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DELIVERABLE D7.5

MATILDA IMPACT ASSESSMENT

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Executive Summary

The overall MATILDA project objective is to design and implement a novel holistic 5G end-to-end services operational framework tackling the overall lifecycle of design, development and orchestration of 5G-ready applications from multiple vertical sectors, and 5G network services over programmable infrastructure, including intelligent mechanisms to increase automation in most of those processes. In order to maximise the MATILDA project results' exploitability and sustainability, a specific activity to monitor and assess the project impact has been foreseen in the project plan running throughout the project course, namely Task 7.6. This deliverable is the direct outcome of Task 7.6, documenting the qualitative and quantitative impact assessment of the project's activities.

In this context, initially an analysis of the research process has been conducted, along with a review of impact assessment classifications, concepts, methodologies and frameworks focusing on R&D projects and activities. As identified, there is no uniquely established way to assess the impact of "research projects" due to their versatility, and in general, impact assessment models are tailored to the nature of each project/action/field, as well as to the interest/focus of the evaluator. Along these lines, the MATILDA impact assessment framework has been defined using a logical model approach applicable to the MATILDA research process, incorporating well defined indicators as criteria for assessment of research impact, emphasizing on activities, output/outcomes, and impact measures.

The MATILDA impact assessment framework is focusing on four domains associated with the four stages of the research process, namely: (1) research results/ output generation, (2) knowledge transfer, (3) community approach and (4) business development. The MATILDA assessment focused on the "contemporary" impact during the lifetime of the project coming out of the first three stages, while for the fourth one, besides the "contemporary" impact for the MATILDA partners, effort has been put to assess "estimated impact" in the forthcoming period, associated with the adoption and penetration of 5G network deployments in the telecommunications' market segment. In particular, the following types of strategic impact have been evaluated with associated "SMART" KPIs:

1. The Technological impact to the field of 5G networks, in the worldwide technology/research community, and on specific vertical markets, has been evaluated against KPIs related to the MATILDA technical output on Lifecycle Management of 5G-ready applications (components and graphs), VNFs (including Forwarding-Graphs and orchestration), and Network Services (associated also to Telecom Layer OSS capabilities). As observed, the project achieved all its technical goals against these KPIs and even exceeded the initially defined targets.
2. The Scientific impact in the research field of 5G networks associated to the Dissemination output of the project has been evaluated against KPIs related to MATILDA participation in conferences / workshops / exhibitions with demonstrators, presentations, papers. In addition, the same strategic impact associated to the Communication output of the project to approach stakeholders and the market has been evaluated against KPIs related to establishing social media and corporate communication channels and generating / presenting material in industrial events/ forums / tutorials/ webinars / website, etc. As observed, the project achieved all its dissemination / communication goals against these KPIs and even exceeded the

initially defined targets, while additional means/ channels of dissemination/ communication were utilised (not initially foreseen).

3. The Business impact on specific domains associated to the project Standardisation activities has been evaluated against KPIs related to monitoring and contribution to standards. As observed, the number of monitored standardisation activities exceeded the initially defined target (5 (compared to the target of 2) monitored standardisation bodies / specification lines) and market consensus was obtained in part of the project work as its contributions have been included and presented in 4 standardisation organisations activities (in ETSI EE TC (Environmental Engineering Technical Committee), in ETSI OSM, in ETSI NFV - IFA029 (the MATILDA NFV Convergence Layer), and presented in ETSI MEC#22, ETSI MEC WG meeting).
4. The Business/ Economic impact on the MATILDA project partners and on the 5G networks' value chain is very difficult to be assessed at project time, since the business activities around the project results are usually evolved with larger steps after the conclusion of the technical work and the project end. At the same time, given the difference in the nature of activities of the partners, and given their different positioning in the value chain, the impact of MATILDA is different for each partner, thus no common KPIs and targets could be set. Therefore, contemporary business impact of MATILDA on partners has been identified on a per partner/ group of partners basis, while the details of the expected business impact in the long run are provided in D7.8. In general, the business impact of MATILDA is positive for all partners and their represented value chain stakeholders, both in terms of economic benefit and in terms of optimising their business activities. At this point it is also notable that a large number of synergies has been achieved both with other 5G-PPP projects and between partners in view of joint exploitation of the MATILDA outcomes.

Overall, the MATILDA impact assessment is positive against all initially defined strategic impact factors, their KPIs and targets and, in most cases, the project succeeded in exceeding performance and enriching the initially defined set of activities.

1 Introduction

The aim of MATILDA is to deliver "a holistic, innovative framework for design, development and orchestration of 5G-ready applications and network services over sliced programmable infrastructure". The MATILDA project provides a solution as realisation of this framework by unifying network slicing, edge computing and multi-tenancy abstractions into an integrated system by methodically following the lifecycle process of development, deployment and operation of 5G use case verticals. In order to maximise the MATILDA project results' exploitability and sustainability, a specific activity to monitor and assess the project impact has been foreseen in the project plan running throughout the project course.

In the context of this task (T7.6), initially an analysis of the research process has been conducted, along with a review of impact assessment classifications, concepts, methodologies and frameworks focusing on R&D projects and activities. As identified at the very first steps of this analysis, there is no uniquely established way to assess the impact of "research projects", as their goals are versatile and depend on the nature of the entities driving the research and on the type of research performed, e.g. theoretical scientific, medical, socio-economic or applied/technology research as well as on numerous other aspects that lead to the categorisation of "impact". In general, models are tailored to the nature of each project/action/field, as well as to the interest/focus of the evaluator.

The first steps followed in order to fulfil this purpose have been the explicit definition of "impact" in the context of MATILDA, with view to the meaning of "impact" in R&D, the identification of relevant impact assessment indicators and the recognition of the challenges appearing in this process, taking into consideration work performed so far in this field. On the basis of this analysis the MATILDA impact assessment framework has been defined using a logical model approach applicable to the MATILDA research process, incorporating the latter indicators as criteria for assessment of research impact, emphasizing on activities, output/outcomes, and impact measures.

This document (Deliverable D7.5) is the direct outcome of task 7.6, documenting the impact assessment process and framework of the project's activities. More specifically:

Section 2 provides an overview of studies and concepts regarding impact assessment definitions, classifications and frameworks.

The latter are used as basis for the positioning of the current MATILDA impact assessment analysis and the definition of Strategic Impact Factors in **Section 3**.

Section 4 provides the assessment of the MATILDA technical impact.

Section 5 focuses on the assessment of the MATILDA scientific impact.

Section 6 addresses the assessment of the MATILDA business impact on 5G networks' domain related to the appeal and effect of MATILDA mainly through standardisation-related work. This section focuses also on the assessment of the MATILDA business (economic, organisational) impact on MATILDA partners.

Finally, conclusions are drawn in **Section 7**.

2 Impact Assessment Framework

In order to maximise the MATILDA project results' exploitation and sustainability, a specific activity to monitor and assess the project impact has been foreseen in the project plan running throughout the project course. For this purpose, initially a review of the research process along with a literature review of impact assessment classifications, concepts, methodologies, frameworks and tools focusing on R&D projects and activities has been conducted. As identified, it is common knowledge that there is no uniquely established way to assess the impact of "research projects/activities", as their goals are versatile and depend on the special "research projects'/activities'" scope, characteristics, nature, etc. However, this work/review, revealed information useful for defining the scope of the activity and the challenges, thus defining a framework using a logical model approach applicable to the MATILDA research process, incorporating specific indicators as criteria for assessment of research impact, emphasizing on activities, output/outcomes, and impact measures. To facilitate reading the key information/findings driving the formulation of this framework are summarised in this chapter.

2.1 The Meaning of Impact in R&D and Classification

Searching the literature one can come up with different conceptions regarding the meaning of impact when referring to R&D. However, it becomes quite obvious to the researcher that a clear definition for the term does not exist. In general terms, impact is described as consequences of an action (project, research or technology) that affect people's lives in areas that matter to them [ESF]. These consequences would not have occurred without the occurrence of the original action, and the consequences may affect aspects of life that do not fall in the "field of the action"; for instance, a technology research project may impact even loosely coupled aspects of life (e.g. slice-enabled, high QoS communications may increase quality of infotainment services, and at the same time, in another aspect, enhance emergency services and contribute to societal health).

To distinguish simple output or results from "impact", the latter shall be considered significant, although in general terms it may not necessarily be beneficial, while a single result of one action may have both positive and negative impact when assessed from different perspectives. At the same time, impact is not always a straightforward result, nor can be considered simply as the final product/outcome of an activity; its meaning extends beyond that. At the same time, it is not simply the direct consequences of an action, since we can never know if and when the consequences of an action are final. Therefore, "impact" is always defined along with a reference to a specific time period.

There are several definitions and along with that classifications of 'impacts' which are used by evaluators. In general, definitions and classifications used take into account attributes of "impacts" such as the following (list based on [EC2010], [Delanghe2010]):

- The nature of the impacts, that is, the human domain to which they appear. In R&D some of these can be (not restricted to) the following:
    - *Science impacts:* related to the impact of the results on the progress of knowledge, the development of scientific disciplines, as well as education in a specific scientific domain. Usually, a measure of scientific impact of a research

can be considered its publications' acceptance in the short term and the number of references to them in the long run, as well as its incorporation in academic/education processes.

- *Technology impacts:* related to the impact of the results on technology products, processes and services, as well as derived technical know-how. Apparently, indicators used for the assessment of these impacts can be versatile and are very technology-domain- and assessment process- specific.
- *Environmental impacts:* related - in very abstract terms - to the management of the environment, in particular to the management of natural resources and pollution, and the effects of climate research.
- *Health impacts:* related to impacts on individual human and public health.
- *Society and Culture/Ethics impacts:* related to people's well-being, behaviour, practices and activities, customs and habits, as well as cultural beliefs, values, attitudes and ethics within society.
- *Policy impacts:* related to the ways research influences policies, decisions and policy makers.
- *Political impacts:* related to the impact on political aspects of society.
- *Business/Economy impacts:* related to the impact on a business' / organization's fiscal situation, including operating costs, revenue, profits, business expansion to other profitable activities/products/portfolios, etc. These impacts also refer to economic returns, either through growth or increased productivity.
- *Business/Organisation impacts:* related to the effects on the business' / organization's processes and workflows engineering, on the market/ business value chains/ business models/ contractual agreements with peers and other market players, etc.
- *Business/Symbolic impacts:* related to non-tangible business benefits such as the brand-name recognition increase, etc.

- The scope of the impact, meaning the extent to which the aforementioned domains are impacted in terms of number/groups/segments of people affected. Of course, the scope depends highly on the nature of the activity and the impact, the field of the activity, the geographic location of both the activity and the domain it addresses. For the latter factor, of course globalisation has played a significant role. In R&D, the scope of impact may affect:
  - The whole society (society-wide impacts);
  - Complete groups of people/Communities, e.g. research communities working at specific research fields, communities with specific societal, locality, etc., characteristics;
  - Specific businesses, by this meaning companies/enterprises (legal entities) with specific business/market activities;

  - A number of individuals (not necessarily organised as groups/communities) with specific common characteristics/status, e.g.: professional, health, societal, locality, etc.

- The timing of the impact related to the timing of the activity and the timing of the assessment. In other words, an impact can be ([EC2010], [Delanghe2010]):
  - "Estimated", when referring to the impact to appear in the future; this is usually the impact that is considered the drive for R&D activities; however, the earlier the phase of R&D activities the less accurate/foreseeable the "estimated" impact. The latter may fall in any of the aforementioned types of impact, even not strictly related to the field of the activity; e.g. a technology research activity may have societal/health/ etc. impact.
  - "Contemporary", when referring to the impact appearing at the time of assessment. In R&D projects, this is quite often measured by the impact of the dissemination and communication activities performed in the sense of acceptance by the research community; in other words, the higher the number of accepted dissemination items of the results, the higher the assessed impact of the project. If the research output is also contributing to collective work frames requiring consensus of externals, the number of expected contributions is more or less a measure of impact of the research activity to the field. Such case is the contribution in standardisation, forums or open source projects work.
  - "Ex-post", when referring to the impact that is assessed after its appearance. Such impact is usually considered as a measure for future steps/activities, etc.

It shall be noted that, one shall consider that different types of impact can be (usually) generated at different phases of a research process, associated with the generated: (1) research output, (2) knowledge transfer (Dissemination/Communication output), (3) community benefit (Standardization, projects' contribution, etc.) and (4) business impact (Business/Economic benefit).

The impact assessment methodology of R&D activities/ projects that will be followed is tightly connected to the type of impact to be measured (domain/scope/timing).

Although a measure of success of research projects is their technology and scientific impact, consideration of the business/economic impact becomes particularly relevant in times of economic recession, a point which has helped shape the US American Recovery and Reinvestment Act 2009 and its allocation of a budget of $126 billion for science and research infrastructures. At the same time, impact definition and assessment can be different when performed by different bodies of interest for the result. Table 1 [EC2010] shows the relationship between the body of interest and the type of impact. The typically noticed strength of the interest is indicated by the number of asterisks shown in each cell of the table.

It shows that, whereas the scientific community and funding agencies will have a major interest in the scientific and technological impact of research infrastructures, other interested parties will have interests in the wider range of impacts identified in this table.

Table 1: Indicative mapping between the type of impact vs body of interest [EC2010]

Interest from	Scientific impact	Technological impact	Economic impact	Social impact	Political impact	Environmental impact
Scientific community	***	**	*	*	*	*
Funding bodies	***	***	*	*	*	*
Policy makers	**	**	***	***	***	***
Business community		***	***			*
General public	**	***	***	***	***	***

To narrow down the scope of MATILDA's impact assessment on the basis of the aforementioned classification and to develop a logical approach and a "SMART" (meaning, as with targets, specific, measurable, attainable, relevant, and time-bound/time-relevant) assessment framework we focused on the following types of impact:

- The Technological impact in the field of 5G networks, in the worldwide technology/research community; contemporary to the project lifetime.

  This is strongly associated with the impact assessment of the technical output of the project.

- The Technological impact on specific vertical markets addressed; that is contemporary to the project lifetime.

  This is also strongly associated with the impact assessment of the technical output of the project.

- The Scientific impact in the research field of 5G networks; that is contemporary to the project lifetime.

  This is strongly associated with the impact assessment of the Dissemination/Communication output of the project.

- The Business impact on specific domains; that is contemporary to the project lifetime.

  This is strongly associated with the impact assessment of the Standardisation/ Communities contribution of the project.

- The Business impact on the MATILDA project partners; that is contemporary to the project lifetime, as well as estimated.

- The Business impact on the 5G networks' value chain; that is estimated to come with the adoption of 5G network infrastructures.

2.2 Indicators for R&D Impact Assessment and Analysis Methods

As next step, in order to develop a "SMART" framework, after identifying the type and scope of the impact assessment, the immediate next action would be to define the key indicators. To this end, one should take into consideration among others, the good conditions and practices regarding the design and use of indicators to provide useful assessment of impact of R&D activities.

At this point, a clear distinction needs to be made between output indicators, result indicators and impact indicators. In general terms, output indicators are related to immediate, tangible yield (product) coming out of certain work/ process and can be final or intermediate -and possibly used to feed other work/ process. Result indicators are generally related to the results deriving from an orderly followed process that is related to the outcome/product, e.g. related to its usage, performance, operation evaluation, etc. On the other hand, impact indicators are related to the broader effect of these outputs/results, to domains/entities that can be other than the ones generating the outcomes/results.

Across the literature, such indicators are generally ad hoc and purpose-built, which results in weak coherence and reduced opportunities for relevant comparisons and international benchmarking. They are also sometimes overloaded in terms of definitions and interpretations, creating a risk of misinterpretation. It becomes also obvious that indicators may vary on the basis of:

- the type of impact to be assessed,
- the specific R&D activity under assessment,
- the time scale to assess the impact, etc.

Especially challenging is the definition of long-term impact indicators, since R&D activities are subject to evolution over time, so indicators shall be designed or even adjusted over time to take into account these evolutions. At the same time, it is a challenge to foresee long-term impact on various domains, thus defining impact indicators capturing unintended long-term impacts.

Another challenging aspect is the assessment of failure in R&D activities, which are by nature risky. Latter risks are highly associated with the fact that highly innovative and pioneering research activities come out of established procedures and foreseeable paths. To this end, depending on the cause and nature of the failure, failure towards specific indicators may be interpreted as or actually result in successful impact towards other indicators.

Besides, the use of indicators to monitor and evaluate R&D activities can in itself bring unwanted effects as identified in [Delanghe2010], by influencing the R&D process towards achieving specific target values for specific indicators, while neglecting significant impact on side-domains, or/and, by providing misleading assessment results stemming by loose correlation between the impact indicators and the impacts themselves, can lead to a situation in which measured and real impacts may differ significantly (mostly for economic and societal impacts).

A direct consequence of the versatility of the impact indicators, even for R&D activities of the same field, is the need for an array of different sources of information and analytical methods to measure and monitor impacts. An indication of these sources, in terms of research methodologies and information requirements, is shown in Table 2 [EC2010].

Table 2: Measuring impacts and methods of analysis [EC2010]

Type of impact:	Measurement of:	Methods of analysis:
Scientific impact	Scientific outputs; rate of utilisation of the resource; training and capacity building	Peer review; bibliometrics; statistical reports; administrative records held by research infrastructures; surveys of users
Technological impact	Actual and potential spin-off products and services; links to private sector; national statistical information on inputs and outputs	Survey of spin off companies and activities; in-depth interviews with scientific staff of research infrastructures; innovation surveys; factor productivity analysis.
Economic impact	Contribution to GDP at regional and national levels; employment and incomes created at local, regional, national and supranational levels	National and regional accounting input output models; autoregressive variance analysis models; analysis of administrative data held by RIs
Social impact	Contribution to family and community wellbeing; amenity value of the facility	Synthetic reviews of evidence from science based on use of RIs; local population surveys
Political impact	Contribution to political stability, cohesion	Interviews with key informants; analysis of media publications
Environmental impact	Impact on air, water quality; energy balances; CO2 footprint	Synthetic reviews of evidence from science based on research infrastructures; analysis of energy use; analysis of environmental measures

Such approaches are taken into account in the definition of MATILDA's impact factors and performance indicators.

In terms of analysis methods, irrespectively of the type of impact to be assessed, a four-step approach is adopted (e.g. as in the framework that links research investment and well-being in [Sharpe2005]), comprising the following steps:

- Definition of the most important domains (social, economic, environmental, etc.), as well as their sub-domains (e.g. for the environmental domain: energy consumption, utilisation of physical resources, etc.).
- Definition of substantial indicators for domains or sub-domains.
- (Optionally) Identification of impact of specific interventions on the research process (e.g. increase of research investments, adoption of policies, etc.) that influence or determine specific indicators and define the procedures through which these interventions and the created knowledge affect the indicators.
- Assessment of the impact of on the basis of particular indicators of interest.

MATILDA impact assessment activities followed this four-step approach, eliminating the third step, as this applies more to the assessment of impact from the policy makers' side, and as no specific interventions have been made during the project lifetime. Guidelines for the MATILDA non-economic impact assessment were retrieved from the aspired strategic

impacts of the Strand 2: Flexible Network Applications of the ICT-08-2017 call, to which MATILDA contributes directly.

2.3 Challenges in R&D Impact Assessment

Assessing the impact of R&D is crucial for many reasons, first of all because R&D is financed by private investments or/and public funding associated with expectations for economic or societal returns as those identified in the classification of impacts (2.1). However, assessing the impact of R&D is not easy. Some of the challenges are related to the definition of the impact factors and the KPIs as mentioned in 2.2, while others are associated with the process of the evaluation/assessment of the KPIs. The most commonly encountered challenges are listed (non-exhaustively) below ([Delanghe2010], [Go8]):

1. **Research and Research Field Specificities**: As mentioned in 2.1, the output/results and impact can be very different for different research fields, even for different researches within the same field, and the definition of KPIs is also a challenge that depends on the type of the impact to be assessed. Thus, a single framework for assessment is quite difficult to achieve, even for comparison reasons.
2. **Lack of appropriate indicators**: It is often quite difficult to define and measure appropriate impact indicators associated with specific research outcomes, due to the lack of appropriate benefit categories and relevant transfer mechanisms.
3. **Measuring impact can distort behaviour**: The identification and use of particular KPIs can itself distort behaviour leading to unintended outcomes (especially if funding allocation depends on these KPIs).

These three challenges have been tackled within MATILDA by focusing on "SMART" strategic impact factors tightly addressed in Strand 2: Flexible Network Applications of the ICT-08-2017 call, to which MATILDA contributes directly, and defining "SMART" KPIs for their assessment that are closely related to the intended research.

4. **Identification of beneficiaries and impacted users**: It can be quite difficult to identify all end users who benefit from a particular research output/result, and even more difficult to identify those who are impacted in any way, mainly referring to long-term impact.
5. **Multiple benefits**: Research may have multiple benefits to diverse users, not all of which might be easily identified. In addition, it is always much more difficult to measure unintended effects than intended ones, making the task of impact assessment even more complicated.

MATILDA has addressed challenges 3 & 4 & 5 in the context of the project exploitation activities, through workshops/discussions/brainstorming analysis/etc. with project partners coming from a broad set of industries (verticals, telecom operators, vendors), as well as in the context of dissemination activities again through partners' information/ opinions/ input gathering from externals. The economically/ business impacted beneficiaries have been analysed in MATILDA D7.4 and D7.8. Longer-term impacted users and impact on loosely associated domains, other than those usually defined in the literature about 5G network softwarization and cloud computing, have been difficult and risky to be identified.

6. **Too many types of impact**: A research project may have many different types of impact achieved through diverse and not always transparent processes.
7. **Complex transfer mechanisms**: The potential mechanisms that can be utilised to transfer research results to society are difficult to identify and describe. The various models that have been developed are mainly empirical and they do not often provide a clear indication of the full impact of such transfers on society.

As with the previous challenges, with MATILDA being a pure technology research project, the identification of such mechanisms is not only challenging, it is very risky as it may just lead to misinterpretations, invalid results and only very loosely justified conclusions regarding the long term impacts on societal fields like health, environment, society & culture and political life. Therefore, the analysis focused on clearly visible impacted domains; namely, technological, scientific, and business (economic, organisational, symbolic) and in a foreseeable timeframe.

8. **Time lags**: Sometimes it may be premature to try to assess the impact of research, since specific research outcomes may require different time spans to generate their full effects. The time needed for an impact to be fully realised can be significant (and beyond the life span of individual research projects or even the researchers themselves). In addition, the apparent short-term impact of a research project can be quite different from the non-apparent long-term one.
9. **Valuation**: In most cases, it is quite difficult to assign a monetary value on non-economic impacts to make them comparable or measurable, due to the lack of concrete, broadly validated mechanisms to assign a monetary value on non-economic impacts. Even the monetary value of the products themselves is quite difficult to assess at early development phases, given the fact that they can be affected by a number of business factors not strictly related to the production cost (e.g. competition, aspiration of attracting large market share with low prices, etc.).

Other challenges that have not appeared in the case of MATILDA are the following:

10. **Dependence on other research**: The impact of the output of a research project may depend on complementary progress in other areas of research or technology.

The impact of MATILDA in the long run and in the broad market is tightly associated with the progress expected in the field of applications development, and more precisely with the cloudification of currently stand-alone applications of vertical sectors, with the adoption of edge computing capabilities from 5G-network operators and the steps to be followed towards 5G-ready applications' support. Of course, these influencing factors are out of control of MATILDA; however, numerous advanced studies foresee rapid adoption of these technologies, thus cannot be considered as impediments for MATILDA adoption and. vice versa. MATILDA is expected to boost these advancements.

11. **Interdisciplinary output**: A research project may have a number of impacts, which may belong to different scientific sectors and may be difficult to be identified in their totality.

With MATILDA being a pure software/network-field project, such challenge is non-existent.

12. **Negative impact**: While the focus of impact assessment tends to be on the beneficial effects of research, it is sometimes inevitable for research to create unintended or unwanted impacts that need to be considered.

Such type of impact has not been identified in MATILDA.

13. **Research can be a high-risk activity (impact-wise)**: The results of a research project cannot be guaranteed to be exactly as the ones promised, predefined, planned, or expected.

Despite the risks, the initially expected results of MATILDA have been completely achieved.

The MATILDA impact assessment framework and results are detailed in the following sections.

3 MATILDA Impact Assessment Framework

3.1 MATILDA Impact Assessment Focus

Following the existing knowledge, methodologies and best practices presented in the previous chapter, the MATILDA impact assessment has been defined on the basis of an applicable, logical model approach and a "SMART" (i.e. specific, measurable, attainable, relevant, and time-bound/time-relevant) assessment framework, emphasizing on MATILDA activities, output/outcomes, and impact measures.

The MATILDA impact assessment framework is focusing on four domains associated with the four stages of the research process; namely:

1. Research output, the first stage where impact can appear, closely related to the technical output/results of the project.
2. Knowledge transfer, the second stage where impact can be visible, through the projects' Dissemination and Communication output/results.
3. Community approach, the third stage, where the R&D activity reaches out the research/ industry/ technology communities for consensus/approval/adoption, e.g. with visible impact in the contribution to standardization.
4. Business Development, the fourth stage, where the R&D activity's outcome/results are transferred to business processes, where the business/economic benefit/impact is visible.

The MATILDA assessment focuses on "contemporary" impact during the lifetime of the project for the first three domains, while for the fourth one (business impact), besides the "contemporary" impact for the MATILDA partners, effort has been put to assess "estimated impact" in the forthcoming period - of about 5 years, associated with the adoption and penetration of 5G network deployments in the telecommunications' market segment. In particular, focus has been put on the following types of strategic impact:

1. The Technological impact in the field of 5G networks, in the worldwide technology/research community; contemporary to the project lifetime.

   This is strongly associated with the impact assessment of the technical output of the project.

2. The Technological impact on specific vertical markets addressed; that is contemporary to the project lifetime.

   This is also strongly associated with the impact assessment of the technical output of the project.

3. The Scientific impact in the research field of 5G networks; that is contemporary to the project lifetime.

   This is strongly associated with the impact assessment of the Dissemination/Communication output of the project.

4. The Business impact on specific domains; that is contemporary to the project lifetime.

   This is strongly associated with the impact assessment of the Standardisation/ Communities contribution of the project.

5. The Business impact on the MATILDA project partners; that is contemporary to the project lifetime, as well as estimated.
6. The Business impact on the 5G networks' value chain; that is estimated to come with the adoption of 5G network infrastructures.

3.2 MATILDA Strategic Generic Impact Factors

As next step, the main impact sub-domains on which the impact of MATILDA is assessed have been nailed down to major Strategic Generic Impact factors. The latter have been refined throughout the project timeline along with the corresponding success indicators.

Table 3: MATILDA Strategic Generic Impact (SGI) Factors

Strategic Generic Impact Factor	
Technological Impact Factors	
SGI#1	Open environments for creation of 5G-ready Apps.
SGI#2	Open repository of 5G-ready Apps to be validated and leveraged by 3rd party developers
SGI#3	Validation at scale of the VNF aggregation capability of MATILDA environment
SGI#4	Quicker development, validation of vertical-specific NSs & Apps (time-to-market)
SGI#5	Acceleration of adoption of NFV with necessary roadmap and blueprints for operators and vendors.
SGI#6	Better integration of industry verticals into 5G networks, by providing the customizable platform for developers to serve specific industries (e.g. Media, Automotive, Industry 4.0, etc.) rather than generic services that do not fully exploit new network capabilities for each vertical.
SGI#7	Repository of open building blocks (micro-services approach) to catalyze 3rd-party developers' efforts
SGI#8	Enabling the operation of next generation VNFs that would operate in a multi site, multi VIM platform in conjunction with PNFs.
SGI#9	Cost reduction and rationalization of OSS/BSS tools and strategies towards total service continuity and reduction of perceived downtime.
Scientific Impact Factors	
SGI#10	Contribution to EU booth at MWC 2019 with demo / testbed showcasing the set of 5G PPP Phase 2 projects results and similar activities
SGI#11	Dissemination of results to the research community
SGI#12	Dissemination of results to the industry & general public (Communication Activities)

Strategic Generic Impact Factor	
SGI#13	Communication of NFV-related roadmap and blueprints to operators and vendors
Business Impact Factors	
SGI#14	Contribution to Standardization Organizations
SGI#15	Business Impact for MATILDA partners
SGI#16	Synergies achieved
SGI#17	Business Impact on 5G Value Chain

At next stage, we have identified "SMART" indicators (i.e. KPIs) to assess these strategic impact factors along with their probing points to be monitored and evaluated, and we have established a KPI monitoring procedure. It shall be noted that, throughout the project lifetime, the impact factor indicators have been periodically monitored and assessed by collecting input from all project structures (Work-Packages, Demonstrators, Partners), in order to maximise impact, and raise awareness among partners about the KPIs' fulfilment criticalities early enough so as to uptake corrective actions.

4 MATILDA Technical Impact Factors and Assessment

The assessment of the technical impact of MATILDA has been carried out against the aspired strategic impacts of the Strand 2: Flexible Network Applications of the ICT-08-2017 call, to which MATILDA contributes directly. The definition of these strategic technical impact factors, the KPIs, the measurement procedure and their assessment at the end of the project lifetime is presented in this chapter.

4.1 SGI#1: Open environments for creation of network apps

Definition: MATILDA aimed at delivering an innovative collaborative development environment supporting the design and development of 5G-ready applications, VNFs and VNF-FGs, including a web-based IDE, verification and graphs composition mechanisms. In addition to the development environment, MATILDA aimed at delivering a set of metamodels representing the applications' components and graphs, the virtual -and physical- network functions and forwarding graphs and a policies' description language denoting policies per end-to-end 5G service, which further facilitate the network apps' creation.

KPIs and Assessment*:* A measure of the contribution of the project to the specific strategic impact has been the delivery of a specific list of components implementing the aforementioned capabilities, namely:

- Application, VNF-FG and Policies Metamodels
- Application & VNF/PNF Development Environments and Marketplace
- 5G-ready & Network-aware Application Graph Composers

The delivery of these components has been verified by direct observation in the MATILDA demonstrator sites, as well as by the reporting of this work as performed in WP1 and WP2 deliverables. As observed, the expected impact of MATILDA to SGI#1 has been achieved towards the initially defined targets. In particular:

Table 4: SGI#1 KPIs Assessment

SGI#1 KPIs	Target	Achieved	Verified	Comments
5G-ready & Network-aware Application Graph Composers	2	2	D2.1, D2.2	A Composer has been developed for 5G-Ready applications' graphs, where the end user is able to declare requirements for NSs/VNFs that have to be activated during deployment of the application graph by the MATILDA OSS. Furthermore, for the composition of NSs, available tools by OSM are adopted.
Application & VNF/ PNF Development Environments and Marketplace	3	3	D2.1, D2.2	3 Environments developed for offering application components, application graphs and VNFs.

SGI#1 KPIs	Target	Achieved	Verified	Comments
Application, VNF-FG and Policies Metamodels developed	3	4	D1.2, D1.3, D1.4, D1.5	4 Metamodels developed: Application components' metamodel, Slice intent metamodel, Application Graph metamodel, & Policies Metamodel.

4.2 SGI#2: Open repository of network apps that may be validated and leveraged by third party developers

Definition: This strategic impact lies within the very core of the MATILDA concept. MATILDA delivered a marketplace including an applications' and VNFs' repository. These two repositories were populated within the context of the project along with a set of mechanisms for supporting the diverse 5G stakeholders in accessing these repositories, uploading, deleting, modifying and deploying its components in various instances. In the context of the project, the marketplace became open to 3rd party application developers and service providers initially being the project use case partners.

Brokering activities through the capability to introduce software made available by 3rd party repositories (open-source or private) are supported by the platform. At the same time validation mechanisms for selecting the optimal component during application graph composition to satisfy specific user requirements are also supported.

The complete software is Apache licensed, and an open-source software release is available upon request; some others are completely open source.

KPIs and Assessment: Measure of the contribution of the project to the specific strategic impact has been the delivery of:

- the aforementioned repositories,
- loaded with a target number of components,
- accessible to a number of 3rd –party developers.

The delivery of these components has been verified by direct observation in the MATILDA demonstrator sites, as well as by the reporting of this work as performed in WP1, WP2, and WP4 deliverables. The engagement of 3rd party application developers has been initially verified in WP6 (work and deliverables) through the testing, evaluation and demonstration activities with MATILDA use case partners being application developers and service providers. As observed, the expected impact of MATILDA to SGI#2 has been achieved towards the initially defined targets.

Table 5: SGI#2 KPIs Assessment

SGI#2 KPIs	Target	Achieved	Verified	Comments
Network apps & VNF Repositories	2	3	D2.1, D2.2	3 Repositories developed: The application Components repository, the application Graphs repository & the VNF repository

SGI#2 KPIs	Target	Achieved	Verified	Comments
Application components included in the repository	>=40	45	D2.1, D2.2, Final Demo	These components regard the set of the components developed in the five MATILDA demonstrators, as well as other open-source components included by third-party libraries.
VNFs included in the repositories	>=15	16	D2.1, D2.2, D4.1, D4.2	15 VNF and 1 PNF packages have been released, each composed of one or more disk images to instantiate the VDU, one VNFD and additional storage volumes for persistency purposes.
Engaged third-party application developers	>=30	40	D2.1, D2.2, D6.1-D6.12	Application developers engaged in the MATILDA demonstrators, as well as interested parties by other 5G PPP projects (e.g. SLICENET, 5GTANGO, etc.).

4.3 SGI#3: Validation at scale of the VNF aggregation capability of the proposed environment

Definition: This strategic impact is fundamentally associated with the MATILDA concept. As verified also with SGI#2, MATILDA delivered a VNFs repository with a number of VNF components, from where various VNFs were aggregated and bundled in order to compose 5G-ready, network-aware applications and services as defined by the MATILDA vertical use cases. Existing VNFs were included in the VNF repository (such as Amarisoft EPC, VyOS, OpenAirInterface, etc.), while additional VNFs were also developed (such as the Bypass VNF developed by CNIT, or qMON client and server VNFs developed by ININ).

Besides, VNF Forwarding Graphs -generic or targeted to specific verticals- were composed based on the MATILDA Graph Composer, leading to a set of network services aggregating VNFs functionality in the form of a service chain. These applications and services, consisting (among others) of aggregated VNFs were validated within the context of the MATILDA demonstrators.

KPIs and Assessment: Measure of the contribution of the project to the specific strategic impact has been the delivery of a VNF repository:

- With a target number of VNFs included,
- With a target number of VNF graphs,
- Validated through a specific number of vertical use case services
- Using all the included VNFs.

The delivery of these components has been verified by direct observation in the MATILDA demonstrator sites, as well as by the reporting of this work as performed in WP1, WP2, and WP4 deliverables. The level of usage of the VNFs in the VNF repository for the development of the MATILDA vertical use case services has been verified in the context of WP6 activities and the associated deliverables. As observed, the expected impact of MATILDA to SGI#3 has been achieved towards the initially defined targets.

Table 6: SGI#3 KPIs Assessment

SGI#3 KPIs	Target	Achieved	Verified	Comments
VNFs included in the repositories	>=15	16	D2.1, D2.2, D4.1, D4.2	15 VNF and 1 PNF packages have been released, each composed of one or more disk images to instantiate the VDU, one VNFD and additional storage volumes for persistency purposes.
VNF-Forwarding Graphs composition	>=10	>=10	D6.2 - D6.12	VNF-Forwarding Graphs composition is tightly associated with the Demonstrators, so at least 6 are exhibited. At the same time one Network Service may have more than one VNF-FG, and a number of VNF-FGs have been composed and tested for each Demonstrator.
Number of discrete vertical applications/services validating	5	5	D6.2 - D6.12	The VNF aggregation capability has been validated through the specification of application aware network slices.
Percentage of VNFs available in the repository, aggregated for the development of services	100%	100%	D6.2 - D6.12	All VNFs have been tested and used for the development of services.

4.4 SGI#4: Quicker development, validation of vertical-specific network services and applications (time-to-market)

Definition: MATILDA aimed at minimising the time-to-market of 5G-ready network-aware applications and services, especially regarding the time to develop a 5G-ready application and validate its deployment a priori, via a set of tools necessary for the application (and VNF/PNF) developers.

- For enabling the 5G-ready network aware applications development process, MATILDA delivered a set of metamodels (4 in total): representing (1) a network service and/or application components and (2) graphs, (3) along with the necessary VNFs/PNFs, and (4) the required policies (via providing a description language denoting policies per end-to-end 5G service).
- For the applications' development and validation process, MATILDA also delivered an innovative collaborative development and validation environment supporting the design and development of 5G-ready applications and VNF-FGs, including a web-based IDE, verification and graphs composition mechanisms, which facilitated the quick development and validation of vertical-specific network services and applications.

These tools have been validated with the work delivered in WP2, WP3 and WP4, as well as in the context of the MATILDA demonstrators. The result of these tools on the speed and efficiency of 5G-ready applications development and validation has been measured in the context of WP6.

KPIs and Assessment: Measures of the contribution of the project to the specific strategic impact have been KPIs related to the efficiency and speed of developing and validating 5G ready applications and services.

The assessment of these aspects has been performed in the context of WP6 activities by the MATILDA development team, but also by the MATILDA vertical use case partners. As observed, the expected impact of MATILDA to SGI#4 has been achieved towards the initially defined targets.

Table 7: SGI#4 KPIs Assessment

SGI#4 KPIs	Target	Achieved	Verified	Comments
Self-reported (by application (and VNF/PNF) developers) decrease in time required to develop and validate 5G-ready network-aware applications and services	>20%	At least > 50%	D6.7, D6.13	Self-assessment of the KPI based on input provided by application developers in the MATILDA demonstrators
Self-reported efficiency increase (by application (and VNF/PNF) developers) in developing and validating 5G-ready network-aware applications and services	>20%	At least > 50%	D6.7, D6.13	Self-assessment of the KPI based on input provided by application developers in the MATILDA demonstrators

4.5 SGI#5: Accelerate the adoption of NFV with necessary roadmap and blueprints for operators and vendors

Definition: The assessment of this strategic impact factor comes hand in hand with SGI#3: "Validation at scale of the VNF aggregation capability of the proposed environment" at the technical level, thus the KPIs are common between these two SGIs. More specifically, MATILDA fostered the adoption of NFV through the delivery of a number of VNFs to be used by operators & vendors, along with the necessary repository/retention environment. At the same time MATILDA has put a lot of effort in the acceleration of the adoption of NFV by 3rd party operators and vendors, by adequately disseminating and documenting the VNFs roadmap and blueprints.

The associated technical work has been validated with the work delivered in WP2 and WP4, while its dissemination to 3rd parties has been documented in WP7 deliverables.

KPIs and Assessment: Measures of the contribution of the project to the specific strategic impact have been KPIs related to the development and retention of VNFs in the context of the project, as well as with the dissemination and documentation of this work to be usable by 3rd parties.

The assessment of these aspects has been performed in the context of WP2 and WP4 activities by the MATILDA development team, as well as in the context of WP6 by the MATILDA vertical use case partners. As observed, the expected impact of MATILDA to SGI#5 has been achieved towards the initially defined targets.

Table 8: SGI#5 KPIs Assessment

SGI#5 KPIs	Target	Achieved	Verified	Comments
VNF and Application Component repositories	2	3	D2.1, D2.2	3 Repositories developed: The application Components repository, the application Graphs repository & the VNF repository
VNFs included in the repositories	>=15	16	D2.1, D2.2, D4.1, D4.2	15 VNF and 1 PNF packages have been released, each composed of one or more disk images to instantiate the VDU, one VNFD and additional storage volumes for persistency purposes.
White papers and contribution to roadmaps	>=5	>=5	D7.2, D7.6	Significant contributions relevant to NFV adoption have been delivered to: the 5G-PPP architecture WG, the 5G-PPP KPIs WG, as well as through common papers with other 5G-PPP projects and through MATILDA white papers. These contributions focused on assisting the cartography of 5G networks/services orchestration ecosystem.

4.6 SGI#6: Better integration of industry verticals into 5G networks by providing the customisable platform for developers to service specific industries (e.g. Media, Industry 4.0, etc.) rather than generic services that do not fully exploit new network capabilities for each vertical

Definition: The integration of a number of vertical industry services with various environments that are different in terms of requirements/ services/ applications/ operation, has been one of the fundamental concepts of the MATILDA approach. MATILDA defined the appropriate abstractions (through delivering the set of the aforementioned metamodels) for the design of 5G-ready applications for industry verticals to be able to take advantage of a 5G programmable infrastructure, rather than the development of generic applications/services that do not fully exploit new network capabilities and services for each vertical.

MATILDA also developed an end-to-end orchestration platform for 5G-ready applications, consisting of the VAO and the OSS, supporting the deployment and runtime management of vertical applications over application-aware network slices, targeted to the needs of distinct industry verticals.

Last but not least, the project provided mechanisms for semi-automated translation of application-specific requirements to programmable infrastructure requirements, triggering

the setup of the appropriate application-aware network slices for supporting applications of an industry vertical in an optimal way.

KPIs and Assessment: KPIs, assessing this impact factor, are related to the engagement in the validation/assessment activities of the project of a number of vertical industries (versatile in nature and requirements) having very different applications/services.

The assessment of these aspects has been performed in the context of WP6 by the MATILDA vertical use case partners. As observed, the expected impact of MATILDA to SGI#6 has been achieved towards the initially defined targets.

Table 9: SGI#6 KPIs Assessment

SGI#6 KPIs	Target	Achieved	Verified	Comments
Industry vertical 5G demonstrators / testbeds	5	5	D6.2 - D6.6	Testbeds: CNIT/UBI/ININ/ORO/UNIVBRIS (and COSM (supportively))
Discrete industry vertical domains addressed	5	6	D6.2 - D6.6	PPDR (ININ) / IoT (ORO)/ Media (ITL & INC)/ Automotive (EXXPERT)/ Logistics (BIBA) / Industry 4.0 (BIBA)

4.7 SGI#7: Repository of open building blocks (microservices approach) to catalyse third-party developer efforts

Definition: The assessment of this SGI comes hand in hand with SGI#2, SGI#3 and SGI#5, thus the KPIs are common between these two SGIs. As aforementioned, MATILDA delivered a marketplace including an application component, application graph and VNF repository and a set of mechanisms for supporting the diverse 5G stakeholders in the context of the project being the vertical use case partners. These repositories have been populated within the context of the project.

Brokering activities are supported by the platform through the capability to introduce software made available by 3rd party repositories (open-source or private). At the same time, matchmaking mechanism for selecting the optimal component (especially with regard to NFV ones) to satisfy specific user requirements are also supported.

KPIs and Assessment: Measures of the contribution of the project to the SGI have been KPIs (common with SGI#2) related to the development and retention of applications, application components and VNFs in the context of the project, as well as with the retention and population of this work to be usable by 3rd parties.

The assessment of these aspects has been performed in the context of WP2 and WP4 activities by the MATILDA development team, as well as in the context of WP6 by the MATILDA vertical use case partners as 3rd parties to use these components. As observed, the expected impact of MATILDA to SGI#7 has been achieved towards the initially defined targets.

Table 10: SGI#7 KPIs Assessment

SGI#7 KPIs	Target	Achieved	Verified	Comments
VNF and Application Component repositories	2	3	D2.1, D2.2	3 Repositories developed: The application Components repository, the application Graphs repository & the VNF repository
Application components included in the repository	>=40	45	D2.1, D2.2, D6.1-D6.12	These components regard the set of the components developed in the five MATILDA demonstrators, as well as other open-source components included by third-party libraries.
VNFs included in the repositories	>=15	16	D2.1, D2.2, D4.1, D4.2	15 VNF and 1 PNF packages have been released, each composed of one or more disk images to instantiate the VDU, one VNFD and additional storage volumes for persistency purposes.

4.8 SGI#8: Enabling the operation of next generation VNFs that would operate in a multi-site, multi-VIM platform in conjunction with physical network functions

Definition: MATILDA supported mechanisms for multi-site network, compute and storage resource management through the developed VAO OSS by:

- Delivering the MATILDA multi-site VIM that supported application and network services deployments over cloud/ edge computing resources that could belong at the same or different administrative domains, also leveraging OpenVolcano, enhanced with functionalities such as bypass capability (Mobile Edge Computing flavour), on-demand deployment of a network/ network slice/service, etc.
- Providing through the MATILDA VAO orchestration and lifecycle management of components and applications deployed at multiple sites, supporting different types of VIMs such as OpenStack-based, MS Azure, etc.
- Providing orchestration and lifecycle management of VNFs deployed at multiple sites through the MATILDA NFVO, interfacing with OSM, etc.

KPIs and Assessment: Measures of the contribution of the project to the SGI have been KPIs related to MATILDA's interfacing with multiple IaaS frameworks, and the capability to support deployments of applications and network functions and services across multiple sites.

The assessment of these aspects has been performed in the context of WP3 and WP4 activities by the MATILDA development team, as well as in the context of WP6 by the MATILDA vertical use case partners. As observed, the expected impact of MATILDA to SGI#8 has been achieved towards the initially defined targets.

Table 11: SGI#8 KPIs Assessment

SGI#8 KPIs	Target	Achieved	Verified	Comments
Support for multi-site management of cloud/edge computing and IoT resources	Yes	Yes	D3.1, D3.2, D4.1, D4.2	Support of multiple VIMs in the VAO and multiple PoPs in the OSS.
Interfaces with IaaS management frameworks (e.g OpenStack, OpenVolcano)	>=3	3	D3.1, D3.2, D4.1, D4.2	Interfaces with OpenStack, OSM, OpenVolcano,
Support for lifecycle management of VNF-FGs	Yes	Yes	D4.1, D4.2, D6.7, D6.13	This is an inherent capability of MATILDA VAO and new Telecom Layer
Sites used (concurrently) through demonstrators	>=3	3	D6.2 - D6.12	Multiple scenarios with use of resources in parallel from multiple sites have been realized (e.g. ININ/ORO demonstrator with resources in the ININ/ORO testbed and the CNIT testbed)

4.9 SGI#9: Cost reduction and rationalization of OSS/BSS tools and strategies towards total service continuity and reduced perceived downtime.

Definition: This strategic impact addresses the following capabilities/ features that MATILDA shall present to align with 5G vision and approach. In particular MATILDA targets:

- Cost reduction and increased efficiency of OSS/BSS procedures, which is achieved through MATILDA's radically new Telecom Layer Platform prototype to manage the entire lifecycle of 5G-ready Vertical Applications (vApps), by leveraging on pools of network services, spanning from the 4/5G radio all the way to the wide-area network, and of computing resources directly accessible by the VAO. This target is also addressed through MATILDA capability to support innovative partnership models built on synergies between network operators, service providers, infrastructure providers and vertical industries which can create new grounds for cost sharing.
- Reduction of perceived downtime which is achieved based on the set of intelligent orchestration mechanisms, including the runtime policies enforcement and the machine learning mechanisms adopted.

KPIs and Assessment: Measures of the contribution of the project to the SGI have been KPIs related to MATILDA's capability to support efficient OSS/BSS procedures and minimisation of required downtime(s). The assessment of these aspects has been performed in the context of

WP4 and WP6 activities and reported in [MATILDA-D6.13]. As observed, the expected impact of MATILDA to SGI#9 has been achieved towards the initially defined targets.

Table 12: SGI#9 KPIs Assessment

SGI#9 KPIs	Target	Achieved	Verified	Comments
Cost reduction of OSS/BSS tools	>5%	>5%	D7.4	The extended OSS realized by MATILDA is characterized by the continuous interaction with monitoring and NFV orchestration mechanisms, which offers telecommunication providers simplification, automation, and reduction of complexity and, as a consequence, lower OPEX, as well.
Increased efficiency of OSS/BSS tools	>5%	>5%	D7.4	The presence of a convergence layer in the OSS allows its integration with NFVOs in a "pluggable" way, in the sense that the NFVCL code currently supports OSM as NFVO but can be easily adapted to other products. As a consequence, it can be a fundamental tool not only to achieve a better management of network slices, but also to enable an easier adoption of 5G technologies for telecom providers.
Perceived downtime of services available through the MATILDA demonstrators	<1%	<1%	D6.2 - D6.6	The downtime of services at MATILDA demonstrators has been about 0% for demo operation, meaning that not considering the time for normal operations, such as development, maintenance, etc., no downtimes occurred after finalization of components' development. Moreover, the runtime policies enforcement capabilities of MATILDA allow for minimization of downtimes required for scaling of resources. It shall be noted also that this KPI is practically meaningful when evaluated at operational environments.

4.10 Technical Impact Assessment Summary

A summary of the technical impact of the project on the basis of its technical output/results is presented in the following table.

Table 13: Technical Impact Assessment Summary

SGI	KPIs	Target	Achieved	Verified
#1	5G-ready & Network-aware Application Graph Composers	2	2	D2.1, D2.2
#1	Application & VNF/ PNF Development Environments and Marketplace	3	3	D2.1, D2.2
#1	Application, VNF-FG and Policies Metamodels developed	3	4	D1.2, D1.3, D1.4, D1.5
#2, #5, #7	Network apps & VNF Repositories	2	3	D2.1, D2.2
#2, #7	Application components included in the repository	>=40	45	D2.1, D2.2, Final Demo
#2, #3, #5, #7	VNFs included in the repositories	>=15	16	D2.1, D2.2, D4.1, D4.2
#2	Engaged third-party application developers	>=30	40	D2.1, D2.2, D6.1-D6.12
#3	VNF-Forwarding Graphs composition	>=10	>=10	D6.2 - D6.12
#3	Number of discrete vertical applications/services validating the VNF aggregation capability	5	5	D6.2 - D6.12
#3	Percentage of VNFs available in the repository, aggregated for the development of services	100%	100%	D6.2 - D6.12
#4	Self-reported (by application (and VNF/PNF) developers) decrease in time required to develop and validate 5G-ready network-aware applications and services	>20%	> 50%	D6.7, D6.13
#4	Self-reported efficiency increase (by application (and VNF/PNF) developers) in developing and validating 5G-ready network-aware applications and services	>20%	> 50%	D6.7, D6.13
#5	White papers and contribution to roadmaps	>=5	>=5	D7.2, D7.6
#6	Industry vertical 5G demonstrators / testbeds	5	5	D6.2 - D6.6

SGI	KPIs	Target	Achieved	Verified
#6	Discrete industry vertical domains addressed	5	6	D6.2 - D6.6
#8	Support for multi-site management of cloud/edge computing and IoT resources	Yes	Yes	D3.1, D3.2, D4.1, D4.2
#8	Interfaces with IaaS management frameworks (e.g OpenStack, OpenVolcano)	>=3	3	D3.1, D3.2, D4.1, D4.2
#8	Support for lifecycle management of VNF-FGs	Yes	Yes	D4.1, D4.2, D6.7, D6.13
#8	Sites used (concurrently) through demonstrators	>=3	3	D6.2 - D6.12
#9	Cost reduction of OSS/BSS tools	>5%	>5%	D6.13
#9	Increased efficiency of OSS/BSS tools	>5%	>5%	D6.13
#9	Perceived downtime of services available through the MATILDA demonstrators	<1%	<1%	D6.2 - D6.13

In a few words, the Technological impact to the field of 5G networks, in the worldwide technology/research community, and on specific vertical markets, has been evaluated against KPIs related to the MATILDA technical output on Lifecycle Management of 5G-ready applications (components and graphs), VNFs (including Forwarding-Graphs and orchestration), and Network Services (associated also to Telecom Layer OSS capabilities). As observed, the project achieved all its technical goals against these KPIs and even exceeded the initially defined targets.

5 Scientific Impact Factors and Assessment

A measure of scientific impact is (among others) the amount of dissemination activities that have been performed, since they reflect the acceptance of the project scientific results by the broader academic/research/scientific communities. Dissemination efforts have been listed in [MATILDA-D7.2] and [MATILDA-D7.6] in detail. Although the impact of dissemination activities cannot always be assessed in the short term, but rather in the long run by the references to the disseminated material, project contemporary impact factors and KPIs have been defined to assess the dissemination work of the project (by the end of it) against the dissemination levels expected by the call.

5.1 SGI#10: Contribution to EU booth at MWC 2019 with demo / testbed showcasing the set of 5G PPP Phase 2 projects results and similar activities

Definition: SGI#10 is defined in the aspired strategic impacts of the Strand 2: Flexible Network Applications of the ICT-08-2017 call, to which MATILDA contributes directly. To this end, MATILDA has contributed with a demonstration of the project results, inside the EC booth in MWC 2019 (EU flagship PPP Phase 2 demonstration), as well as inside partners' booths (namely ORO), where the PPDR and smart lighting vertical use case demonstrators have been exhibited. Additionally to that the consortium pursued wide dissemination events to raise awareness about the project results, and has achieved participation with more than 9 booths in conferences and exhibitions; thus the initially defined SGI#10 has been extended to assess also such activities. Details about these activities have been presented in [MATILDA-D7.2] and [MATILDA-D7.6].

KPIs and Assessment: Measures of the contribution of the project to the SGI have been KPIs related to MATILDA's participation to MWC (especially MWC 2019), as well as KPIs related to the dissemination and exhibition of demonstrators in various public and project specific events. The assessment of these aspects has been performed in the context of WP6 and WP7 activities. As observed, the expected impact of MATILDA to SGI#10 has been achieved, even exceeded towards the initially defined targets. It shall be noted that MATILDA participated with presentations also at early stages of the project in MWC 2018.

Table 14: SGI#10 KPIs Assessment

SGI#10 KPIs	Target	Achieved	Verification - Comments
Demonstrators made available by the MWC event organization	5	3	3 demos at MWC 2019 -given the competitiveness of MWC 2019: Live presentation by UBI & ININ, Booth & Demo by ATOS/UBI/ININ, Booth & Demo by ORO. *To address this target however a large number of demos/booths at other events were pursued as in the following (new) KPI.*

SGI#10 KPIs	Target	Achieved	Verification - Comments
Number of Demonstrations/Booths @ events		>9	Such as: 2x Demos at EUCNC 2018 in Ljubljana (ININ & UBI/ININ), Booth & Demo at PSCE 2018 in Slovenia (ININ), Demo at ICT2018 -part of 5GPPP Booth (UBI/ININ), & 2x Booths & Demos at MWC19, x2 Booths (one in 5GPPP SME & by one ININ/UBI/ITL) at EuCNC 2019 in Valencia, Booth & Demo at Digital Assembly 2019 (ORO)
Participation at MWC 2019	Yes	Yes	https://twitter.com/matilda5g
Contribution to EU booth at MWC 2019 with demo / testbed showcasing MATILDA results	Yes	Yes	https://twitter.com/matilda5g https://www.ubitech.eu/ubitech-demonstrates-the-maestro-5g-applications-orchestrator-in-the-mobile-world-congress-2019/

5.2 SGI#11: Dissemination of results to the research community

Definition: A complete dissemination and communication activities strategy had been devised (D7.1) and followed throughout the project, targeting the maximization of the project's impact to research and academic communities. Dissemination activities have been presented in detail in [MATILDA-D7.2] and [MATILDA-D7.6]. As mentioned in 2.2, Dissemination activities can be considered as a measure of acceptance of the project activities by the communities, as well as an estimated impact to assess the project results' sustainability beyond the project end.

KPIs and Assessment: The KPIs and the targets along with the achieved impact is summarized in the table below. As observed, the expected impact of MATILDA to SGI#11 has been achieved, even exceeded, towards the initially defined targets.

Table 15: SGI#11 KPIs Assessment

SGI#11 KPIs	Target	Achieved	Verification - Comments
Scientific papers submitted in high-impact topic-specific journals in the domain	>=10	>13	As reported in D7.2 and D7.6
Scientific papers submitted in high-impact topic-specific conferences in the domain	>=20	>32	As reported in D7.2 and D7.6, MATILDA contributed with >32 conferences papers (> 20 conference participations/ presentations)

Posters presented in high-impact topic-specific conferences in the domain	>=3	4	**5.3** 1 general poster, 1 at EUCNC 2018 (INC/ITL), 1 at Lecture at Faculty of Computer Science - Iași, Romania (ORO) and 1 at EuCNC 2019 (ATOS/UBI/COSM)
Number of scientific & technical workshops organized	2	5	MATILDA co-organized 4 scientific & technical workshops at EuCNC'18, 1 scientific and stakeholders clustering (with NGPAAS) workshop at EuCNC'19 (co-located with 7th Global 5G Event)
Book Chapters	0	3	As reported in D7.6

5.4 SGI#12: Dissemination of results to the industry and general public (Communication Activities)

Definition: In line with the MATILDA dissemination and communication activities strategy [MATILDA-D7.1], communication activities focused on maximizing impact especially on industry communities. Communications activities have been presented in detail in [MATILDA-D7.3] and [MATILDA-D7.7]. Also in this case, as mentioned in 2.2, communication activities can be considered as a measure of acceptance of the project activities by the communities, as well as an estimated impact to assess the project results' sustainability beyond the project end.

KPIs and Assessment: The KPIs and the targets along with the achieved impact are summarized in the table below. It shall be noted that some activities performed have not been foreseen at the initial proposal/project stages, thus the initial KPIs table has been extended to include these activities. In general terms, the SGI#12 targets have been exceeded in many cases, which reflects the high acceptance of MATILDA work by the scientific/research/industry communities.

Table 16: SGI#12 KPIs Assessment

SGI#12 KPIs	Target	Achieved	Verification - Comments
Presentations at forums, industrial events		~30	A number of presentations, invited talks and representations at panel discussions have been performed as detailed in D7.2 and D7.6
Press Releases & other official communication/ news		>6	COSM, ORO have issued press releases, while UBI, ININ and other partners have a number of news posts in their official websites.
Project website	1	1	http://www.matilda-5g.eu/
Additional website pages		2	COSMOTE, UBITECH

SGI#12 KPIs	Target	Achieved	Verification - Comments
Project Logo	1	1	http://www.matilda-5g.eu/
Social media accounts (Twitter, Facebook, LinkedIn)	3	4	http://www.facebook.com/sharer.php?u=http://www.matilda-5g.eu/index.php/outcomes , http://twitter.com/share?url=http://www.matilda-5g.eu/index.php/outcomes&text=MATILDA%20Outcomes, http://www.linkedin.com/shareArticle?mini=true&url=https://plus.google.com/share?url=http://www.matilda-5g.eu/index.php/outcomes
YouTube channels	1	1	As in: https://www.youtube.com/channel/UCFbGjARCa32akAXlVKy7-IQ
Videos uploaded on YouTube channel	>=3	5	
Public presentations available online (e.g. on Prezi)	>=4	>=25	Almost all presentations at events (Conferences, Workshops, etc.) are available online at the MATILDA official Website (URL: https://www.matilda-5g.eu/index.php/outcomes)
Training material (user manuals, related documents & presentations)	>=10	>=10	>3 white papers, >2 University trainings, 1 user manual online at the MATILDA official Website, >5 training presentations to stakeholders
Wikipedia pages created	1	0	Due to Wikipedia policies, it is not possible to have separate Wikipedia page for (EU, etc.) projects
Newsletters distributed to identified stakeholders	4	4	Issue #1 on March 2018 with 763 downloads, Issue #2 on November 2018 with 353 downloads, Issue #3 on March 2019 with 406 downloads, Issue #4 on November 2019 with 414 downloads
Leaflets and flyers distributed at various events	>=250	Yes	Events: @MWC 2018 and 2019, EUCNC 2018 and 2019, ICT 2019 & Others

5.5 SGI#13 Communication of NFV-related roadmap and blueprints to operators and vendors

Definition: SGI#13 also lies within the very core of the MATILDA approach. Besides the technical impact indicators reported in 4.5, an additional one is related to the dissemination of the relevant information through a set of white papers that were produced, contributing to 5G PPP roadmaps and blueprints.

KPIs and Assessment: SGI#13 has been assessed by the number of dissemination/ communication activities and material that has been generated in the context of MATILDA, that are especially targeting the NFV technical field. Such KPIs are summarised below. As

observed, the expected impact of MATILDA to SGI#13 has been achieved towards the initially defined targets.

Table 17: SGI#13 KPIs Assessment

SGI#13 KPIs	Target	Achieved	Comments
White papers and contribution to roadmaps	>=5	>=5	Significant contributions relevant to NFV adoption have been delivered to: the 5G-PPP architecture WG, the 5G-PPP KPIs WG, as well as through common papers with other 5G-PPP projects and through MATILDA white papers. These contributions focused on assisting the cartography of 5G networks/services orchestration ecosystem.
Number of industrial & stakeholders clustering workshops organised	2	3	1. MOBISLICE/5GNETApp clustering workshop organized by UBI and CNIT, in conjunction with the 4th IEEE Conference on NFV and SDN, in Verona, Italy, 27/11/2018. 2. Clustering workshop with EU2020 project SLICENET, 12-14 /11/2019. (Organized by ORO, in conjunction with MATILDA plenary meeting) 3. Final technical and industrial workshop (entitled, MATILDA – Autonomic deployment and lifecycle management of 5G & beyond services) organized alongside the 2nd 6G Wireless Summit 2020, in Levi, Lapland, 17 –20 /3/2020. Organized by AALTO and CNIT. Due to COVID-19 situation the workshop was eventually performed online.
Number of invited persons in a position to push MATILDA to the market (e.g. investors)	>=10	>=10	MATILDA has been presented in a wide number of industry events and forums where key stakeholders were approached. At the same time, persons from industry that can influence the market have been invited at the workshops organized by MATILDA.

5.6 Scientific Impact Assessment Summary

A summary of the scientific impact of the project on the basis of its performed dissemination and communication activities is summarized in the following table.

Table 18: Scientific Impact Assessment Summary

SGI	KPIs	Target	Achieved
#10	**Demonstrators made available by the MWC event organisation**	5	3
#10	**Number of Demonstrations/Booths @ events**		>9
#10	**Participation in MWC 2019**	Yes	Yes

SGI	KPIs	Target	Achieved
#10	Contribution to EU booth at MWC 2019 with demo / testbed showcasing MATILDA results	Yes	Yes
#11	Scientific papers submitted in high-impact topic-specific journals in the domain	>=10	>13
#11	Scientific papers submitted in high-impact topic-specific conferences in the domain	>=20	>32
#11	Posters presented in high-impact topic-specific conferences in the domain	>=3	4
#11	Number of scientific & technical workshops organized	2	5
#11	Book Chapters	0	3
#12	Presentations at forums, industrial events		~30
#12	Press Releases		>6
#12	Project website	1	1
#12	Additional website pages		>2
#12	Project Logo	1	1
#12	Social media accounts (Twitter, Facebook, LinkedIn)	3	4
#12	YouTube channels	1	1
#12	Videos uploaded on YouTube channel	>=3	5
#12	Public presentations available online (e.g. on Prezi)	>=4	>=25
#12	Training material (user manuals, related documents & presentations)	>=10	>=10
#12	Wikipedia pages created	1	0
#12	Newsletters distributed to identified stakeholders	4	4
#12	Leaflets and flyers distributed to various events	>=250	Yes
#13	White papers and contribution to roadmaps	>=5	>=5
#13	Number of industrial & stakeholders clustering workshops organized	2	3
#13	Number of invited persons in a position to push MATILDA to the market (e.g. investors)	>=10	>=10

At this point it shall be noted that dissemination and communication activities have been realised not only from MATILDA channels, but also from partners' ones as presented in detail in [MATILDA-D7.7]. Indicatively, ATOS has conducted three twitter campaigns namely for EuCNC 2019, for 6G-Summit Workshop and for the BVME whitepaper, where the captured public impression (in a way, the impact on public), has been:

- EuCNC 2019: 1196 impressions (number of times the tweet was shown), 22 interactions (likes, comments, clicks...) and from the @ATOS account: 4.700 impressions and 47 interactions
- 6G Summit Workshop: 1743 impressions, 31 interactions, 6 tweets
- BVME whitepaper: 345 impressions, 3 interactions, 2 tweets.

In a nutshell, the scientific impact in the research field of 5G networks associated to the Dissemination output of the project has been evaluated against KPIs related to MATILDA participation in conferences / workshops / exhibitions with demonstrators, presentations, papers. In addition, the same strategic impact associated to the Communication output of the project to approach stakeholders and the market has been evaluated against KPIs related to establishing social media and corporate communication channels and generating / presenting material in industrial events/ forums / tutorials/ webinars / website, etc. As observed, the project achieved all its dissemination / communication goals against these KPIs and even exceeded the initially defined targets, while additional means/ channels of dissemination/ communication were utilised (not initially foreseen).

6 Business Impact Factors and Assessment

6.1 Business Impact on 5G Networks Industry

As mentioned in 2.2, measure of business impact on the general industry at the early stages of the project -although not necessary- can be the accepted contributions of the project to standards. However, the latter is usually related with pieces of the complete work performed in a project, and industry sector consensus at standardisation level usually comes in slow steps; thus, though it cannot be considered a very indicative measure of impact in the short term, but rather in the long run, it can provide some initial indication. MATILDA standardisation efforts have been provided in [MATILDA-D7.6] in detail.

6.1.1 SGI#14 Contribution to Standardization Organizations

Definition: SGI#14 reflects the standardization contribution of MATILDA as a measure of preliminary business impact on 5G networks domain; the domain targeted by the project. MATILDA standardisation efforts have been provided in [MATILDA-D7.6] in detail.

KPIs and Assessment: The KPIs and the targets along with the achieved impact are summarized below.

Table 19: SGI#14 KPIs Assessment

Impact Factor	KPI	Target	Achieved	Comments
SGI#14	Number of Monitored Standardization bodies	>2	>5	1. ETSI EE TC (Environmental Engineering Technical Committee) (CNIT, ITL) 2. ETSI MEC, ETSI NFV (ITL, CNIT) 3. OSM (ATOS, UNIVBRIS) 4. 3GPP (ERICSSON) 5. TM FORUM - ZOOM (ATOS) TMF has been explored, but we have come to the conclusion that the scope of TMF is closer to the user/business layer, and not so much to the NFV operational scope that MATILDA's OSS has.
SGI#14	Number of Contributions to Standards	>1	4	1. ETSI EE TC (Environmental Engineering Technical Committee), (new Working Item (WI) named RES/EE-EEPS43 GAL v3.0 has been created with the support of CNIT /ITL) 2. ETSI MEC - MATILDA architectural solution proposed was presented upon invitation in MEC#22, ETSI MEC WG meeting 3. OSM (ATOS) - Network slice management – MATILDA NFV convergence layer Multi-site orchestration 4. ETSI NFV - IFA029 – MATILDA NFV Convergence Layer

In general, the Business impact on specific domains associated to the project Standardisation activities has been evaluated against KPIs related to monitoring and contribution to standards. As observed, the number of monitored standardisation activities exceeded the initially defined target (5 monitored standardisation bodies / specification lines) and market consensus was obtained in part of the project work as its contributions have been included in ETSI EE TC (Environmental Engineering Technical Committee), new Working Item (WI) named RES/EE-EEPS43 GAL v3.0, in ETSI OSM development (the MATILDA NFV convergence layer Multi-site orchestration), and in ETSI NFV - IFA029 (the MATILDA NFV Convergence Layer), and presented in ETSI MEC#22, ETSI MEC WG meeting (the Mobile Edge Computing environment architectural solution).

6.2 Business/Economic Impact on MATILDA partners

The Business/Economic impact is very difficult to be assessed at project time, since the business remains to be evolved after the technical development finishes with the project end. Estimations about the expected business/economic impact on partners as well as on target stakeholders in the 5G value chain in the long run have been analysed as part of [MATILDA-D7.8]. KPIs highlighting the business impact of the project at this stage are summarized in the following sections.

6.2.1 SGI#15: Business Impact on MATILDA partners

Definition: SGI#15 reflects the impact of MATILDA on the business activities of the partners in terms of economic / business benefit achieved from participating in the project, as well as in terms of foreseen business/ economic benefit and foreseen organizational impact from the adoption of MATILDA at later stages by partners – and as an extent by represented stakeholders.

KPIs and Assessment: Given the difference in the nature of activities of the partners, and given their different positioning in the value chain, the impact of MATILDA is different for each partner (and for stakeholders with similar roles in the value chain); thus, no common KPIs and targets could be defined, and at the same time qualitative approaches were used to identify this impact. An in-depth analysis of the business impact of MATILDA on partners has been provided in [MATILDA-D7.8] in their exploitation plans. KPIs reported below simply summarize some highlights of these analyses.

KPI #1: Economic/Business Impact of MATILDA project for partners

For the industrial partners that are strongly involved in the development of the MATILDA solution, besides the direct economic benefits linked to funding of the development activities, either leveraging existing products or starting new line products, economic/ business benefits are linked to the interaction with other consortium partners with complementary expertise, or/and with partners defining their business and technical requirements – which otherwise would be very difficult (time and cost consuming) to collect.

As first example, such benefits are visible in the **CNIT – ATOS – UBI – ERICSSON- UNIBRIS** interaction in the development of the new Telecom Layer and the interaction between this, the NFVO and the VAO, while similar benefits have been achieved in the **UBI – INTRA – S5 – UPRC** interaction in the development of the VAO. Such benefits and further company developments are detailed on a per partner basis in [MATILDA-D7.8].

Likewise, as second example, benefits are visible for partners aiming at developing vertical applications, namely in the collaboration between **INC** and **ITL**, as well as for **ININ**. In particular, for INC, through the participation in MATILDA, R&D expertise has been gained with respect to the "Service-Mesh" approach as well as the development of a Smart Venue Recommendation module (related to the *High-Resolution Media on Demand Services* (5G-PACE) demonstrator), therefore reaching a significant milestone for INCELLIGENT product strategy. Besides the direct benefit of the funding of this activity, indirect benefits, not easily estimated in terms of cost, include the interaction with the other consortium partners speeding up the process of technologies development, of achieving synergies, especially with ITL for the joint demonstrator, and ultimately of technologies adoption.

From **ITL** side, their participation in MATILDA was initially focused on the development of the "High resolution Media on Demand" demonstrator adopting the MATILDA framework for the implementation of a 5G-ready vertical application. This provided benefits in terms of knowledge acquisition related to technical and business aspects to be taken in account in 5G adoption. Notably, after the start of the MATILDA project, ITL and INC, in charge of providing a "Smart Retail Recommendation System" application, have foreseen a potential complementarity of their proposed solutions that resulted in the implementation of a novel demonstrator, namely 5GPACE, obtained integrating the two applications. In this case, the associated benefits include the interaction with the other partner that speeded up the development process, and the achievement of this synergy that can facilitate entering in new market sectors.

For **ININ**, through participation in MATILDA, the company clearly benefited in extending their expertise in cloud-native and 5G solutions, in particular in the domain of service-mesh, services orchestration and VNF/MANO systems. MATILDA concepts were successfully applied in ININ's public safety and quality assurance product portfolio (iMON and qMON) and services suite. The obtained technological know-how and business insights can be evaluated directly in the corresponding funding while other less tangible, indirect gains derived through ININ's R&D collaboration with MATILDA partners and broader 5G PPP community.

At third level, benefits are visible for partners representing the vertical sectors, that is; for partners that at some point shall adopt and take advantage of 5G capabilities. For these partners benefits are associated to their own business activities, as summarised below:

For **EXXPERT**, MATILDA is the first platform used to develop and test FastWAN feasibility on wireless networks, so although a direct assessment of the cost benefit is not possible (apart from the funding part), the company gained expertise that would have been very difficult to be obtained otherwise.

ORO and **COSM**, being telecom operators, thus positioned in the core of the 5G networks value chain, have pursued to acquire significant know-how with regard to 5G applications' deployment and service provisioning, and to identify at early stages the associated opportunities and challenges for such business activities so as to be prepared and uptake required actions proactively. Obviously, telecom operators can acquire technical information directly from vendors related to their systems operation, but this is tied to vendors' specific implementations. At the same time, verticals' requirements/ perspective and possible disruptions in the value chain cannot be easily captured, even from the marketing departments of the companies as these require working together with verticals and solution developers besides the well-established telecom vendors. Last but not least, experimentation

with pre-commercial solutions (usually not possible) is a significant cost for telecom operators in terms of human resources and baseline infrastructure, which cannot be always undertaken, while operator requirements/adjustments are considered after purchase leading to significant delays in the delivery of a commercial solution. Through the collaboration of MATILDA developing partners with ORO and COSM, telecom operator requirements have been addressed in the solution (also making it more competitive compared to similar products).

Furthermore, in terms of business impact **ORO** is considering MATILDA 5G framework to orchestrate the end to end life cycle of the 5G ready vertical applications that will monetize ORO's commercial programmable infrastructure. An excellent recognition for MATILDA innovations and business opportunities occurred November 2019 when Orange Group press released that Orange Romania has become the first country within the Orange Group footprint to commercially launch 5G services. The new ORO 5G commercial network enabling vertical applications such as Smart Connected City Intelligent Lighting and partners' ecosystem such as MATILDA was the result of an intensive programme of tests, pilots and trials conducted in Romania with key industrial, academia, SMEs and municipalities partners. Such initiatives will serve as key use cases for further development and underpin the Orange Group's ambitions to deliver an unmatched experience to their customers as, starting with ORO, Orange begin its migration towards the next generation of networks.

Last but not least, through participation in MATILDA an SME like S5 was able to acquire a deeper knowledge of the 5G Networks domain, especially concerning the application of policies & rules management mechanisms and interfaces. From a business perspective, the inclusion of 5G in the application domains that the data analytics solutions provided by the company cover is considered for **S5** an important benefit which can potentially create new business opportunities in the near future.

KPI #2: Foreseen Impact from adopting MATILDA advancements

This KPI is directly linked to the adoption of MATILDA by the solution developing partners as well as by the vertical sectors and the telecom operators. This benefit is directly linked to partners' exploitation plans (presented in detail in [MATILDA-D7.8]) as well as to the value propositions analysed for the various vertical sectors and stakeholders (Small or Existing Telecom Operators, Application developers, etc.). Some highlights related to the adoption of MATILDA solution/ advancements are summarised below (taking as basis indicative partners representative of vertical sectors):

Considering the *Emergency Infrastructure with SLA Enforcement Vertical / Demonstrator*, MATILDA's 5G and cloud-native approach presents a new paradigm of how mobile systems and PPDR services will be built and run in the future. *ININ*'s gained know-how and successful adaptation of MATILDA technologies into their product portfolio has set an important technology baseline that has already set new directions in ININ's portfolio roadmap planning and its integration into newly established partnership ecosystems. Materialization of the adopted MATILDA concepts was reflected also in ININ's new established partnerships with relevant stakeholders in the EU research domain and hence, had set the ground for new scientific and research cooperation, as well as building a new commercial partnership with recognised 5G and cloud-based stakeholders in the EU arena.

The *High-Resolution Media on Demand Services Vertical / Demonstrator* is represented by *INC* and *ITL*, both being industrial partners developing the vertical service. Therefore, the

foreseen benefit from adopting MATILDA advancements is visible from the perspective of this type of stakeholders. In particular, the MATILDA-like "Service Mesh" and orchestrator-based approach is within INC's immediate technology adoption milestones. The MATILDA framework entails a 5G service mesh environment, enabling the deployment of INC's products/ solutions to other cloud infrastructures. The acquired know-how will aid the company's personnel enhance its existing product line-up, which involves advanced machine learning tools for both network management and vertical applications in the context of big data technologies. At the same time, INC has already started its transition to a modular microservices software architecture with respect to its product strategy, where the company already boasts a diverse range of products. Furthermore, the adoption of a microservice framework will impact significantly the cooperation with other partners. In detail, it will facilitate the integration of different inter-operating systems into a unique framework through the micro-service approach ("Service Mesh"), as is the case with the combined ITL and INC Demonstrator systems. This way the interworking processes between the different systems and applications are greatly simplified and more easily deployed by avoiding the development of proprietary interaction mechanisms.

At the same time, the MATILDA approach on deploying vertical services over the 5G network infrastructure opens new market opportunities for ITL products. Indeed, the novel way of building and deploying 5G-ready applications defined by MATILDA, enables moving from traditional applications built to be sold to telco operators to applications developed to fulfil needs concerning other vertical sectors. In particular, a media management application can be adapted to be used not only by telco operators but also by other service providers (e.g. media broadcasters, media content producers, live events managers). From another perspective the microservice-based methodology of MATILDA is in line with the "Open Innovation" approach adopted by ITL. Indeed, due to the possibility to integrate easily different SW components, it enables the collaboration with other companies/partners (e.g. SMEs) for providing new solutions to market, minimizing the development, integration and testing time.

Considering the *Automobile Electrical Systems Remote Control Vertical / Demonstrator*, the work done in MATILDA will result in a wireless and 5G-ready solution of FastWAN services as foreseen by *EXXPERT*. This communication solution will expand the business use case reach of FastWAN into wireless and mobile systems. As also detailed in EXXPERT's exploitation plan in [MATILDA-D7.8], an impact from adopting MATILDA is the expansion of know-how and the high probability of opening into new markets with innovative products followed by the expansion of technological competitiveness.

Last but not least, considering *Telecom Operators and Small Telecom operators'* role in the value chain, the foreseen benefit from *COSM* and *ORO* adopting MATILDA has been detailed in the companies' exploitation plans and it is tightly linked to the MATILDA value proposition Telecom Operators in [MATILDA-D7.8].

6.2.2 SGI#16: Synergies achieved

Definition: SGI#16 reflects the impact of MATILDA on the business activities of the partners in terms of synergies achieved through the project. Especially synergies between commercial companies are subject to a number of regulations / rules/ restrictions / confidentiality from the participating sides, and require a lot of time to be established; thus, the number of synergies achieved is expected to increase after the project end.

KPIs and Assessment: The main KPI associated with this impact factor is the number of synergies. For the contemporary situation, the assessment is based on the exploitation activities and plans reported in [MATILDA-D7.8]; however, the number is expected to increase after the project end.

KPI #1: Number of Synergies

Within MATILDA, a set of synergies have been established in terms of:

1. collaboration with other 5G PPP projects,
2. collaboration between partners in view of joint exploitation of the MATILDA outcomes.

In the first place, strong collaboration has taken place with the SLICENET project, leading to common activities in terms of support of the Smart Cities demonstrator, led by ORO, as well as the examination of the usage of the VAO with the slice management APIs provided by SLICENET. Furthermore, joint workshops and exchange of knowledge has taken place, aiming at promoting common specifications in terms of network slice definition and management aspects. Collaboration has been also established with other 5G PPP projects, such as the 5GTANGO project, where a series of joint workshops took place, while collaboration with 5GCITY and NGPAAS projects, led to a common paper about low latency – mission critical aspects in 5G networks. (Other synergies involving information exchange have been reported in [MATILDA-D7.2].)

Furthermore, collaboration among existing partners of the consortium has led to exploitation and extension of MATILDA outcomes in new initiatives. For instance, with the participation of CNIT, UBITECH and ERICSSON, the SPIDER project for cybersecurity management in 5G domain is extending the MATILDA VAO and OSS for supporting security management actions.

Discussions among partners regarding potential exploitation of joint outcomes are also in progress, in parallel with identification of potential market opportunities. Such strong synergies involve ATOS and CNIT which have worked together in the development of the NFVCL component, sharing 50% of ownership each, INC and ITL sharing in the development of the 5GPACE application and so on. More details about the achieved synergies between partners have been included in [MATILDA-D7.8].

6.3 Business/Economic Impact on 5G Value Chain

6.3.1 SGI#17: Business Impact on 5G Value Chain

Definition and Assessment: SGI#17 reflects the impact of MATILDA on the business roles and activities of the stakeholders in the 5G value chain. The transformation of the current telecommunications ecosystem to future 5G ecosystem and the way MATILDA innovations affect the business roles and business activities of stakeholders have been analysed in [MATILDA-D7.4] and [MATILDA-D7.8], which is tightly associated to the value proposition and lean canvas analyses of MATILDA offerings.

In general, MATILDA is expected to have impact on the business activities of the following target stakeholders/ roles:

- The large TSPs (Telco Service Providers, also called Telco Operators) can be supported through VAO in the communication between their customers (vertical industries) and their personnel, since, by giving them the means to interpret the advanced 5G-ready applications' resource requirements in an optimised, homogeneous and automatic way, a direct communication between them will be no longer required. Also the (cloud) App Provider may be willing to adopt the VAO, having the OSS provided by a TSP.
- Small TSPs can rely for a major part of their business activities on the VAO+OSS packages in a holistic way, as these stakeholders do not have their own OSS, so they will need the whole solution. For this reason, small TSPs are considered by the Consortium as the main targeted customer of the MATILDA solution, thus their problems and particularities have been considered. The fact that these emerging small Telco Operators have not implemented their own orchestration systems underlines that the adoption of the MATILDA framework would be very beneficial, allowing them to easily register their programmable 5G resources and provide their services without the need to buy or implement their own OSS and orchestration systems.
- Under the classification of VNFs it is distinguished whatever belongs to the domain of the Network Service Provider (NSP) and falls under the MATILDA NFVO orchestration. So, in this way NSPs will be also supported in their role/business activities in the 5G value chain by this part of the MATILDA solution.
- The vertical industries will be also supported in their business role and activities through the MATILDA 5G-ready Application development and execution environment.

In general, the foreseen business impact of the MATILDA solution will be to facilitate the interaction of a large number of existing and upcoming stakeholders, and especially the interaction between the 5G-ready application developers, the TSPs and small TSPs, and the NSPs and contribute to the adoption of 5G technologies by vertical industries. The foreseen business impact on vertical industries at next stage is associated with their individual business activities and services.

6.4 Business Impact Assessment Summary

The Business/Economic impact is very difficult to be assessed at project time, since the business remains to be evolved after the technical development finishes with the project end. Estimations about the expected business/economic impact on partners as well as on target stakeholders in the 5G value chain in the long run have been analysed as part of [MATILDA-D7.8]. Highlights of the business impact of the project at this stage have been summarized in this chapter. As observed:

- As far as the impact on 5G industry reflected in standardization activities is concerned, the number of monitored standardisation activities exceeded the initially defined target (5 out of 2 monitored standardisation bodies / specification lines) and market consensus was obtained in part of the project work as its contributions have been included in ETSI EE TC (Environmental Engineering Technical Committee), new Working Item (WI) named RES/EE-EEPS43 GAL v3.0, in ETSI OSM development (the MATILDA NFV convergence layer Multi-site orchestration), and in ETSI NFV - IFA029 (the MATILDA NFV Convergence Layer), and presented in ETSI MEC#22, ETSI MEC WG meeting (the Mobile Edge Computing environment architectural solution).

- For the industrial partners that are strongly involved in the development of the MATILDA solution, besides the direct economic benefits linked to funding of the development activities, either leveraging existing products or starting new line products, economic/ business benefits are linked to the interaction with other consortium partners with complementary expertise, or/and with partners defining their business and technical requirements – which otherwise would be very difficult (time and cost consuming) to collect. For vertical sector representatives and telecom operators, the reciprocal benefit lies in the fact that they obtained useful knowledge related to vertical services requirements/ perspective and possible disruptions in the value chain that cannot be easily captured, even from the marketing departments of the companies as these require working together with verticals and solution developers besides the well-established telecom vendors.
- The foreseen business impact of the adoption of MATILDA by the solution developing partners, as well as by the vertical sectors and the telecom operators, is directly linked to partners' exploitation plans (presented in detail in [MATILDA-D7.8]), as well as to the value propositions analysed for the various vertical sectors and stakeholders (Small or Existing Telecom Operators, Application developers, etc.).
- A number of synergies, either with other 5G-PPP projects or between MATILDA partners, reflect the aforementioned business impact on the business activities of partners. The number of synergies is expected to increase after the project end.
- Last but not least, the business impact on 5G value chain can be summarised as the facilitation of the interaction of the large number of existing and upcoming stakeholders, and especially the interaction between the 5G-ready application developers, the TSPs, small TSPs and NSPs, and can contribute to the adoption of 5G technologies by vertical industries. The foreseen business impact on vertical industries at the next stage is associated with their individual business activities and services. This impact analysis constitutes a large part of [MATILDA-D7.8].

7 Summary and Conclusions

The overall MATILDA project objective is to design and implement a novel holistic 5G end-to-end services operational framework tackling the overall lifecycle of design, development and orchestration of 5G-ready applications from multiple vertical sectors, and 5G network services over programmable infrastructure, including intelligent mechanisms to increase automation in most of those processes. In order to maximise the MATILDA project results' exploitability and sustainability, a specific activity to monitor and assess the project impact has been foreseen in the project plan running throughout the project course, namely Task 7.6.

In this context, initially an analysis of the research process has been conducted, along with a review of impact assessment classifications, concepts, methodologies and frameworks focusing on R&D projects and activities. As identified, there is no uniquely established way to assess the impact of "research projects", as their goals are versatile and depend on the special "research projects'/activities'" scope, characteristics, nature, etc. At the same time, the assessment depends on the nature of the impacts, that is, the human domain to which they appear (Scientific, technology, environmental, health, etc.), on the scope of the impact in terms of number/groups/segments of people affected, and the timing of the impact related to the timing of the activity and the timing of the assessment – being estimated, contemporary or ex-post. Therefore, it is usual that impact assessment models are tailored to the nature of each project/action/field, as well as to the interest/focus of the evaluator.

Along these lines, the MATILDA impact assessment framework has been defined using a logical model approach applicable to the MATILDA research process, incorporating well defined indicators as criteria for assessment of research impact, emphasizing on activities, output/outcomes, and impact measures. The MATILDA impact assessment framework is focusing on four domains associated with the four stages of the research process; namely: (1) research results/ output generation, (2) knowledge transfer, (3) community approach and (4) business development.

To narrow down the scope of MATILDA's impact assessment on the basis of the aforementioned classification, and to develop a logical approach and a "SMART" assessment framework we focused on the following types of impact:

- The Technological impact in the field of 5G networks (in the worldwide technology/research community), as well as on specific vertical markets addressed; contemporary to the project lifetime; associated with the technical output of the project.
- The Scientific impact in the research field of 5G networks; contemporary to the project lifetime; associated with the impact assessment of the Dissemination/ Communication output of the project.
- The Business impact on specific domains; contemporary to the project lifetime; associated with the impact Standardisation contribution of the project.
- The Business impact on the MATILDA project partners; contemporary to the project lifetime, as well as estimated.
- The Business impact on the 5G networks' value chain; estimated to come with the adoption of 5G network infrastructures.

In this context, the assessment of the technological impact of MATILDA in the field of 5G networks and verticals has been evaluated against KPIs related to the MATILDA technical output on Lifecycle Management of 5G-ready applications (components and graphs), VNFs (including Forwarding-Graphs and orchestration), and Network Services (associated also to Telecom Layer OSS capabilities). As observed, the project achieved all its technical goals against these KPIs and even exceeded the initially defined targets. Indicatively, the number of 5G-ready and Network-aware Application Graph Composers, the number of Application & VNF/ PNF Development Environments / Marketplaces, the number of available VNFs and VNF-Forwarding Graphs have been as foreseen in KPI targets, while the number of Application, VNF-FG and Policies Metamodels, Network apps and VNF Repositories have exceeded initial targets addressing requirements and enhancing the MATILDA solution design. At the same time, the number of discrete industry vertical domains has exceeded the initially planned number of 5 to 6 with BIBA supporting two use case vertical applications in the project (the smart logistics and Industry 4.0). As far as the technical performance achievements are concerned, these are summarised in detail in [MATILDA-D6.8] to [MATILDA-D6.13], on the basis of the vertical demonstrators/use cases KPIs and the MATILDA performance advantages are reflected in the self-reported (by application (and VNF/PNF) developers) decrease in time required and increase in efficiency in developing and validating 5G-ready network-aware applications and services which was rated a lot more than the initial target of 30%.

The assessment of the scientific impact in the research field of 5G networks associated to the Dissemination output of the project has been evaluated against KPIs related to MATILDA participation in conferences / workshops / exhibitions with demonstrators, presentations, papers. In addition, the same strategic impact associated to the Communication output of the project to approach stakeholders and the market has been evaluated against KPIs related to establishing social media and corporate communication channels and generating / presenting material in industrial events/ forums / tutorials/ webinars / website, etc. As observed, the project achieved all its dissemination / communication goals against these KPIs and even exceeded the initially defined targets, while additional means/ channels of dissemination/ communication were utilised (not initially foreseen). Highlights of these achievements, not initially foreseen, are the large number of demonstrations and booths at events (9 in total), the large number of presentations at forums and industrial events, the number of press releases and corporate communication references, the number of public presentations and the number of clustering workshops.

The assessment of the Business impact associated to the project Standardisation activities revealed that the number of monitored standardisation activities exceeded the initially defined target (5 monitored standardisation bodies / specification lines) and market consensus was obtained in part of the project work as its contributions have been included in ETSI EE TC (Environmental Engineering Technical Committee), new Working Item (WI) named RES/EE-EEPS43 GAL v3.0, in ETSI OSM development (the MATILDA NFV convergence layer Multi-site orchestration), and in ETSI NFV - IFA029 (the MATILDA NFV Convergence Layer), and presented in ETSI MEC#22, ETSI MEC WG meeting (the Mobile Edge Computing environment architectural solution).

In the process of defining the impact factors and the KPIs for the assessment of the Business/ Economic impact on the MATILDA project partners and on the 5G networks' value chain, it became obvious the difficulty to assess such impact at project time, since the business

activities around the project results are usually evolved with larger steps after the conclusion of the technical work and the project end. At the same time, given the difference in the nature of activities of the partners, and given their different positioning in the value chain, the impact of MATILDA is different for each partner, thus no common KPIs and targets could be set. Therefore, contemporary business impact of MATILDA on partners has been identified on a per partner/ group of partners' basis, while the analysis of the expected business impact in the long run provided in [MATILDA-D7.8] can reveal the benefits. Highlighting the conclusions of these assessment and analyses, the business impact of MATILDA is positive for all partners and their represented value chain stakeholders, both in terms of economic benefit and in terms of optimising their business activities. At this point it is also notable that a large number of synergies has been achieved both with other 5G-PPP projects (notably with SLICENET and 5G-TANGO) and between partners in view of joint exploitation of the MATILDA outcomes (notably, contemporarily, between ATOS and CNIT, as well as between INC and ITL).

Overall, the MATILDA impact assessment is positive against all initially defined strategic impact factors, their KPIs and targets, and in most cases the project succeeded in exceeding performance and enriching the initially defined set of activities.

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