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Multimodal Extreme Scale Data Analytics for Smart Cities Environments

D7.2: Market Analysis and Preliminary Business Modelling[†]

Abstract: This deliverable presents the work performed in WP7, Task7.1 “Market Definition and Analysis” that supports the activities of T1.1, by determining the market context of MARVEL and the relevant business and societal challenges. Moreover, it will conduct a comprehensive market study using different analytical tools as necessary (PEST and SWOT analysis, questionnaires, annual company reports, analysis reports, etc.). This study will quantify the size of the market, identify key competitors, market needs and trends, identify stakeholders, possible clients and users, and formulate potential business models to exploit project outcomes. It will also drive both the business and the technical activities of the ecosystem and prepare for the long-term sustainability and potential commercialisation uptake to the primary market segments.

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List of Abbreviations

AI	Artificial Intelligence
C API	Application Programming Interface in Language C
DoA	Description of Action
EC	European Commission
E2F2C	Edge to Fog to Cloud
EU	European Union
GDPR	General Data Protection Regulation
GPU	Graphic Processing Unit
GPGPU	General-Purpose Graphics Processing Unit
ICT	Information Communications Technology
IPR	Intellectual Property Rights
IoT	Internet of Things
KER	Key Exploitable Results
MEMS	Micro-electro-mechanical systems
ML	Machine Learning
MIT	Massachusetts Institute of Technology
MsC	Master of Science
PEST	Political, Economic, Social, Technological
PhD	Philosophiae Doctor
R&D	Research and Development
RIA	Research & Innovation Action
SDK	Software Development Kit
SLA	Service Level Agreement
SME	Small, Medium Enterprise
SWOT	Strengths, Weaknesses, Opportunities, Threats
TBD	To Be Defined
TRL	Technology Readiness Level
WP	Work Package

Executive Summary

This deliverable provides a market analysis for the MARVEL project, as part of T7.1. The objective of this report is to assess the market potential of the knowledge, software, hardware, services, and methodologies of the MARVEL project.

The market analysis has been carried out with the aim of identifying and assessing the different market segments that could affect or influence the exploitation strategy of the Key Exploitable Results (KERs) developed in MARVEL. It includes a first overview of the expected KERs of the project, with high commercialisation potential, in order to define better the targeted markets where MARVEL could be better positioned in the future.

The analysis is based on (i) Demand-side: which includes a PEST analysis to understand the political, economic, social, and technological context in which MARVEL partners has to develop its exploitation activities; an overview of the targeted market(s), with particular attention to market size and growth trends; and the initial target segments identified as potential customers for MARVEL and (ii) Supply-side: which is focused on competitors' analysis, particularly similar solutions to MARVEL; and relevant market trends worth to be taken into account.

A SWOT analysis is also included identifying Strengths, Weaknesses, Opportunities, and Threats that could affect the commercial launch of the MARVEL solutions.

Finally, a high-level outline has been drawn up for the potentially viable business models of the MARVEL products and solutions that will be designed. These business models will be refined during the project as the MARVEL results are being better defined, and there will also be a refinement process, whereby some of the high-level business models may eventually be discarded, while those that are better suited to MARVEL's characteristics will be further developed.

This document will be continuously updated and complemented in subsequent deliverables D7.4-‘Exploitation strategy and activities’ and D7.5-‘Final business model and long-term sustainability report’.

1 Introduction

1.1 Purpose of the document

The exploitation activities carried out during Y1 of the project implementation are to achieve several objectives for MARVEL. As identified in the MARVEL Grant Agreement [1], the generic objective of task T7.1 is “to determine the market context of MARVEL and the relevant business and societal challenges. Moreover, it will conduct a comprehensive market study using different analytical tools as necessary (PEST and SWOT analysis, questionnaires, annual company reports, analysts’ reports, etc.). This study will quantify the size of the market, identify key competitors, market needs and trends, identify stakeholders, possible clients and users, and formulate potential business models to exploit project outcomes. It will also drive both the business and technical activities of the ecosystem and prepare for the long-term sustainability and potential commercialisation uptake to the primary market segments.”

The main objective of this document is to analyse the **initial context** of the MARVEL project in terms of exploitation and sustainability. For this, internal factors such as the exploitable assets, their Intellectual Property Rights (IPR) conditions, and their market potential are analysed according to our market research. In addition, an analysis of the micro-environment is carried out, studying in-depth the state of the smart cities market and similar solutions in Europe.

The main outputs that are intended to be generated from this analysis in this first version of MARVEL strategic diagnosis will be used to lay the foundations for both individual and potential joint-partners’ exploitation. Of course, business models are also part of this strategy, and we include a first overview of feasible business models for MARVEL that will be refined in consecutive iterations.

1.2 Intended readership

The deliverable D7.2 Market Analysis and Business Modelling is a Public document, as it has been established in the DoA. The content found in this document aims to guide partners in their exploitation strategies as well as laying the foundations for joint exploitation and sustainability.

1.3 Document structure

This deliverable presents the following structure:

- Section 3 presents the Internal Analysis with the Key Exploitable Results and its corresponding Intellectual Property considerations, and the MARVEL Value Proposition.
- Section 4 exposes the External Analysis from two different perspectives: Demand-side and Supply-side.
- Section 5 describes the SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) of the MARVEL Value Proposition.
- Section 5 presents the description of feasible Business Models.
- Section 6 concludes the document.

1.4 Relation to other work packages, deliverables and activities

The technical solutions of the project as well as the environment in which they are intended to be commercialised are changing by continually evolving factors, so an update of this study will

be presented in the following deliverables D7.4 and D7.5. These documents will refine the conclusions mentioned here and will specify the joint actions carried out by the consortium to increase the impact of MARVEL technologies on the market.

The building blocks of MARVEL, defined as individual, autonomous technologies, will be developed in WP2-WP4, and utterly in the integrated E2F2C framework provided in WP5. The outputs of these work packages will feed the final exploitation and sustainability strategy to ensure the impact of MARVEL by improving the usability of the MARVEL tools and applying them beyond the context of the MARVEL project. [1]

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2 Internal Analysis

In this section, we have outlined the **main exploitable results** that have been forecasted by the MARVEL project along its lifecycle.

MARVEL will deliver the following outcomes according to three different categories:

- **Individual Assets:** enumeration of all the components developed in the context of the MARVEL project by just one owner.
- **Pilots:** MARVEL will be validated in three different contexts. Different combinations of the MARVEL assets will be tested to solve specific smart-cities problems related to big data processing, aiming to provide insights and predictive capability for better management of outdoor events and activities.
- **MARVEL Framework:** the integration of MARVEL technologies and tools will provide a framework that will fully harness the edge (including data capturing), fog and cloud resources to effectively orchestrate and distribute computational and Artificial Intelligence (AI)-related tasks.

2.1 Identification of MARVEL building blocks

The expected MARVEL inputs encompass a list of **29 technologies** developed under the project scope classified as:

- **Software/Hardware Developments:** this category refers to tangible outcomes, namely sensors and software solutions.
- **Methodologies:** they help to formalise user requirements into technological requirements.
- **Services:** The word “Service” refers to the traditional meaning of IT services. These are future services offered around MARVEL, which aim at improving the effective use of MARVEL solutions and at providing in-depth customised assistance.

MARVEL is a Research and Innovation Action (RIA), so the expected Technology Readiness Level (TRL) is 5-6 on average, which involves a real-life environment technology validation and demonstration. This will be achieved, mostly, with the validation of the assets in the industrial-relevant smart city environments of Malta, Trento, and Novi Sad. Most of the components will be tested in the MARVEL use cases. Next, Table 1 summarises the main aspects of the list of MARVEL Results.

Table 1: List of MARVEL Results

KER	Components	Type of component	Owner	Expected TRL	Licensing
Sensing and perception subsystem					
1	Advanced MEMS microphones	Software/ Service	IFAG	8	Open source License TBD
2	SED@Edge	Software	FBK	8	Open source License TBD
3	GRNEdge	Hardware	GRN	6	Proprietary
4	AVDrone	Hardware/ Software	UNS	4-5	TBD
5	CATFlow	Software	GRN	7	Proprietary

Security, Privacy and Data Protection Subsystem					
6	EdgeSec	Software	FORTH	5	Proprietary
7	VideoAnony	Software	FBK	6	Open source License TBD
8	AudioAnony	Software	FBK	4	Open source License TBD
9	devAIce-SDK	Software	AUD	6	Proprietary
Data Management and Distribution Toolkit					
10	Data Fusion Bus	Software	ITML	6	Proprietary
11	StreamHandler	Software	INTRA	8	Proprietary
12	DatAna	Software	ATOS	6	Apache 2.0
13	Hierarchical Data Distribution System	Methodology	CNR	6	MIT
Audio, visual and multimodal AI subsystem					
14	Visual anomaly detection component	Software/Methodology	AU	5	Open source License TBD
15	Audio-Visual anomaly detection component	Software/Methodology	AU	5	Open source License TBD
16	Visual crowd counting component	Software/Methodology	AU	5	Open source License TBD
17	Audio-Visual crowd counting component	Software/Methodology	AU	5	Open source License TBD
18	Automated audio captioning	Service	TAU	3	Open source License TBD
19	Acoustic scene classification	Service	TAU	5	Open source License TBD
20	Sound Event Detection component	Service	TAU	5	Open source License TBD
21	Sound event localisation and detection component	Service	TAU	5	Open source License TBD
Optimised E2F2C processing and deployment subsystem					
22	GPURegex component	Software	FORTH	5	Proprietary
23	DynHP component	Methodology	CNR	4	MIT
24	FedL component	Software	UNS	5	Apache
25	Karvdash component	Service	FORTH	5	Open source License TBD
E2F2C infrastructure					
26	HPC infrastructure	Service	PSNC	9	Proprietary
27	Management and orchestration of HPC resources	Service	PSNC	9	Proprietary
User interactions and decision-making toolkit					
28	SmartViz component	Software	ZELUS	6	Apache 2.0

29	MARVEL Data Corpus-as-a-Service	Service	STS	5	Public
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1. IPR Management

There are 29 assets owned by just one owner. In addition, although it is still early, as some partners have not yet decided under which type of license, they want to market their results, there is a perceived mix of **Open Source licenses**, but also **Proprietary licenses**, so a 100% Open Source approach will not be possible. In the future, the asset owners will consider the possibility of releasing parts of the developed technologies under MARVEL as Open Source approach. The Open Source licenses provided up to now, as MIT or Apache 2.0 do not present incompatibilities among them.

2. Value Proposition Components

Each of these components provides a specific added value to the final solution that will constitute MARVEL that is detailed below.

Table 2: MARVEL Value Proposition Components

KER	Value Proposition Components
1	Advanced MEMS microphones The Advanced MEMS microphones cater customer needs by gathering high quality, low noise acoustic data, which can be used for speech recognition, audio recording, and acquisition of surrounding noise for applications like noise cancellation.
2	SED@Edge SED@Edge is a solution to port state-of-the-art deep learning models for the detection of urban acoustic events on low-cost low-power microcontrollers.
3	GRNEdge GRNEdge facilitates the synchronisation of different data streams (such as audio and video) for processing. It has the ambition to be a fully compliant plug-and-play sensor for smart city management This is possible once data-processing, such as audio-video anonymisation can also be done at the edge.
4	AVDrone The proposed system will enable target users to classify the crowd behaviour without breaking any privacy issues.
5	CATFlow CATFLOW transforms road camera information to anonymous data. Through a few clicks, our dashboards then present this data and provide critical insights and detailed reports identifying a range of mobility types, trajectories, and junction turning ratios.
6	EdgeSec The goal of this component within the scope of the MARVEL project is to enable secure computing and focus on the preservation of the confidentiality and integrity of the applications, especially in the edge layer.
7	VideoAnony The Component VideoAnony will detect the faces of persons and perform anonymisation on the detected faces by blurring at the initial stage, and potentially with face conversion at a later stage.
8	AudioAnony

	It helps anonymising audio data, possibly close to the source while preserving the acoustic content.
9	<p style="text-align: center;">devAIce SDK</p> <p>devAIce SDK is a full-blown audio analysis SDK meant to enable customers to perform intelligent audio analytics on their local premises.</p>
10	<p style="text-align: center;">Data Fusion Bus (DFB)</p> <p>The innovative aspects of a facilitating data management platform, such as DFB, lies mainly in the overall trustworthiness, performance, and quality of the implementation, focusing on security, scalability, redundancy or any other horizontal, non-functional need that is critical to the project at hand.</p>
11	<p style="text-align: center;">StreamHandler</p> <p>The key capabilities and features offered by the Streamhandler platform are: Real-time monitoring and event-processing; Interoperability with all modern data storage technologies and popular data sources; Distributed messaging system; High fault-tolerance - Resiliency to node failures and support of automatic recovery; Elasticity - High scalability and Security (encryption, authentication, authorisation).</p>
12	<p style="text-align: center;">DatAna</p> <p>DatAna is a framework based on the usage of the Apache NiFi ecosystem to allow the processing of data flows between edge/fog and the cloud. In MARVEL we expect to provide template data flows for typical smart cities solutions and functionalities for agent management in the edge.</p>
13	<p style="text-align: center;">Hierarchical Data Distribution System (HDD System)</p> <p>HDD is a set of distributed adaptive data delivery and access algorithmic schemes for guaranteeing real-time delay requirements while effectively prolonging network lifetime in wireless industrial edge networks. HDD targets large-scale network deployments which are characterised by an inherent computational intractability when it comes to the algorithmic management of the available data.</p>
14	<p style="text-align: center;">Visual anomaly detection component</p> <p>It is a software deployed on all/some of the following: edge, fog, cloud. It includes a methodology improving performance for visual anomaly detection.</p>
15	<p style="text-align: center;">Audio-Visual anomaly detection component</p> <p>It is a software deployed on all/some of the following environments: edge, fog, cloud. It includes a methodology improving performance for audio-visual anomaly detection.</p>
16	<p style="text-align: center;">Visual crowd counting component</p> <p>It is a software deployed on all/some of the following environments: edge, fog, cloud. It includes a methodology improving performance for visual crowd counting.</p>
17	<p style="text-align: center;">Audio-Visual crowd counting component</p> <p>It is a software deployed on all/some of the following environments: edge, fog, cloud. It includes a methodology improving performance for audio-visual crowd counting detection.</p>
18	<p style="text-align: center;">Automated audio captioning</p> <p>This technology aims to improve upon current methods for automated audio captioning. It provides the audio analysis component that can be acted upon in the next stages of the MARVEL system.</p>
19	<p style="text-align: center;">Acoustic Scene Classification</p>

	This technology aims to improve upon current methods for acoustic scene classification. It provides the audio analysis component that can be acted upon in the next stages of the MARVEL system.
20	Sound Event Detection component
	This technology aims to improve upon current methods for sound event detection. It provides the audio analysis component that can be acted upon in the next stages of the MARVEL system.
21	Sound event localisation and detection component
	This technology aims to improve upon current methods for sound event detection and localisation. It provides the audio analysis component that can be acted upon in the next stages of the MARVEL system.
22	GPURegex component
	FORTH offers a real-time high-speed pattern matching engine that leverages the parallelism properties of GPGPUs to accelerate the process of string and/or regular expression matching. It is offered as a C API and allows developers to build applications that require pattern matching capabilities while simplifying the offloading and acceleration of the workload by exploiting the available GPU(s).
23	DynHP component
	DynHP makes it possible to execute the interference and training steps of audio-video real-time analytics on devices with limited compute capabilities at the edge of the network, which otherwise cannot be used due to insufficient memory or energy or processing resources.
24	FedL component
	Federated learning offers an effective technique for model training with privacy protection and network bottleneck mitigation at the same time. As a result, such distributed approach has been widely accepted as an effective technique for addressing the problem of large, complex, and time-consuming training procedures, and is also particularly suited for edge computing.
25	Karvdash component
	This will be an evolution of FORTH's open-source PLATFORMA execution environment for scientific data extraction and analysis (using "notebooks"). This execution platform already shows promise as an early realisation of the MARVEL E2F2C architectural framework, where the multimodal processing and AI/ML workloads relevant to MARVEL use-cases and pilots can be instantiated as orchestrated containers, and deployed via appropriate automation to execution sites selected by a dynamic online optimisation strategy.
26	HPC infrastructure
	This component will help preparing of pilot and pre-production testbeds for the deployment of the MARVEL framework and its validation. In addition, it will provide resources for the software development process: testing, integration, validation, and benchmarking.
27	Management and orchestration of HPC resources
	This component will allow for the effective use of the HPC infrastructure by: <ul style="list-style-type: none"> • providing the means for accessing HPC in terms of authentication, resource discovery, and job monitoring. • managing an efficient way to run hybrid, cloud-based applications within the HPC environment accessing GPU and specialised low-latency networks and high throughput storage. • provisioning and orchestration of resources among multiple infrastructures.
28	SmartViz component

	The tool's key advantages are its highly rated user-friendliness and the flexibility it provides to even a non-IT user to customise its templates according to their needs in an efficient and intuitive way. Its availability, reliability, and operational performance are of course very important as well since they are the foundation of a competitive tool.
29	MARVEL Data Corpus as a Service
	MARVEL corpus will give the possibility for SMEs and start-ups to build on top of these data assets and create new business by exploring extreme-scale multimodal analytics. Furthermore, by adopting an SLA enabled Big Data analytics framework, it is expected to maximise the impact that the MARVEL corpus will have on the international scientific and research community.

2.2 MARVEL Pilots

The MARVEL components can be configured depending on the customer's requirements to offer a specific solution in terms of security and well-being for smart cities citizens. Three different combinations of these individual technologies will give way to three different pilots, whose exploitation potential will be analysed during the project, to conclude if they could be used as successful reference cases for the MARVEL offered as products or services:

2.2.1 MT Pilot in the City of Trento: City monitoring

The aim of this pilot is to monitor the public space of Trento, in particular selected areas, and to inform the local police in case of any anomalous signals that may indicate a dangerous situation: theft, aggression/fighting, drug trafficking, traffic accidents, etc. Events will be notified to the central station via an alarm and by creating a custom view on a smart interface to highlight the relevant cameras. Events will also be saved for further analysis.

The aim of the experiment is to perform [3]:

- **Batch analysis** to study the trend of phenomena over time and to foresee possible problems in relation to external information (e.g., weather in case of traffic, events such as Christmas markets in case of criminal threats).
- **Real-time analysis** to send an alert in case of potentially dangerous situations in order to reduce the response time of authorities to prevent and counteract criminal events and to also reduce the expenditure of officials for risk assessment of criminal attacks at public spaces and events.

The prevention and prediction of dangerous situations will contribute to the overall improvement of the local region and the quality of life of citizens.

2.2.2 GNR Pilot in Malta: Road Traffic in Cities

Malta has limited space and low active mobility usage rates; planning for roadworks is compounded because it necessitates rerouting traffic. In addition, the density of the road network means that intersections are both the source of additional hazard and additional delays. Through our pilot we will learn how to use data monitoring and analysis in order to plan **infrastructure upgrades** or implement **mobility management measures**, thus:

- balancing the needs of mixed traffic, planning, and use of shared road space;
- understanding behaviour by mode of transport, including
 - the preferred pedestrian crossing routes, and
 - the ways cyclists use junctions;

- improving perceived safety for active mobility modes, especially when crossing intersections; and creating anonymisation tools for road-monitoring cameras.

So far, these problems are being addressed utilising major investments to increase road capacity across the island as part of the arterial road improvement and reconstruction project to reduce travel times. New infrastructure for safer facilities and for cleaner alternative travel modes has also been implemented, encouraging modal shift.

The local agency in charge of road works often tenders and hires consultants or road engineers to study specific intersections and make recommendations. They can use physical surveys, pneumatic tubes or their own temporary camera installations to collect the necessary data and develop the designs. The MARVEL pilot can provide a faster vision for deploying green, safe, and inclusive measures while ensuring the fundamental right to safe mobility for all.

2.2.3 UNS Experiments in the City of Novi Sad: Crowd Monitoring and Security

The Laboratory of Acoustics and Speech Technology of the University of Novi Sad will perform at least 2 experiments at the campus of the University of Novi Sad, deploying a drone with mounted camera, MEMS microphones, and environmental sensors to provide additional audio-visual footage, while mobile phones empowered by devAIce (AUD), will be distributed to people participating in the experiments making them able to record environmental audio-visual data throughout the day.

The experiments will support the cases tested in the Municipality of Trento (city square surveillance) and the Municipality of Malta (traffic surveillance) and will give the opportunity to experiment with the processing of complementary information (aerial view from drone-captured video) that will not be available in the other experiments.

Audio-visual emotion recognition has an important role in affect-related human-machine interaction systems. It is applied in various areas such as disease diagnosis (autism, schizophrenia), marketing, entertainment, transport, security. It may also be useful in robotics, for monitoring agents in call centres, in medicine, job interviews, education, and also for monitoring clients in banks and other public administration facilities.

The role of audio-visual emotion recognition algorithms is to predict behaviour of a person or a group faster and possibly more reliably than it could be done by human perception. Currently, a number of professionals are employed for security monitoring whereas computer-aided systems may speed up the recognition process and reduce costs.

The development of algorithms for audio-visual emotion recognition within the MARVEL project will lead to the objective and precise estimation of the observed events in short time based on both audio and visual information modalities. Human decision may need more time and a number of involved professionals for the desired accuracy levels.

2.3 MARVEL Framework Value Proposition

MARVEL offers an Edge-to-Fog-to-Cloud (E2F2C) decentralised and scalable architectural solution capable of achieving fast and automatic recognition of environmental events based on real-time processing of large batches of audio and visual data. In particular:

WHAT – MARVEL competitive advantages:

- MARVEL provides a complete, packaged offering as well as individual, customisable components, for sound analytics, agile event monitoring and identification, and ML situation assessment.

- It allows cities or regional authorities to harness the power of their existing audio and video infrastructure and transform the way they think about and do smart city management.
- Makes visual and audio data anonymised, possibly close to the source, while preserving the contextual content of the audio-visual scene, thus minimally impacting the later-on perception tasks. This is crucial to meet privacy and ethics requirements while allowing high-level audio and vision-based AI tasks.
- MARVEL addresses societal and industrial opportunities in the smart city domain (e.g., criminality).
- It raises the technological level of research centres.
- It maximises market opportunities and potential of SMEs.
- Last but not least, it raises awareness of the benefits of big data analytics to the general public as distinct value propositions.

HOW – MARVEL Innovations

- Improvement upon current methods for audio-visual anomalies detection on resource-constrained computation environments to provide the detection data that can be acted upon in the next stages of the MARVEL system.
- Extraction of acoustic patterns for event detection.
- Collection of meaningful events to complete a picture of an urban context.
- Image and video processing-based analytics for event detection and situational awareness.
- Audio-based analytics for event detection and situational awareness.
- Joint audio-visual based analytics.
- Data management, acquisition, distribution, and storage.
- Federated learning and edge processing.
- GPU accelerated stream processing.
- Decision-making and data visualisations for faster response in the case of an anomaly and preventing larger scale problems.

WHO – MARVEL Stakeholders

Obtained information can be useful for diverse stakeholder groups for statistics purpose, or for prompt intervention:

- Data owners/providers, data analysts, Internet of Things (IoT) providers, data enrichers, and data facilitators.
- Governmental agencies, public authorities, first responders.
- Smart services providers, image and sound recognition technology providers.
- Big Data-, IoT- and AI-relevant associations.
- Participants, project partners, and relevant stakeholders active in the H2020 programme related to big data technologies and extreme-scale analytics in the ICT sector and beyond.
- Researchers.
- Smart Cities decision-makers.
- EU, National, Regional and Local authorities.

In addition, each of the components that will be part of the MARVEL framework has its own contribution to the value proposition, providing specific functionalities that will allow us to offer a more evolved and competitive result.

3 External Analysis

External analysis will cover a wide range of topics including among others a review of the Smart Cities market, focused on the use of the huge, sensitive amount of data that provides a smart city, that can be used for **machine learning based decision making**.

Both points of view, **demand and supply side**, will be described at this initial stage: what the sector demands from the surveillance smart cities solutions and what is already provided by the market (a particular approach to MARVEL competitors is also described in this section).

An approach to the current market trends will also put the magnifier on what is the path to follow when a smart city surveillance solution has to cause a relevant impact on the market identified.

3.1 Demand side

IoT technologies are being deployed at an increasingly rapid pace in cities and communities around the world. Sensor devices can be deployed for environmental sensing, traffic monitoring, traffic video surveillance, street lighting and infrastructure control, power and water grid regulation - all use cases that make them a critical component of civil society.

All of these uses make these devices a critical component in maintaining the security and functioning of a city. Newer devices are smarter, equipped with advanced networking and edge computing capabilities, which means that they can offer more functionalities and have a greater impact on transforming processes and services.

3.1.1 PEST Analysis

The PEST analysis will describe the macro-economic factors which can impact the organisation activity, from a Political, Economic, Social, and Technological perspective.

Table 3: PEST Analysis

Political-legal	Economic
<ul style="list-style-type: none"> • Next Generation Eu funds • Impact of GDPR in business and research • EU commitments on the environment • Demand for Data Ownership and Sovereignty 	<ul style="list-style-type: none"> • Economic uncertainty • Alignment of jobs, services, and products with society • Lack of incentives for data-driven value generation • Increased appetite for investments
Societal	Technological
<ul style="list-style-type: none"> • Growing environmental awareness • Growing awareness of the surrounding • Lack of jobs and growth • Uncertainty and perception of technology by EU citizens • Growing demand of automated services without interruption. 	<ul style="list-style-type: none"> • Less overall energy consumption • Diversity in terms of standards • Computer processing and AI decision making is moving more towards Fog & Edge

3.1.1.1 Political and legal

Next Generation Eu funds

The Next Generation Eu funds will provide financial resources to Member States that will enable them to invest in and reform their still insufficiently digitised public administrations.

EU institutions and Member States have been confronted in 2020 with an unprecedented health crisis, but they also need to address long-term challenges such as climate change or lagging digitisation. These objectives cannot be achieved without taking into account other factors, such as specific local needs, reducing geographical disparities (such as the rural divide), or the problem posed by the aging of the average population [6].

Impact of the GDPR in business and research

On the one hand, the data gathered by smart cities demands responsible management of this information. It must be ensured that no personal data are saved and especially that no personal data is used for malicious purposes. On the other hand, this data gives the opportunity to adjust laws precisely to society's needs in alignment with technological development in time.

The decision of the EU community to adopt in 2016 the General Data Protection Regulation (GDPR) 2016/679 in the European Union and European Economic Area is having a wide impact on how it is possible to treat personal data of individuals in business and research. While this is a great improvement on giving individuals control over their personal data and on unifying the regulation within the EU, at the same time it makes the task to collect, process, and share data more complex.

This could have an important impact on small companies/institutions that cannot have dedicated power to implement GDPR compliance. This has brought a boost of new technological tools which helps to meet the law making a precise and appropriate application of legislation.

EU commitments on the environment

In the Europe's Digital Decade: digital targets for 2030 [7] the EU committed to not only secure but also sustainable digital infrastructures, as a contribution to the global targets related to the environment and the use of natural resources (circular economy / green economy), as well as climate change (mitigation and adaptation). In the "Data - Edge & Cloud", EU's Digital Decade has foreseen 10,000 climate-neutral highly secure edge nodes. EU governments need to support the companies, especially the small ones, to undertake the transformation to enter the new edge-driven ecosystem that is taking shape.

Demand for Data ownership and sovereignty

Knowledge is power. Smart cities are likely to demand data ownership and sovereignty. Data is one of the most important resources that any city can own and there will be an increased demand for multimodal data management and processing. Data may be the tax that we will pay tomorrow. Already in Europe, mobility providers may need to open their data in exchange for a licence to operate. Data sovereignty is becoming increasingly important and the power of the state and trust from its people will be intertwined.

The business potential in the data-driven services to further support the deployment of smart cities is huge; the exploitation of such data can create huge economic potential for cities.

3.1.1.2 Economic

Economic uncertainty

After months of lethargy and a period neutralised by COVID, things are starting to pick up again in international business. Many lessons have been learned in the wake of the virus and what is clear is that companies of a certain size are preparing to face the new times.

The month of May 2021 has been a record month in the mergers and acquisitions market, with more than half a million dollars of transactions between companies, with a special emphasis on international companies. Many are mega-deals, with more than 10 billion dollars. Mistrust is fading and the economic uncertainty that has prevailed until now is being reduced. This year the volume of mergers and acquisitions worldwide could exceed \$5 trillion [8].

It is to be expected that the economic situation will eventually return to normal after the COVID crisis, and in some sectors, it could even rebound and grow faster than expected, but this turnaround is still incipient, and many small and medium-sized enterprises are still cautious about making new investments until this improvement in the economy takes hold.

Alignment of jobs, services and products with society

The knowledge gained through the data collected and processed in smart cities shows the needs and assets of the society and their locations more precisely than ever. MARVEL can help rise awareness regarding this knowledge as well enable from the one hand: organisations to leverage it in order to develop products and services which cover those needs and on the other hand individuals to participate in ideation, provide feedback to any new development, etc. Creating new jobs and meeting the most urgent and latest (created through new technology) needs of society is aligned with the economic and social impact pursued by the MARVEL project.

Lack of incentives for data-driven value generation

The deeper and wider adoption of analytics, and the recent technology advance, make it possible to establish new data-driven business models, which are built on shared value generation. However, often there is a lack of incentives for users to share data since they do not fully recognise the potential benefits. This limitation is partially due to non-economic factors, such as the uncertainty around the legal issues of data sharing and around the availability of technical means to enforce ownership and data governance. These factors may be reduced by ongoing scientific and technological progress, e.g., via federated learning approaches, which can boost data-driven value generation in the market.

Increased appetite for investments in data driven solutions

We live in a world where the focus is on economic efficiency. The demand for data-driven efficiency and automation will cause investors and entrepreneurs to invest their time and money in growth sectors that can be more lucrative. Moreover, economic blocs that fail to invest in data could suffer from a lag in economic growth relative to those that are taking the lead in this area.

When it comes to (potentially personal) data fusion and management, it is crucial to create a framework of trust for the citizens and society in general. A trustworthy framework will ensure that citizens actually trust the systems managing and exploiting their data.

3.1.1.3 Societal

Growing environmental awareness

Smart cities have emerged as a possible solution to sustainability problems deriving from rapid urbanization. They are considered imperative for a sustainable future [9].

Cities use <2% of the earth's surface yet consume more than 75% of the natural resources available globally. As a result, cities are expected to experience challenges related to growth, performance, competitiveness and residents' livelihood [9].

Growing awareness of the surrounding

The inhabitants of smart cities will be more aware of their environment, as the knowledge provided to citizens will allow them to know the effects of their actions and make them feel that their positive actions are valued and seen. This will encourage positive behaviours such as helping people in need and making citizens aware of potential hazards (e.g., potholes). In this way, citizens are involved in the management of the city, and its maintenance and good condition become more the result of a collective effort.

Lack of jobs and growth

Developing, deploying, and maintaining smart city infrastructures and services requires specific skills, which may not be available evenly across Europe, because of various reasons such as: in some areas, under-investment in connectivity and other basic digital services, which hampers the widespread adoption of IT skills; the IT job market has become more unstable during the COVID-19 pandemics, with an increasing number of remote working positions [10], which can drain existing competences from EU towards countries with a more dynamic and vibrant market job, such as the US.

Uncertainty and perception of technology by EU citizens

Conspiracy theories are taking root in Europe and in the world due to the complex events in which we have been immersed in the last few decades. Just to mention a few, the humanity passed through the global financial crisis started in US in 2007-2008 and influencing Europe, refugees 'crisis in 2015, growing terroristic attacks in Europe in the recent years and now the COVID-19. Researchers found a clear correlation between conspiracy theory thinking and people uncertainty perception during crisis, as people are in need of easy answers to complex problems and to single out culprits for the negative developments.

These considerations also affect the perception of technology. For example, there is an increasing activity of the anti-5G movement across EU. In addition, AI is perceived with some worry by our society, as a mean to substitute humans at work or control them in everyday life, and, of course, the common feeling in some percentage of EU citizens that our data are not sufficiently protected but stolen through technology is also a consequence of the uncertainty.

Growing demand of automated services without interruption

Citizens are demanding more efficient use of their taxes and more efficient transport systems. In addition, there is a growing acceptance of, and expectation for, automated services that operate 24/7. These factors continue to raise the demand for services developed in this project.

3.1.1.4 Technological

Less overall energy consumption

Through more data processing in the edge and less data traffic, the overall energy consumption will go down with respect to the knowledge extracted surrounding the society in a smart city. As the processors of edge devices are less powerful the algorithms used on those processors have to become more efficient, clustering knowledge faster in less iterations – thereby using less energy. Furthermore, less data traffic accounts for less energy consumption and less points for cyber-attacks.

Diversity in terms of standards

The rapid development of applications and frameworks for big data and real-time analytics in smart cities has led to the definition of several standards, in standards developing organisations, industrial alliances, and open-source communities. It is still unclear whether a small subset of these standards will eventually dominate the ecosystem of technologies or the fragmentation will persist in the medium- and long-term. Until then, diversity will be a barrier, especially for EU's SMEs to enter the market due to up-front costs required to cover a broad range of scenarios adhering to different standards.

Cloud computing is moving to the Fog layer & Edge layer

As more and more IoT devices are available and powerful and also considering the growing trend towards privacy-preserving technology, “data analytics technologies begin to live outside of the traditional data center and cloud environments, they’re moving closer to the physical assets [11]. The benefits are related to the fact that data are processed at the edge, near the user (i.e., the data owner) and what is sent around is a compressed information, most of the time not containing sensitive and personal data, but anonymised elaboration of them. Furthermore, the benefits are technological, since latency is reduced, optimisation of resources is done at the edge and scalability is easier.

Fog and edge computing have emerged as a viable and appropriate solution to mobility support, geo-distribution, and location-awareness where real-time is very important. Edge and Fog Computing will enable the Cloud Computing service to penetrate further into the market and give a new lease of life to cloud-based platforms.

3.1.2 Market Overview

Depending on the source, the data may differ, but in general, they agree on the solid annual growth of the smart cities market, which is already of a significant size.

As a study by the firm MarketsandMarkets points out [12], the global **smart cities market currently stands at no less than \$410.8 billion and estimates that it could double in five years, to a size of \$820.7 billion in 2025.**

This represents an **average annual growth of close to 15%.**

The experts at this consultancy firm attribute this positive evolution to the increase in demand for communications and public safety infrastructures, the empowerment of the citizen, and the increase in the urban population.

Some of the segments that will experience the greatest growth are:

- **Transport:** an essential part of any smart city project if a sustainable economy is to be achieved because the mobility of people but also the delivery of goods and services depends on it. To achieve this, infrastructure and platform solutions are needed, as well as solutions that enable real-time traffic monitoring to reduce congestion and optimise traffic flow.
- **Smart buildings:** which will increase billing for services aimed at reducing energy consumption and automating tasks that are useful to their inhabitants. In this area, opting for services will reduce fixed costs.
- **Public safety:** This is the segment in which MARVEL project would be located and is also an important growth lever. In smart cities, technologies such as video surveillance, DNA phenotyping, and real-time license plate and facial recognition are widely used for public safety, indicating the need for monitoring to ensure the safety of citizens.

The COVID-19 crisis has reinforced and boosted these trends.

The need for innovative smart city solutions that can be effectively combined with IoT, big data, analytics, cloud, security, and network connectivity is increasing in these application areas. The adoption of IoT in smart city focus areas, such as smart utilities and smart citizen services, is expected to drive the adoption of smart city solutions during the pandemic, as regulatory authorities in several countries focus primarily on monitoring the health, safety, and living standards of their citizens. To meet the need to manage IoT devices in various cities, smart city solution providers need to enhance the management capabilities of their solutions to make a real impact.

From another side, privacy and security is a major area of concern in smart city projects. As the ecosystem of smart cities depends majorly on IoT and central access points for different data, the vulnerability of the whole ecosystem is high. To solve the privacy and security challenges in smart cities, stakeholders (security professionals and smart city planners) must address issues holistically to make sure that the challenges will not continue plaguing the rest of the smart network.

MARVEL also addresses this concern by providing anonymisation techniques, compliant with the GDPR requirements law, but also includes security features for the encryption of data and network traffic, in order to protect them from unauthorised access, and attestation of the programs in order to ensure that only the correct, unmodified programs are being executed in a genuine SGX enclave. MARVEL project is committed to enable secure computing and focus on the preservation of the confidentiality and integrity of the applications, especially in the edge layer.

3.1.3 Targeted segment

For this first exploitation deliverable, the initial segmentation of the market considers the type of targets MARVEL would address. This considers the following categories:

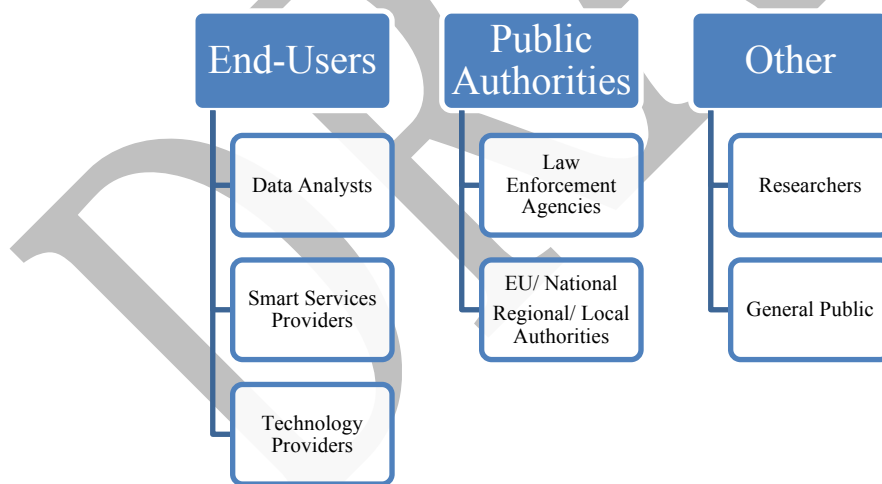


Figure 1. Targeted Segments

3.1.3.1 End-Users

In the context of MARVEL, three groups of potential users have been identified:

- **Data Analysts:** they are organisations that generate, exploit, collect and analyse digital data intensively and use what they learn to improve their business. They represent the demand side of the Data Market.

It is estimated nearly 535,000 organisations of Data Analysts in the EU27 and to nearly 716,000 units in the EU27 plus the U.K, with a growth of 0,6% in 2019 [13].

Data organisations are in a consolidation phase in the EU, with more stable growth rates. They provide tools and platforms which offer data management and analytics tools to extract knowledge from data, curate and visualise them.

- **Smart Services Providers:** they develop Big Data applications on top of the tools and platforms to provide services to user enterprises. As stated in D1.1 [4], MARVEL will provide specific added value to:
 - Transportation-related services providers.
 - Information spreading services especially in situations of large-scale impact which require citizens coordinated action and quick response such as the case of the COVID pandemic.
 - Services to provide better crime detection and evidence collection (e.g., recognition of images in the subway).
- **Audio/Video Technology Providers:** data generators and providers who create, collect, aggregate, transform and model *raw sound/image/video data* from various public and non-public sources and offer them to customers.

MARVEL is expected to have a significant impact regarding innovation potential in **the microelectromechanical system (MEMs) microphone market**. The growing use of microphones in industrial applications for the evaluation of ambient or environmental noise, increased demand for microphone-embedded medical devices, growing implementation of different types of microphones in security cameras and audio/video-enabled surveillance systems, and the growing demand for IoT enabled connected devices with voice command feature push strongly this segment [14]. The major players include Knowles (US), AAC Technologies (China), TDK (Japan), Goertek (China), and STMicroelectronics (Switzerland). In MARVEL, this role is represented by IFAG.

3.1.3.2 Public Authorities

They could be direct beneficiaries of the MARVEL project, by having new real-time monitoring tools that would help them to react more quickly and effectively to violent incidents and accidents, as well as to manage the resources available in a smart city.

- **Law Enforcement Agencies:** Detailing the law enforcement agencies of each EU country would be beyond the scope of this deliverable. In addition, most EU countries have complex structures for these purposes as a consequence of their structure and history, distinguishing between different bodies that can be special, local or state police. There are also particular cases such as Germany, which has federal authorities, or Spain, which has two distinct police groups with different functions, the Guardia Civil and the National Police. The specific added value which MARVEL releases to this segment is to speed-up the information in real-time to enable reacting instantly in criminal occurrences.
- **EU/ National/ Regional/ Local authorities:** The demand for smart city solutions is heavily dependent on national and local governments. As long as the public administration is committed to investing in smart city transformation, both research and the private sector will be able to provide adequate solutions.

It is easy to understand that even if governments have the need, vision, and clarity for such transformations, the lack of budget allocations for any large-scale implementation

hinders the pace of the transformation process, either directly or indirectly. Such heavy investments could also add to the financial burden of indebted governments or local municipal authorities, negatively affecting future overall budgets.

MARVEL provides to this segment information in real-time for effective data-driven decision-making, and engagement with public bodies to eliminate the lack of citizens' trust in the authorities.

3.1.3.3 Other

- **Researchers:** This refers to any organisation, group, initiative or individual conducting research related to the areas that lie within the MARVEL scope: ubiquitous E2F2C approach, multi-modal perception close to the source, and security and prevention, also related technologies as high-performance computing, edge computing, and federated learning.
This category comprises universities (including MSc and PhD students), research institutes, or similar R&D projects.
They are mainly interested in the research exploitation model, aspiring re-utilisation of the research know-how acquired in future research activities.
- **General public:** according to the MARVEL Description of Action (DoA) [1], they are individuals who benefit from the project outcomes. (i) Acquire new expertise and utilise the project results in scenarios that are addressed to the general public for gathering feedback; (ii) Increase general awareness.

3.2 Supply side

MARVEL will enhance the competitiveness of providers of smart cities services solutions, particularly those focused on surveillance and public safety, by delivering a disruptive E2F2C ubiquitous computing framework, that enables multi-modal perception and intelligence for AV scene recognition, event detection in a smart city environment.

3.2.1 Competitor's analysis

As usual in emerging markets, it is not uncommon for potential consumers to build their own tailor-made solutions in the absence of a defined offering that could otherwise have been covered by MARVEL.

It is expected that the industry will progressively fill this gap in the market, investing in specific solutions for the problems stated by MARVEL. For the purpose of this analysis, we have identified some commercial solutions which share with MARVEL some of its functionalities, that could act as competitors in a commercial context.

After analysing the existing options in the current market we can establish three different groups of companies that could be competitors of a product based on the MARVEL project.

- **Audio Analytics Companies:** organizations focused on the recognition of a larger number of **audio events and acoustic scenes**, usually using AI and ML, and multimodal perception techniques to process the information received.
- **Video Analytics Companies:** organizations focused on the recognition of a larger number of **image events and video scenes**, usually using AI and ML techniques and multi-modal perception techniques to process the information received.
- **Big Data Analytics for Smart Cities:** as the title suggests, in this category, we classify those companies which build services on top of big data to release added-value solutions to smart cities. A large number of companies offer this type of services in Europe, so

for the Market Analysis we have limited ourselves to companies which offer similar solutions to those offered by MARVEL.

Table 4: MARVEL Industrial Competitors

Competitor	Description/ Synergy with MARVEL
Audio Analytics Companies	
Audio Analytic www.audioanalytic.com	Audio Analytic is a British company that has developed a patented sound recognition software framework called ai3 which provides technology with the ability to understand context through sound, using ML techniques.
Securaxis https://securaxis.com/about/	Securaxis combines acoustic signal processing with deep learning and data science to turn sounds into information and actionable insights for applications such as traffic monitoring, intelligent lighting, and noise measurement in real-time.
Video Analytics Companies	
Avigilon https://www.avigilon.com/	Avigilon is specialised in the design, development and manufacture of advanced AI, video analytics, network video management software, and hardware, surveillance cameras, and access control products.
Cogniac https://cogniac.ai/	<p>Cogniac’s no-code solution enables organisations to capitalize on the latest developments in AI and convolutional neural networks to deliver image-based information processed.</p> <p>This solution is very focused on Industry 4.0, and it is not addressed to smart cities market, as MARVEL.</p>
iMotions https://imotions.com/	<p>iMotions is an integrated analysis platform made to execute human behavior research with high validity. iMotions seamlessly integrates and synchronises multiple biometric sensors that provide different human insight; such as Eye Tracking and Facial Expression Analysis.</p> <p>It provides specific insights just for emotion detection using facial analysis.</p>
Milestone Systems https://www.milestonesys.com	<p>Milestone designs, develops and produces video management solutions.</p> <p>Their technology partners aim to solve problems quite similar to those stated by MARVEL: understand customer behavior; prevent vandalism; gather evidence for criminal investigations; respond to medical emergencies; control access to restricted areas; provide situational awareness.</p>
Valossa www.valossa.com	Valossa provides video recognition and content intelligence software platform for businesses working with video. Valossa AI technology combines multimodal video analysis and recognition with high-level semantic inferencing to make sense of video content data. Valossa builds computer software that sees, hears, and profiles video content based on its semantic information.
Big Data Services for Smart Cities	
Altada https://www.altada.com/meet-aidexter/	<p>Altada is an AI data compliance startup, founded because of the lack of ethical and trustworthy AI products. Altada transforms data-rich clients into data-driven companies using a powerful AI platform to cleanse and organise data environments.</p> <p>Altada is not as specialised as MARVEL in smart cities services, but both solutions share the same concerns about providing added-value information assuring the protection of personal data.</p>
HaaS Alert https://www.haasalert.com/	They provide a digital warning system for road safety. When emergency fleets activate their lights, Safety Cloud automatically delivers real-time

	notifications to approaching drivers before they encounter response personnel in or near the roadway. These alerts are received by nearby motorists through navigation apps that give drivers time to slow down and move over.
LotaData https://lotadata.com/	LotaData offer accurate and anonymised insights about the presence, activity and movement of people uses trillions of data points from more than a billion devices every month from GeoODK [15].
QLue https://www.qlue.co.id/	QLue commercialises smart city solutions focusing on AI, IoT, and mobile workforce technology. In the Automotive segment, they provide advanced data analytics to give all the valuable insights to know better about the traffic ecosystem.
SAS www.sas.com	SAS solution for Smart Cities offers to integrate, visualise, transform and analyse IoT data across the ecosystem – edge devices, data centers or the cloud to provide specific insights about vehicles traffic management and public safety.

In our market analysis we are not aware of, or at least we have not found a software solution that offers audio or video information processing, with the purpose of providing relevant insights in real-time to increase the level of public safety, both for surveillance purposes (e.g., crime) and incident prevention (e.g., traffic jams, potholes on the road) in a smart city context.

The solutions that have been found only partially cover some of the functions offered by MARVEL and most of them are specialised in other fields of application.

MARVEL is the only solution on the market capable of providing real-time processed audio and visual data using big amounts of city-wide data capturing deployments (see Figure 2).

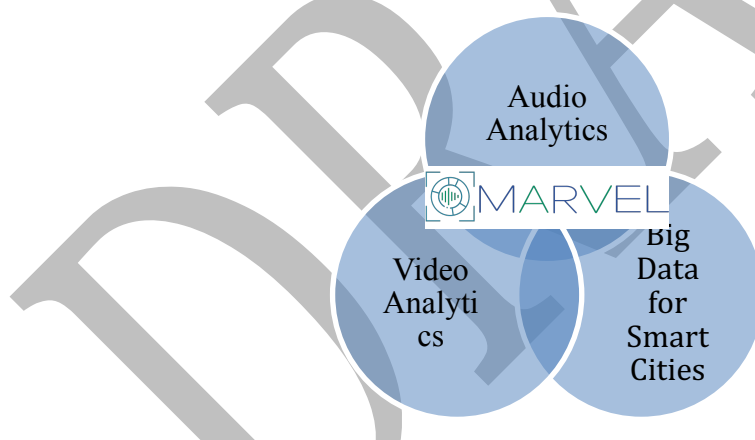


Figure 2. MARVEL Markets Convergence

3.2.2 Related projects

This section of the deliverable considers related research and innovation projects positioned in the same topics (big data economy and multimodal AV intelligence) where the goal is to investigate the possibility to build on top of tools and technologies that have common ground irrespective of the differences in the objectives and the envisioned outcome.

These projects were already listed in D1.1 [4] but are also listed below due to their relevance for the market analysis, so they can act as competitors or collaborators depending on the context. The shared similarities among these research projects and MARVEL have been extracted from D1.1:

Table 5: MARVEL-Related Projects

Project	Sinergy with MARVEL
Elastic – A Software Architecture for Extreme-ScaLe Big-Data Analytics in Fog ComputIng ECosystems (H2020 EU-funded, GA No 825473). https://elastic-project.eu	The common aspects that the two projects share MARVEL are: target smart cities applications, fog computing, distributed data analytics, data fusion potential aligned standardisation efforts and explore possibilities for considering elastic fog.
ExaMode - EXtreme-scale Analytics via Multimodal Ontology Discovery & Enhancement (H2020 EU-funded, GA No 825292). https://www.examode.eu	MARVEL and ExaMode are applied to different domains (smart cities with MARVEL versus healthcare with EXAMODE), however, they share common ground that will be further explored related to multimodal analytics, extreme-scale analytics, and modelling for heterogeneous data.
ExtremeEarth - From Copernicus Big Data to Extreme Earth Analytics (H2020 EU-funded GA No 825258). http://earthanalytics.eu	Both projects will apply DL methods for extreme-scale analytics and will also consider spatial aspects of the data (e.g., spatial events localisation) and related applications that MARVEL aims to examine in depth.
INFORE - Interactive Extreme-Scale Analytics and Forecasting (H2020 EU-funded GA No 825070). http://www.infore-project.eu	MARVEL and INFORE have different objectives, application domains, datasets and will follow different DL approaches. However, the projects share common advanced algorithms for deep analysis that will be investigated by MARVEL.
CloudButton - Serverless Data Analytics Platform (H2020 EU-funded GA No 825184) https://cloudbutton.eu	Even though the two projects will be validated in different application domains and will develop different technologies, MARVEL will also aim at optimising the data lifecycle but in the context of E2F2C processing with special emphasis on edge-based technologies.
SmartDataLake - Sustainable Data Lakes for Extreme-Scale Analytics (H2020 EU-funded GA No 825041) https://smartdatalake.eu	MARVEL will investigate data management and visualisation technologies developed within the project for the Data-Corpus-as-a-Service and also within the MARVEL decision-making toolkit with advanced visualisations and forensics.
I-BiDaaS - Industrial-Driven Big Data as a Self-Service Solution (H2020 EU-funded GA No 780787) https://www.ibidaas.eu	MARVEL can take advantage of scalable tools built within I-BiDaaS, to facilitate the signal processing needed. It will also use visualisation techniques from I-BiDaaS in the use-cases at hand. All implementations done in I-BiDaaS can easily feed MARVEL.
SILENSE - (Ultra)Sound Interfaces and Low Energy iNtegrated SEnsors (H2020 EU-funded GA No 737487)	IFAG performs the research towards using the MEMS microphones for ultrasound technology – emitter and detector. Some basic development boards and algorithms for data analysis and signal filtering are planned to be used within MARVEL.
OpenDR – Open Deep Learning for Robotics Toolkit for Robot (H2020 EU-funded GA No 871449) http://opendr.eu/	MARVEL can take advantage of efficient DL models developed in the OpenDR toolkit for computer vision and end-to-end UAV navigation to facilitate real-time operation in visual surveillance scenarios.
QROWD - Because Big Data Integration is Humanly Possible (H2020 EU-funded GA No 732194) http://qrowd-project.eu	MARVEL will consider using the results from QROWD related to data acquisition and data visualisation.
SoBigData++ - European Integrated Infrastructure for Social Mining and Big Data	The SoBigData++ results will naturally feed into MARVEL, where they will be extended to cope with the specific focus of the project on multimodal

Analytics (H2020 EU-funded GAs No 654024 and 871042) http://www.sobigdata.eu/index	learning and perception. They will thus be extended to optimise their performance in these environments.
iTRACK - Integrated system for real-time TRACKing and collective intelligence in civilian humanitarian missions (H2020 EU-funded GA No 700510) https://www.itrack-project.eu	iTRACK and MARVEL have a common interest in real-time information and as such best practices from iTRACK can be transferred to MARVEL.
City Sensing	MARVEL will take advantage of the physical infrastructure deployed within City Sensing to carry out signal processing of video and audio sources.
STARDUST - HOLISTIC AND INTEGRATED URBAN MODEL FOR SMART CITIES (H2020 EU-funded GA No 774094) https://stardustproject.eu	MARVEL will build upon the infrastructure, both physical and ICT, deployed and tested within STARDUST.
DataBench - Evidence Based Big Data Benchmarking to Improve Business Performance (H2020 EU-funded GA No 780966) https://www.databench.eu	MARVEL will take full advantage of the DataBench Toolbox to search for suitable benchmarks and potentially automate the deployment and usage of benchmarking initiatives in the related tasks.
HumaneAI-Net - HUMAN-CENTERED ARTIFICIAL INTELLIGENCE (H2020 EU-funded GA No 952026) https://www.humane-ai.eu/	The HumanAI-Net results will feed into MARVEL, specifically for what concerns the implementation of decentralised ML algorithms for data analysis.
SAI - Social Explainable AI (CHIST-ERA, Call 2019) http://cnd.iit.cnr.it/SAI/index.html	The SAI results will feed MARVEL, specifically for what concerns the development of decentralised AI-based intelligence taking also into account social relationships between users.
DECENTER - Decentralised technologies for orchestrated cloud-to-edge intelligence (H2020 EU-funded GA No 815141) https://www.decenter-project.eu	The use case of Trento aims to realise two smart crossings leveraging the technologies of the Decenter project to make these crossings more secure by detecting and alerting the subjects (pedestrians, cyclists, drivers, etc.) in case of danger.
PROTECTOR - PROTECTing places of wORship (EU-funded GA No 101034216)	The PROTECTOR project is tightly connected with the MARVEL project. In fact, the study case of Trento aims to collect and analyse visual data gathered from static surveillance cameras and mobile sensors in order to detect and track the motion of people and relevant objects (e.g. vehicles) in the scene.

3.2.3 Market trends

The latest trends in the ICT industry [16] continue in line with the initial project approach and can be summarised as follows:

Increasing malware and ransomware attacks in the IoT ecosystem

According to IDC [16], attacks could increase by 20% by 2021. The growing number of IoT devices is increasing in parallel with their level of vulnerability, creating a digital system that makes us as a society dependent and vulnerable as long as there is no increased investment in IoT security.

Remote working is exploding

According to IDC [16], by 2021, 45% of communities will shift to a hybrid workforce that will use cloud-based applications, digital collaboration tools, and mobile technologies to maintain services and ensure work-life balance.

Municipal jobs have traditionally been almost 100% face-to-face. This all changed in 2020, and urban centres are now expected to offer a more flexible working model that has been proven to be just as effective as the face-to-face model.

Increased use of digital tools by law enforcement agencies.

One of the most important trends in the smart cities market and one that is directly related to the objectives of the MARVEL project is the increasing use of technological tools by authorities to ensure the safety of citizens.

This trend was already mentioned in D1.1 [4], but is highlighted again in this report, due to its importance for MARVEL: Only 10-20% of the calls to emergency call centres pertain to violent crime. The remaining 80-90% relate to misdemeanours (public intoxication, public disorder, etc.) and are committed by a small subset of individuals struggling with mental health, addiction, juvenile delinquency, homelessness, and other social problems; a general trend is that ~10% of the population accounts for ~80% of the caseload.

As a result, there has been a growing interest in alternative response models that can provide more targeted assistance to citizens, and that can involve all community safety agencies (health, education, social services, police, etc.).

Encouraging the use of private transport solutions in cities with more than 500,000 inhabitants

Strategically, cities have two options. They can continue to run scheduled routes with passenger limits on buses and metro, or they can embrace change by expanding into other private transport options that can offer lower ridership and density, but wide coverage.

Private transport solutions - including mobility-as-a-service (MaaS) operators, car-sharing, car-sharing, and micro-mobility services - will become a more important factor in how cities redesign and redistribute transport for their users.

Increased citizen interaction with local administrations through the use of high-level digital and hybrid physical-digital experiences.

People increasingly live in a world where physical and digital experiences are blended, with online social media personas, digital relationships, and experiences that are partially consumed or experienced digitally. For example, a person may use a mobile app to pay for parking, receive a paper parking ticket and pay for it online. As this becomes a core expectation for the government experience, more products and services will be offered through specifically designed high touch and augmented digital experiences.

High demand of innovation for telecommunications technologies.

Edge technology is considered a quite obvious driver of innovation in technology. Therefore, it is of utmost importance to ensure that the gathered data is already of the highest possible quality. This challenge is faced by IFAG for example through high-quality acoustic MEMS sensors with their low self-noise, wide dynamic range, low distortion, and high acoustic overload point. Further needs are good communication technology to cope with the data traffic produced by this rising amount of edge devices, despite better edge processing. Here 5G plays a significant role. Furthermore, filtering algorithms and fog processing need a high amount of attention.

In conclusion, there is a high demand for innovations in sensor technology, communication technology, and the development of algorithms in the field of AI and ML. To achieve that, it is

necessary to open society's view on those topics and to obtain funding for their development in an environment detached from pure industrial goals, like MARVEL.

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4 SWOT

Based on the internal and external environment analysis performed in previous sections, we have built a SWOT analysis that categorizes internal and external aspects that may directly or indirectly influence the development and commercialisation strategies of the MARVEL solutions into strengths, weaknesses, opportunities, and threats.

Table 6: MARVEL SWOT analysis

	Strengths	Weaknesses
Internal	<ul style="list-style-type: none"> • S1: Innovative technologies in the smart cities field. • S2: Privacy-preserving model sharing. • S3: Strong team of scientists passionate about their subject. • S4: Modular solutions 	<ul style="list-style-type: none"> • W1: High technological complexity. • W2: High Development costs. • W3: Big consortium, with different interests among partners. • W4: Focus on compliance can suffocate the entrepreneurial spirit.
	Opportunities	Threats
External	<ul style="list-style-type: none"> • O1: Accelerating digital transformation. • O2: Next Generation EU Funds. • O3: GDPR compliance. • O4: Data collection is becoming increasingly cheap. 	<ul style="list-style-type: none"> • T1: Global recession due to COVID-19 • T2: Increase of the GDPR requirements. • T3: Gap between science and industry. • T4: Technology changing faster than regulations can keep up with

4.1 Strengths

S1. Innovative technologies in the smart cities field

MARVEL will deliver a set of technology advancements and tools that will offer extreme-scale audio-visual analytics, based on innovative multi-modal audio-visual scene classification and event detection methods that will be adopted for event recognition and prediction in IoT-based smart cities.

Small devices, with limited compute capabilities, are used today mainly for data acquisition or for the inference phase of ML. This is because the memory, processing, and energy limitations do not allow the execution of the training phase of most ML algorithms of practical use. In MARVEL, we will define methodologies to compress the Neural Network models that make it feasible to execute the training step of ML on small devices. This will allow training to happen close to real-time sensing of data, which in turn unlocks the true decentralisation of the overall real-time analytics process, with benefits in terms of reduced outbound traffic and power consumption on beyond-the-edge layers of the system.

S2. Privacy-preserving model sharing

MARVEL will investigate the use of federated learning techniques, which make it possible to improve the quality of Neural Network models without disclosing the actual data, which may be impractical or impossible under the current legal framework in the EU.

This means that the privacy of data is preserved by definition: this can encourage the different actors in the smart cities ecosystem to share their models, for mutual benefit or with the help of

economic incentives, eventually leading to more accurate predictions in analytics without the need to share the sensed data.

S3: Strong team of scientists passionate about their subject

The MARVEL consortium is very rich in scientists and innovators, this means genuine curiosity in the subject and a wealth of ideas. They say that “science is what we do when we do not know what we are doing”, and the MARVEL agreement gives a degree of flexibility to explore and focus on the several building blocks of MARVEL cutting edge science.

The MARVEL team is composed of 17 diverse European entities among which, public authorities, research institutes, universities, and enterprises. This brings a wealth of know-how and connections which if invested wisely would provide unique depth and rich teamwork.

S4: Modular solutions

MARVEL framework has been envisioned as a set of multiple modules packaged in a single offering that will enable multiple stakeholders within a smart city to leverage audio-visual data in order to address various challenges and explore opportunities within the space of public safety and citizen wellbeing. Although the packaged offering can release the full potential of these modules combined in one system, it is important to mention that each of them has its value and can be utilised independently or as part of other solutions. This flexibility is a key strength of MARVEL, enabling compatibility with other solutions as well as relevance for other research initiatives.

4.2 Weaknesses

W1. High technological complexity

Many of the optimisations proposed in MARVEL, including for instance federated learning, the E2F2C orchestration process, and the data management platform, go into the direction of a distributed management of the resources. While they can bring significant advances in terms of performance, if perfectly tuned, there is also the risk that the added complexity on the management plane will lead to sub-optimal performance, with a vanishing overall improvement.

W2. High development costs

Current analytics frameworks and Software Development Kits are designed for high-end servers or specialised hardware, e.g., Graphical Processing Unit. However, in MARVEL we will also target smaller devices at the edge and fog layers, which may not be supported or optimised by all the products in the market. This means that additional development will be needed to support the full range of devices in smart city scenarios, especially at the edge layer where it is common to employ non-Intel architectures or even microcontrollers. The added cost for development, test, and integration may significantly impact the time-to-market and business viability of products based on the MARVEL technologies.

W3: Big consortium, with different interests among partners

Successful new solutions require the ability to make decisions and change them with agility. A new product often requires numerous iterations until a product is found that fits the market. As a research consortium, it is necessary to accept that not all products developed at MARVEL

will have a commercial focus and that it is necessary to build products aligned with market needs.

Furthermore, the consortium is composed of 17 partners, with different profiles (academia, research, industry...) and different commercial interests. Moreover, the intellectual property of the solution to be generated is fragmented.

All these issues will be addressed from the exploitation task, with continuous monitoring of the market we want to address, and in the design of MARVEL's sustainability strategy, where we will decide how we want to give continuity to the solution once the official project is finished.

W4: Focus on compliance can suffocate the entrepreneurial spirit

MARVEL is an EU-funded project, so it requires a balance between the reporting and documentation of the results in the corresponding deliverables, as well as reaching meaningful commercial milestones, which include solution development and new paying customers to push innovations adoption provided by the project.

4.3 Opportunities

O1: Accelerating digital transformation

The COVID epidemic has accelerated the digital transformation of the public and private sectors so that changes have taken place in the course of a year that under normal circumstances would have taken a much longer period. This technological transformation has also been a consequence of deep societal changes such as the consolidation of teleworking, increased awareness about the importance of science and technology to provide solutions to solve the major challenges which face humanity. This social and digital paradigm shift is not yet measurable, and it is expected to take full advantage of emerging technologies such as IoT, Edge-Fog-Cloud computing, AI/ ML, and multi-modal perception techniques.

O2: Next Generation EU funds

The resources provided by the Next Generation EU funds are a great opportunity to support our cities in their transition towards the smart cities of the future, so the challenges of a smart city are strongly aligned with the three macro-objectives of the Next Generation EU plan (green, digitalisation and social inclusion) [5].

O3: GDPR compliance

Due to GDPR concerns and sensitivity of data, it is desirable to do the processing as close to the edge as possible so that only numerical or anonymous data is transmitted and reaches the servers or cloud. Once all the data is processed as soon as it is collected there will be no risk of personal data infringement and this will give greater confidence and possibilities for smart city developments.

O4: Data collection is becoming increasingly cheap

Gathering data is becoming increasingly cheap with off-the-shelf-solutions, but with huge volumes of data at different speeds: storing, processing, and retrieving useful information is the real challenge. MARVEL's software advancements paired with technological advancements on the hardware side can bring significant opportunities.

4.4 Threats

T1: Budget constraints due to global recession due to COVID-19

The economic impact of the COVID-19 epidemic is not yet measurable, but we already know that it has pushed the world economy into a new recession. The business sector is holding back on spending, as it always does in times of uncertainty, and revising growth forecasts downwards. In this much more conservative scenario, investment in innovative technologies is often re-examined and even put on hold until a more favourable economic environment comes.

T2: Increased GDPR compliance

Currently, transport authorities are halting plans to install digital road infrastructure because they are considered too close to residential areas and seen to pose a GDPR threat. Conservative Data protection commissioners or Data Protection Officers may halt technical progress because of fear of the unknown or lack of understanding of underlying risk mitigation measures.

T3: Gap between science and industry

There is a traditional gap between science and industry. Potential customers are often risk-averse and choose reputable solutions that are convenient, easy to adopt, and known to deliver the results they need, rather than solutions that might better solve their problems but are as yet unproven.

To be sustainable in the long term, we have to create solutions that customers want and offer them real benefits that they are willing to pay for. It is better to offer a solution that meets customers' needs and works on the existing infrastructure than to offer more complex solutions that are not compatible with the existing infrastructure.

T4: Technology changing faster than regulations can keep up with

The speed technology advances are known to be faster than the one that states can legislate about. Legislation restrictions or more important future changes, yet to be conceptualised according to observations and social studies that will only showcase results in the future, may have an impact on the possibility of the solution(s) to be commercialised, given not the novelty of the technologies used as well as the duration of the project.

5 Identification of feasible Business Models

In general, MARVEL has different options for being deployed in the market. In order to create a comprehensive exploitation plan further on, we have identified **three well-known BM as the most promising ones for MARVEL**:

- **Business-to-Business (B2B2C Consulting Business Model):** The **B2B Consulting** business model aims to provide custom-made solutions based on the core MARVEL results. As MARVEL deployment would likely demand support for installation, configuration, and customisation to the company needs **on premises**, and customer support services, this business model would offer consulting services to the tentative customers to optimise the use of the framework. The revenue stream envisaged for this business model is through an initial fee for implementation and successive periodic fees.
- **Business-to-Customer (B2C): Marketplaces.** The MARVEL partners interested in taking part as a solution provider can offer the assets in a new and dedicated market place or an already existing one (FIWARE, Amazon Web Services, etc.). Using this business model, technology providers can get closer to end customers and set the MARVEL assets in one or several downloadable packaged software tools, offering a catalogue and the corresponding manuals and tutorials to customers.
- **Platform-as-a-Service:** It is a cloud computing model where a third-party provider delivers hardware and software tools to users over the internet. Cloud hosting and the ease of access through a website would be the most highly valued features of this business model.

The next step would be to analyse how we can map the selected business models with the MARVEL offering in Section 2 and the targeted market segments in Section 3.1.3 to provide specific scenarios to commercialise MARVEL Results. Figure 3 below illustrates the summary of the variables used for this purpose.

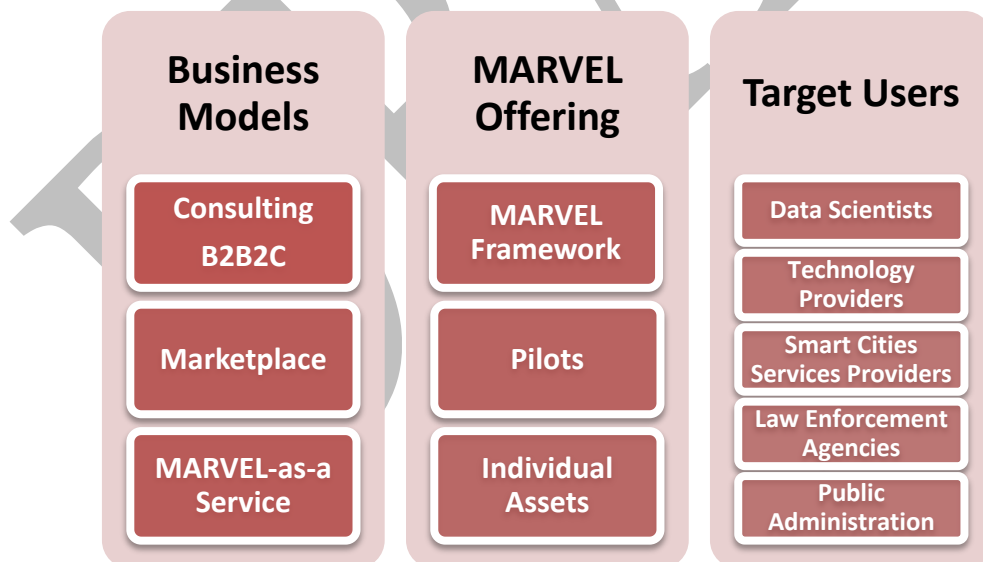


Figure 3. MARVEL Business Models Factors

For this first release, to assure that this analysis was feasible beyond a theoretical approach, we have asked the **pilot partners** their preferences if they were in the role of customers. To conduct this assessment, a questionnaire was used to collect information from the pilot partners. The template of the questionnaire has been annexed in this report (Annex: Pilot's Questionnaire).

Taking into account the conclusions offered after processing the mentioned questionnaires, we provide here 3 different scenarios that could be developed as specific business models for MARVEL Results.

5.1 Potential Business Model 1: B2B2C Consulting Business Model

The preferred option for the pilots' partners to go-to-market has been the **B2B Consulting** option, meanwhile the other two available options have been considered difficult to implement in the case of MARVEL Framework.

Complementary services as deployment, testing, integration, training, maintenance, and updates have been found extremely important by the pilot partner's side.

- **MARVEL Offering:** As it has been stated in the Value Proposition (see Section 2.3), the MARVEL Framework fully harnesses the edge (including data capturing), fog and cloud resources to effectively orchestrate and distribute computational and AI-related tasks. The customisation of this framework gives as result the pilots, which are customised solutions, adapted to the customer's requirements.

The high-level of customisation of the pilots, as well as the fact that they could need support for its implementation and configuration on premises, makes this business model the most likely to be used.

As it has been described in Section 2.2, **Pilots** in the MARVEL context are three different specific solutions to particular smart cities challenges. Similar solutions can be created as commercial products in the future.

- **Targeted Users:** Data Scientists from private sector domains, Law Enforcement Agencies or Public Administration authorities would be considered as the main targets for the MARVEL Framework.

5.2 Potential Business Model 2: Marketplace

This business model is focused on the development of new products or services based on individual assets, but it is highly unlikely for the implementation of a complex solution, such as the MARVEL framework. The envisioned solution involves uncertainty about the effort to introduce it to existing infrastructures with regards to the needed personalisation of the assets, or increased costs to adapt it and install the MARVEL architecture, complicating to commercialise the entire solution just through a marketplace.

- **MARVEL Offering:** MARVEL Individual Assets (software, hardware or services) owned by individual partners (see Section 2.1) that could be incorporated into existing solutions in the portfolios of technology providers through their innovation and development units.

Products should be fairly closed so that end-customers can use them "off the shelf" or sell them in combination with other support services (customer support, maintenance, training, integration).

- **Targeted Users:** Technology Providers and Smart Cities Services Providers could be those who reap a major benefit of this type of offering, to add it to their own offering (see Section 3.1.3). Investors and other private and/or public funding bodies can further invest in these assets.

5.3 Potential Business Model 3: Platform-as-a-Service

This mode of implementation has been found undesirable from the pilot partners' side due to the data-intensive nature of MARVEL and the need to protect personal data. It has been included in this section for completeness, but it is highly unlikely that this BM would be chosen to bring MARVEL to the market.

This is an initial approach for the tentative business model for MARVEL corresponding to the early stage of the project (M08), that will be refined in detail in future releases when the expected maturity of the results invites to a clearer vision since the commercial point of view.

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6 Conclusions

The present document, i.e., D7.2, is part of the final exploitation plan which is divided into three deliverables: this is released in M08 and it is mainly focused on the market analysis conducted in order to understand the best positioning of MARVEL and to identify feasible business models that will be refined in consecutive iterations as the results become more mature and more concrete. The next two deliverables are planned for M18 (D7.4 Exploitation Strategy and Activities) and M36 (D7.5 Final Business Model and Long-term Sustainability Report) which will continue the work started in the present deliverable, in order to define an exploitation and sustainability strategy for the project once completed.

After months of lethargy and a period neutralised by COVID-19, things are starting to pick up again in international business. Many lessons have been learned in the wake of the virus and what is clear is that companies of a certain size are preparing to face the new times. Next Generation Eu funds open a new phase for the EU Member States and their public administrations as an opportunity to definitively digitise those technological and social structures that remain obsolete.

GDPR continues as one of the most important levers driving the acceleration of digital society. The need to be compliant with the requirements of the European Personal Data Protection Law has boosted a myriad of innovative solutions which helps to meet the law making a precise and appropriate application of legislation.

According to international firms as MarketsandMarkets, the Smart Cities market solutions may multiply by two its size in the next five years, being two of the segments that will experience the greatest growth: Mobility and Public Safety, both of them analysed within the MARVEL pilots. The need of specific solutions for both domains has been reinforced after the COVID crisis.

All these factors, extensively explained in our market analysis are expected to push the smart city solutions market, driven by the economic recovery after COVID, and the boost to digitisation in public administration as a result of the investments to rebuild the European economy.

We include in this document an extensive analysis of similar solutions to MARVEL which could act as competitors. We have found several solutions which cover some of the functionalities tackled by the MARVEL framework, but we are not aware of a single turn-key solution that can provide audio and video insights in real-time, processing a big amount of data into a smart-city context. In this sense, MARVEL offers a differential value within the solutions found in the market: on the one hand, it is more ambitious than the existing audio and video tools; on the other hand, it offers added value to a specific domain such as smart cities, as it is specially designed to meet the needs and requirements of its stakeholders.

The innovative approach of technological tools in the smart cities' context as multimodal perception, AI/ ML techniques, and its cloud-fog-edge approach, as well as its privacy-preserving model sharing, make MARVEL a unique solution in the market.

Despite its uniqueness, in order to go to market, MARVEL will have to deal with the typical problems found by research projects, such as the traditional gap between science and business, or the different commercial interests that we need to reconcile in a consortium of 17 different partners. We will solve this difficulty with continuous monitoring of the market in alignment with the potential customers' needs, and we will design a sustainability strategy during the last year to satisfy the different particularities of each partner with regard to exploitation.

Finally, we have selected three business models that we believe are the most feasible for MARVEL, and we have asked the pilot partners, who represent the potential customers in this project, about the advantages and disadvantages of each of them.

This is the first approach to a business model proposal that will be improved as more defined and mature results are obtained in the project. Finally, there is a robust market, in which MARVEL can position itself with a clear value proposition, and we have identified several alternatives to reach the targeted segments with a commercial product that will be refined in subsequent phases.

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8 Annex: Fiche Component

1. Component name
2. Type of outcome: software, hardware, methodology, service deployed over (Name of the project)
<ul style="list-style-type: none"> • <i>Software/ Hardware Developments</i>: this category refers to tangible outcomes. • <i>Services</i>. The word “Service” refers to the traditional meaning of IT services. These are future services offered around SerIoT, which aims at improving customers' effective use of SerIoT solutions and to provide in-depth customised assistance.
3. Expected TRL and justification (how you expect to reach this TRL)
4. Tentative License (Open Source/ Proprietary License)
<p>Indicate the type of license of the component:</p> <ul style="list-style-type: none"> • <i>Closed source</i>: Such programs come with restrictions against modifying the software or using it in ways unintended by the original creators. • <i>Open source</i>: (Examples: Copyleft, Apache Software License 2.0, GNU General Public License (GPL), MIT License (MIT), Common Development and Distribution License (CDDL)... • <i>Distribution agreement</i>: the inventor company licenses the software IP to one or more software vendors. Vendors typically pay an upfront fee to the lessor company. • <i>Patent</i>
5. Value Proposition
How this technology caters customer needs. Which problem does it solve. Innovation value and benefits for the target users
6. Current Business Model of the component
Explain how your organisation is currently channelling this component to reach customers and make profit.

9 Annex: Pilot's Questionnaire

Please fill in the row of the tables below with your answers. Also, try to be very specific about the information provided.

1. Which specific problem are you aiming to solve in your organisation?

Please, develop your response:

--

2. How were you solving this specific problem within your organisation?

Please, develop your response:

--

3. Which competitors or alternatives do you know in the market for MARVEL?

Please, develop your response:

--

4. Which benefits will bring to your organisation the adoption of MARVEL?

Please, develop your response:

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5. Which one of the following models would you prefer to obtain the services offered by MARVEL?

Please, develop your response below the chosen one.

<p>MARVEL Consulting Services: deployment will be preferably performed on the organisation premises. Consultants analyses customers' needs and offers them a customised service offering. It includes IT Services (Deployment, maintenance, support...) and specific services delivered by the MARVEL solution (still pending to be defined) The main Revenue Streams Source are:</p> <ol style="list-style-type: none"> a) Initial consulting fees for platform set-up and customisation according the company needs, b) Periodic service fee that covers support and platform maintenance/updates

<p>MARVEL as a Service: the customer access to the selected MARVEL services through a website interface. This model is addressed to a customer that has a clear vision about the organisation needs, and does not need consulting support. The customer pays for subscription (periodic support fee, subscription model...).</p>

<p>Marketplace: dedicated marketplace or an already existing one (FIWARE, Amazon Web Services, etc.) where the organisation can download and purchase the MARVEL software.</p>

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6. If you decided to adopt MARVEL as a Service, how would you rate the following features?

	Extremely important	Very important	I don't know	Not very important	Totally not important
Cloud hosting					
Subscription model					
Ease of access (website)					
IT Consulting Services					

7. If you decided to adopt MARVEL Consulting Services, how would you rate the following IT complementary services?

	Totally not important	Not much important	I do not know	Very important	1. Extremely important
Deployment					
Testing					
Integration					
Technical Support					
Training					
Consulting					
Maintenance					
Updates					

12. If you decided to adopt MARVEL Marketplace, how would you rate the following features?

	3. Extremely important	Very important	I don't know	5. Not very important	6. Totally not important
Flexibility					
IT Developers Autonomy					
Low price					