.7). Note that these numbers are not final (at the time of drafting the report) but will be finalised later.

Figure 17 shows a matrix where the KPIs are listed in the rows of the sheet (here: 4, 8, 12, and 14) and the Use Cases are shown in the columns (here: 1, 2, and 3). Whenever a KPI is not used in a Use Case, the cells are greyed out, otherwise results are shown, comprising

- the baseline measurement result;
- the To-Be measurements;
- the expected change;
- the assigned SAVF;
- the threshold value (dependent on the 'Best Performance' approach);
- the calculated impact indicator for the Use Case and the respective KPI; and
- the calculated weights for each KPI

At the bottom of the sheet the total result for each Use Case, the weights of the Use Cases, and the overall result for the Pilot Site are shown. The results shown here are preliminary and will change as soon as the 'best possible performance' (see section 4.2.7) has been defined and implemented in the calculations. All results will be saved in an extra spreadsheet for further evaluation.

Input:

Pilot Site:

PS SK

Calculate

Results:

		Use Cases		
KPIs		1	2	3
4	As-Is	5065	65597	525
	To-Be	3160	73840.67	663.3333
	Change	-37.6%	12.6%	26.3%
	Expected	-30,0%	-15,0%	-20,0%
	SAVF	23	23	23
	Threshold	-30.0%	-30.0%	-30.0%
	Indicator	1	0	0
	Weight	0.431	0.378	0.5
8	As-Is	0	60.5	
	To-Be	41.4	99.9	
	Change	0.0%	65.1%	
	Expected	10,0%	70,0%	
	SAVF	21	21	
	Threshold	20.0%	20.0%	
	Indicator	1	1	
	Weight	0.384	0.337	
12	As-Is		0.8	
	To-Be		2.911111	
	Change		263.9%	
	Expected		1,0%	
	SAVF		21	
	Threshold		20.0%	
	Indicator		1	
	Weight		0.123	
14	As-Is	30	57	20
	To-Be	50	57	50
	Change	66.7%	0.0%	150.0%
	Expected	40,0%	71,0%	30,0%
	SAVF	21	21	21
	Threshold	30.0%	30.0%	30.0%
	Indicator	1	0	1
	Weight	0.185	0.162	0.5
Indic. UC		1	0.46	0.5
Weights UC		0.333	0.333	0.333
IMPACT INDICATOR				0.653

Figure 17: Calculation of results for Pilot Sites (here: PS SK)

5.5 Calculate uncertainties

Following the concept of sensitivity or uncertainty analysis using Monte-Carlo simulations as described in section 4.3, this section demonstrates the calculations performed and shows the results using the same example (PS SK) as used in section 5.4. The principle flow chart for this calculation is shown in Figure 18.

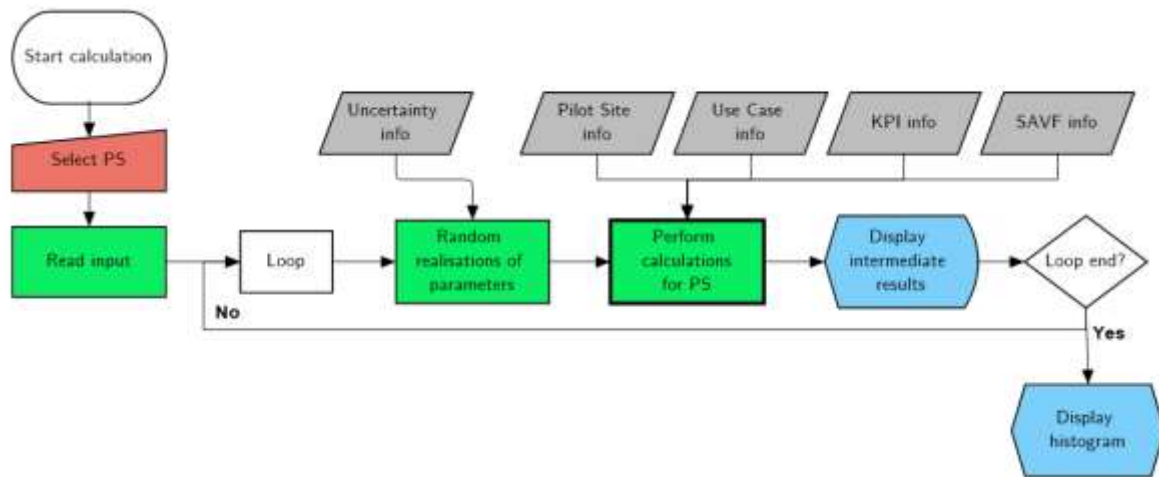


Figure 18: Principal flow chart of FEMCAHP uncertainty calculations

From Figure 18 it can be seen that the uncertainty analysis is centred around the calculations for the Pilot Site (box with thick line in Figure 18) as described in section 5.4. The key difference is that for each loop new (realisations of) parameters will be used, therefore resulting in variations of the overall impact indicator.

The uncertainty simulations are performed in sheet 'Calc_UNC' of FEMCAHP. Figure 19 shows this sheet after the calculations have been performed for the Slovakian Pilot Site.

The top part of Figure 19 shows the input which has been used for the simulations which is directly taken from the General Input screen (see section 5.2.1). The lower part shows the results, first for the deterministic calculation (as described in section 5.4), and then showing all 10,000 simulations in a histogram where the average result is 0.630 (so close to the deterministic result as shown in Figure 17). The detailed data for the histogram are shown in the table on the left (percentage and number of realisations for each class of the histogram).

Input:

Pilot Site: PS SK

Parameter:

sD Meas: 10.0%
KPI weights: 5.0%
UC weights: 5.0%
SAVF perc.: 5.0%
SAVF type: fixed

Distr. Type:

N
N
N
N

Calculation:

nSim: 10000
nDisp: 2000
nClass: 20

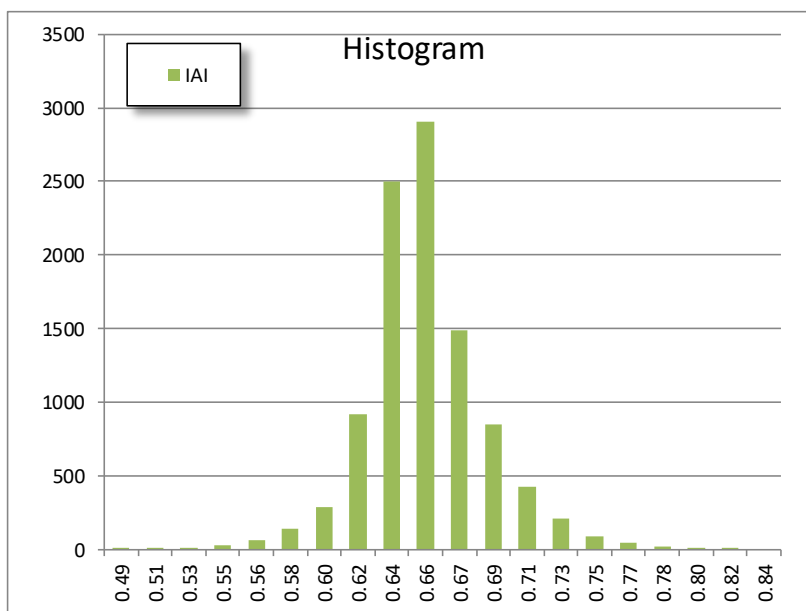
Start simulation

Output:

IAI(det.) = 0.653
i = 10000
R(iA) = 0.661
Min(iA) = 0.491
Max(iA) = 0.857

deterministic result of IAI for Pilot Site
simulation number
realisation of impact assessment of Pilot Site
Minimum impact assessment
Maximum impact assessment

No.	Perc.	IAI
1	0.49	3
2	0.51	11
3	0.53	12
4	0.55	26
5	0.56	64
6	0.58	144
7	0.60	286
8	0.62	916
9	0.64	2496
10	0.66	2904
11	0.67	1485
12	0.69	850
13	0.71	428
14	0.73	208
15	0.75	93
16	0.77	44
17	0.78	24
18	0.80	3
19	0.82	2
20	0.84	



0 9999

0.491 Minimum
0.857 Maximum
0.665 Mean
0.033 Standard deviation
5.0% CoV

Figure 19: Temporary results of uncertainty simulations in FEMCAHP

The figure shows that there are many variations of this result, distributed in a bell-shape curve around the average. The latter was to be expected since only normally-distributed parameters have been used as input. The standard deviation of the result is 0.033 which corresponds to a CoV of about 5%. The logic behind this result is that the curve will get wider (spread over a larger range of results) the more parameters are considered to be uncertain and the higher the CoV for these parameters are selected.

The simulation time for this example (3 Use Cases, 4 KPIs, 10,000 simulations) is less than 10 seconds on a Windows 10 64-bit operating system with an Intel i7 2.6GHz processor and 16 GB RAM. Final simulations for each Pilot Site will be based on a larger amount of simulations to further minimise the variability of the results.

5.6 Summary

Chapter 5 has discussed the calculations performed within the newly created Excel-based software FEMCAHP. It has provided the details of the calculations which can be performed by the software together with the required hardware needs to run it.

The different input requirements have been discussed, including the user input, Pilot Site, Use Case, and KPI details. More detailed descriptions have been provided for the dependencies in between the aforementioned inputs, the Single-Attribute Value Functions (SAVF), and the KPI baseline and To-Be measurements.

Detailed explanations were given for the calculation of KPI weights based on AHP (section 5.3) and the calculation of the overall impact assessment indicator for each Pilot Site (section 5.4) which, after the user has provided sufficient input for the Pilot Site, is a One-Click exercise. The results, however, provided in this draft version of the deliverable are not yet final and will be updated in future versions of the report when more and updated data are available.

Section 5.5, eventually, discusses the Monte-Carlo simulations for addressing the inherent uncertainties in the methods and measurements. Example simulations were performed demonstrating how the software works and which type of results will principally be available.

The results still need to be 'scaled' using one of the measures discussed in Step VII of the underlying methodology (section 4.2.7) which, depending on the selection of the "best possible performance" measure, will still change the results and allows for a comparison of the different Pilot Sites.

It should also be mentioned that an overall FENIX impact assessment indicator could be achieved by bringing together the results for all Pilot Sites. This would require the same approach than already used to 'merge' the results of the Use Cases, by introducing weighing factors for each Pilot Site.

6 RESULTS

This chapter summarises the key results after the methodology has been applied to all FENIX Pilot Sites using the processed KPI measurements from the Use Cases and all further steps described in the methodology in chapter 4. Whilst specific results for all Pilot Sites are described in the respective Pilot Site reports, chapter 6 here will show some selected results, provide an overview of results, and discuss specific cases where changes were necessary either to the discussed methodology, the software used, or the KPI measurements, respectively.

Section 6.1 will first provide some results of the deterministic calculations for the KPIs, the Use Cases, and the associated Pilot Sites. Section 6.2 will describe the uncertainty analysis performed based on the aforementioned results, and using some variations of input parameters for these uncertainty simulations. In the last section (7), some observations and special cases are discussed. Final conclusions regarding the recommended set of input parameters are also drawn.

6.1 Overall results

An overview of all Pilot Sites, the Use Cases, and the used KPIs has already been provided in Figure 16. It shows that the overall number of KPIs per Use Case (ignoring that the same KPI might be used in several Use Cases of this Pilot Site) varies from 2 (minimum, Pilot Site BE1) to 22 (maximum, Pilot Site Italy 2). A complete list of which KPI is used in which Use Case of which Pilot Site is given in Annex A.

Table 15 shows an overview of the data used for the analysis where the columns of the table are the Pilot Sites and the rows indicate the Use Cases for these Pilot Sites.

Table 15: Overview of data used per Use Case and for each Pilot Site of FENIX

UC/PS	PS AT	PS BE1	PS BE2	PS DE	PS ES	PS FR	PS GR	PS IT1	PS IT2	PS NL	PS SK
1	3	3	-	5	2	2	10		3	3	3
1a								1			
1b								1			
2	2	2	-	2	9	3	-		5	4	4
3		-	-	1	-	3	2	1	3		2
4			-	5	15	3	3		-		
4a								-			
4b								4			
4c								1			
4d								-			
5			-		6	3	5		-		
6					1	3		1	5		
7					-	5			7		
7a								-			
7b								2			
7c								1			
8								1	4		
9								-	-		

The number of data rows for each Use Case varies in between zero (indicated as '-') and 15 (Use Case 4 of the Spanish Pilot Site). Note that data for PS BE2 and PS IT1 were not yet fully processed at the time of writing of this deliverable. For any Use Case where no data could be found (or data were believed to be invalid), the Use Case is not considered in any further calculations.

Invalid data were found in a very high number of the submitted log files of the Pilot Sites and were therefore further analysed to understand the key reasons or issues in these data. The following reasons lead to data rows being marked as invalid:

- There are 'As-Is' measurements but no 'To-Be' measurements: whilst 'As-Is' measurements have been performed, there are no data available to compare them to. Therefore, it was decided to not consider these data;
- Only 'To-Be' measurements are available but no 'As-Is' measurements were reported or were available;
- Both 'As-Is' and 'To-Be' measurements were not available;
- Units for 'As-Is' and 'To-Be' measurements are different and reasons for the differences could not be resolved;

All other cases were used for the analysis which also comprised the following cases:

- 'As-Is' and 'To-Be' measurements are identical indicating that there were no changes in the performance;
- 'As-Is' or 'To-Be' measurements are simulations rather than real data measurements;
- 'To-Be' measurements were zero (0), e.g. indicating that a time reduction is 100%;
- Units were not specified (accurately enough) but values for 'As-Is' and 'To-Be' measurements were provided.

Overall, more than 240 data rows were analysed of which more than 100 were declared 'invalid'. About 130 data rows were further processed and used for the analysis.

The overall results for all Pilot Sites (except PS BE2 and PS IT1 where data were not fully processed yet) are shown in Table 16. In Table 16 all Use Cases are listed in the first column and all Pilot Sites are listed in the first row. Grey cells mean that the combination of Use Cases and Pilot Sites do not exist, the symbol "---" means that there were no data available (yet) to calculate anything. The results are presented using the ranking as provided by a shippers' perspective.

Table 16: Overview of impact assessment results for all Pilot Sites of FENIX (stakeholder: Shipper)

1		0,602	0,993	---	0,391	1	0,836	0,605		0,267	0,462	1
1a									0,167			
1b									1			
2		1	0,979	---	1	1	0,667	---		0,267	0,819	0,46
3			---	---	1	---	0,749	1	1	0,267		0,5
4				---	0,451	0,479	0,415	0,023		---		
4a									---			
4b									0,455			
4c									1			
4d									---			
5				---		0	0,603	0,896		---		
6						1	0,812		1	0,605		
7						---	0,771			0,342		
7a			Stakeholder perspective						---			
7b			--> Shipper						0,054			
7c									1			
8									1	0,441		
9									---			
TOTAL		0,801	0,986	0	0,711	0,696	0,693	0,631	0,742	0,365	0,64	0,653

More detailed results of these calculations, including the calculation of individual KPIs per Pilot Site are available in the Pilot Site reports (see Annex B and Deliverable D5.1). It should also be noted that the results were not discussed with the Pilot Sites due to the limited time available in between receiving the final data set and the deadline to deliver this report.

As discussed before, results are expected as values in between "0" and "1" where "0" means that there was no improved performance due to the use of the FENIX connectors and "1" means that the overall defined threshold of improvement (defined per KPI) has been reached. Zero results ("0") were checked in more detail and typically result from cases where either the 'To-Be' measurements were the same as the 'As-Is' measurements or the opposite result was achieved than desired, e.g. the CO₂ consumption increased rather than decreased. Since the latter could be also due to more traffic resulting from an increased speed of administrative matters (and would therefore be more positive rather than negative), these results would need further processing. Due to time restrictions, this could not be done within the scope of the remaining project duration.

Even without the aforementioned clarification, the results show an overall very positive picture indicating that the performance measured by the KPIs used in the various Use Cases of the Pilot Sites has increased significantly, therefore proving that the federation of networks has been a very useful step to improve transport and logistics operations across a full range of criteria.

An overview of the results per key performance indicator (KPI) is provided in Table 17. This table shows the KPI in the first column, indicates in which Use Case it has been used (2nd column), and shows the results for each of the eleven Pilot Sites in the remaining columns.

The orange colours highlight results which are lower than 0.2 and therefore indicate impacts of the installation of the FENIX connectors which are small whereas the green cells show numbers above 0.9 which indicate large impacts after the installation of the connectors.

If a certain minimum bandwidth of KPIs is selected (meaning the KPIs have been used in at least three different Pilot Sites) and a certain minimum number of measurements (meaning that at least 5 measurements have been performed with this KPI), the following conclusions with respect to the impact can be observed:

- **High impact:**
 - **KPI 8** (Product/shipment visibility): 15 measurements were available across 5 Pilot Sites at the time of reporting. 14 measurements resulted in an impact of “1” showing a very high impact. This had to be expected since increased digitisation of the transport processes will lead to a higher visibility of the goods and processes involved;
 - **KPI 14** (workflow automation): 11 measurements were available across 6 Pilot Sites where 9 measurements resulted in an impact of “1”. The increased digitisation and connection to existing platforms allows for an increased automation of the processes involved so that this results could be expected, too. KPI 14 was either measured by estimating the percentage of automation or by the amount of time saved for performing the respective workflow.
 - **KPI 15** (administration worktime): 8 measurements across 4 Pilot Sites where 7 measurements resulted in the highest possible impact of “1”. Similarly to KPI 14 this shows that the increased digitisation leads to a (sometimes significantly) lower administration worktime, which explains the high impact measured by this KPI.
- **Low impact:**
 - **KPI 10** (turnaround times): 9 measurements across 4 Pilot Sites where all except one measurement have not shown any changes (no impact).
 - **KPI 2** (waiting times): 16 measurements were performed across 6 Pilot Sites with about half the measurements indicating no or almost no impact whereas the other measurements indicate that also waiting times can be very positively affected by the FENIX connectors.

The table also shows that the KPI results can be quite inconsistent over the different Use Cases and Pilot Sites. This could be due to a different interpretation of the definition of a KPI or, alternatively, the use of different units to measure the same KPI. It should be noted here again that for all KPIs (across all Use Cases and Pilot Sites) the same threshold value was used to make the KPI performance better comparable. If different systems for comparison are used, the differences could also result from different (subjective) thresholds.

Table 17: Overview of impact assessment results per key performance indicator

KPI	Use Case	PS AT	PS BE1	PS BE2	PS DE	PS ES	PS FR	PS GR	PS IT1	PS IT2	PS NL	PS SK
1	1				0,428			0,000				
	3						0,295					
	4				0,428							
	4b								0,303			
	5						0,295					
	7						0,295					
	7b								0,000			
	8									0,590		
2	1						0,673	0,417		0,018		
	1a								0,167			
	2						0,673			0,018	1,000	
	3						0,673			0,018		
	4					0,000		0,056				
	4b								0,797			
	5a								0,741			
	6						0,673					
3	1				0,000							
	4				0,000							
	8									0,263		
4	1	0,741						0,000			0,000	1,000
	2	1,000				1,000					1,000	0,000
	3											0,000
	4					1,000	0,000					
	5					0,000						
	6									0,000		
	7b								0,108			
5	1		1,000									
	2		1,000									
	3							1,000				
	7									0,000		
6	1		0,958									
	2		0,958									
	6						0,651					
	7						0,651					
7	1							1,000				
	2					1,000						
	6									1,000		
8	1				1,000		1,000	1,000				1,000
	2				1,000		1,000					1,000
	3						1,000					
	4				1,000							
	5						1,000	1,000				
	6						1,000					
	7						1,000			0,000		
9	1				0,286							
	4				0,286							
	4b								0,202			
	5						0,000					

KPI	Use Case	PS AT	PS BE1	PS BE2	PS DE	PS ES	PS FR	PS GR	PS IT1	PS IT2	PS NL	PS SK
10	1									0,000		
	2						0,000			0,000	0,000	
	3									0,000		
	4b								0,333			
	7						1,000					
10a	1					1,000						
	4					0,000						
	5					0,000						
11	1									0,510		
	2									0,510		
	3									0,510		
12	2											1,000
	4				1,000							
14	1		1,000								1,000	1,000
	2											0,000
	3											1,000
	5							1,000				
14a	1							1,000				
	2										1,000	
	3								1,000			
	4						1,000					
	4c								1,000			
	6									1,000		
	7									1,000		
	7c								1,000			
	8									0,667		
15	1					1,000		1,000			1,000	
	2					1,000						
	4					1,000						
	5					0,000						
	6					1,000				1,000		
16	7									0,955		
17	5							1,000				
18	5							1,000				
20	1	0,113										
	2	1,000										
25	1b								1,000			
	8								1,000			
26	4						1,000					
29	6								1,000			
31	5							0,208				
33	1	0,625										
34	4							0,000				
35	4							0,000				
36	4					0,000						
	8									0,608		
37	3				1,000			1,000				

Low impacts are in most cases resulting either from small variations of the related KPIs, or, if zero, from changes of the KPIs in the opposite direction than foreseen (e.g. an increase of the KPI performance was expected but a decrease has been measured). If several of these low impacts have

been measured for the KPIs within one Use Case, the Use Case itself will also show a low(er) impact. The latter will also depend on the weight of the respective KPI.

The following more detailed information has been provided to the Pilot Sites and are included in Deliverable D5.1 (and included here as Annex B):

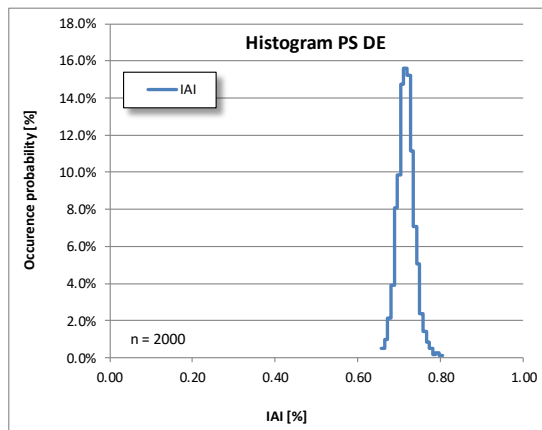
- data overview
- KPI overview
- calculation details
- weight calculation KPIs (for the ranking from a shippers' perspective)
- weight estimation UCs
- evaluation of results

6.2 Uncertainty calculations

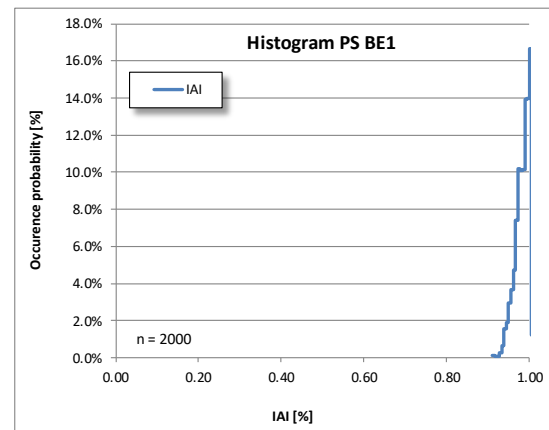
Following the description of the workflow for uncertainty calculations under section 5.5, Monte-Carlo simulations have been performed for all Pilot Sites, with a standard deviation of input parameters set to 5% and 2,000 simulations. The aim for this fast first runs was to get a principal understanding of the type of variability for all Pilot Sites. Three typical results are shown in Figure 20 where four Pilot Site results are shown (PS DE, PS BE1, PS ES, and PS AT).

Figure 20 shows very different results which will be further explained in the following:

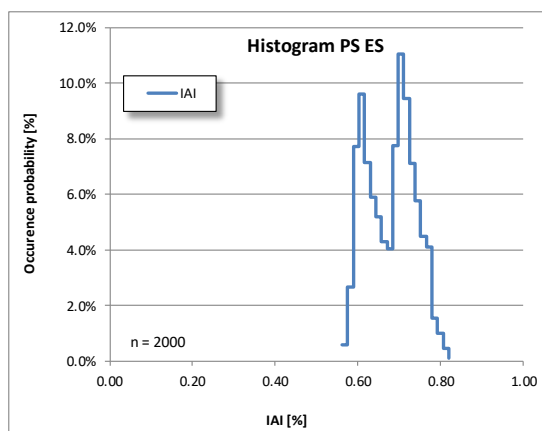
- **Standard type:** the result for the German Pilot Site (PS DE) represents the most often occurring and most typical type of distribution. The histogram for this type shows a small standard deviation around the average result where the latter is typically very close to the deterministic calculation of the impact assessment indicator (IAI).
- **Boundary type:** if the average result is close to the left or right boundary (IAI cannot get smaller than 0 or larger than 1), the distribution will be 'cut off' at the respective boundary. The distribution for the Belgian Pilot Site (PS BE1) shows this type where the average result is 0.98 and therefore close to 1.
- **Multi-peak type:** The Spanish Pilot Site (PS ES) shows an atypical result with three peaks resulting in a (relatively) large standard deviation of the result. This type is triggered by the three distinctive Use Cases which have a very high impact and two Use Cases with a very low impact. These 'extremely' different results are then merged by averaging these results into an overall impact assessment, leading to distinctive peaks. If the standard deviation of input parameters increases (as compared to the 5% which were used here) it can be expected that the three peaks are getting merged into one big (and wide) peak.
- **Left-sided type:** this type shows a relatively wide left side and a steep and small right side. The analysis for the Austrian Pilot Site (PS AT) showed that this results from only two Use Cases where the average result of the first is around 0.5 and the average result of the other is around 1, so not very close to each other. The averaging of these impacts result in various values in between 0.5 and 1 with more emphasis (more results) around 1.



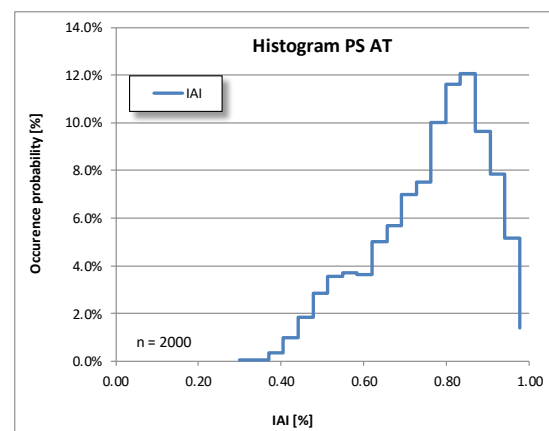
Type 1: standard type



Type 2: boundary type



Type 3: multi-peak type



Type 4: left-sided type

Figure 20. Typical results of uncertainty calculations for four Pilot Sites with standard deviations of input parameters set to 5% (Normal distribution) and 2,000 simulations

In conclusion, the uncertainty analysis identifies the scatter of results around the average. If homogeneous results are reached within the Use Cases, the scatter corresponds to the variability of the input parameter but a much wider range can be reached when the results of the Use Cases within one Pilot Site are wider spread or if there are only few Use Cases.

Table 18: Overview of uncertainty analysis results for all Pilot Sites with standard deviations of input parameters set to 5% (Normal distribution) and 2000 simulations

PS	IAI	no. sim.	Mean	Min.	Max.	CoV
PS AT	0.801	2000	0.763	0.298	1.012	18.1%
PS BE1	0.986	2000	0.983	0.910	1.022	2.8%
PS BE2	-	-	-	-	-	-
PS DE	0.711	2000	0.716	0.656	0.812	3.7%
PS FR	0.693	2000	0.661	0.472	0.778	6.3%
PS GR	0.631	2000	0.663	0.589	0.783	5.7%
PS IT1	0.742	2000	0.738	0.596	0.842	5.8%
PS IT2	0.365	2000	0.380	0.223	0.531	13.2%
PS NL	0.64	2000	0.644	0.580	0.718	3.7%
PS SK	0.653	2000	0.659	0.610	0.716	3.2%
PS ES	0.696	2000	0.680	0.561	0.833	8.9%

Table 18 shows that most of the resulting coefficient of variations (CoV, relative standard deviation) is in the same order of magnitude than the CoV for all input parameters (5%). Only three Pilot Sites (PS AT, PS IT2, and PS ES) show larger CoVs for one of the aforementioned reasons (Type 3 or 4 in Figure 20).

Typically, Monte-Carlo simulations need a lot of simulations to show a 'stable' standard deviation (CoV). One method to identify this stability is to run Monte-Carlo simulations with different numbers of simulations to see when the CoV does not change any more.

For this purpose, all aforementioned tests for the Pilot Sites have been repeated with 5,000, 10,000, and 20,000 simulations, respectively. All other parameters were kept the same. For Type 1 (standard type) and one Pilot Site (PS DE), the number of simulations were further increased to 40,000, 50,000, 75,000 and 100,000 simulations. The results of the latter Pilot Site, incl. all simulations is shown in Table 19.

Table 19: Variation of the number of simulation for the German Pilot Site (PS DE) and standard deviations of input parameters set to 5% (Normal distribution)

PS	IAI	no. sim.	Mean	Min.	Max.	CoV
PS DE	0.711	2000	0.716	0.645	0.818	3.8%
PS DE	0.711	5000	0.717	0.636	0.826	3.4%
PS DE	0.711	10000	0.716	0.644	0.827	3.1%
PS DE	0.711	20000	0.716	0.630	0.839	3.1%
PS DE	0.711	40000	0.716	0.634	0.834	3.0%
PS DE	0.711	50000	0.716	0.635	0.838	3.0%
PS DE	0.711	75000	0.716	0.634	0.849	3.1%
PS DE	0.711	100000	0.716	0.436	0.840	3.1%

Table 19 shows that the CoV after these simulations seems to stabilise from about 20,000 simulations onwards so that for any further investigation the standard number of simulations was assumed to be 20,000. A check was also performed for all other Pilot Sites showing that the results (Cov) for 20,000 and 10,000 simulations did not change at all or at least not significantly, therefore confirming this assumption.

The next step of the analysis was to increase the variability of the input parameters (from 5% to 10%). Table 20 shows the results for all Pilot Sites for either 5% or 10%, respectively, and using 20,000 simulations.

Table 20: Comparison of results for all Pilot Sites for 5% and 10% variability and 20,000 simulations

PS	IAI	no. sim.	10%				5%			
			Mean	Min.	Max.	CoV	Mean	Min.	Max.	CoV
PS AT	0.801	20000	0.713	0.157	1.060	26.1%	0.756	0.299	1.021	18.8%
PS BE1	0.986	20000	0.973	0.785	1.064	3.4%	0.983	0.897	1.031	1.9%
PS BE2	-						-	-	-	-
PS DE	0.711	20000	0.738	0.577	0.963	6.2%	0.716	0.630	0.839	3.1%
PS FR	0.693	20000	0.609	0.323	0.840	11.9%	0.660	0.486	0.787	5.9%
PS GR	0.631	20000	0.692	0.538	0.890	7.7%	0.662	0.574	0.817	5.2%
PS IT1	0.742	20000	0.741	0.518	0.936	8.4%	0.738	0.586	0.855	5.4%
PS IT2	0.365	20000	0.399	0.174	0.660	18.6%	0.381	0.209	0.590	13.2%
PS NL	0.64	20000	0.648	0.440	0.824	7.0%	0.643	0.576	0.747	3.0%
PS SK	0.653	20000	0.666	0.446	0.861	6.1%	0.659	0.602	0.750	2.5%
PS ES	0.696	20000	0.693	0.501	0.914	9.9%	0.679	0.551	0.852	8.7%

As expected, Table 20 confirms that the CoV for the results is increasing if the CoV is double as high for the input parameters. The increase of the CoV varies in between a factor of 1.4 and 2.4, indicating that also the type of distribution (see Figure 20) may play a role in the variability of the results.

Overall, the analysis of the uncertainties of the results for the impact assessment indicate that stable results can be achieved when the KPIs and Use Cases were more or less homogeneously distributed over the Pilot Site and when sufficient data were available. Inhomogeneous KPI performance and/or fewer data trigger a larger uncertainty (CoV) and therefore a more unstable prediction of the impact assessment.

7 Discussion

The results of the impact assessment across the various Pilot Sites in FENIX has shown that a quite significant impact of the installation and use of FENIX connectors has been achieved. This is indicating that the increased digitisation and better connections between (existing) platforms have improved the Pilot Site conditions, not only indicated by the expected KPIs (less administration time, less waiting times, better visibility of goods, etc.) but also by KPIs which were less obvious such as CO₂ emission or (un)loading times, the latter although to a lesser extent.

Due to the limited time available at the end of the project, not all factors influencing the impact assessment could be investigated at full. The following list comprises some of the factors which might play a role:

- **Stakeholder profile:** depending on the stakeholder, the importance of KPIs will be evaluated differently since it is very obvious that the relevance of KPIs may be very different to a shipper or a hub operator or to customs, for example. The stakeholder 'ranking' is used in the analysis to give weights to KPIs within a Use Case and will therefore have an influence on the overall impact assessment. For better comparison, the same stakeholder perspective (shipper) has been used across all Use Cases of all Pilot Sites. For some Use Cases, different stakeholder views should be considered so that stakeholder viewpoints are differing from Use Case to Use Case. This will eventually lead to higher impact assessment results.
- **Performance threshold:** the different cases for setting the best performance threshold for a KPI have already been discussed in section 4.2.7. The best performance for the analysis in this report was using the 'benchmark case' which means that an overall benchmark has defined per KPI. Although this might be a subjective choice, checks against the other options have shown that it more objective than the 'expectation case' since that leaves the threshold for each KPI to the Use Case operators. Also, a comparison between KPIs across different Use Cases and Pilot Sites is no longer possible then. Furthermore, the 'comparative case' was not considered here since it would lead to cases where outstanding results in one Pilot Site would have reduced the performance of other Use Cases in the same or different Pilot Sites. In addition to this argument, the measurements for KPIs were performed differently, even using different units which sometimes do not allow a direct comparison.
- **KPI measurements:** The key performance indicators (KPIs) were defined at the beginning of the project and a planning was made which KPI to use in which Use Case. The latter has not always worked out at the end, so that these plans had to be revised and a final list could only be derived after all measurements were processed so that, for example, in case of invalid measurements the KPI has been removed from the list. KPIs were sometimes measured in different ways or using different units. If that was the case, the KPI had been split to make these KPIs comparable to the same KPI in a different Use Case or Pilot Site. The KPIs 14 and 14a, for example, are identical KPIs, but measured differently. In this way, different units could be accounted for.

- **Single- Attribute Value Function (SAVF):** the SAVF assigns the KPI performance to a value in between '0' and '1'. This can be done by a boolean, linear, or non-linear function with different thresholds (described in section 4.2.6 and 5.2.4). The standard SAVF is a linear function which is believed to be best solution in case there is no additional information available. Tests were done, however, in which the SAVF type was changed (randomly) and results were compared to the results using the pre-defined linear function. This has not led to any significant changes so that the pre-defined SAVFs were considered for all analysis cases.

From the aforementioned factors, the most influencing one was the stakeholder perspective on the ranking of KPIs where all the others were negligible. Further calculations were performed with three different stakeholder views, such as:

- Authorities (AUT)
- Customer (CUS)
- Terminal operators (TOP)

These stakeholders were selected because of their potentially very different views on the relevance of KPIs. Overall results for the three stakeholder views are shown in Table 21, Table 22, and Table 23, respectively, and are comparable to the shippers' perspective in Table 16.

Table 21: Overview of impact assessment results for all Pilot Sites of FENIX (stakeholder: AUT)

Use Case	KPI	PS AT	PS BE1	PS BE2	PS DE	PS ES	PS FR	PS GR	PS IT1	PS IT2	PS NL	PS SK
1		0,669	0,988	---	0,447	1	0,836	0,483				1
1a									0,167			
1b									1			
2		1	0,979	---	1	1	0,71	---		0,159	0,919	0,383
3			---	---	1	---	0,576	1	1	0,159		0,5
4				---	0,568	0,743	0,26	0,022		---		
4a									---			
4b									0,325			
4c									1			
4d									---			
5				---		0	0,343	0,854		---		
6						1	0,808		1	0,533		
7						---	0,627			0,422		
7a			Stakeholder perspective						---			
7b			--> Authorities						0,054			
7c									1			
8									1	0,555		
9									---	---		
TOTAL		0,835	0,983	0	0,754	0,749	0,594	0,59	0,727	0,331	0,612	0,628

Table 22: Overview of impact assessment results for all Pilot Sites of FENIX (stakeholder: CUS)

Use Case	KPI	PS AT	PS BE1	PS BE2	PS DE	PS ES	PS FR	PS GR	PS IT1	PS IT2	PS NL	PS SK
1		0,493	0,993	---	0,585	1	0,836	0,678		0,176	0,667	1
1a									0,167			
1b									1			
2		1	0,979	---	1	1	0,72	---		0,176	0,75	0,652
3			---	---	1	---	0,75	1	1	0,176		0,5
4				---	0,642	0,4	0,667	0,019		---		
4a									---			
4b									0,394			
4c									1			
4d									---			
5				---		0	0,6	0,826		---		
6						1	0,857		1	0,75		
7						---	0,771			0,297		
7a			Stakeholder perspective						---			
7b			--> Customers						0,054			
7c									1			
8									1	0,537		
9									---	---		
TOTAL		0,746	0,986	0	0,807	0,68	0,743	0,631	0,735	0,352	0,708	0,717

Table 23: Overview of impact assessment results for all Pilot Sites of FENIX (stakeholder: TOP)

Use Case	KPI	PS AT	PS BE1	PS BE2	PS DE	PS ES	PS FR	PS GR	PS IT1	PS IT2	PS NL	PS SK
1		0,399	0,988	---	0,447	1	0,836	0,71		0,289	0,795	1
1a									0,167			
1b									1			
2		1	0,979	---	1	1	0,354	---		0,289	0,578	0,521
3			---	---	1	---	0,668	1	1	0,289		0,5
4				---	0,644	0,266	0,823	0,01		---		
4a									---			
4b									0,406			
4c									1			
4d									---			
5				---		0	0,45	0,813		---		
6						1	0,761		1	0,835		
7						---	0,8			0,811		
7a			Stakeholder perspective						---			
7b			--> Terminal Operator						0,054			
7c									1			
8									1	0,579		
9									---	---		
TOTAL		0,7	0,984	0	0,773	0,653	0,67	0,633	0,736	0,515	0,687	0,674

Depending on the stakeholder's view, the results of the Use Cases and, consequently, the Pilot Sites may differ. The difference may go in both directions, either smaller or larger results, and results for some Pilot Sites may differ more than for other Pilot Sites. The largest difference found in the results was 32% (PS IT2), the second largest was 10% (PS FR), and the smallest difference was 0.1% (PS BE1), the latter showing that the different stakeholder perspective did not result in a different impact. No differences result, if the impacts of the KPIs in each Use Case are close to each other (so that different weights do not play a significant role) or if the relative weight of the KPIs in that specific Use Case is similar in the stakeholder perspectives which were compared.

Considering that different stakeholders should be used for different Use Cases in the Pilot Site, the maximum results from this analysis could even be exceeded which would lead to an even better assessment of the impacts of using the FENIX connectors.

Table 24 summarises the results for each Pilot Site, incl. the number of Use Cases, the KPIs used, the number of data, and the overall results (IAI) for the four stakeholder perspectives.

Table 24: Overview of results for each Pilot Site

Acr.	No. UCs	No. KPIs	Data	IAI (SHP)	IAI (AUT)	IAI (TOP)	IAI (CUS)
PS AT	2	5	5	0.801	0.835	0.700	0.746
PS BE1	3	5	5	0.986	0.983	0.984	0.986
PS BE2	5	-	-	-	-	-	-
PS DE	4	10	13	0.711	0.754	0.773	0.807
PS ES	7	13	33	0.696	0.749	0.653	0.680
PS FR	7	22	22	0.693	0.594	0.670	0.743
PS GR	5	15	20	0.631	0.590	0.633	0.631
PS IT1	18	14	14	0.742	0.727	0.736	0.735
PS IT2	9	21	27	0.365	0.331	0.515	0.352
PS NL	2	7	7	0.640	0.612	0.687	0.708
PS SK	3	9	9	0.653	0.628	0.674	0.717
Total	65		155				

8 Annex A: Pilot Sites, Use Cases, KPIs

Pilot Site	Use Case	1	2	3	4	5	6	7	8	9	10	10a	11	12	14	14a	15	16	17	18	20	25	26	29	31	33	34	35	36	37	TOTALS
PS AT	1 Track & trace solutions				X																X					X					3
PS AT	2 Customs corridor				X																X										2
PS BE1	1 Reservation of time slot					X	X								X																3
PS BE1	2 Real-time vehicle tracking					X	X																								2
PS BE1	3 Capacity management																														0
PS BE2	1 On-time delivery																														0
PS BE2	2 Track & trace																														0
PS BE2	3 Dangerous goods service																														0
PS BE2	4 Digital document exchange																														0
PS BE2	5 Sustainability (CO2-NOx transparency)																														0
PS FR	1 Dynamic status slot verification		X						X																						2
PS FR	2 Slot management		X						X		X																				3
PS FR	3 Multimodal ETA for cargo optimization	X	X						X																						3
PS FR	4 Dangerous goods				X											X							X								3
PS FR	5 CO2 reduction	X							X	X																					3
PS FR	6 Customs optimisation		X				X		X																						3
PS FR	7 C-ITS for logistics	X	X				X		X		X																				5
PS DE	1 Multimodal Freight Capacity	X		X					X	X																					4
PS DE	2 Intermodal Railway Capacity								X																						1
PS DE	3 Intermodal Corridor Data Hub																														0
PS DE	4 Mode Free Capacity Planning	X		X					X	X				X																	5
PS GR	1 Digitalisation of port processes	X	X		X			X	X							X	X														7
PS GR	2 Balanced use of modal availability along the																														0
PS GR	3 Monitoring of status of transport operations					X																									1
PS GR	4 Traffic management & parking availability		X																								X				2
PS GR	5 Yellow Pages & KPI								X						X				X	X					X						5

[illegible]

Pilot Site	Use Case	1	2	3	4	5	6	7	8	9	10	10a	10b	10c	11	12	14	15	16	17	18	20	31	34	35	36	37	TOTALS
PS IT1	1a																											0
PS IT1	1b																											0
PS IT1	1c																											0
PS IT1	2a																											0
PS IT1	2b																											0
PS IT1	3																											0
PS IT1	4a																											0
PS IT1	4b																											0
PS IT1	4c															X												1
PS IT1	4d																											0
PS IT1	5a																											0
PS IT1	5b																											0
PS IT1	6																											0
PS IT1	7a																											0
PS IT1	7b																											0
PS IT1	7c															X												1
PS IT1	8																											0
PS IT1	9																											0
PS IT2	1		X								X	X																3
PS IT2	2		X								X	X																3
PS IT2	3		X								X	X																3
PS IT2	4																											0
PS IT2	5																											0
PS IT2	6				X			X							X	X												4
PS IT2	7		X			X			X						X		X											5
PS IT2	8	X		X											X									X				4
PS IT2	9																											0
PS NL	1				X									X		X												3
PS NL	2		X		X						X				X													4
PS SK	1				X				X					X														3
PS SK	2				X				X				X	X														4
PS SK	3				X				X																			2
PS ES	1										X					X												2
PS ES	2				X			X								X												3
PS ES	3																											0
PS ES	4		X		X						X					X								X				5
PS ES	5				X						X					X												3
PS ES	6															X												1
PS ES	7																											0
TOTALS:		6	13	3	12	2	4	3	15	3	9	3	2	3	8	8	1	1	1	2	1	1	1	1	2	2	0	

9 Annex B: Pilot Site results

9.1 Pilot Site Austria (PS AT)

In this section the results of the impact assessment for the aforementioned Pilot Site are displayed. The following structure will be used:

- Overview of Use Cases
- Overview of used KPIs, incl. ranking and weights
- Overview of data used for the assessment
- Details of calculations and overall impact assessment indicator (IAI)
- Discussion of results

The overall methodology of how the impact assessment has been performed has been detailed in Deliverable D5.4. The approach is identical for all Pilot Sites which allows for a comparison of the results (also done in D5.4).

The following table lists the Use Cases of the Pilot Site, incl. the number of valid data measured for each of these Use Cases. 'Valid' is defined here when the measurements were performed in a way that data were available for 'As-Is' and 'To-Be' measurements and these measurements were using the same units.

Use Cases:	2	Valid data
	1: Track & trace solutions	3
	2: Customs corridor	2

Following the overview of Use Cases, the table below provides an overview of unique Key Performance Indicators (KPIs) which were used in these Use Cases. 'Unique' means that KPIs might have been used in several Use Cases but are only listed here once. The number of usages in the Use Cases has also been listed. It should be noted that these numbers are based on the valid data which have been received (see below).

Unique KPIs:	3	Used
	4: (Physical) document number exchange	2
	20: Companies interested in logistics node	2
	33: Overall corridor transit time	1

The used KPIs have then been sorted according to a ranking of KPIs performed for different stakeholders. For this analysis a 'shipper' perspective has been chosen. This might not be the best stakeholder perspective for this specific Pilot Site or the Use Cases herein, but will allow for a comparison of Pilot Sites with each other. The impact of different stakeholder perspectives is discussed in Deliverable D5.4 in more detail. The table below lists the KPIs, the rank according to a complete list of KPIs sorted after the preference of the stakeholder, and a transformation into a 'scale' from 1 to 9

which was used for comparison purposes of the KPIs following the Analytical Hierarchy Process (AHP) method as described in Deliverable D5.4. This scale has then been used to calculate the weights of each KPI to determine the impact assessment for each Use Case of the Pilot Site.

Ranking and weights of used KPIs:

KPI	Rank	Scale (1-9)
4	6	2.538
20	21	7.154
33	3	1.615

The data available for this Pilot Site is listed in the following. It contains a reference number, the Use Case (UC), the KPI, the average 'As-Is' and 'To-Be' measurements, the calculated change, the expected values (if available), the unit of measurement, and the Single-Attribute Value Function (SAVF) as explained in Deliverable D5.4.

Measured data:

No.	UC	KPI	As-Is	To-Be	Change	Expect.	Unit	SAVF
1	1	4	6	4.666667	-22.2%	-20,0%	-	23
2	1	20	56	62.333	11.3%	30,0%	-	22
3	1	33	6	5.25	-12.5%	-20,0%	h	23
4	2	4	4	2	-50.0%	-100,0%	-	23
5	2	20	56	67.66667	20.8%	40,0%	-	22

Using the measurements for the aforementioned KPIs, the following results were achieved where the Use Cases are shown as columns, and the KPIs are shown in the rows of the table, respectively. For each of these combinations, an indicator and a weight is calculated. The overall results for each Use Case is shown in the columns at the bottom of the table, and the overall indicator for the Pilot Site is also provided.

Calculation of results:

		Use Cases:	
KPIs		1	2
4	As-Is	6	4
	To-Be	4.666667	2
	Change	-22.2%	-50.0%
	Expected	-20,0%	-100,0%
	SAVF	23	23
	Threshold	-30.0%	-30.0%
	Indicator	0.741	1
	Weight	0.342	0.5
20	As-Is	56	56
	To-Be	62.333	67.66667
	Change	11.3%	20.8%
	Expected	30,0%	40,0%
	SAVF	22	22
	Threshold	20.0%	20.0%
	Indicator	0.113	1
	Weight	0.121	0.5
33	As-Is	6	
	To-Be	5.25	
	Change	-12.5%	
	Expected	-20,0%	
	SAVF	23	
	Threshold	-20.0%	
	Indicator	0.625	
	Weight	0.537	
Indic. UC		0.602	1
Weights UC		0.5	0.5
IMPACT INDICATOR		0.801	

Overall, the result for the Pilot Site (IAI = 0.794) shows that the implementation of the FENIX connector has a very positive impact on the performance of the Pilot Site suggesting that the digitalisation of the Pilot Site is a key prerequisite for better performance. In more detail, both Use Cases have reached or almost reached the thresholds set for the improved KPI performance indicating a significant impact.

It should be noted for the Austrian Pilot Site that the results of the 'To-Be' measurements were based on simulations only. The results were, however, used in the same way than measured results so that the Pilot Site can be compared to other Pilot Sites.

9.2 Pilot Site Belgium (PS BE1)

In this section the results of the impact assessment for the aforementioned Pilot Site are displayed. The following structure will be used:

- Overview of Use Cases
- Overview of used KPIs, incl. ranking and weights
- Overview of data used for the assessment
- Details of calculations and overall impact assessment indicator (IAI)
- Discussion of results

The overall methodology of how the impact assessment has been performed has been detailed in Deliverable D5.4. The approach is identical for all Pilot Sites which allows for a comparison of the results (also done in D5.4).

The following table lists the Use Cases of the Pilot Site, incl. the number of valid data measured for each of these Use Cases. 'Valid' is defined here when the measurements were performed in a way that data were available for 'As-Is' and 'To-Be' measurements and these measurements were using the same units.

Use Cases:	3	Valid data
1: Reservation of time slot		3
2: Real-time vehicle tracking		2
3: Capacity management		0

Following the overview of Use Cases, the table below provides an overview of unique Key Performance Indicators (KPIs) which were used in these Use Cases. 'Unique' means that KPIs might have been used in several Use Cases but are only listed here once. The number of usages in the Use Cases has also been listed. It should be noted that these numbers are based on the valid data which have been received (see below).

Unique KPIs:	3	Used
5: Delivery reliability		2
6: Order fulfillment cycle time		2
14: Workflow automation		1

The used KPIs have then been sorted according to a ranking of KPIs performed for different stakeholders. For this analysis a 'shipper' perspective has been chosen. This might not be the best stakeholder perspective for this specific Pilot Site or the Use Cases herein, but will allow for a comparison of Pilot Sites with each other. The impact of different stakeholder perspectives is discussed in Deliverable D5.4 in more detail. The table below lists the KPIs, the rank according to a complete list of KPIs sorted after the preference of the stakeholder, and a transformation into a 'scale' from 1 to 9 which was used for comparison purposes of the KPIs following the Analytical Hierarchy Process (AHP)

method as described in Deliverable D5.4. This scale has then been used to calculate the weights of each KPI to determine the impact assessment for each Use Case of the Pilot Site.

Ranking and weights of used KPIs:

KPI	Rank	Scale (1-9)
5	2	1.308
6	14	5
14	17	5.923

The data available for this Pilot Site is listed in the following. It contains a reference number, the Use Case (UC), the KPI, the average 'As-Is' and 'To-Be' measurements, the calculated change, the expected values (if available), the unit of measurement, and the Single-Attribute Value Function (SAVF) as explained in Deliverable D5.4.

Measured data:

No.	UC	KPI	As-Is	To-Be	Change	Expect.	Unit	SAVF
6	1	5	0	30	0.0%	100,0%	%	21
7	1	6	96	50	-47.9%	-20,0%	min	23
8	1	14	0	44.8	0.0%	100,0%	%	21
9	2	5	0	11.1	0.0%	100,0%	%	21
10	2	6	96	50	-47.9%	-20,0%	min	23

Using the measurements for the aforementioned KPIs, the following results were achieved where the Use Cases are shown as columns, and the KPIs are shown in the rows of the table, respectively. For each of these combinations, an indicator and a weight is calculated. The overall results for each Use Case is shown in the columns at the bottom of the table, and the overall indicator for the Pilot Site is also provided.

Calculation of results:

		Use Cases:			
KPIs		1	2	3	
5	As-Is	0	0		
	To-Be	30	11.1		
	Change	0.0%	0.0%		
	Expected	100,0%	100,0%		
	SAVF	21	21		
	Threshold	20.0%	20.0%		
	Indicator	1	1		
	Weight	0.675	0.5		
6	As-Is	96	96		
	To-Be	50	50		
	Change	-47.9%	-47.9%		
	Expected	-20,0%	-20,0%		
	SAVF	23	23		
	Threshold	-50.0%	-50.0%		
	Indicator	0.958	0.958		
	Weight	0.176	0.5		
14	As-Is	0			
	To-Be	44.8			
	Change	0.0%			
	Expected	100,0%			
	SAVF	21			
	Threshold	30.0%			
	Indicator	1			
	Weight	0.149			
Indic. UC		0.993	0.979	---	
Weights UC		0.5	0.5	0	
IMPACT INDICATOR			0.986		

Overall, the result for the Pilot Site (IAI = 0.986) shows that the implementation of the FENIX connector has an extremely positive impact on the performance of the Pilot Site suggesting that the digitalisation of the Pilot Site is a key prerequisite for better performance. In more detail, 2 out of 3 Use Cases have reached or almost reached the thresholds set for the improved KPI performance, where only 1 Use Cases did not report data and could therefore not be included in the analysis.

9.3 Pilot Site Germany (PS DE)

In this section the results of the impact assessment for the aforementioned Pilot Site are displayed. The following structure will be used:

- Overview of Use Cases

- Overview of used KPIs, incl. ranking and weights
- Overview of data used for the assessment
- Details of calculations and overall impact assessment indicator (IAI)
- Discussion of results

The overall methodology of how the impact assessment has been performed has been detailed in Deliverable D5.4. The approach is identical for all Pilot Sites which allows for a comparison of the results (also done in D5.4).

The following table lists the Use Cases of the Pilot Site, incl. the number of valid data measured for each of these Use Cases. 'Valid' is defined here when the measurements were performed in a way that data were available for 'As-Is' and 'To-Be' measurements and these measurements were using the same units.

Use Cases:	4	Valid data
	1: Multimodal Freight Capacity	5
	2: Intermodal Railway Capacity	2
	3: Intermodal Corridor Data Hub	1
	4: Mode Free Capacity Planning	5

Following the overview of Use Cases, the table below provides an overview of unique Key Performance Indicators (KPIs) which were used in these Use Cases. 'Unique' means that KPIs might have been used in several Use Cases but are only listed here once. The number of usages in the Use Cases has also been listed. It should be noted that these numbers are based on the valid data which have been received (see below).

Unique KPIs:	6	Used
	1: CO2 emissions	2
	3: Load factor	2
	8: Product/shipment visibility	3
	9: NOx emissions	2
	12: Modal shift	1
	37: Shipment status updates	1

The used KPIs have then been sorted according to a ranking of KPIs performed for different stakeholders. For this analysis a 'shipper' perspective has been chosen. This might not be the best stakeholder perspective for this specific Pilot Site or the Use Cases herein, but will allow for a comparison of Pilot Sites with each other. The impact of different stakeholder perspectives is discussed in Deliverable D5.4 in more detail. The table below lists the KPIs, the rank according to a complete list of KPIs sorted after the preference of the stakeholder, and a transformation into a 'scale' from 1 to 9 which was used for comparison purposes of the KPIs following the Analytical Hierarchy Process (AHP) method as described in Deliverable D5.4. This scale has then been used to calculate the weights of each KPI to determine the impact assessment for each Use Case of the Pilot Site.

Ranking and weights of used KPIs:

KPI	Rank	Scale (1-9)
1	19	6.538
3	4	1.923
8	7	2.846
9	19	6.538
12	23	7.769
37	8	3.154

The data available for this Pilot Site is listed in the following. It contains a reference number, the Use Case (UC), the KPI, the average 'As-Is' and 'To-Be' measurements, the calculated change, the expected values (if available), the unit of measurement, and the Single-Attribute Value Function (SAVF) as explained in Deliverable D5.4.

Measured data:

No.	UC	KPI	As-Is	To-Be	Change	Expect.	Unit	SAVF
33	1	1	729	666.6667	-8.6%	650	kg	23
34	1	3	96.5	90.7	-6.0%	98,0%	%	21
35	1	8	12.5	21.7	73.6%	20,0%	%	21
36	1	8	0	1064.333	0.0%	20,0%	-	22
37	1	9	363.5	332.3333	-8.6%	330	g	23
38	2	8	0	5.662058	0.0%	10,0%	%	21
39	2	8	0	11348.25	0.0%	10,0%	-	22
40	3	37	4	25	525.0%	8	-	22
41	4	1	729	666.6667	-8.6%	650	kg	23
42	4	3	96.5	90.7	-6.0%	98,0%	%	21
43	4	8	12.5	21.7	73.6%	20,0%	%	21
44	4	9	363.5	332.3333	-8.6%	330	g	23
45	4	12	18.5	29.3	58.4%	25,0%	%	21

Using the measurements for the aforementioned KPIs, the following results were achieved where the Use Cases are shown as columns, and the KPIs are shown in the rows of the table, respectively. For each of these combinations, an indicator and a weight is calculated. The overall results for each Use Case is shown in the columns at the bottom of the table, and the overall indicator for the Pilot Site is also provided.

Calculation of results:

		Use Cases:			
KPIs		1	2	3	4
1	As-Is	729			729
	To-Be	666.6667			666.6667
	Change	-8.6%			-8.6%
	Expected	650			650
	SAVF	23			23
	Threshold	-20.0%			-20.0%
	Indicator	0.428			0.428
	Weight	0.13			0.117
3	As-Is	96.5			96.5
	To-Be	90.7			90.7
	Change	-6.0%			-6.0%
	Expected	98,0%			98,0%
	SAVF	21			21
	Threshold	30.0%			30.0%
	Indicator	0			0
	Weight	0.442			0.398
8	As-Is	12.5	0		12.5
	To-Be	21.7	5.662058		21.7
	Change	73.6%	0.0%		73.6%
	Expected	20,0%	10,0%		20,0%
	SAVF	21	21		21
	Threshold	20.0%	20.0%		20.0%
	Indicator	1	1		1
	Weight	0.298	1		0.269
9	As-Is	363.5			363.5
	To-Be	332.3333			332.3333
	Change	-8.6%			-8.6%
	Expected	330			330
	SAVF	23			23
	Threshold	-30.0%			-30.0%
	Indicator	0.286			0.286
	Weight	0.13			0.117
12	As-Is				18.5
	To-Be				29.3
	Change				58.4%
	Expected				25,0%
	SAVF				21
	Threshold				20.0%
	Indicator				1
	Weight				0.099
37	As-Is			4	
	To-Be			25	
	Change			525.0%	
	Expected			8	
	SAVF			22	
	Threshold			50.0%	
	Indicator			1	
	Weight			1	
Indic. UC		0.391	1	1	0.451
Weights UC		0.25	0.25	0.25	0.25
IMPACT INDICATOR					0.711

Overall, the result for the Pilot Site (IAI = 0.711) shows that the implementation of the FENIX connector has a very positive impact on the performance of the Pilot Site suggesting that the digitalisation of the Pilot Site is a key prerequisite for better performance. In more detail, 2 out of 4 Use Cases have reached the thresholds set for the improved KPI performance, and the remaining Use Cases also indicate an impact, although the score here is a little lower than average.

9.4 Pilot Site Spain (PS ES)

In this section the results of the impact assessment for the aforementioned Pilot Site are displayed. The following structure will be used:

- Overview of Use Cases
- Overview of used KPIs, incl. ranking and weights
- Overview of data used for the assessment
- Details of calculations and overall impact assessment indicator (IAI)
- Discussion of results

The overall methodology of how the impact assessment has been performed has been detailed in Deliverable D5.4. The approach is identical for all Pilot Sites which allows for a comparison of the results (also done in D5.4).

The following table lists the Use Cases of the Pilot Site, incl. the number of valid data measured for each of these Use Cases. 'Valid' is defined here when the measurements were performed in a way that data were available for 'As-Is' and 'To-Be' measurements and these measurements were using the same units.

Use Cases:	7	Valid data
1: Rail Planning		2
2: B2A & A2B services with Customs		9
3: Dangerous Goods Authorization		0
4: Booking of slots for operations in Dry Port		15
5: Loading & Discharge lists management of cargo by train		6
6: Port2DryPort Track & Trace		1
7: Business Intelligence applied to intermodal operation		0

Following the overview of Use Cases, the table below provides an overview of unique Key Performance Indicators (KPIs) which were used in these Use Cases. 'Unique' means that KPIs might have been used in several Use Cases but are only listed here once. The number of usages in the Use Cases has also been listed. It should be noted that these numbers are based on the valid data which have been received (see below).

Unique KPIs:	6	Used
	2: Waiting times	1
	4: (Physical) document number exchange	3
	7: Custom Procedures	1
	10a: Turnaround time	3
	15: Administration work time	5
	36: Time the driver spends on that drive to pick up/deliver the container at the te	1

The used KPIs have then been sorted according to a ranking of KPIs performed for different stakeholders. For this analysis a 'shipper' perspective has been chosen. This might not be the best stakeholder perspective for this specific Pilot Site or the Use Cases herein, but will allow for a comparison of Pilot Sites with each other. The impact of different stakeholder perspectives is discussed in Deliverable D5.4 in more detail. The table below lists the KPIs, the rank according to a complete list of KPIs sorted after the preference of the stakeholder, and a transformation into a 'scale' from 1 to 9 which was used for comparison purposes of the KPIs following the Analytical Hierarchy Process (AHP) method as described in Deliverable D5.4. This scale has then been used to calculate the weights of each KPI to determine the impact assessment for each Use Case of the Pilot Site.

Ranking and weights of used KPIs:

KPI	Rank	Scale (1-9)
2	11	4.077
4	6	2.538
7	10	3.769
10a	16	5.615
15	17	5.923
36	15	5.308

The data available for this Pilot Site is listed in the following. It contains a reference number, the Use Case (UC), the KPI, the average 'As-Is' and 'To-Be' measurements, the calculated change, the expected values (if available), the unit of measurement, and the Single-Attribute Value Function (SAVF) as explained in Deliverable D5.4.

Measured data:

No.	UC	KPI	As-Is	To-Be	Change	Expect.	Unit	SAVF
114	1	10a	90	100	11.1%	100,0%	%	12
115	1	15	10	0.0001	-100.0%		min	23
116	2	4	50	0.0001	-100.0%	2	-	23
117	2	7	150	1	-99.3%	7.5	min	23
118	2	15	150	1	-99.3%	7.5	min	23
119	2	4	66	0.0001	-100.0%	3	-	23
120	2	7	180	1	-99.4%	9	min	23
121	2	15	180	1	-99.4%	9	min	23
122	2	4	4	0.0001	-100.0%	0-1	-	23
123	2	7	140	1	-99.3%	7	min	23
124	2	15	140	1	-99.3%	7	min	23
125	4	2	1	1	0.0%	30,0%	min	23
126	4	4	4	2	-50.0%		-	23
127	4	10a	67	67	0.0%	100,0%	%	12
128	4	15	0.7	0.5	-28.6%	30,0%	min	23
129	4	36	10	10	0.0%	8	min	23
130	4	2	1	1	0.0%	30,0%	min	23
131	4	4	1	1	0.0%		-	23
132	4	10a	67	67	0.0%	100,0%	%	12
133	4	15	0.7	0.5	-28.6%	30,0%	min	23
134	4	36	10	10	0.0%	8	min	23
135	4	2	1	1	0.0%	30,0%	min	23
136	4	4	1	1	0.0%		-	23
137	4	10a	67	67	0.0%	100,0%	%	12
138	4	15	0.7	0.5	-28.6%	30,0%	min	23
139	4	36	10	10	0.0%	8	min	23
140	5	4	2	2	0.0%		-	23
141	5	10a	98	98	0.0%	100,0%	%	12
142	5	15	150	150	0.0%	3	min	23
143	5	4	2	2	0.0%		-	23
144	5	10a	98	98	0.0%	100,0%	%	12
145	5	15	150	150	0.0%	3	min	23
146	6	15	10	0.0001	-100.0%	50,0%	min	23

Using the measurements for the aforementioned KPIs, the following results were achieved where the Use Cases are shown as columns, and the KPIs are shown in the rows of the table, respectively. For each of these combinations, an indicator and a weight is calculated. The overall results for each Use Case is shown in the columns at the bottom of the table, and the overall indicator for the Pilot Site is also provided.

Calculation of results:

		Use Cases:						
KPIs		1	2	3	4	5	6	7
2	As-Is				1			
	To-Be				1			
	Change				0.0%			
	Expected				30,0%			
	SAVF				23			
	Threshold				-30.0%			
	Indicator				0			
	Weight				0.209			
4	As-Is		50		4	2		
	To-Be		0.0001		2	2		
	Change		-100.0%		-50.0%	0.0%		
	Expected		2					
	SAVF		23		23	23		
	Threshold		-30.0%		-30.0%	-30.0%		
	Indicator		1		1	0		
	Weight		0.476		0.335	0.532		
7	As-Is		150					
	To-Be		1					
	Change		-99.3%					
	Expected		7,5					
	SAVF		23					
	Threshold		-30.0%					
	Indicator		1					
	Weight		0.32					
10a	As-Is	90			67	98		
	To-Be	100			67	98		
	Change	11.1%			0.0%	0.0%		
	Expected	100,0%			100,0%	100,0%		
	SAVF	12			12	12		
	Threshold	100.0%			100.0%	100.0%		
	Indicator	1			0	0		
	Weight	0.5			0.152	0.24		
15	As-Is	10	150		0.7	150	10	
	To-Be	0.0001	1		0.5	150	0.0001	
	Change	-100.0%	-99.3%		-28.6%	0.0%	#####	
	Expected		7,5		30,0%	3	50,0%	
	SAVF	23	23		23	23	23	
	Threshold	-20.0%	-20.0%		-20.0%	-20.0%	-20.0%	
	Indicator	1	1		1	0	1	
	Weight	0.5	0.204		0.144	0.228	1	
36	As-Is				10			
	To-Be				10			
	Change				0.0%			
	Expected				8			
	SAVF				23			
	Threshold				-20.0%			
	Indicator				0			
	Weight				0.16			
Indic. UC		1	1	---	0.479	0	1	---
Weights UC		0.2	0.2	0	0.2	0.2	0.2	0

IMPACT INDICATOR

0.696

Overall, the result for the Pilot Site (IAI = 0.696) shows that the implementation of the FENIX connector has a very positive impact on the performance of the Pilot Site suggesting that the digitalisation of the Pilot Site is a key prerequisite for better performance. In more detail, 3 out of 7 Use Cases have completely reached the thresholds set for the improved KPI performance, 2 Use Cases did not indicate a significant impact, and 2 other Use Cases did not provide valid data for an analysis. The lower performance in two Use Cases is mainly due to no changes in the measured KPIs. This should be further monitored. On the other hand, the Pilot Site has provided the highest amount of data as compared to other Pilot Sites.

9.5 Pilot Site France (PS FR)

In this section the results of the impact assessment for the aforementioned Pilot Site are displayed. The following structure will be used:

- Overview of Use Cases
- Overview of used KPIs, incl. ranking and weights
- Overview of data used for the assessment
- Details of calculations and overall impact assessment indicator (IAI)
- Discussion of results

The overall methodology of how the impact assessment has been performed has been detailed in Deliverable D5.4. The approach is identical for all Pilot Sites which allows for a comparison of the results (also done in D5.4).

The following table lists the Use Cases of the Pilot Site, incl. the number of valid data measured for each of these Use Cases. 'Valid' is defined here when the measurements were performed in a way that data were available for 'As-Is' and 'To-Be' measurements and these measurements were using the same units.

Use Cases:	7	Valid data
1: Dynamic status slot verification		2
2: Slot management		3
3: Multimodal ETA for cargo optimization		3
4: Dangerous goods		3
5: CO2 reduction		3
6: Customs optimisation		3
7: C-ITS for logistics		5

Following the overview of Use Cases, the table below provides an overview of unique Key Performance Indicators (KPIs) which were used in these Use Cases. 'Unique' means that KPIs might have been used in several Use Cases but are only listed here once. The number of usages in the Use Cases has also been listed. It should be noted that these numbers are based on the valid data which have been received (see below).

Unique KPIs:	9	Used
	1: CO2 emissions	3
	2: Waiting times	5
	4: (Physical) document number exchange	1
	6: Order fulfillment cycle time	2
	8: Product/shipment visibility	6
	9: NOx emissions	1
	10: Turnaround time	2
	14a: Workflow automation	1
	26: Number of accidents	1

The used KPIs have then been sorted according to a ranking of KPIs performed for different stakeholders. For this analysis a 'shipper' perspective has been chosen. This might not be the best stakeholder perspective for this specific Pilot Site or the Use Cases herein, but will allow for a comparison of Pilot Sites with each other. The impact of different stakeholder perspectives is discussed in Deliverable D5.4 in more detail. The table below lists the KPIs, the rank according to a complete list of KPIs sorted after the preference of the stakeholder, and a transformation into a 'scale' from 1 to 9 which was used for comparison purposes of the KPIs following the Analytical Hierarchy Process (AHP) method as described in Deliverable D5.4. This scale has then been used to calculate the weights of each KPI to determine the impact assessment for each Use Case of the Pilot Site.

Ranking and weights of used KPIs:

KPI	Rank	Scale (1-9)
1	19	6.538
2	11	4.077
4	6	2.538
6	14	5
8	7	2.846
9	19	6.538
10	16	5.615
14a	17	5.923
26	27	9

The data available for this Pilot Site is listed in the following. It contains a reference number, the Use Case (UC), the KPI, the average 'As-Is' and 'To-Be' measurements, the calculated change, the expected values (if available), the unit of measurement, and the Single-Attribute Value Function (SAVF) as explained in Deliverable D5.4.

Measured data:

No.	UC	KPI	As-Is	To-Be	Change	Expect.	Unit	SAVF
11	1	2	33.2	26.5	-20.2%	0,0%	%	23
12	1	8	66.7	82	22.9%	100,0%	%	21
13	2	2	33.2	26.5	-20.2%	0,0%	%	23
14	2	8	66	82	24.2%	100,0%	%	21
15	2	10	27	93.435	246.1%	<20	?	23
16	3	1	5570.354	5241.472	-5.9%	<1000	g/km	23
17	3	2	33.2	26.5	-20.2%	0,0%	%	23
18	3	8	66	82	24.2%	100,0%	%	21
19	4	4	6	14.88	148.0%	75,0%	-	23
20	4	14a	5	2.603261	-47.9%	<2	min	23
21	4	26	130.6667	2	-98.5%	<20	-	23
22	5	1	5570.354	5241.472	-5.9%	<800	g/km	23
23	5	8	66	82	24.2%	100,0%	%	21
24	5	9	1.95	2085.5	106848.7%	<1.6	g/tkm	23
25	6	2	33.2	26.5	-20.2%	0,0%	%	23
26	6	6	9.69	6.535	-32.6%	<7	d	23
27	6	8	66	82	24.2%	100,0%	%	21
28	7	1	5570.354	5241.472	-5.9%	<1000	g/km	23
29	7	2	33.2	26.5	-20.2%	0,0%	%	23
30	7	6	9.69	6.535	-32.6%	<7	d	23
31	7	8	66	82	24.2%	100,0%	%	21
32	7	10	183.37	93.435	-49.0%		h	23

Using the measurements for the aforementioned KPIs, the following results were achieved where the Use Cases are shown as columns, and the KPIs are shown in the rows of the table, respectively. For each of these combinations, an indicator and a weight is calculated. The overall results for each Use Case is shown in the columns at the bottom of the table, and the overall indicator for the Pilot Site is also provided.

Calculation of results:

		Use Cases:						
KPIs		1	2	3	4	5	6	7
1	As-Is			5570.354		5570.3537		5570.354
	To-Be			5241.472		5241.4724		5241.472
	Change			-5.9%		-5.9%		-5.9%
	Expected			<1000		<800		<1000
	SAVF			23		23		23
	Threshold			-20.0%		-20.0%		-20.0%
	Indicator			0.295		0.295		0.295
	Weight			0.204		0.233		0.136
2	As-Is	33.2	33.2	33.2			33.2	33.2
	To-Be	26.5	26.5	26.5			26.5	26.5
	Change	-20.2%	-20.2%	-20.2%			-20.2%	-20.2%
	Expected	0,0%	0,0%	0,0%			0,0%	0,0%
	SAVF	23	23	23			23	23
	Threshold	-30.0%	-30.0%	-30.0%			-30.0%	-30.0%
	Indicator	0.673	0.673	0.673			0.673	0.673
	Weight	0.5	0.317	0.327			0.308	0.218
4	As-Is				6			
	To-Be				14.88			
	Change				148.0%			
	Expected				75,0%			
	SAVF				23			
	Threshold				-30.0%			
	Indicator				0			
	Weight				0.585			
6	As-Is						9.69	9.69
	To-Be						6.535	6.535
	Change						-32.6%	-32.6%
	Expected						<7	<7
	SAVF						23	23
	Threshold						-50.0%	-50.0%
	Indicator						0.651	0.651
	Weight						0.251	0.177
8	As-Is	66.7	66	66		66	66	66
	To-Be	82	82	82		82	82	82
	Change	22.9%	24.2%	24.2%		24.2%	24.2%	24.2%
	Expected	100,0%	100,0%	100,0%		100,0%	100,0%	100,0%
	SAVF	21	21	21		21	21	21
	Threshold	20.0%	20.0%	20.0%		20.0%	20.0%	20.0%
	Indicator	1	1	1		1	1	1
	Weight	0.5	0.454	0.469		0.535	0.441	0.312
9	As-Is					1.95		
	To-Be					2085.5		
	Change					106848.7%		
	Expected					<1.6		
	SAVF					23		
	Threshold					-30.0%		
	Indicator					0		
	Weight					0.233		

Calculation of results:

		Use Cases:						
KPIs		1	2	3	4	5	6	7
10	As-Is		27					183.37
	To-Be		93.435					93.435
	Change		246.1%					-49.0%
	Expected		<20					
	SAVF		23					23
	Threshold		-20.0%					-20.0%
	Indicator		0					1
	Weight		0.23					0.158
14a	As-Is				5			
	To-Be				2.6032613			
	Change				-47.9%			
	Expected				<2			
	SAVF				23			
	Threshold				-30.0%			
	Indicator				1			
	Weight				0.251			
26	As-Is				130.66667			
	To-Be				2			
	Change				-98.5%			
	Expected				<20			
	SAVF				23			
	Threshold				-30.0%			
	Indicator				1			
	Weight				0.165			
Indic. UC		0.836	0.667	0.749	0.415	0.603	0.812	0.771
Weights UC		0.143	0.143	0.143	0.143	0.143	0.143	0.143
IMPACT INDICATOR								0.693

Overall, the result for the Pilot Site (IAI = 0.693) shows that the implementation of the FENIX connector has a very positive impact on the performance of the Pilot Site suggesting that the digitalisation of the Pilot Site is a key prerequisite for better performance. In more detail, all Use Cases have almost reached the thresholds set for the improved KPI performance, which is a very positive outcome given the relative high number of unique KPIs .

9.6 Pilot Site Greece (PS GR)

In this section the results of the impact assessment for the aforementioned Pilot Site are displayed. The following structure will be used:

- Overview of Use Cases
- Overview of used KPIs, incl. ranking and weights

- Overview of data used for the assessment
- Details of calculations and overall impact assessment indicator (IAI)
- Discussion of results

The overall methodology of how the impact assessment has been performed has been detailed in Deliverable D5.4. The approach is identical for all Pilot Sites which allows for a comparison of the results (also done in D5.4).

The following table lists the Use Cases of the Pilot Site, incl. the number of valid data measured for each of these Use Cases. 'Valid' is defined here when the measurements were performed in a way that data were available for 'As-Is' and 'To-Be' measurements and these measurements were using the same units.

Use Cases:	5	Valid data
1: Digitalisation of port processes		10
2: Balanced use of modal availability along the corridor		0
3: Monitoring of status of transport operations		2
4: Traffic management & parking availability		3
5: Yellow Pages & KPI		5

Following the overview of Use Cases, the table below provides an overview of unique Key Performance Indicators (KPIs) which were used in these Use Cases. 'Unique' means that KPIs might have been used in several Use Cases but are only listed here once. The number of usages in the Use Cases has also been listed. It should be noted that these numbers are based on the valid data which have been received (see below).

Unique KPIs:	15	Used
1: CO2 emissions		1
2: Waiting times		2
4: (Physical) document number exchange		1
5: Delivery reliability		1
7: Custom Procedures		1
8: Product/shipment visibility		2
14: Workflow automation		1
14a: Workflow automation		1
15: Administration work time		1
17: Digital services		1
18: Corridor indicators visualized		1
31: Data updating frequency		1
34: Level of traffic service		1
35: Travel time to Port gate		1
37: Shipment status updates		1

The used KPIs have then been sorted according to a ranking of KPIs performed for different stakeholders. For this analysis a 'shipper' perspective has been chosen. This might not be the best stakeholder perspective for this specific Pilot Site or the Use Cases herein, but will allow for a

comparison of Pilot Sites with each other. The impact of different stakeholder perspectives is discussed in Deliverable D5.4 in more detail. The table below lists the KPIs, the rank according to a complete list of KPIs sorted after the preference of the stakeholder, and a transformation into a 'scale' from 1 to 9 which was used for comparison purposes of the KPIs following the Analytical Hierarchy Process (AHP) method as described in Deliverable D5.4. This scale has then been used to calculate the weights of each KPI to determine the impact assessment for each Use Case of the Pilot Site.

Ranking and weights of used KPIs:

KPI	Rank	Scale (1-9)
1	19	6.538
2	11	4.077
4	6	2.538
5	2	1.308
7	10	3.769
8	7	2.846
14	17	5.923
14a	17	5.923
15	17	5.923
17	12	4.385
18	13	4.692
31	20	6.846
34	18	6.231
35	15	5.308
37	8	3.154

The data available for this Pilot Site is listed in the following. It contains a reference number, the Use Case (UC), the KPI, the average 'As-Is' and 'To-Be' measurements, the calculated change, the expected values (if available), the unit of measurement, and the Single-Attribute Value Function (SAVF) as explained in Deliverable D5.4.

Measured data:

No.	UC	KPI	As-Is	To-Be	Change	Expect.	Unit	SAVF
46	1	1	0	30099.2	0.0%	20000	km	23
47	1	2	8	7	-12.5%	50,0%	min	23
48	1	4	1120	2168.2	93.6%	50,0%	-	23
49	1	4	130	764.4	488.0%	50,0%	-	23
50	1	4	800	153.6	-80.8%	50,0%	-	23
51	1	4	1120	1133.4	1.2%	50,0%	-	23
52	1	7	150	5	-96.7%	5	min	23
53	1	8	0	1133.4	0.0%	500	-	22
54	1	14a	90	2.5	-97.2%	10	s	23
55	1	15	390	17.6	-95.5%	30	min	23
56	3	5	1.553904	8.821472	467.7%		%	21
57	3	37	0	3	0.0%	2	-	22
58	4	2	10	9.833333	-1.7%		%	23
59	4	34	35.66667	34.33333	-3.7%		km/h	21
60	4	35	44.3	44.7	0.9%		%	23
61	5	8	0	1077.333	0.0%		?	21
62	5	14	0	24	0.0%	24	s	21
63	5	17	2	4.666667	133.3%	5	-	22
64	5	18	20	39.33333	96.7%	35	-	22
65	5	31	8	9.666667	20.8%	10	-	22

Using the measurements for the aforementioned KPIs, the following results were achieved where the Use Cases are shown as columns, and the KPIs are shown in the rows of the table, respectively. For each of these combinations, an indicator and a weight is calculated. The overall results for each Use Case is shown in the columns at the bottom of the table, and the overall indicator for the Pilot Site is also provided.

Calculation of results:

KPIs		Use Cases:											
		1	2	3	4	5							
1	As-Is	0											
	To-Be	30099.2											
	Change	0.0%											
	Expected	20000											
	SAVF	23											
	Threshold	-20.0%											
	Indicator	0											
	Weight	0.088											
2	As-Is	8						10					
	To-Be	7						9.8333333					
	Change	-12.5%						-1.7%					
	Expected	50,0%											
	SAVF	23						23					
	Threshold	-30.0%						-30.0%					
	Indicator	0.417						0.056					
	Weight	0.14						0.413					
4	As-Is	1120											
	To-Be	2168.2											
	Change	93.6%											
	Expected	50,0%											
	SAVF	23											
	Threshold	-30.0%											
	Indicator	0											
	Weight	0.226											
5	As-Is												1.553904
	To-Be												8.821472
	Change												467.7%
	Expected												
	SAVF		21										
	Threshold		20.0%										
	Indicator		1										
	Weight		0.5										
7	As-Is	150											
	To-Be	5											
	Change	-96.7%											
	Expected	5											
	SAVF	23											
	Threshold	-30.0%											
	Indicator	1											
	Weight	0.152											

		Use Cases:				
KPIs		1	2	3	4	5
8	As-Is	0				0
	To-Be	1133.4				1077.3333
	Change	0.0%				0.0%
	Expected	500				
	SAVF	22				21
	Threshold	20.0%				20.0%
	Indicator	1				1
	Weight	0.201				0.317
14	As-Is					0
	To-Be					24
	Change					0.0%
	Expected					24
	SAVF					21
	Threshold					30.0%
	Indicator					1
	Weight					0.152
14a	As-Is	90				
	To-Be	2.5				
	Change	-97.2%				
	Expected	10				
	SAVF	23				
	Threshold	-30.0%				
	Indicator	1				
	Weight	0.097				
15	As-Is	390				
	To-Be	17.6				
	Change	-95.5%				
	Expected	30				
	SAVF	23				
	Threshold	-20.0%				
	Indicator	1				
	Weight	0.097				
17	As-Is					2
	To-Be					4.6666667
	Change					133.3%
	Expected					5
	SAVF					22
	Threshold					50.0%
	Indicator					1
	Weight					0.206
18	As-Is					20
	To-Be					39.333333
	Change					96.7%
	Expected					35
	SAVF					22
	Threshold					30.0%
	Indicator					1
	Weight					0.192

		Use Cases:				
KPIs		1	2	3	4	5
31	As-Is					8
	To-Be					9.6666667
	Change					20.8%
	Expected					10
	SAVF					22
	Threshold					30.0%
	Indicator					0.208
	Weight					0.132
34	As-Is				35.666667	
	To-Be				34.333333	
	Change				-3.7%	
	Expected					
	SAVF				21	
	Threshold				20.0%	
	Indicator				0	
	Weight				0.27	
35	As-Is				44.3	
	To-Be				44.7	
	Change				0.9%	
	Expected					
	SAVF				23	
	Threshold				-10.0%	
	Indicator				0	
	Weight				0.317	
37	As-Is			0		
	To-Be			3		
	Change			0.0%		
	Expected			2		
	SAVF			22		
	Threshold			50.0%		
	Indicator			1		
	Weight			0.5		
Indic. UC		0.605	---	1	0.023	0.896
Weights UC		0.25	0	0.25	0.25	0.25
IMPACT INDICATOR						0.631

Overall, the result for the Pilot Site (IAI = 0.631) shows that the implementation of the FENIX connector has a very positive impact on the performance of the Pilot Site suggesting that the digitalisation of the Pilot Site is a key prerequisite for better performance. In more detail, 3 out of 5 Use Cases have reached or almost reached the thresholds set for the improved KPI performance, where only 1 Use Cases did not indicate a significant impact, and one other Use Case did not report any (valid) data. The Greek Pilot Site has used the highest number of unique KPIs across the 5 Use Cases where most of the KPIs were only used once across the Use Cases.

9.7 Pilot Site Italy 1 (PS IT1)

In this section the results of the impact assessment for the aforementioned Pilot Site are displayed. The following structure will be used:

- Overview of Use Cases
- Overview of used KPIs, incl. ranking and weights
- Overview of data used for the assessment
- Details of calculations and overall impact assessment indicator (IAI)
- Discussion of results

The overall methodology of how the impact assessment has been performed has been detailed in Deliverable D5.4. The approach is identical for all Pilot Sites which allows for a comparison of the results (also done in D5.4).

The following table lists the Use Cases of the Pilot Site, incl. the number of valid data measured for each of these Use Cases. 'Valid' is defined here when the measurements were performed in a way that data were available for 'As-Is' and 'To-Be' measurements and these measurements were using the same units.

Use Cases:	Valid data
18	
1a: Development app for truck arrivals	0
1b: Track & trace of vehicles	1
1c: ETA trucks	0
2a: CO ₂ & NO _x emission reduction	0
2b: Carbon footprint	0
3: Multimodal route planning & re-routing	1
4a: Track & trace of trains (Trieste)	0
4b: Track & trace vehicle/shipment	4
4c: Vehicle movement track & trace between ports	1
4d: Track & trace of trucks entering the port of Trieste	0
5a: TM2.0 services across the TEN-T corridors	0
5b: TM2.0 services across the TEN-T corridors	0
6: Parking booking service	1
7a: Pre-gate operations	0
7b: B2A, A2B services such as Customs	2
7c: International Fast Trade Lane between Europe and Turkey	1
8: Dangerous goods/eCall EGNOS/Galileo	1
9: Carrier certification & eCMR testing in progress	0

Following the overview of Use Cases, the table below provides an overview of unique Key Performance Indicators (KPIs) which were used in these Use Cases. 'Unique' means that KPIs might have been used in several Use Cases but are only listed here once. The number of usages in the Use Cases has also

been listed. It should be noted that these numbers are based on the valid data which have been received (see below).

Unique KPIs:	8	Used
1: CO2 emissions		2
2: Waiting times		3
4: (Physical) document number exchange		1
9: NOx emissions		1
10: Turnaround time		1
14a: Workflow automation		3
25: Delay on the estimated arrival time (ETA reliability)		2
29: Application downloading		1

The used KPIs have then been sorted according to a ranking of KPIs performed for different stakeholders. For this analysis a ‘shipper’ perspective has been chosen. This might not be the best stakeholder perspective for this specific Pilot Site or the Use Cases herein, but will allow for a comparison of Pilot Sites with each other. The impact of different stakeholder perspectives is discussed in Deliverable D5.4 in more detail. The table below lists the KPIs, the rank according to a complete list of KPIs sorted after the preference of the stakeholder, and a transformation into a ‘scale’ from 1 to 9 which was used for comparison purposes of the KPIs following the Analytical Hierarchy Process (AHP) method as described in Deliverable D5.4. This scale has then been used to calculate the weights of each KPI to determine the impact assessment for each Use Case of the Pilot Site.

Ranking and weights of used KPIs:

KPI	Rank	Scale (1-9)
1	19	6.538
2	11	4.077
4	6	2.538
9	19	6.538
10	16	5.615
14a	17	5.923
25	1	1
29	20	6.846

The data available for this Pilot Site is listed in the following. It contains a reference number, the Use Case (UC), the KPI, the average ‘As-Is’ and ‘To-Be’ measurements, the calculated change, the expected values (if available), the unit of measurement, and the Single-Attribute Value Function (SAVF) as explained in Deliverable D5.4.

Measured data:

No.	UC	KPI	As-Is	To-Be	Change	Expect.	Unit	SAVF
66	1a	2	510	484.5	-5.0%	-5,0%	min	23
67	1b	25	5	3	-40.0%	5,0%	%	23
68	3	14a	13.63889	4.5	-67.0%	60,0%	min	23
69	4b	1	487.49	457.95	-6.1%		kg	23
70	4b	2	4.6	3.5	-23.9%	5,0%	min	23
71	4b	9	29.39	27.61	-6.1%	5,0%	g	23
72	4b	10	15	14	-6.7%	5,0%	min	23
73	4c	14a	12.25	5.863333	-52.1%	10,0%	min	23
74	5a	2	4.5	3.5	-22.2%	5,0%	h	23
75	6	29	2500	3394.253	35.8%	5,0%	-	22
76	7b	1	464	498.6667	7.5%	5,0%	g	23
77	7b	4	31	30	-3.2%	5,0%	-	23
78	7c	14a	3107.005	403.1167	-87.0%	60,0%	min	23
79	8	25	5	3	-40.0%		%	23

Using the measurements for the aforementioned KPIs, the following results were achieved where the Use Cases are shown as columns, and the KPIs are shown in the rows of the table, respectively. For each of these combinations, an indicator and a weight is calculated. The overall results for each Use Case is shown in the columns at the bottom of the table, and the overall indicator for the Pilot Site is also provided.

Calculation of results:

		Use Cases:											
KPIs		1a	1b	1c	2a	2b	3	4a	4b	4c	4d		
1	As-Is								487.49				
	To-Be								457.95				
	Change								-6.1%				
	Expected SAVF								23				
	Threshold Indicator								-20.0%				
	Weight								0.303				
2	As-Is	510								0.21			
	To-Be	484.5								4.6			
	Change	-5.0%								3.5			
	Expected SAVF	-5.0%								-23.9%			
	Threshold Indicator	23								5,0%			
	Weight	-30.0%								23			
		-30.0%								-30.0%			
		0.167								0.797			
		1								0.336			
4	As-Is												
	To-Be												
	Change												
	Expected SAVF												
	Threshold Indicator												
	Weight												
9	As-Is								29.39				
	To-Be								27.61				
	Change								-6.1%				
	Expected SAVF								5,0%				
	Threshold Indicator								23				
	Weight								-30.0%				
									0.202				
									0.21				
10	As-Is								15				
	To-Be								14				
	Change								-6.7%				
	Expected SAVF								5,0%				
	Threshold Indicator								23				
	Weight								-20.0%				
									0.333				
									0.244				
14a	As-Is						13.639			12.25			
	To-Be						4.5			5.86333333			
	Change						-67.0%			-52.1%			
	Expected SAVF						60,0%			10,0%			
	Threshold Indicator						23			23			
	Weight						-30.0%			-30.0%			
							1			1			
							1			1			
25	As-Is	5											
	To-Be	3											
	Change	-40.0%											
	Expected SAVF	5,0%											
	Threshold Indicator	23											
	Weight	-20.0%											
		1											
		1											
29	As-Is												
	To-Be												
	Change												
	Expected SAVF												
	Threshold Indicator												
	Weight												
Indic. UC		0.167	1	---	---	---	1	---	0.455	1	---		
Weights UC		0.111	0.111	0	0	0	0.111	0	0.111	0.111	0		

IMPACT INDICATOR

Calculation of results:

KPIs	5a	5b	6	7a	7b	7c	8	9
1 As-Is					464			
To-Be					498.666667			
Change					7.5%			
Expected					5,0%			
SAVF					23			
Threshold					-20.0%			
Indicator					0			
Weight					0.5			
2 As-Is	4.5							
To-Be	3.5							
Change	-22.2%							
Expected	5,0%							
SAVF	23							
Threshold	-30.0%							
Indicator	0.741							
Weight	1							
4 As-Is					31			
To-Be					30			
Change					-3.2%			
Expected					5,0%			
SAVF					23			
Threshold					-30.0%			
Indicator					0.108			
Weight					0.5			
9 As-Is								
To-Be								
Change								
Expected								
SAVF								
Threshold								
Indicator								
Weight								
10 As-Is								
To-Be								
Change								
Expected								
SAVF								
Threshold								
Indicator								
Weight								
14a As-Is					3107.005			
To-Be					403.116667			
Change					-87.0%			
Expected					60,0%			
SAVF					23			
Threshold					-30.0%			
Indicator					1			
Weight					1			
25 As-Is							5	
To-Be							3	
Change							-40.0%	
Expected								
SAVF							23	
Threshold							-20.0%	
Indicator							1	
Weight							1	
29 As-Is			2500					
To-Be			3394.253					
Change			35.8%					
Expected			5,0%					
SAVF			22					
Threshold			20.0%					
Indicator			1					
Weight			1					
Indic. UC	0.741	---	1	---	0.054	1	1	---
Weights UC	0	0	0.111	0	0.111	0.111	0.111	0
IMPACT INDICAT								0.742

Overall, the result for the Pilot Site (IAI = 0.742) shows that the implementation of the FENIX connector has a very positive impact on the performance of the Pilot Site, especially considering the high number of Use Cases (although not all Use Cases were able to provide measurements). The results suggest that the digitalisation of the Pilot Site is a key prerequisite for better performance. In more detail, 7 out of 18 Use Cases have reached or almost reached the thresholds set for the improved KPI performance, 8 Use Cases have not reported (valid) data, and only three Use Cases reported less significant impacts.

9.8 Pilot Site Italy 2 (PS IT2)

In this section the results of the impact assessment for the aforementioned Pilot Site are displayed. The following structure will be used:

- Overview of Use Cases
- Overview of used KPIs, incl. ranking and weights
- Overview of data used for the assessment
- Details of calculations and overall impact assessment indicator (IAI)
- Discussion of results

The overall methodology of how the impact assessment has been performed has been detailed in Deliverable D5.4. The approach is identical for all Pilot Sites which allows for a comparison of the results (also done in D5.4).

The following table lists the Use Cases of the Pilot Site, incl. the number of valid data measured for each of these Use Cases. 'Valid' is defined here when the measurements were performed in a way that data were available for 'As-Is' and 'To-Be' measurements and these measurements were using the same units.

Use Cases:	9	Valid data
1: Expected Time of arrival – ETA (Milan)		3
2: Reduction of CO ₂ & NO _x emission (Milan)		5
3: Dangerous goods transportation monitoring (Milan)		3
4: B2A /A2B services like Customs (Milan)		0
5: Safety and eCustom (Milan)		0
6: Digitalization of documental flows		5
7: Machine-assisted replanning of operation in case of disruptions		7
8: Machine-assisted optimization of truck missions		4
9: Machine-assisted planning of rail shunting maneuvers		0

Following the overview of Use Cases, the table below provides an overview of unique Key Performance Indicators (KPIs) which were used in these Use Cases. 'Unique' means that KPIs might have been used in several Use Cases but are only listed here once. The number of usages in the Use Cases has also been listed. It should be noted that these numbers are based on the valid data which have been received (see below).

Unique KPIs:	13	Used
	1: CO2 emissions	1
	2: Waiting times	4
	3: Load factor	1
	4: (Physical) document number exchange	1
	5: Delivery reliability	1
	7: Custom Procedures	1
	8: Product/shipment visibility	1
	10: Turnaround time	3
	11: (Un)Loading time	3
	14a: Workflow automation	3
	15: Administration work time	1
	16: Terminal saturation time	1
	36: Time the driver spends on that drive to pick up/deliver the container at the te	1

The used KPIs have then been sorted according to a ranking of KPIs performed for different stakeholders. For this analysis a 'shipper' perspective has been chosen. This might not be the best stakeholder perspective for this specific Pilot Site or the Use Cases herein, but will allow for a comparison of Pilot Sites with each other. The impact of different stakeholder perspectives is discussed in Deliverable D5.4 in more detail. The table below lists the KPIs, the rank according to a complete list of KPIs sorted after the preference of the stakeholder, and a transformation into a 'scale' from 1 to 9 which was used for comparison purposes of the KPIs following the Analytical Hierarchy Process (AHP) method as described in Deliverable D5.4. This scale has then been used to calculate the weights of each KPI to determine the impact assessment for each Use Case of the Pilot Site.

Ranking and weights of used KPIs:

KPI	Rank	Scale (1-9)
1	19	6.538
2	11	4.077
3	4	1.923
4	6	2.538
5	2	1.308
7	10	3.769
8	7	2.846
10	16	5.615
11	5	2.231
14a	17	5.923
15	17	5.923
16	16	5.615
36	15	5.308

The data available for this Pilot Site is listed in the following. It contains a reference number, the Use Case (UC), the KPI, the average 'As-Is' and 'To-Be' measurements, the calculated change, the expected values (if available), the unit of measurement, and the Single-Attribute Value Function (SAVF) as explained in Deliverable D5.4.

Measured data:

No.	UC	KPI	As-Is	To-Be	Change	Expect.	Unit	SAVF
80	1	2	19	18.9	-0.5%	50,0%	%	23
81	1	10	121	176.87	46.2%	10,0%	min	23
82	1	11	41	36.82	-10.2%	10,0%	min	23
83	2	10	121	176.87	46.2%	10,0%	min	23
84	2	11	41	36.82	-10.2%	10,0%	min	23
85	2	2	19	18.9	-0.5%	50,0%	%	23
86	2	10	121	176.87	46.2%	10,0%	min	23
87	2	11	41	36.82	-10.2%	10,0%	min	23
88	3	2	19	18.9	-0.5%	50,0%	%	23
89	3	10	121	176.87	46.2%	10,0%	min	23
90	3	11	41	36.82	-10.2%	10,0%	min	23
91	6	4	42.9	57.1	33.1%	57,1%	%	23
92	6	15	624	121.83	-80.5%		min	23
93	6	14a	120	0.0001	-100.0%	<0.08	s	23
94	6	14a	97	0.0001	-100.0%	<0.08	s	23
95	6	7	5.3	3.083333	-41.8%	3	d	23
96	7	2	3	1.0625	-64.6%	100,0%	h	23
97	7	5	30	10	-66.7%	10,0%	%	21
98	7	14a	1920	960	-50.0%	-50,0%	h	23
99	7	16	60	37.08333	-38.2%	30	min	23
			60					
100	7	16	20 parked	19.75	-99.7%	5	-	23
101	7	8	100	100	0.0%	100,0%	%	21
102	7	8	0	100	0.0%	100,0%	%	21
103	8	1	4638.2	4090.74	-11.8%	4393.2	kg CO2	23
104	8	3	54.5	58.8	7.9%	59,0%	%	21
105	8	14a	55	44	-20.0%	25	min	23
106	8	36	100.5	85.22	-15.2%	99	h	23

Using the measurements for the aforementioned KPIs, the following results were achieved where the Use Cases are shown as columns, and the KPIs are shown in the rows of the table, respectively. For each of these combinations, an indicator and a weight is calculated. The overall results for each Use Case is shown in the columns at the bottom of the table, and the overall indicator for the Pilot Site is also provided.

Calculation of results:

		Use Cases:								
KPIs		1	2	3	4	5	6	7	8	9
1	As-Is								4638.2	
	To-Be								4090.74	
	Change								-11.8%	
	Expected								4393,2	
	SAVF								23	
	Threshold								-20.0%	
	Indicator								0.59	
	Weight								0.148	
2	As-Is	19	19	19				3		
	To-Be	18.9	18.9	18.9				1.0625		
	Change	-0.5%	-0.5%	-0.5%				-64.6%		
	Expected	50,0%	50,0%	50,0%				100,0%		
	SAVF	23	23	23				23		
	Threshold	-30.0%	-30.0%	-30.0%				-30.0%		
	Indicator	0.018	0.018	0.018				1		
	Weight	0.281	0.281	0.281				0.144		
3	As-Is								54.5	
	To-Be								58.8	
	Change								7.9%	
	Expected								59,0%	
	SAVF								21	
	Threshold								30.0%	
	Indicator								0.263	
	Weight								0.505	
4	As-Is						42.9			
	To-Be						57.1			
	Change						33.1%			
	Expected						57,1%			
	SAVF						23			
	Threshold						-30.0%			
	Indicator						0			
	Weight						0.395			
5	As-Is							30		
	To-Be							10		
	Change							-66.7%		
	Expected							10,0%		
	SAVF							21		
	Threshold							20.0%		
	Indicator							0		
	Weight							0.448		
7	As-Is						5.3			
	To-Be						3.08333			
	Change						-41.8%			
	Expected						3			
	SAVF						23			
	Threshold						-30.0%			
	Indicator						1			
	Weight						0.266			
8	As-Is							100		
	To-Be							100		
	Change							0.0%		
	Expected							100,0%		
	SAVF							21		
	Threshold							20.0%		
	Indicator							0		
	Weight							0.206		

Calculation of results:

		Use Cases:								
KPIs		1	2	3	4	5	6	7	8	9
10	As-Is	121	121	121						
	To-Be	176.87	176.87	176.87						
	Change	46.2%	46.2%	46.2%						
	Expected	10,0%	10,0%	10,0%						
	SAVF	23	23	23						
	Threshold	-20.0%	-20.0%	-20.0%						
	Indicator	0	0	0						
	Weight	0.204	0.204	0.204						
11	As-Is	41	41	41						
	To-Be	36.82	36.82	36.82						
	Change	-10.2%	-10.2%	-10.2%						
	Expected	10,0%	10,0%	10,0%						
	SAVF	23	23	23						
	Threshold	-20.0%	-20.0%	-20.0%						
	Indicator	0.51	0.51	0.51						
	Weight	0.514	0.514	0.514						
14a	As-Is						120	1920	55	
	To-Be						0.0001	960	44	
	Change						-100.0%	-50.0%	-20.0%	
	Expected						<0.08	-50,0%	25	
	SAVF						23	23	23	
	Threshold						-30.0%	-30.0%	-30.0%	
	Indicator						1	1	0.667	
	Weight						0.169	0.099	0.164	
15	As-Is						624			
	To-Be						121.83			
	Change						-80.5%			
	Expected									
	SAVF						23			
	Threshold						-20.0%			
	Indicator						1			
	Weight						0.169			
16	As-Is							60		
	To-Be							37.08333		
	Change							-38.2%		
	Expected							30		
	SAVF							23		
	Threshold							-40.0%		
	Indicator							0.955		
	Weight							0.104		
36	As-Is								100.5	
	To-Be							85.22		
	Change							-15.2%		
	Expected							99		
	SAVF							23		
	Threshold							-20.0%		
	Indicator							0.608		
	Weight							0.183		
Indic. UC		0.267	0.267	0.267	---	---	0.605	0.342	0.441	---
Weights UC		0.167	0.167	0.167	0	0	0.167	0.167	0.167	0
IMPACT INDICATOR										0.365

Overall, the result for the Pilot Site (IAI = 0.365) shows that the implementation of the FENIX connector has some impact on the performance of the Pilot Site, especially considering the high number of Use

Cases. The results suggests that the digitalisation of the Pilot Site is a key prerequisite for better performance. In more detail, 3 Use Case have reported the same data with a not very high performance which results in a relative high weight of this result. Three other Use Cases have not reported (valid) data, so that it was mostly Use Cases 6.7. and 8 which contributed to the result.

9.9 Pilot Site The Netherlands (PS NL)

In this section the results of the impact assessment for the aforementioned Pilot Site are displayed. The following structure will be used:

- Overview of Use Cases
- Overview of used KPIs, incl. ranking and weights
- Overview of data used for the assessment
- Details of calculations and overall impact assessment indicator (IAI)
- Discussion of results

The overall methodology of how the impact assessment has been performed has been detailed in Deliverable D5.4. The approach is identical for all Pilot Sites which allows for a comparison of the results (also done in D5.4).

The following table lists the Use Cases of the Pilot Site, incl. the number of valid data measured for each of these Use Cases. 'Valid' is defined here when the measurements were performed in a way that data were available for 'As-Is' and 'To-Be' measurements and these measurements were using the same units.

Use Cases:	2	Valid data
1: e-CMR		3
2: e-GATE		4

Following the overview of Use Cases, the table below provides an overview of unique Key Performance Indicators (KPIs) which were used in these Use Cases. 'Unique' means that KPIs might have been used in several Use Cases but are only listed here once. The number of usages in the Use Cases has also been listed. It should be noted that these numbers are based on the valid data which have been received (see below).

Unique KPIs:	6	Used
2: Waiting times		1
4: (Physical) document number exchange		2
10: Turnaround time		1
14: Workflow automation		1
14a: Workflow automation		1
15: Administration work time		1

The used KPIs have then been sorted according to a ranking of KPIs performed for different stakeholders. For this analysis a 'shipper' perspective has been chosen. This might not be the best

stakeholder perspective for this specific Pilot Site or the Use Cases herein, but will allow for a comparison of Pilot Sites with each other. The impact of different stakeholder perspectives is discussed in Deliverable D5.4 in more detail. The table below lists the KPIs, the rank according to a complete list of KPIs sorted after the preference of the stakeholder, and a transformation into a 'scale' from 1 to 9 which was used for comparison purposes of the KPIs following the Analytical Hierarchy Process (AHP) method as described in Deliverable D5.4. This scale has then been used to calculate the weights of each KPI to determine the impact assessment for each Use Case of the Pilot Site.

Ranking and weights of used KPIs:

KPI	Rank	Scale (1-9)
2	11	4.077
4	6	2.538
10	16	5.615
14	17	5.923
14a	17	5.923
15	17	5.923

The data available for this Pilot Site is listed in the following. It contains a reference number, the Use Case (UC), the KPI, the average 'As-Is' and 'To-Be' measurements, the calculated change, the expected values (if available), the unit of measurement, and the Single-Attribute Value Function (SAVF) as explained in Deliverable D5.4.

Measured data:

No.	UC	KPI	As-Is	To-Be	Change	Expect.	Unit	SAVF
107	1	4	25	80	220.0%	75,0%	%	23
108	1	14	50	80	60.0%	80,0%	%	21
109	1	15	60	38.33333	-36.1%	30	min	23
110	2	2	17	4.8	-71.8%	5	min	23
111	2	4	15	2.4	-84.0%	2	-	23
112	2	10	3	3.2	6.7%	3	min	23
113	2	14a	53.33333	10.1	-81.1%	10	min	23

Using the measurements for the aforementioned KPIs, the following results were achieved where the Use Cases are shown as columns, and the KPIs are shown in the rows of the table, respectively. For each of these combinations, an indicator and a weight is calculated. The overall results for each Use Case is shown in the columns at the bottom of the table, and the overall indicator for the Pilot Site is also provided.

Calculation of results:

		Use Cases:	
KPIs		1	2
2	As-Is		17
	To-Be		4.8
	Change		-71.8%
	Expected		5
	SAVF		23
	Threshold		-30.0%
	Indicator		1
	Weight		0.249
4	As-Is	25	15
	To-Be	80	2.4
	Change	220.0%	-84.0%
	Expected	75,0%	2
	SAVF	23	23
	Threshold	-30.0%	-30.0%
	Indicator	0	1
	Weight	0.538	0.399
10	As-Is		3
	To-Be		3.2
	Change		6.7%
	Expected		3
	SAVF		23
	Threshold		-20.0%
	Indicator		0
	Weight		0.181
14	As-Is	50	
	To-Be	80	
	Change	60.0%	
	Expected	80,0%	
	SAVF	21	
	Threshold	30.0%	
	Indicator	1	
	Weight	0.231	
14a	As-Is		53.33333
	To-Be		10.1
	Change		-81.1%
	Expected		10
	SAVF		23
	Threshold		-30.0%
	Indicator		1
	Weight		0.171
15	As-Is	60	
	To-Be	38.33333	
	Change	-36.1%	
	Expected	30	
	SAVF	23	
	Threshold	-20.0%	
	Indicator	1	
	Weight	0.231	
Indic. UC		0.462	0.819
Weights UC		0.5	0.5
IMPACT INDICATOR		0.64	

Overall, the result for the Pilot Site (IAI = 0.640) shows that the implementation of the FENIX connector has a very positive impact on the performance of the Pilot Site suggesting that the digitalisation of the Pilot Site is a key prerequisite for better performance. In more detail, both Use Cases have reached or almost reached the thresholds set for the improved KPI performance.

9.10 Pilot Site Slovakia (PS SK)

In this section the results of the impact assessment for the aforementioned Pilot Site are displayed. The following structure will be used:

- Overview of Use Cases
- Overview of used KPIs, incl. ranking and weights
- Overview of data used for the assessment
- Details of calculations and overall impact assessment indicator (IAI)
- Discussion of results

The overall methodology of how the impact assessment has been performed has been detailed in Deliverable D5.4. The approach is identical for all Pilot Sites which allows for a comparison of the results (also done in D5.4).

The following table lists the Use Cases of the Pilot Site, incl. the number of valid data measured for each of these Use Cases. 'Valid' is defined here when the measurements were performed in a way that data were available for 'As-Is' and 'To-Be' measurements and these measurements were using the same units.

Use Cases:	3	Valid data
1: ERP -> ERP / ERP -> TMS		3
2: ERP "WHS" -> TMS -> ERP "customer"		4
3: ERP MDLZ -> TMS -> ERP "Customer"		2

Following the overview of Use Cases, the table below provides an overview of unique Key Performance Indicators (KPIs) which were used in these Use Cases. 'Unique' means that KPIs might have been used in several Use Cases but are only listed here once. The number of usages in the Use Cases has also been listed. It should be noted that these numbers are based on the valid data which have been received (see below).

Unique KPIs:	4	Used
4: (Physical) document number exchange		3
8: Product/shipment visibility		2
12: Modal shift		1
14: Workflow automation		3

The used KPIs have then been sorted according to a ranking of KPIs performed for different stakeholders. For this analysis a 'shipper' perspective has been chosen. This might not be the best stakeholder perspective for this specific Pilot Site or the Use Cases herein, but will allow for a comparison of Pilot Sites with each other. The impact of different stakeholder perspectives is discussed in Deliverable D5.4 in more detail. The table below lists the KPIs, the rank according to a complete list of KPIs sorted after the preference of the stakeholder, and a transformation into a 'scale' from 1 to 9 which was used for comparison purposes of the KPIs following the Analytical Hierarchy Process (AHP) method as described in Deliverable D5.4. This scale has then been used to calculate the weights of each KPI to determine the impact assessment for each Use Case of the Pilot Site.

Ranking and weights of used KPIs:

KPI	Rank	Scale (1-9)
4	6	2.538
8	7	2.846
12	23	7.769
14	17	5.923

The data available for this Pilot Site is listed in the following. It contains a reference number, the Use Case (UC), the KPI, the average 'As-Is' and 'To-Be' measurements, the calculated change, the expected values (if available), the unit of measurement, and the Single-Attribute Value Function (SAVF) as explained in Deliverable D5.4.

Measured data:

No.	UC	KPI	As-Is	To-Be	Change	Expect.	Unit	SAVF
147	1	4	5065	3160	-37.6%	-30,0%	-	23
148	1	8	0	41.4	0.0%	10,0%	%	21
149	1	14	30	50	66.7%	40,0%	%	21
150	2	4	65597	73840.67	12.6%	-15,0%	-	23
151	2	8	60.5	99.9	65.1%	70,0%	%	21
152	2	12	0.8	2.911111	263.9%	1,0%	%	21
153	2	14	57	57	0.0%	71,0%	%	21
154	3	4	525	663.3333	26.3%	-20,0%	-	23
155	3	14	20	50	150.0%	30,0%	%	21

Using the measurements for the aforementioned KPIs, the following results were achieved where the Use Cases are shown as columns, and the KPIs are shown in the rows of the table, respectively. For each of these combinations, an indicator and a weight is calculated. The overall results for each Use Case is shown in the columns at the bottom of the table, and the overall indicator for the Pilot Site is also provided.

Calculation of results:

		Use Cases:		
KPIs		1	2	3
4	As-Is	5065	65597	525
	To-Be	3160	73840.67	663.3333
	Change	-37.6%	12.6%	26.3%
	Expected	-30,0%	-15,0%	-20,0%
	SAVF	23	23	23
	Threshold	-30.0%	-30.0%	-30.0%
	Indicator	1	0	0
8	Weight	0.431	0.378	0.5
	As-Is	0	60.5	
	To-Be	41.4	99.9	
	Change	0.0%	65.1%	
	Expected	10,0%	70,0%	
	SAVF	21	21	
	Threshold	20.0%	20.0%	
12	Indicator	1	1	
	Weight	0.384	0.337	
	As-Is		0.8	
	To-Be		2.911111	
	Change		263.9%	
	Expected		1,0%	
	SAVF		21	
14	Threshold		20.0%	
	Indicator		1	
	Weight		0.123	
	As-Is	30	57	20
	To-Be	50	57	50
	Change	66.7%	0.0%	150.0%
	Expected	40,0%	71,0%	30,0%
	SAVF	21	21	21
	Threshold	30.0%	30.0%	30.0%
	Indicator	1	0	1
	Weight	0.185	0.162	0.5
	Indic. UC	1	0.46	0.5
	Weights UC	0.333	0.333	0.333
	IMPACT INDICATOR			0.653

Overall, the result for the Pilot Site (IAI = 0.653) shows that the implementation of the FENIX connector has a positive impact on the performance of the Pilot Site suggesting that the digitalisation of the Pilot Site is a key prerequisite for better performance. In more detail, 1 out of the 3 Use Cases has reached the thresholds set for the improved KPI performance, where the other two Use Cases have shown good, but slightly lower results.