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A computing toolkit for building efficient autonomous applications leveraging humanistic intelligence (TEACHING)

D6.4: Market analysis, business plan and long-term sustainability report[†]

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List of Abbreviations

API	Application Programming Interface
AD	Autonomous Driving
AI	Artificial Intelligence
APAC	Asia-Pacific
BMC	Business Model Canvas
CAGR	Compound Annual Growth Rate
CPSs	Cyber Physical Systems
CPSoSs	Cyber Physical Systems of Systems
DL	Deep Learning
DMU	Decision-Making Unit
EC	European Commission
EU	European Union
HIDS	Host-based intrusion detection system
HUMS	Health Usage and Monitoring Systems
IoT	Internet of Things
IT	Information Technology
IRR	Internal rate of return
M2M	Machine-to Machine
ML	Machine Learning
NPV	Net present value
OEM	Original Equipment Manufacturer
PEST	Political-Economic-Social-Technological
ROI	Return of Investment
SWOT	Strengths-Weaknesses-Opportunities-Threats
SDF	Sensor Data Fusion
SoSs	System of systems
SotA	System-of-the-Art
SIEM	Security Information and Event Management
SoMs	System on Modules
SW	Software
SME	Small and Medium Enterprise
WP	Work Package
WSN	Wireless Sensor Network

Executive Summary

This deliverable presents the work performed in WP6, Task6.2 “Exploitation, Sustainability management and Business continuity” that will support the activities of T1.1, by defining the TEACHING market context with the objective of identifying suitable hardware platforms, sensors, technologies and available software tools. Additionally, it conducts an in-depth market study using different analytical tools as necessary (PEST and SWOT analysis, questionnaires, annual company reports, analysis reports, etc.) to pinpoint the relevant business and societal challenges. In this respect, the report determines the size of the market, identifies key competitors, market needs and trends, identify stakeholders, possible clients and users and formulate potential business models to exploit the project outcomes. It also drives both the business and the technical activities towards long-term sustainability and potential commercialization uptake to the primary market segments.

1 Introduction

This report presents a market analysis of computing platforms and associated toolkits for human centric **Cyber-Physical System-of-System (CPSoS)** environments that can be applied in the domain of autonomous navigation of vehicles and aircrafts. The main objective of the work presented is to identify the attractiveness and the dynamics of the mentioned market. By conducting this analysis, valuable data can be gathered that will help to identify the market size and its trends, the key drivers and the regulations, incentives and legal aspects. Additionally, it will assess the roles, expectations and benefits for different relevant stakeholders to understand how to leverage and engage them. This market analysis determines the unique characteristics of a particular market and by analysing this information, will help the consortium to make future decisions for business plans. In this respect, market opportunities, challenges and barriers as well as influencing factors and relevant actors will be identified to assist the TEACHING partners to monitor them during the service/toolkit development stage.

As mentioned above, the report reveals information to the consortium partners to be able to refine product development and define best exploitation strategies for each application and geographical contexts. To this end, several specific objectives have been identified in this report and are listed as follows:

- to outline the market potential and to explore the existing market of computing platform for human centric CPSoS applications
- to consider barriers and opportunities by conducting PEST and SWOT analysis
- to outline the end-user's profile; to understand their needs and preferences to find out correlation between different factors potentially influencing users' interest in the TEACHING platform
- to create the main exploitable assets and summarize the TEACHING value proposition/offerings
- to define the marketing/pricing strategies
- to outline a baseline plan for the financial forecast of the project

To achieve the aforementioned objectives both primary and secondary research methods have been implemented. In the former case, the research has been proactively oriented to the TEACHING project. The primary sources of information, that has been obtained in a form of questionnaire survey with potential stakeholders, was recognized as necessary, since the services that the project offers are innovative and therefore requires in-depth knowledge on the customer segment. The stakeholder engagement questionnaire (see in APPENDIX I) is formed by ten (10) questions referring to several questions regarding the current preferences in using hardware platforms and software toolkits similar to TEACHING as well as evaluating their potential interest regarding the TEACHING platform and associated toolkits. In contrast, secondary research is research that has already been conducted for other purposes but still is valuable and beneficial for the project market analysis. The following source of information have been used: information available on the Internet (i.e. reports, databases, analyses, articles, direct information on websites). This information will be gathered through desk research that will be conducted using the Internet resources. Desk research will enable to explore supply and demand conditions, the market of similar services to the TEACHING platform as well as to outline main characteristics of the potential stakeholders.

1.1 Relation to other deliverables and work packages

The development of the market analysis, business plan and long-term sustainability report is supported by Task 6.1 and Task 6.2. The report drives most of the work performed within WP6 while it significantly impacts the work in Task1.1, in terms of tracking the technological trends in the scope of the TEACHING project and analysing the market of CPS. Finally, it is a parallel activity which is strongly interconnected with the technical development of the project and with the work conducted in WP2-WP5.

1.2 Structure of the deliverable

The deliverable is structured as follows:

Chapter 2 presents an overview of CPSoS/CPS market analysis, outlining the market size, segmentation, key CPSoS/CPS enabling technologies and application domains. It also gives an overview of the autonomous driving and aerospace markets, underpins the market drivers and barriers. The chapter also illustrates key competitors, SWOT and PEST analysis of the TEACHING project.

Chapter 3 presents the TEACHING business plan, updated business model canvas focusing mainly on the TEACHING value proposition/TEACHING offerings. The chapter introduces the analysis of the 1st TEACHING's stakeholders' analysis, followed by TEACHING marketing and pricing strategies. The chapter ends with a plan for future financial forecasts.

Chapter 4 summaries and provides concluding remarks

2 The CPS/CPSoS market

A **Cyber-Physical System-of-System (CPSoS)** is an integration of stand-alone **Cyber-Physical Systems (CPSs)** that provides services that go beyond the services of any of its isolated CPSs [1]. Coined in 2006, **CPSs** are defined as cyber-physical systems with embedded sensors, processors and actuators that are designed to sense and interact with the physical world (including the human users), and support real-time, to collaborate and guaranteed performance in safety-critical applications [1,2,3]. As shown in Figure 1, the physical part consists of various resources, which can be summarized as "human/machine/material/environment". The cyber part, which has various ubiquitous apps and services, incorporates smart data management, analytics, and computing capabilities. The physical part senses and collects data, and executes decisions from the cyber/digital part, while the cyber/digital part analyses and processes data, and then makes decisions [4].

Figure 1: Mapping between physical and cyber/digital worlds

Leveraging on vital fundamental technologies enabling digitalisation, (e.g., machine-to-machine (M2M) communication, Internet of Things (IoT), cloud/edge computing, wireless sensor network (WSN), AI, embedded software technologies, cybersecurity etc.) these systems bring intelligence everywhere and are considered key drivers of the innovation capacity of European industries, generating sustainable economic growth and supporting meaningful jobs for citizens.

From a functional perspective, their role in complex systems is becoming increasingly dominant (in cars, trains, airplanes, health equipment, etc.) because of the new functionalities they provide (including safety, security, autonomy). They are also required for the interconnection and interoperability of systems of systems (smart cities, air traffic management, etc.) [5]. Important sectors such as transportation and smart mobility, health, energy and industrial automation have already made remarkable progress in applying innovative CPSs. In this respect, it is envisioned,

that by 2050, these systems may interact with humans in multiple domains moving alongside people in their daily lives and working within a variety of industries.

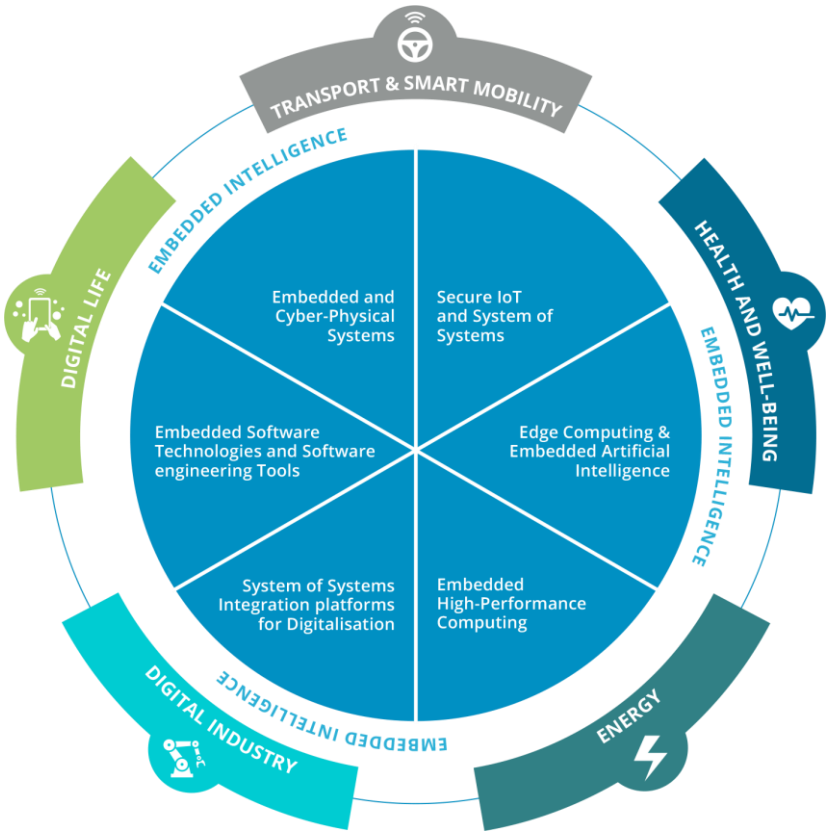


Figure 2: Embedded and Cyber-Physical Systems [5]

The industry visions for CPSs indicate that there are many opportunities for the future. The European Union is already investing $343 million per year for 10 years to pursue "world leadership" through advanced strategic research and technology development related to CPS [6] however Europe is not prominent in driving such platforms today and the aim is to identify how Europe could stimulate a new wave of innovation and capitalise on new CPS markets. The intention is to bootstrap ecosystems around platforms driven by EU actors exploiting synergies across sectors and applications [7].

2.1 The market size and segmentation

CPSs are enabling a new generation of 'smart systems' – and the economic impacts could be enormous. Although it is hard to determine the CPS market size due to its application in variety of domains but based on the recent "Global Cyber Physical System Market" report [8], the global CPS market is projected to reach $12720 M by the end of 2026 with a CAGR of 10.2% between 2021 and 2026. Interestingly, a recent report estimates that the technical innovations of CPS could find direct application in sectors currently accounting for more than $32.3 trillion in economic activity, and with the potential to grow to $82 trillion of output by 2025—about one half of the global economy [9].

The disruptive technologies emerging from combining the cyber and physical worlds could provide an innovation engine for a broad range of industries, creating entirely new markets and platforms for growth. Furthermore, as the primary components of a CPS are storage units, sensors, actuators, computing unit decreasing cost of these elements have led to the growth of CPS market mainly in developing economies and various industry sectors. The risk of human

life may also drive the increase in use of the CPS mostly in areas like chemical factories, nuclear power plants and hazardous remote locations etc [10].

North America is expected to hold a major share in the global market for CPSs. The incorporation of these systems in the region has enabled the introduction of automated products such as autonomous or self-driving cars, medical robots that are employed for complex surgeries, and industrial robots as a replacement for human labor, among others. Manufacturing industries in the region are continuously focusing on introducing a larger volume of such automated products, with the intention of offering a seamless experience to end users.

On the other hand, Western Europe is expected to slowly catch up with North America in terms of adoption. The European Commission is known for investing heavily on the research and development of new products and for the adoption of new products and services. This encourages the adoption of CPSs, which as a result boosts the growth of the market in Europe. Western Europe is in the limelight in the global market because of the presence of leading players in the region who are constantly innovating to stay competitive and to retain their user base in both Western and Eastern Europe [11].

Table 1: Overview of the CPS Market Segmentation

In terms of industrial sector	Healthcare, Manufacturing, Military, Transportation, Energy, Agriculture, Infrastructure, Communication etc.
In terms of geography	North America, Europe (Germany, France, UK, Russia & Italy), Asia-Pacific (Japan, China & Korea), Middle East & Africa, etc.
In terms of product type	Hardware, software, services
Key market players	Dell EMC, Siemens, VMware Inc. ITIH, Intel, SAP SE, Microsoft, Honeywell Schneider Electric, Galois, Astri, MathWorks, NIST, EIT Digital, Tcs, SEI, IBM Corporation, Oracle, Hewlett Packard Enterprises

2.1.1 CPS key enabler technologies

To build such complex systems, it is important to develop and incorporate various technologies such as actuators, security technologies, optimization SW, Artificial Intelligence (AI), technologies for data collection and analysis simultaneously, in addition to sensor technologies [12]. In this context, CPS is related to and incorporates several existing technologies including Wireless Sensor Networks (WSN), Internet of Things (IoT), AI, Machine to Machine (M2M) communications, Big Data, Embedded Systems etc. A brief introduction of these technologies, their market forecasts as well as requirements of CPS technology are presented below:

2.1.2 Wireless Sensor Networks (WSN)

Wireless sensor and actuator networks play an essential role in CPSs, since they are the bridge between the cyber and physical worlds. These embedded devices are wirelessly networked to sense, monitor and control the physical world [13].

Wireless Sensor Network (WSN) Market was valued at USD 47.55 Billion in 2019 and is estimated to reach USD 166.74 Billion by 2027, growing at a CAGR of 18.32% from 2020 to 2027 [14]. The future of the wireless sensor network market looks promising with opportunities

in the building automation, consumer electronics, industrial, automotive, and healthcare industries. The major drivers for this market are increasing demand for smartphones and wearable devices, growth in internet connectivity, reducing cost of sensors, and increasing demand for remote monitoring services [15].

Figure 3: Global Wireless Sensor Network Market growth, forecast for 2020 to 2027

The increasing use of automated systems in various industrial verticals is one of the driving factors of the WSN Market. In manufacturing industries, the use of automated systems is increasing rapidly, as it reduces human errors and provides better efficiency, which is going to provide huge growth to the WSN market. Similarly, the use of automated systems in agriculture, chemical and other industries for fetching data from far distances for the safety of the employees is going to boost the WSN market. Furthermore, the introduction of smart technologies such as AI, IoT and 5G is going to boost the wireless sensor network market. The use of IoT is increasing rapidly in home automation, industries, automotive and other applications for better fetching data from far distances going to boost the WSN market. Similarly, many industries are utilizing AI for better work efficiency, by using different sensors, which is going to provide huge growth to the WSN market. Additionally, the introduction of 5G is going to provide faster connectivity of sensor-based devices located at far distance and increasing the working efficiency, which is going to boost WSN market [16].
Key Market Players: NXP Semiconductor N.V, Infineon Technologies AG, Eurotech S.p.A, Sensirion AG, ABB Ltd., STMicroelectronics N.V., TE Connectivity Ltd., Robert Bosch GmbH, Siemens AG [17].

2.1.3 Internet of Things (IoT)

Internet of Things (IoT) is contributing significantly to increasing the capabilities of CPS and many other technology classes (Big Data, AI etc.). It also plays a crucial role in many areas unrelated to CPS such as business services and purely virtual systems. Some communities proclaim that the IoT is a key foundation that enables the deployment of CPSs while some field experts argue the IoT is related—but not identical to the field of CPSs [18]. For IoT applications, a real-time feedback control of physical processes may not be necessary. In contrast, the final services in CPSs are physical systems performing real-time control tasks in the physical world. Some IoT applications provide smart actuator commands from real-time sensor readings. However, these actions are sometimes limited to the activation of information functions (e.g., message display, sound notifications) for surveillance, logistics, and monitoring. These simple actions are limited to information awareness, while not completing a physical process by themselves. Instead, CPSs perform control actions in a way that alters the

new state of the sensor readings and consequently the states in the control loop by actuator commands with physical effects. Finally, there is some degree of overlapping between the fields of CPSs and the IoT. Mainly, some CPS applications are being connected to the Internet to use data-accessing and processing services [19]. Generally, we can say that a CPS is mainly concerned with the collaborative activity of sensors or actuators to achieve a certain goal and to do this CPS uses an IoT system to achieve the collaborative work of the distributed systems [20].
In revenue terms, the total IoT market in 2019 was worth US$465 billion (€424 billion), a figure which will rise to US$1.5 trillion (€1.3 trillion) in 2030 [21]. Services, including connectivity, will account for 66% of spend, with the remainder accounted for by hardware, in the form of dedicated IoT devices, modules and gateways. Geographically, China, North America and Europe dominate, accounting for 26%, 24% and 23% respectively of the total value of the IoT market in 2030.

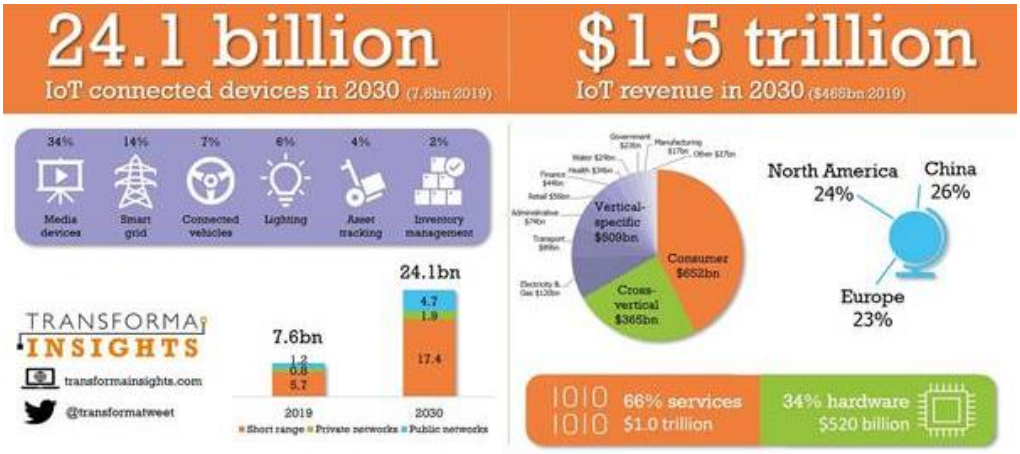


Figure 4. Global IoT market growth, forecast for 2019 to 2030

Key Market Players: SAP SE, Ziemens AG, Bosch Software Innovations GmbH, ARM holding, Dassault Systèmes

2.1.4 **Artificial Intelligence (AI) technologies**

There exists a global effort headed towards the utilization of AI applications in a plethora of aspects. A forecast made by Business Research Company [22] states that the global artificial intelligence market size is expected to reach $99 million in 2023, at a rate of 34.86%. Among several regions, the North American AI market accounts for the largest share in the global artificial intelligence market.

Such growth entails a large expansion of the multiple uses which AI is involved in, with a multitude of aspects extending deeply through autonomous vehicles of all types. Moreover, the situation towards adopting AI looks rather promising, with companies expected to adopt an average of 35 AI-oriented projects in place. Another aspect which further expands the purposes for which AI is utilized is governments globally adopting towards using AI in enforcing social distance regulations, and the fact that 16% of EU countries are considering automation through AI to reduce the effects of COVID-19.

Now more than ever, enterprises, governments, and institutions take the initiative to employ AI and machine learning (ML) in their current day-to-day and future operations. In this context, AI market size was highest for the ML segment and is expected to maintain this trend in the coming years, owing to increase in demand for industry solutions.

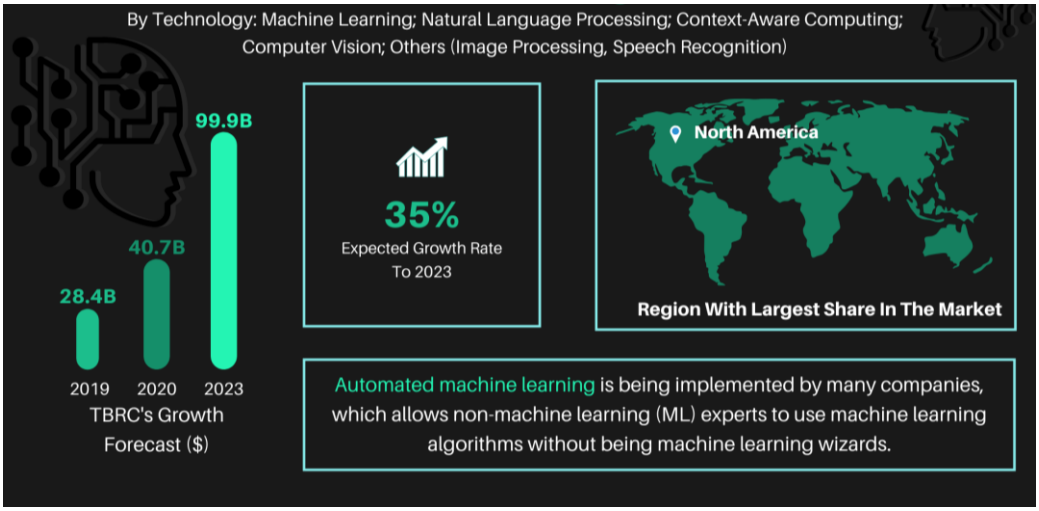


Figure 5: Global Artificial Intelligence Market growth, forecast for 2019 to 2023

Key Market Players: Alphabet (Google Inc.), Apple Inc., Baidu, IBM, IPsoft, Microsoft Corporation, MicroStrategy, Inc., NVIDIA, Qlik Technologies Inc., and Verint Systems Inc (Next IT Corp) are provided in this report [23].

2.1.5 Big Data technologies

Current industrial evolution is guiding industry toward maximum leverage from benefits of interconnected systems in big data environment where companies with more futuristic vision to establish new methodologies in their culture will have the opportunity of being significantly successful and profitable in the future [24]. Big Data Market size was valued at USD 37.69 Billion in 2018 and is projected to reach USD 139.58 Billion by 2026, growing at a CAGR of 17.8% from 2019 to 2026 [25].

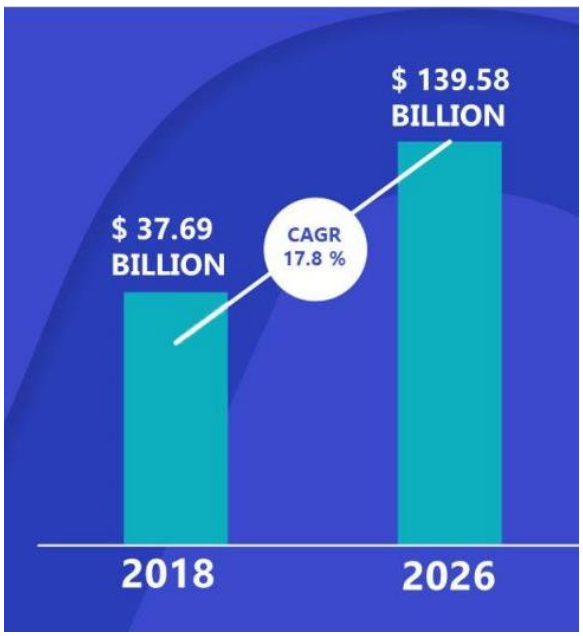


Figure 6: Global Big Data Market size, forecast for 2019 to 2026

The rising adoption of ML, AI, IoT, data analytics, cybersecurity, as well as 5G infrastructures is changing the landscape of big data technology and significantly driving the growth of the

market. Moreover, Big data technology is gaining traction in the market owing to the rising investments and spending on various technological projects by the government and key players [25].

All CPS applications generate, connect and analyse big data. For instance, the intelligent transportation system would generate big data consisting of driver's behaviour, passenger information, vehicles' locations, traffic signals management, accidents' reporting, automated fare calculations, and so on. Each one of the CPS applications produces large amount of data that needs to be stored, processed and analysed in order to improve services and applications' performance.

Key Market Players: Microsoft Corporation, IBM Corporation, Oracle Corporation, SAP, Amazon Web Services, SAS Institute, Hewlett Packard Enterprise, Dell Technologies, Teradata, Splunk.

2.1.6 **Machine to Machine (M2M) communications**

M2M communications is a term tightly connected with existing CPSoS. Via various components (such as actuators, sensors, memory, power and communication modules) an event (motion, temperature, inventory level, etc.) is captured and transferred through communication technologies (such as 4G, 5G, Wi-Fi, Ethernet, Zigbee, Powerline) to an application (software program) that translates the captured event into meaningful information and can trigger an actuation. The market is expected to grow from USD 19.31 billion in 2016 to USD 27.62 billion in 2023, at a CAGR of 4.6% from 2017 to 2023. The number of M2M connections was 1.47 billion connections in 2016 and is estimated to reach 3.00 billion by 2023.

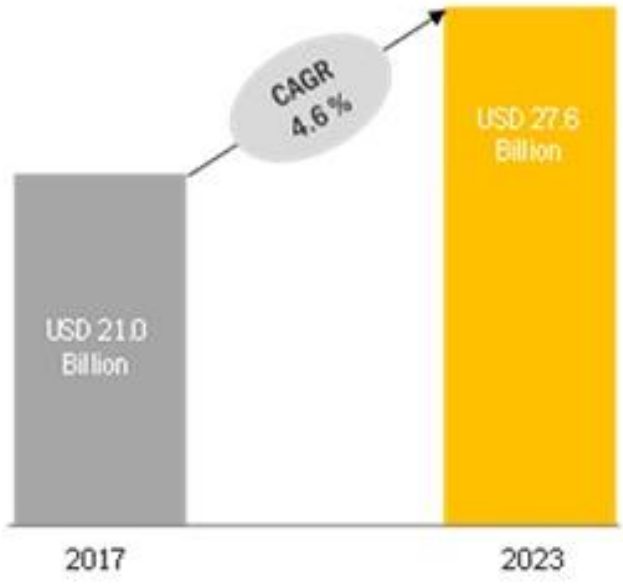


Figure 7: Global M2M communication market growth, forecast for 2017 to 2023

Due to its technological advancements, the North America, it is the most advanced region currently [26]. North America is followed by Europe and APAC. Europe is expected to hold 28.45% of market share over the 2020-2027 period. Well established automotive and manufacturing industry is mainly propelling market growth in the region [27].

Key Market Players: Axeda Corp., Atmel Corp, Cisco Systems, Imetrik Machine to Machine solutions, Inc., Cypress Semiconductor Corp, Infineon Technologies, Freescale Semiconductor, Inc., NEC Corp. NTT Docomo, Inc., and Novatel Wireless, Inc [28].

2.1.7 Embedded System Technologies

The global market for embedded systems exceeded USD 100 billion in 2019 and is predicted to reach more than USD 160 billion by growing at a CAGR of over 6% from 2020 to 2026 [29].

Figure 8: The global market growth for embedded systems, forecast from 2020 to 2026

The embedded system market is primarily categorized into hardware and software. The hardware components includes processor IP, MPU/MCU (microcontrollers and microprocessors), RAM, flash memory, digital signal processors (DSP), application-specific integrated circuit (ASIC), field processing gate arrays (FPGA), embedded boards and embedded hardware design. The software component are categorized into operating systems (OS), software development and testing tools, middleware and open-source software and tools [30]. The rising tendency of automation to minimize energy, material, and labour waste is likely to accelerate the demand for the market. In manufacturing, these embedded systems work as a programmable operating system that performs several tasks including adjusting temperature, driving, motors, networking equipment, and controlling assemble line speed. These systems are also highly implemented by car manufacturers for various functions including security, ignition, pollution control and audio systems accelerating their demand in the global market.
Key Market Players: Atmel Corporation, Texas Instrument, NXP Semiconductors, Microsoft Corporation, etc [29].

2.1.8 Edge/Cloud computing technologies

Edge computing: The technology introduces a great level of business complexity, as it requires an extensive range of stakeholders for IT infrastructure, connectivity, application development, traffic delivery, and service management. Edge also brings together hardware and software solutions and networking architecture that address the vast number of use cases pursued across several industry verticals [31]. The global edge computing market size was valued at USD 4.68

billion in 2020 and is expected to expand at a CAGR of 34.9% from 2019 to 2027 to reach $28.07 billion by 2027 [32].

Figure 9: The global edge computing market growth, forecast from 2019 to 2027

Growing acceptance of IoT, rising demand for low-latency processing, automated decision-making solutions, the need for lightweight frameworks and systems to enhance the efficiency of edge computing solutions are expected to create ample opportunities for edge computing vendors [33]. Geographically, North America dominated in the market, followed by Europe, Asia-Pacific, Latin America, and Middle East & Africa. The major share of North America is attributed to the high acceptance of new technology by consumers and large number of companies in the region adopting edge computing to enhance their IT infrastructure and leverage the benefits of new technologies, such as 5G and IoT [32].

Key Market Players: Cisco Systems, Inc., Microsoft Corporation, Amazon Web Services (AWS), Inc., Moxa Inc., NVIDIA Corporation, Belden Inc. Dell Technologies Inc. Hewlett Packard Enterprise Co.

Cloud computing: According to Technavio studies, the Global Cloud Computing Market will grow by USD 190.32 billion from 2018 to 2023 [34]. The introduction of emerging technologies enables cloud growth by empowering companies to tap into AI capabilities. Furthermore, the COVID-19 pandemic, has emerged it as the latest trend and is expected to continue in the long term [35].

Figure 10: The global cloud computing market forecast from 2018 to 2023

Cloud computing can be easily integrated within CPS systems to handle the management and processing of aggregated sensor data. In such a way, the decision-making methods based on a cloud model will enhance CPS' systema capabilities [36].

Key Market Players: Adobe Inc., Alibaba Cloud, Amazon Web Services Inc., Google LLC, Hewlett Packard Enterprise Development LP, IBM Corp., Microsoft Corp., Oracle Corp., Salesforce.com Inc., and SAP SE.

2.2 CPS applications in different sectors

The main application fields of CPS are presented in the table below. The variety of these applications is a strong indicator for the importance of CPS also indicating a potential applicability of the services of TEACHING in the future.

Table 2. Examples of CPS application by industry

Sector	Use-case example	Needs and Challenges
Transportation (automotive, aerospace, and rail)	connected autonomous cars/trains intelligent vehicles and traffic control systems unmanned air vehicles	Transportation systems should meet mobility and people requirements by providing safety and security. Minimizing traffic-related negative impacts in the transportation domain, the goal is to eliminate fatalities and accidents. Energy consumption is another and environmental protection is also challenging for future transportation. CPS technologies can potentially eliminate accidents caused by human error, which currently account for at least 90% of the annual automotive crashes [37]. In addition, CPS is expected to help protect the environment through reducing greenhouse emissions [38].
Manufacturing/ Industry 4.0	Smart manufacturing systems, production equipment, processes, automation, control, new product design	The efficiency of a supply chain has constantly increased over the past years. Yet there is a room for optimisation of complex industrial processes, satisfaction of rising customer demand, reduction of energy costs and mitigation of environmental issues. CPS technologies can help integrate procurement, production, logistics and product delivery in a holistic ecosystem, where increasing cooperativeness is taking place, allowing for multidimensional optimization and exchange [39].
Agriculture	Precision agriculture, Food security	The 2020 World Population Data Sheet indicates that the global population is expected to reach 9.9 billion people by 2050 [40]. Producing the needed agricultural products for future generations will demand practices, processes, and systems that will bring in a sustainable economy, environment, and humanity. CPS can play a key role in tackling the increasing food demand-supply gap, it can collect information about climate, ground and develop accurate agricultural management systems to enhance the ability to deliver safe high-quality and nutritious food. Via predicting food processing and

		distribution properties, it can increase the efficiency throughout the value chain, reduce wastes and environmental footprint [39, 41, 42, 43].
Energy	Smart utility grids and smart buildings structures	Breakthroughs in fuel economy and use of renewable fuels are critical to increase cost-efficiency and reduce environmental impact. Major steps include the development of plug-in electric and hybrid-electric power trains and the development of hydrogen fuel cell power plants. While CPS research cannot contribute directly to the development of renewable fuels, it can play a major role in making the integrated system that utilizes these fuels more efficient and economical to operate [38]. CPS are critical for the transformation of centralised, high-carbon energy systems to decentralised, low-carbon energy provision. These technologies can optimize and manage resources, facilities and improve reliability, security and efficiency of electricity delivery and consumption. Intelligent CPS have the possibility of finding pathways that can help humankind to meet the ambitious decarbonisation and emissions targets that are at present deemed unreasonable and unattainable [44].
Healthcare	Personalized medicine, body area networks and assistive systems	Rising healthcare costs, an aging population, and diminishing medical resources are driving health-care providers to seek technological innovations. CPS technology has already made a multitude of medical advancements. From a smart monitoring system that tracks cancer patients' response to treatment to a smart continuous tool that sends data on glucose levels to the wearer's smartphone, the field of health care has greatly improved because of CPS science and technology [42, 45].
Smart Emergency Response System	detection and surveillance systems, communication networks, and emergency response equipment	Natural disasters are events resulting from natural processes that cause serious damage and loss to a community, whose impacts exceed the local capacity to restore normality. Globally, over the past decade, natural disasters accounted for an average of 0.1% of total deaths [46]. Overall losses from world-wide natural catastrophes in 2020 totalled $210 billion dollars, significantly higher than $166 billion in 2019 [47]. CPSs can provide an intuitive interface, a human-to-human, man-to-machine, and machine-to-machine interaction mechanism, by facilitating continuous network connectivity and refined application control by users, which can improve resilience to natural disasters and also facilitate prediction and mitigation of these events [48].

Military	Smart weapons, remotely piloted aircrafts/ unmanned aerial vehicles soldier equipment	Complex, networked systems are increasingly critical for meeting military and national defense needs. Providing actionable information to military forces requires persistent surveillance on a 24/7 basis. There are also potential law-enforcement applications that add privacy and civil rights constraints. Such capabilities can only be achieved through the development of highly intelligent, agile, unmanned systems that can provide long-duration coverage of wide areas and, consequently, generate enormous quantities of data that must be rapidly reviewed and integrated to generate coherent and actionable information. CPS technology advances are essential for the high level of intelligent autonomy demanded by these systems and for the complex fusion and integration of mega data streams into knowledge [38].
This list is a subject to expansion		

In the following sections the key domains of TEACHING including the business opportunities and any associated obstacles currently exist are studied in more detail.

2.2.1 **Autonomous driving (AD) market**

With the evolution of digital technologies, such as robotics, internet of things, artificial intelligence, high-performance computers and powerful communication networks, vehicles in general, and cars in particular, are quickly changing [49]. The global Autonomous Vehicle Market is projected to reach USD 724.36 billion by 2026, registering a CAGR of 39.47% from 2019 to 2026 according to a recent report by Allied Market Research [50].

In the EU, fully autonomous car market is expected to reach 191.6 billion by 2030, growing at a CAGR of 37.4% during the period 2023–2030. Geographically, the European autonomous car market is categorized into Germany, the UK., France, Italy, Spain, and Rest of Europe. Among these, Germany was the largest market and held a market share of over 20% in 2018, in terms of volume [51, 52]. The market is driven by the traditional large car manufacturers but there are some disruptions from new companies as well (such as Tesla). For SMEs the opportunities are in providing electronic components, sensors, and supporting toolsets for software development/certification.

Figure 11: Europe autonomous car market growth, forecast for 2023 to 2030

Table 3: Overview of the AD Market Segmentation

AD market in terms of geography	US, Europe (Germany, the UK, France, Italy Spain), Asia-Pacific (Japan, China & Korea)
AD market in terms of equipment and service requirements	• Sensors and cameras (optical, infrared, radar, laser, etc.), • Automated controls (steering, braking, signals, etc.), • Software, servers and power supplies, •Short range vehicle-to-vehicle communication networks, plus Internet access for maps, software upgrades and road reports. • GPS Navigation systems and special maps
AD Key market players	Google, Inc., Volkswagen Group, PSA Group, and Renault Group, Tesla Inc., Daimler AG, BMW Group, General Motors Company, Fiat Chrysler Automobiles N.V., Ford Motor Company, and Toyota Motor Corporation Audi AG, Mercedes-Benz, etc.

2.2.2 **Market drivers and barriers**

Drivers: One of the key benefits from autonomous functionality in cars is enhanced safety. It has been reported that 94% of car crashes are caused by human error in addition although driving was down in 2020 because of the pandemic, traffic fatality rates surged 24% - the highest spike in nearly a century [53]. The co-operative systems in autonomous vehicles deliver valuable information regarding the surrounding traffic situation and provide direct support in complex and difficult driving environments. Furthermore, there is also high potential for a reduction in emissions through implementing new connected car technologies that provides the opportunity to optimise the efficiency of the modes of transport which together comprise the traffic system by better utilising its full capacity. For both passenger and goods transportation, the aim is to improve traffic fluidity, reduce congestion and hence decrease CO_2 emissions [54]. Furthermore, the prevalent laws are well suited for the progress of the European autonomous car market. The rules governing the product liability, intellectual property, cybersecurity, and corporate transactions are quite favourable for the development of autonomous vehicles. For instance, in Spain, the Directorate General of Traffic (DGT) encourages the operation of all self-driving vehicles up to level 5 on the roads. In 2017, DGT collaborated with Mobileye with the purpose of preparing Spain's regulatory policy and infrastructure ecosystem for autonomous cars. Additionally, an amendment was made to the German Road Traffic Act in June 2017, enabling a driver to pass off driving control to an autonomous car [55]. Other strengths of adopting autonomous driving include accessibility to non-drivers, potential to decrease the number of road accidents and decrease the number of parking spaces needed, freeing space for other more productive land uses. Finally, existing sensor types and smart devices can be easily utilised in advanced AD infrastructures. Current experience in the commercial use of big data, such as in online advertising, opens competitive opportunities for existing internet-based companies in the context of autonomous vehicles [56].

Barriers: The advanced SW/HW and emerging technologies involved in the AD cars make manufacturing a costly affair that is currently one of the key factors restraining the growth of the European autonomous car market. The vehicles are extremely innovative and technologically advanced, which is the primary reason for the higher cost [57]. In addition, public trust in adoption of AD cars is another major barrier to uptake. Autonomous vehicles are vulnerable to hacking and cyber-attacks. A Consumer Watchdog report [58] warned that all

of the top ten 2020 car models are vulnerable to fleet-wide hacks because of their Internet connectivity. It is envisioned that in the upcoming years there will be an on-going arms race between hackers and software designers over autonomous vehicles control, which will add costs and risks [59].

2.2.3 **Aerospace market**

According to the current Avionics Market trends, the global avionic market size is valued at USD 74 billion in 2018 and is anticipated to exhibit growth of around 3% from 2019 to 2025.

The adoption of next-generation flight management systems with improved air traffic management functionality and reduction in operation cost is a major factor promoting the avionics market growth. Additionally, the advancement of IoT in aviation technology, the rise in the number of up-gradation programs from leading OEMs, is further forecasted to support the Avionics Market growth in near future [60].

According to the recent research analysis, the global autonomous aircraft market is projected to grow from an estimated USD 6,409.13 Million in 2021 to 19,820.32 million by 2026, at a CAGR of 25.3% for the forecast period. The growth is mainly due to adapting to the renewed operation while recovering from the COVID-19 impact, which had earlier led to restrictive containment measures involving social distancing, remote working, and the closure of commercial activities that resulted in operational challenges. Furthermore, the market expansion may also be attributed to the increased autonomy brought via robust technologies such as AI, big data analytics which can result in cost savings, reduced human error etc. [61].

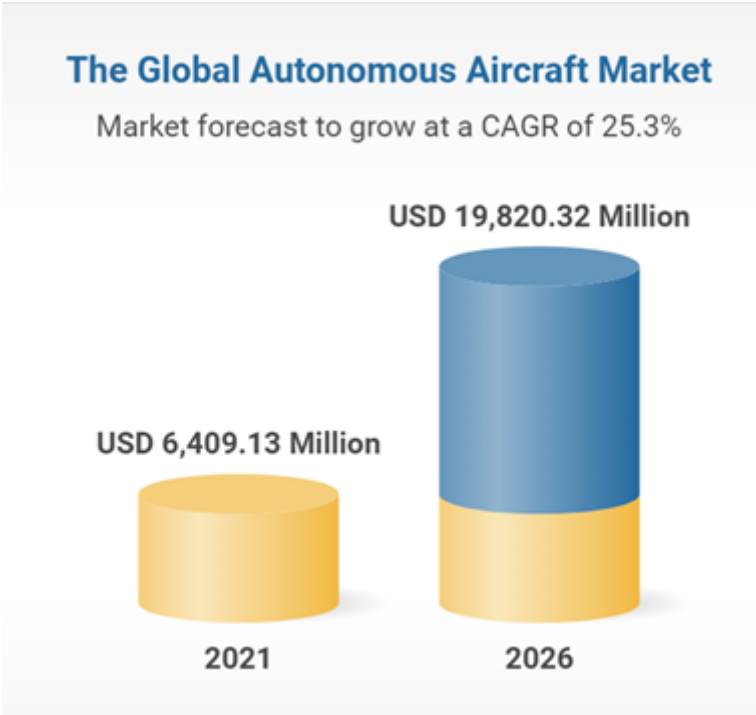


Figure 12: Global Autonomous Aircraft Market growth, forecast for 2021 to 2026

From a geographical perspective, North America is anticipated to hold the leading global Avionics Market share on account of the rising demand for aircraft for both commercial and defense purposes. The EU market is also estimated to grow at a substantial level owing to the increasing demand from the military sector. This growth is driven by significant investments in R&D. In fact, in 2019, the R&D expenditure on aeronautics and defence from both industry

and governments is estimated at a level of €18bn, with a possible 40/60 split between civil and military activities [62].

Table 4: Overview of the Avionic Market Segmentation

Avionic market in terms of geography	North America, Europe (Germany, the UK, France), Asia-Pacific (Japan, China & India)
Avionic market in terms of component and technology	• Components: Radars &Transponders, Propulsion Systems, Cameras, Sensors, Actuation System, Air Data Inertial, Intelligent Servos, Reference Units, Flight Management Computers &Software • Technology: Fully Autonomous, Increasingly Autonomous
Avionic Key market players	Northrop Grumman Corporation, Rockwell Collins, Lockheed Martin Corporation, Boeing, Elbit Systems Ltd., Airbus S.A.S, Textron Inc., BAE Systems plc, Saab AB, and Aeronautics Ltd.

2.2.4 Market drivers and barriers

Drivers: The reduction of human errors, via incorporation of AI, big data and IoT based technologies, can increase the precision and efficiency the operation of the aircraft thus can be considered as one of the main driving forces in the market. Through managing aircraft and activities with AI-powered technologies, airlines and flight operators can significantly reduce their operating costs and expenses. To boost operating performance, prevent expensive errors and increase customer loyalty, Airbus is currently using AI to analyse data from multiple factories and determine when manufacturing process variations take place. The autonomous technology bricks set to integrate are based sensors and algorithms for situational awareness and obstacle detection; fly-by-wire for enhanced auto-pilot; and an advanced human-machine-interface - in the form of a touchscreen and head worn display for inflight monitoring and control [63]. In this context, the implication of the autonomous technologies reduces the workloads on pilots, which are augmenting growth of the global automated aircrafts market [64, 65].

Barriers: Liability, security, and privacy concerns represent a substantial barrier to widespread implementation of autonomous innovation technologies in the avionic sector. In fact, the safety and security-critical nature of the aviation infrastructure is one of the reasons behind slow uptake, as a system failure, or a malicious attack could have dramatic results. Having said this, each innovative solution needs to strictly comply with national, regional and world-wide standards. Furthermore, the lack of presence of profitable airlines coupled with absence of key players especially in the emerging economies is restraining growth of the autonomous aircraft market. Additionally, high costs, thus requirement of large investment in the market is hampering autonomous aircraft market growth especially in the developing economies [65, 66]. Finally, no matter how far industry progress goes, the key to autonomous flight will be its customers. In a larger study conducted in 2018, appx. 60 % of passengers were unwilling to fly on an autonomous commercial airliner. The authors of the survey believed that lack of knowledge about automation is one of the critical factors here, and that the public would feel better about automated flying if they knew more about the benefits of automation – such as extremely reliable automated warning systems to prevent mid-air collisions and crashes [67].

2.2.5 **TEACHING SWOT analysis**

SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis has been used to identify internal and external factors that can either contribute or emerge limitation in the process of achieving the TEACHING project objectives. Particularly, the analysis pinpoints the strengths of the TEACHING projects including the developed solutions and overall concept, it defines the weaknesses, which the consortium will try to minimize later on as well as acknowledges the possible threats and treat them in a planned and organized way

Table 5: TEACHING SWOT analysis

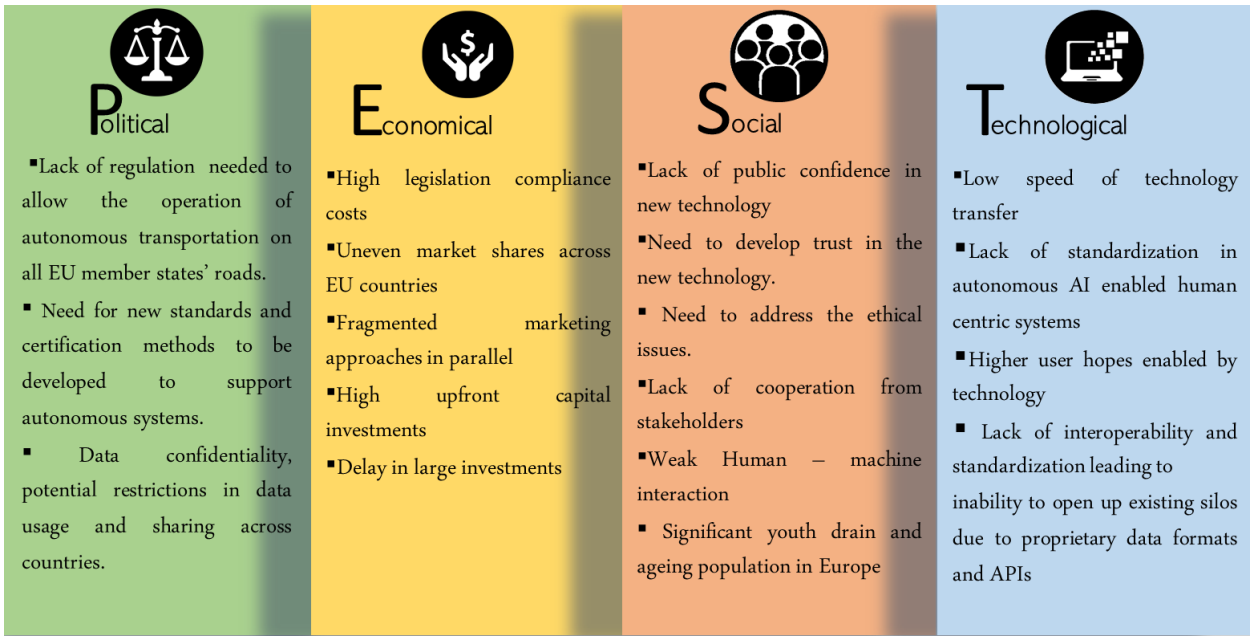
STRENGTHS	WEAKNESSES
TEACHING has strong research/academy partners as well as domain experts from both, SMEs and larger companies TEACHING positions the needs, comfort and well-being of a human at the core of complex CPSoS operation. TEACHING exploits two safety and security critical domains (automotive and avionics) both of those posing a clear autonomous challenge with high dependability needs. TEACHING leverages and extends already existing state-of-the-art tools, to provide a computing platform based on a cloud-edge continuum. TEACHING exploits AI-enabled solutions in cybersecurity to address the emerging challenges of CPSoS from security perspectives.	Parts of proprietary assets that cannot be fully integrated and combined within the TEACHING platform. Compatibility problems between products or solutions of different members Conducive market environment with a large and comparatively wealthy consumer base in Europe and expansion in foreign markets Diversity in the provided technology solutions could lead to complications when integrating into the framework. Adopting and integrating the TEACHING technology within existing systems may be time-consuming and difficult. This may hamper TEACHING's market entrance.
OPPORTUNITIES	**THREATS**
TEACHING consortium with good combination of partners from industry and academia Provide a holistic framework consisting of toolkits which are flexible in nature to be used both combined within the TEACHING platform or individually Further scientific and technical knowledge advances in key CPSoS domains. Use of emerging technologies and exploitation of human feedback to solve current problems in autonomous systems.	The outbreak of COVID-19 significantly hinders collaboration on technical discussions by preventing physical meetings for the foreseeable future Legal restrictions, data protection and GDPR could hinder the final usability of the TEACHING framework Low/delayed society acceptance rate. Because the project is focused on delivery of dependable, safe and secure systems, any failure can have serious consequences.

2.2.6 TEACHING PEST analysis

PEST analysis has been used to draw macroeconomic factors which can impact TEACHING outcomes. This method analyses opportunities and threats due to Political, Economic, Social, and Technological forces and helps the consortium to get a comprehensive picture of the status and trends of important factors that are beyond its control but have an impact on the project.

Combined with the overall analysis of the market drivers and barriers as well as SWOT analysis conducted in previous chapters PEST analysis will help to better understand the macroeconomic environment and the potentials of the TEACHING project.

Table 6: TEACHING PEST analysis



2.3 TEACHING competitors' analysis

"Smart Everywhere" is already happening and there are some success stories – but there are still technology and knowledge gaps [7]. The aim of this chapter is to deliver research on the possible competitive solutions like the TEACHING platform and the associated toolkits. It is mainly based on analysing the landscape of existing CPSoS platforms and their specificities regarding a number of aspects. A baseline of most successful platforms regarding the kind of the products (open or commercial), their capabilities to support and integrate new cooperating computational elements as well as current rapidly expanding technologies based on AI/ML/DL algorithms. A general situation concerning the TEACHING platform specifically in autonomous driving and avionic industries will be referred to.

To identify TEACHING relevant CPSoS platforms, associated toolkits and applications a general online research has been conducted. Several survey documents were reviewed and analysed. The objective here is to get a broader insight into the structure of the current platforms/toolkits/devices landscape. In the following table the main results of the conducted survey are presented.

Product/solution description	Application domain	Product type	Ref.
CATIE CATIE's **PEAC²H** platform dedicated to behavioural and cognitive assessment. It enables companies to better integrate human beings into complex and innovative systems. The company also develops complex electronic boards requiring hardware and software layers.	Start-ups, SMEs, intermediate size companies	Commercial	[68]
TOSHIBA Toshiba offers IoT Reference Architecture as an open and common framework for developing and operating IoT services as CPS. It is based on international standards and various requirements for industrial IoT.	Energy, Manufacturing, Logistics, Telecommunications etc.	Commercial	[69]
OxTS OxTS navigation systems combine the best of sensors to collect position, time, orientation, and dynamics measurements. It creates a real-time network capable of tracking multiple targets, calculating distance, time to collision, and other measurements relative to the vehicle under test.	Automotive	Commercial	[70]
GE Digital The engineering solutions of GE include hardware and software components to build cyber-physical systems in the automation domain.	Automotive, aviation, industry, energy and power generation, telecommunication	Commercial	[71]
ST ST provides connected and automated driving solutions. It aims to set-up a cross-border testing facility pooling investments across Europe and connecting various stakeholders (AI-experts, automotive OEMs, communication service providers and more).	Automotive	Commercial	[72]
Nauto The company develops a real-time, AI-powered Driver Behavior Learning Platform to predict and prevent high-risk events and achieve measurable safety.	Automotive Transportation	Commercial	[73]
A4 Systems A4 Systems builds cyber physical system products to create and collect quality data to	Agriculture, Energy, Manufacturing, Mining etc.	Commercial	[74]

deliver analytics and insights. Every project is data centric and aids in the improvement of data management for the business.			
Ansys Ansys applications provide key safety analysis methods and embedded software development tools to efficiently ensure functional safety, mitigate cybersecurity threats and develop certified embedded software.	Aerospace, Automotive, Energy, Healthcare etc.	Commercial	[75]
Galois Galois brings new approaches to the software design of critical embedded systems and makes CPS easier to program, safer, and more secure.	Automotive, Industrial, Defense Medical, infrastructures.	Open source	[76]
Argo AI Argo AI is a self-driving technology platform company. It builds software, hardware, maps, and cloud-support infrastructure that power self-driving vehicles.	Automotive	Commercial	[77]
Voyage The company introduces self-driving autonomous cars to senior communities to help elderly people move around the city in a safe and better way.	Automotive	Commercial	[78]
Fraunhofer IESE Fraunhofer IESE advises and supports companies in engineering dependable AI systems and accompanies them throughout the entire lifecycle: from AI strategy via AI development to the assurance of AI including AI validation and AI auditing and compliance with legal and normative requirements.	Smart Mobility, Industry 4.0 Digital Health etc.	Commercial	[79]
Altair Altair's provides multiple products/services that accelerate product development, enhance passenger safety and experience. Furthermore, it offers simulation technologies to develop complex, high-fidelity finite-element models for the predictive virtual testing of airframes, engines, and aircraft interiors.	Various industrial domains including Aerospace and Automotive domains	Commercial	[80]
AutoBrains	Automotive	Commercial	[81]

The company applies deep learning with a new approach that is closer to human driving perception. AutoBrains offers solutions for the next generation of autonomous vehicles – providing safer, superior performance at lower energy consumption and less cost.			
Arduino Arduino offers open-source hardware boards empowering users to build them independently and eventually adapt them to their needs.	Hobbyist community	Commercial	[82]
Raspberry Pi Foundation It is a UK-based entity that offers low-cost high-performance computing to fit a wide range of embedded applications.	Hobbyist community	Commercial	[83]
Kontron S&T Kontron's IoT-ready KBox family offers industrial computing platforms, designed for process optimization in connected environments.	Smart automation Industry 4.0	Commercial	[84]
IAdiy The company builds up an embedded computer system product line including embedded computers on modules or embedded single board computer.	Industry, IoT Robotics	Commercial	[85]
Arcturus The company supplies high-quality embedded boards, modules, SoMs and hardware platforms.	IoT, Edge AI Connected industry	Commercial	[86]

EU projects/initiatives/communities

Product/solution description	Application domain	Product/service/activity type	Ref.
ARTEMIS Artemis association offers a framework for defining and implementing a Strategic Agenda and for integrating research activities in Embedded and Cyber-Physical Systems across the EU.	Transport & Smart Mobility, Digital Industry, Energy and Health	European Technology Platform	[87]
ACARE Advisory Council for Aviation Research and innovation in Europe (ACARE) is provides a network for strategic research in aeronautics and air transport so that aviation satisfies the needs of society and secures global leadership for Europe. ACARE is essential in bringing together	Aeronautics Air transport	Strategic Strategic Research Agenda (SRA) for aviation research, development and innovation	[88]

the right stakeholders to turn the air transport vision in Europe into reality.			
EASA The European Aviation Safety Agency (EASA) promotes the highest common standards of safety and environmental protection in civil aviation. The Agency develops common safety and environmental rules at the European level. It monitors the implementation of standards through inspections in the Member States and provides the necessary technical expertise, training and research.	Aviation	Drafting aviation safety legislation, analysis, research and training to improve aviation safety.	[89]
EUCAR EUCAR is the European Council for Automotive R&D of the major European passenger car and commercial vehicle manufacturers. EUCAR facilitates and coordinates pre-competitive research and development projects and its members participate in a wide range of collaborative European R&D programmes.	Automotive	Facilitating and coordinating research and development projects	[90]
ERTRAC The European Road Transport Research Advisory Council (ERTRAC) is the European Technology Platform (ETP) for Road Transport which is recognized and supported by the European Commission.	Road and Transport	European Technology Platform	[91]
EuroCPS EuroCPS is an EU project that gathers several design centres to boost and initiate synergies between innovative companies, major CPS-platforms and CPS-competency providers.	Smart mobility, factory, agriculture, And smart cities	Several technology platforms covering the needs of various CPS application domains.	[92]
CPS PWG Established by NIST, the CPS Public Working Group (CPS PWG) fosters and captures inputs from those involved in CPS, both nationally and globally.	Manufacturing, Energy, Transportation, Healthcare	Open-source CPS Framework	[93]
EARPA European Automotive Research Partners Association (EARPA) is the association of automotive R&D organisations. It brings together the most prominent independent R&D providers in the automotive sector throughout Europe. Its membership counts	Automotive	Platform towards contributing to the European Automotive Research Area and the future EU RTD funding programmes.	[94]

at present 52 members ranging from large and small commercial organisations to national institutes and universities.			
CPSVO Cyber-Physical Systems Virtual Organization (CPSVO) fosters collaboration among CPS professionals in academia, government, and industry. It encourages communities to come together through cyber-physical systems research initiatives to tackle common challenges arising in their fields, ranging from devices to solving larger problems.	Energy Transportation Energy Healthcare Smart communities	European Collaborative Platform among CPS professionals In addition, the CPS-VO is now home to several research conferences and workshops focusing on cyber-physical systems,	[95]
TAPPS The TAPPS project provides an open platform for CPS apps by addressing as solution all necessary layers, from hardware over software to a marketplace, to ensure security and full real-time support for the apps.	Automotive Healthcare Industry 4.0	Open platform for CPS apps	[96]
CPS4EU The ultimate objective of CPS4EU is to strengthen the CPS value chain by creating world class European SMEs and by providing CPS technologies that in turn will sustain the leadership of the large European groups in key economy sectors and, in this way will stimulate innovative products to support the massive digitization increasingly integrated into our everyday environment.	Automotive, Smart grid Industry	Pre-integrated architecture with key enabling technologies/ CPS modules	
Adaptive The project develops automated driving applications for daily traffic by dynamically adapting the level of automation to situation and driver status. The project addresses legal issues that might impact successful market introduction. It investigates how drivers' intentions and actions should be taken into account in the design of automated systems.	Automated driving systems	Automated driving applications	[97]
CPSwarm The project defines a complete toolchain that enables to set-up collaborative	Unmanned Aerial Vehicles	A toolchain for autonomous CPSs	[98]

autonomous CPSs; to test the swarm performance with respect to the design goal; and deploy solutions towards "reconfigurable" CPS devices.	Autonomous driving Swarm logistics		
DREAMS The DREAMS project develops a cross-domain architecture and design tools for networked complex systems where application subsystems of different criticality, executing on networked multi-core chips, are supported. It delivers architectural concepts, meta-models, virtualization technologies, model-driven development methods, tools, adaptation strategies and validation, verification and certification methods.	Avionic, Wind power, Healthcare	A cross-domain architecture and tools for complex CPSs	[99]
ADMORPH The ADMORPH project, uses a novel, holistic approach to the specification, design, analysis and runtime deployment of adaptive, i.e., dynamically morphing, mission- and safety-critical CPSoS that are robust against both component failures and cyber-attacks.	Autonomous aerospace Radar surveillance Subway transportation	Methodologies, and tools for maintaining safe and secure control of CPSoS	[100]
AMASS The project AMASS creates and consolidates the de-facto European-wide open tool platform, ecosystem, and self-sustainable community for assurance and certification of CPS in the largest industrial vertical markets.	automotive, Railway, Aerospace, Energy.	Open platform, for assurance and certification of CPS	[101]
CPSoS The project provides a forum and an exchange platform for systems of systems related communities and ongoing projects, focusing on the challenges posed by the engineering and the operation of technical systems in which computing and communication systems interact with large complex physical systems.		An exchange platform for large complex cyber-physical systems of systems	[102]
CPSoSaware CPSoSaware creates a new holistic model-based design paradigm that is extended during the operational phase of the CPSoS and supports an autonomic, cognitive, self-	Connected and Autonomous Vehicles industrial manufacturing (Human-Robot	model-based solutions for CPSoS	[103]

awareness mechanism for the CPSoS components and system as a whole.	interaction in manufacturing environment)		
Road2CPS Road2CPS focuses on identifying and developing opportunities for novel technologies, applications and services in the field of CPS, and the identification of solutions to problems associated with it, as well as the socioeconomic issues accompanying these innovative changes.		Tools/services/application for CPSs	[104]
CARAMEL CARAMEL's goal is to proactively address modern vehicle cybersecurity challenges applying advanced AI and ML techniques and also to continuously seek methods to mitigate associated safety risks.	Autonomous and connected vehicles	AI/ML solutions for cybersecurity and safety issues.	[105]
1-SWARM The project focuses on the design-operations for CPSoS with the specific focus on the industrial sector of large scale distribution and logistics. The project aims at achieving an industrially acceptable level of robustness of CPSoS whose operation emerges as "Swarm Intelligence".	Industrial sector (food packaging, logistics), Automated guided vehicle Aerial drones	Modular framework for designing robust CPSoS networks	[106]

3 TEACHING business plan

For this first release we have formulated the initial TEACHING business plan that could be exploited for TEACHING commercial launch in the future. This plan is in its preliminary form focusing on three main questions:

- What are the TEACHING outcomes (TEACHING offerings) and what are their innovation capacities with respect to similar products?
- What is the TEACHING stakeholder landscape, who are the TEACHING potential key customers? And how interested they are about the TEACHING offerings.
- What are the TEACHING marketing strategies, the key distribution channels?

This plan will be further evolved in line with the project developments and will be updated based on the project's pilot partners (**AVL** and **TRT**) and their direct business connections, who represent potential customers and early-adopters within the consortium.

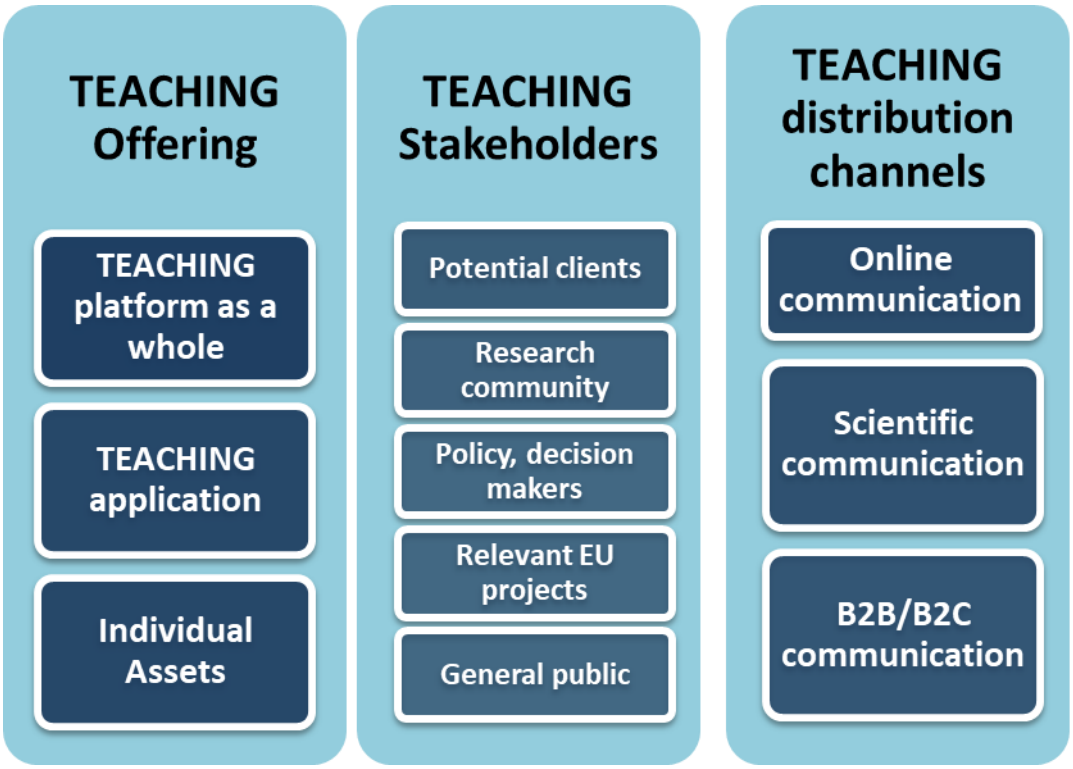


Figure 13: TEACHING business plan components

Before moving through each pillar of the TEACHING business plan presented in Figure 13, it is essential to present an updated version of the Business Model Canvas (BMC), whose initial version has been described in the previous D6.1 (M3). It is worth mentioning that interested readers may look for D6.1 (section 3.4), where all nine building blocks of the TEACHING's BMC have been presented and thoroughly analysed. In this report, we aim to introduce and discuss in more detail the Value Proposition (TEACHING Offerings) block which has been advanced extensively as a result of technical development conducted in the course of the M3-M20 project period.

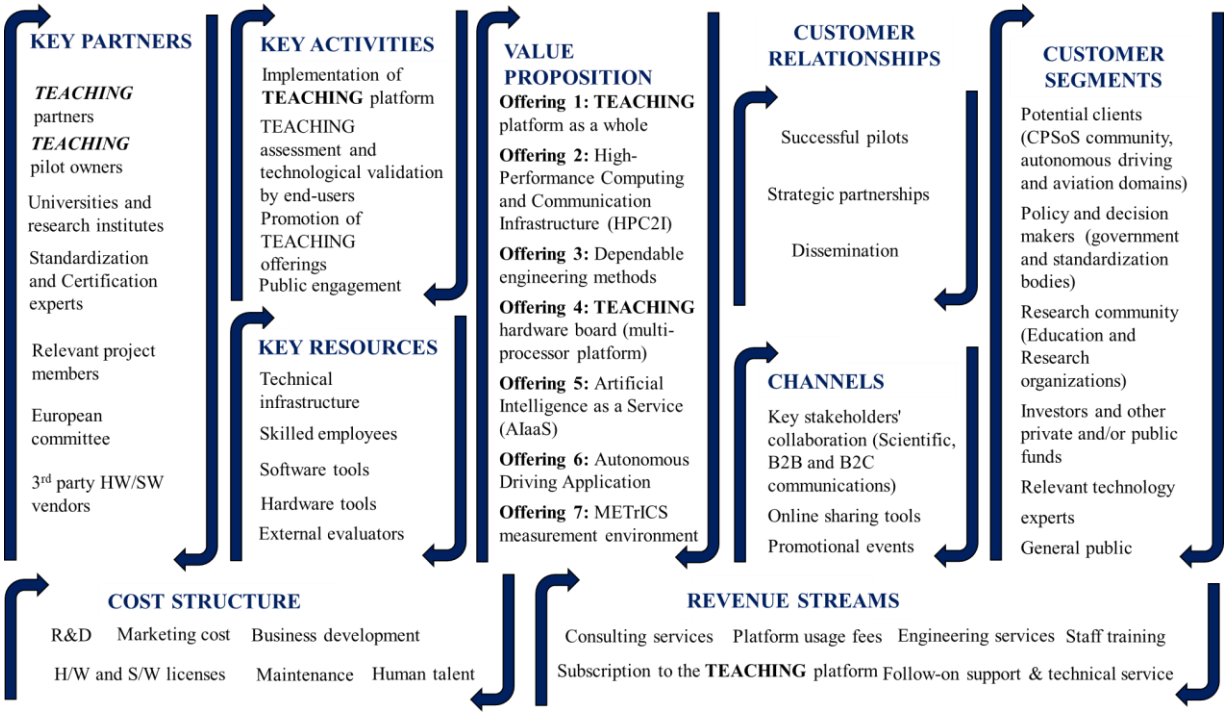


Figure 14: TEACHING business model canvas (updated version)

3.1 TEACHING Value Proposition (TEACHING Offerings)

This section describes the TEACHING's products and services envisioned to be developed in the scope of the project. In this regard, the project has created a fully exploitable TEACHING platform that combines six vertical offerings (offered either separately or in a combined bundle). Each of these offerings are presented in the table below.

Table 7: TEACHING offerings

TEACHING Offerings	Offering type (Individually or combined with other products/services)	Leading partner	Other involved partners
TEACHING platform as a whole	-	all	
High-Performance Computing and Communication Infrastructure (HPC^2I)	Product (Software). Offered both individually and integrated in the TEACHING platform	CNR	other WP2 partners
Dependable engineering methods	Engineering methods (best practices, recommendations). Offered both individually and integrated in the TEACHING platform	TUG	M, ITML, HUA, other WP3 partners
Hardware boards (multi-processor platform)	Product (Hardware board). Offered both individually and integrated in the TEACHING platform	I&M	-

Artificial Intelligence as a Service (AIaaS)	Product (Software). Offered both individually and integrated in the TEACHING platform	UNIPI	HUA, CNR, I&M, other WP4 partners
Autonomous Driving Application	Product (Software)	AVL	I&M, TUG, input from WP4 partners
METrICS measurement environment	Technology Brick	TRT	-

Apart from the whole TEACHING platform, each offering has a leading partner from the consortium and other partners as a backend support. Every offering can be offered individually or as a combined service together with other TEACHING modules. It is up to the client to select the desired bundle of products/services from the TEACHING platform's portfolio. Below is presented the value proposition canvas for each element to discriminate the TEACHING offerings.

3.1.1 **TEACHING platform**

The TEACHING platform is defined as a combined stack of the computing platform and software toolkit upon which

i) a vendor installs it along with a TEACHING application in vehicles or in an airplane
ii) a developer develops and deploys CPSoS applications (other than TEACHING)

The platform can be considered as an environment that enables CPSs applications to close the human-feedback loop and comprises of four (4) main properties:

- Monitoring: which monitors the human state using appropriate sensors and possibly considering external factors, such as the environment to which the system is operating
- Quantification: which models the human state and quantifies it in a way that is meaningful to the DMU
- Integration: which incorporates the quantified human state in the system state so as for the DMU to use it.
- Programmable: which provides an interface that enables the dynamic creation of the TEACHING applications.

Innovation capacity: The TEACHING platform is an addition to an existing CPSs rather than a built-in feature. As a CPS, it maintains the properties of CPSs however in comparison to conventional CPS, TEACHING introduces a new objective to the control loop, through the integration of a new, potentially undependable system. This system brings along a new array of sensors for monitoring its state, different from the ones that the original CPS is using. The new integrated system of systems (SoSs) extends the original CPS, and it remains a CPS itself.

3.1.2 High-Performance Computing and Communication Infrastructure (HPC^{2}I)

The combined set of hardware, system software, development methodologies, orchestration strategies, and network protocols used in TEACHING realizes the High-Performance Computing and Communication Infrastructure (HPC2I). HPC2I has been designed to support the execution of the TEACHING platform for the leveraging of humanistic intelligence and satisfy the specific requirements associated both with the automotive and avionics use cases, basically ensuring the viability of the HPC2I infrastructure to serve as an execution platform. HPC2I encompasses solutions, technologies and algorithms that enable efficient exploitation of the resources realizing the TEACHING CPSoS. HPC2I has been designed to be flexible and inclusive to support a broader set of scenarios and use cases.

Innovation capacity: *HPC2I is not intended to be an infrastructure built from scratch; instead, it builds upon state-of-the-art technologies that blend to produce a mix of value higher than the sum of its parts. This approach outlines its vocation on technology combination-customization-innovation-exploitation, essentially balancing the re-use of state-of-the-art approaches with the development of novel solutions. As such, it represents a highly valuable solution to enable, from an infrastructural viewpoint, the exploitation of human feedback in a highly distributed, heterogeneous environment, while avoiding a complete redefinition of technologies but instead opting for innovations to the existing spectrum of solutions, when this is viable. This creates opportunities for companies to adopt HPC2I without dealing with a disruptive change in their infrastructure management processes.*

3.1.3 Dependable engineering methods

The rising demand for adaptive, cloud-based and AI-based systems is calling for an upgrade of the associated dependability concepts. That demands instantiation of dependability-orientated processes and methods to cover the whole life cycle. However, a common solution is not in sight yet, especially evident for continuously learning AI and/or dynamic runtime-based approaches. In this context, the TEACHING engineering methods and design patterns can support the development of dependable AI-based autonomous systems and/or dynamic runtime-based systems. As such, the body of knowledge and engineering use-cases refined by the TEACHING project can provide the industry with latest state-of-the-art approaches and provide support for development of the systems according to the best knowledge. The dependable engineering methods consider architectural concepts and their applicability to different scenarios to ensure the dependability of evolving AI-based CPSoS. The modular engineering approaches can be tailored for the specific need of the individual industry and provide good practices to speed up development.

Innovation capacity: *The dependable engineering methods consider architectural concepts, proven good practices and can be tailored for the different application scenarios of evolving AI-based CPSoS. The modular engineering approaches can be tailored for the specific need of the individual industry and provide good practices to speed up development. The methods, pattern, and approaches represent the latest state-of-the-art and provide thus evidence for the engineering according to SotA.*

3.1.4 **Hardware boards (multi-processor platform)**

The SDF (Sensor Data Fusion) platform is a heterogeneous system suited for intensive and safe tasks. It is based on two processors, one is a state-of-the-art safety microcontroller from the automotive domain, ensuring the highest safety grade that is ASIL D. The other one is a powerful multi-core i.MX8 Quad Max System-on-Chip with embedded GPUs that can be used for acceleration, for instance for AI-based applications using TensorFlow Lite. The concept is that the i.MX8 runs a rich OS like Linux and optionally a hypervisor and is responsible for the AI or Sensor fusion tasks. The safe microcontroller, an Aurix from Infineon, is responsible for safety-critical tasks and health monitoring of the system, including the i.MX8. Both processors also have encryption/hashing accelerators for improved performance in security tasks.

The interfaces of the board are diverse and include wireless communication, CAN bus, Gigabit Ethernet, and others. The two processors can communicate by means of an Ethernet switch complying with many Time Sensitive Networking standards, ensuring predictable routing of data. The system has been designed in a modular manner, that is the i.MX8 can be replaced with other processors by swapping the module on which it is mounted, giving the possibility to explore other architectures and processors. The system comes in a ruggedized aluminum case that protects and also ensures passive heat dissipation of the processor.

Innovation capacity: *The platform has a diverse set of interfaces that make it suitable for development and prototypes. But it also includes automotive interfaces for vehicle integration. Moreover, being designed in a modular manner, it allows to swap the module hosting the i.MX8 with other ones. Finally, having two different processors on board allows to have a separation of tasks based on the criticality and the computation power required.*

3.1.5 **AI-as-a-service (AIaaS)**

The TEACHING AIaaS is a software toolkit designed to support the development and the deployment of distributed, adaptive and dependable CPSoS applications, enabling them to exploit sustainable human feedback to drive, optimize and personalize the provisioning of the CPSoS services.

The TEACHING AIaaS leverages cutting-edge research on Artificial Intelligence and Deep Learning to provide:

- An easy-to-use software interface that supports the ability to learn continuously from heterogeneous sensor devices, including environmental sensors and wearables;
- AI on the edge with scalable learning algorithms, enabling both inference and – crucially – also user optimization and personalization both on high and low powerful devices.
- Humanistic intelligence, i.e., exploiting the ability to learn human cognitive, emotional, and physiological patterns for self-adaptation in autonomous vehicles applications.
- Federated, dependable, safe, and privacy-preserving AI methodologies already bundled by design.

Innovation capacity*: The TEACHING AIaaS software toolkit helps software developers to create intelligent distributed CPSoS applications and represents a decisive step forward with respect to currently available software solutions. In this sense, the TEACHING AIaaS toolkit is distinctively characterized by:*

- A simple and user-friendly API that allows the developer to design the application in a highly declarative fashion, minimizing the cognitive load on low-end details and allowing to focus on the conceptual design only.

- A set of easy configurable AI tools and workflows to set up human state monitoring for self-adaptation in CPSoS services provisioning, e.g., in autonomous driving applications.
- Sustainable learning algorithms enabling low-energy and fast adaptation also on edge devices, where commonly used AI frameworks - like PyTorch and TensorFlow - only support inference.
- A native support for Federated and Continual Learning, with bundled Dependability, Safety and Privacy-preserving guarantees.

3.1.6 METrICS Measurement Environment for Embedded Critical Systems

METrICS is a measurement environment for embedded critical systems that is able to capture the behaviour of the software on the hardware both in terms of timing and hardware resource usage. In the past METrICS has been used for hardware and software characterization exploiting hardware performance counters and relying on statistical analysis techniques while focusing on having a negligible impact on timing behaviour.

Such a characterization is especially necessary for the introduction of multi-core architecture within time-critical systems, to capture the timing interference phenomenon of different applications accessing concurrently shared hardware resources, while not being allowed to delay co-running applications to fulfil the time isolation property required by the safety standards.

The TEACHING project is an opportunity to replace the post-processing statistical analysis we used to perform for the characterization with artificial intelligence to detect safety or security issues, allowing METrICS to be part of HUMS, HIDS or SIEM systems, and extending its initial safety scope to security aspects.

Monitoring is also an important part of both the safety process and the security process, where it can detect and correct errors on the fly, detect failures and start safety-related procedures to fail back to a nominal state as quickly as possible, or detect intrusion and cyber-attacks. This monitoring activity would benefit from an introduction of AI-based algorithms using the hardware events traces as input, while not impacting the ability to certify autonomous piloting which cost needs to be controlled.

In the TEACHING project this technology is demonstrated on an avionic use-case as a cyber-blackbox, whose role is to ensure the correct behaviour of the software on the hardware, the traces of events acting as signature of this particular behaviour.

Innovation capacity: *Coupling monitoring and AI in HIDS/SIEM systems is a trending research topic, but most signature-based techniques rely on identifying well-known cyber-threat signatures at hardware level, similarly to what anti-virus are performing at software level. Our specificity in TEACHING is to learn the nominal signature of the embedded critical applications, and to detect cyber-attacks as deviation from these signatures, detecting the impact of these attacks on the regular critical applications, therefore not restricting ourselves to a subset of well-known attacks.*

3.1.7 Autonomous Driving Application

The key benefits of the ever so more evident driving automation include improvements in terms of road safety and driving comfort. The safety improvements are based on the expectation of reduced number and effect of road accidents, the majority of which are resulting from human

errors. Driving automation offers superior performance over human reaction times, distraction levels, tiredness, or influence of (legal/illegal) performance altering substances.

TEACHING tackles complex driving scenarios through improved control strategies based on the human perception of comfort and safety. The perception is the decisive factor for the user acceptance and ability to take over control from the autonomous driving system. The system functions seek cooperation between autonomous safety-critical CPSoS, IoT, and vehicle's advanced control strategies.

The combination of functional interactions highlights the challenge of creating a reliable solution for autonomous and safety-critical distributed systems of networking computing elements and humans in the autonomous driving context. The human-centred approach is supported through the integration of AI techniques at the edge leveraging the physiological, emotional and cognitive state of vehicle occupants for the adaptation and optimisation of the AD applications. While AI algorithms are extremely promising contributors to the success of AD, they are unlikely to replace the entire human decision-making soon, due to the need to ensure critical safety and due to a lack of standardised certification methods.

Innovation capacity: *As the societal expectations towards mobility are evolving, there is a need for a firmer link and an improved interface between humans and machines. TEACHING offers insights needed for strengthening that link, which is also forming the basis for further improvements of autonomous driving functionalities. The improvements are also offering an added benefit of customization to the needs of either specific groups or even to individuals. Such an offer is also contributing to the improvement of mobility as a service proposition. The automotive application is directly contributing towards human-centred enhancements to driving automation by improved involvement of human modes into the safety-critical systems. It also contributes towards balancing the equilibrium between AI and automotive safety.*

3.2 First insights from the TEACHING's stakeholders' analysis

A clear outline of the TEACHING stakeholders (including their needs and preferences) is an important prerequisite for analysing the context and market for TEACHING. In fact, to gather feedback from end-users/customers early on helps to formulate a strong value proposition and identify optimal communication channels.

The TEACHING stakeholder engagement strategy is thoroughly presented in D6.3 (Section 4). As part of this strategy, and aiming to trigger an interest of primary stakeholders, first insights from the TEACHING stakeholder analysis are formulated in this section based on the 1st stakeholder engagement survey released according to the stakeholder engagement plan presented in D6.3.

3.2.1 **Results**

The primary purpose of this questionnaire is to investigate which platforms, software toolkits and how many of them are being used within the company/organizations targeted by the TEACHING project. Therefore, the participants have been asked to specify the different elements their organizations/companies usually demand (related with the TEACHING platform) by specifying the type of license and approximate price of the tool.

The questionnaire was distributed amongst a stakeholder group (external participants) brought by each partner. Due to the GDPR restrictions and reluctance to disclose the company's information, each of the partners distributed the questionnaire to their relevant contacts.

Overall, 18 responses were achieved as a result of this survey campaign. The achieved survey answers can be helpful to approximately give us an insight on how companies and organizations use TEACHING relevant products/tools and reveal their interest in exploring the TEACHING offerings in future. Some important insights are presented below:

Demographic information: Figure 15 illustrates the geographical distribution of the respondents. As shown the survey participants are from six EU countries (almost 28%, 22%, 17%, 11% and 6% of respondents from Italy, Germany, Austria, Greece, Czech Republic and Latvia respectively).

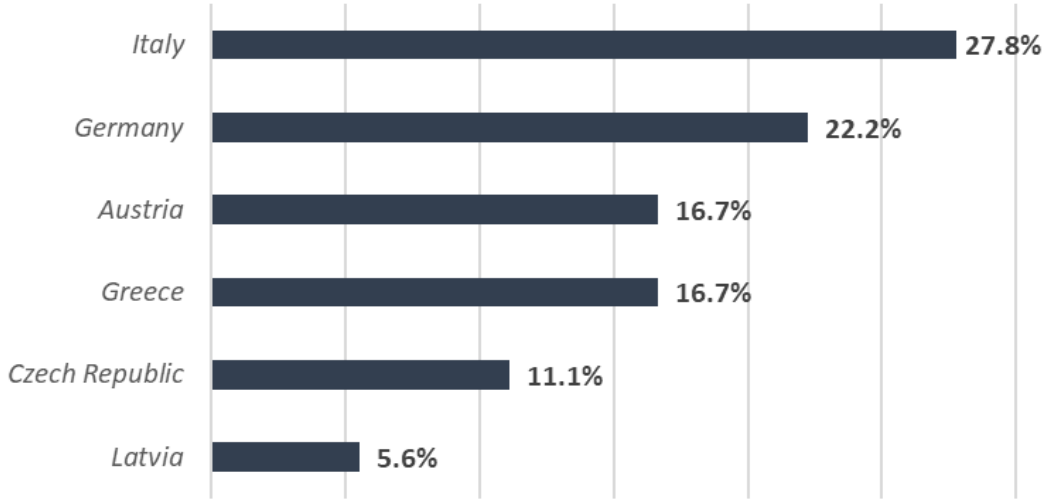


Figure 15: Respondents' geographical distribution

Type of organization: Respondents' organizations were classified in terms of five categories. Figure 16 indicates, the largest number of respondents represent academic/research institutions (50% respondents), followed by representatives from automotive industry (22% participants), as well as respondents from software and hardware suppliers (22 and 17% respectively). Finally, appx.11% of participants did not fit within any category, and hence were categorized as "other".

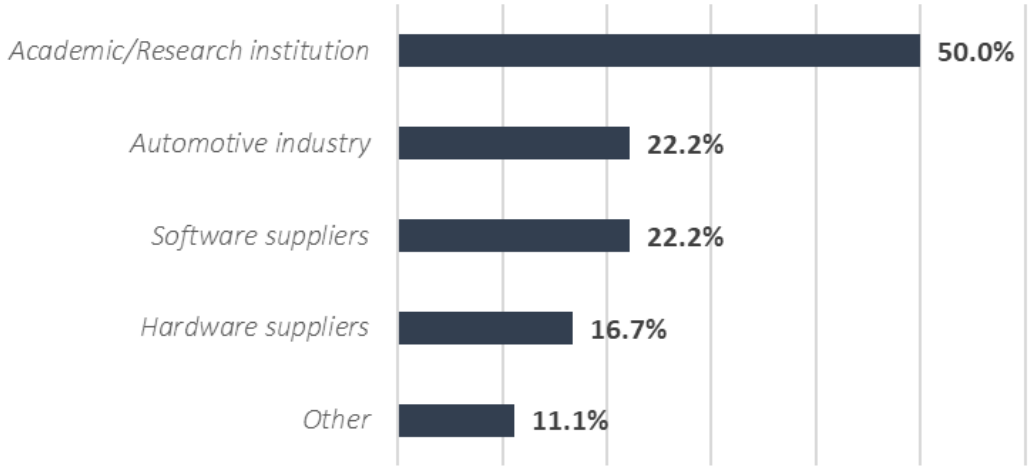


Figure 16: Type of organization

Organizational Role: Aiming to identify the areas of expertise of the survey participants the respondents were asked to indicate the role/position in their organizations. As depicted in Figure 17, the survey participants occupy a variety of roles including project managers: appx. 21%, researcher/senior scientists: appx. 21%, R&D engineers/developer engineers and professors/faculty members appx.14% each. The list also comprises of PhD student, consultant, SW developers and deputy director of a development.

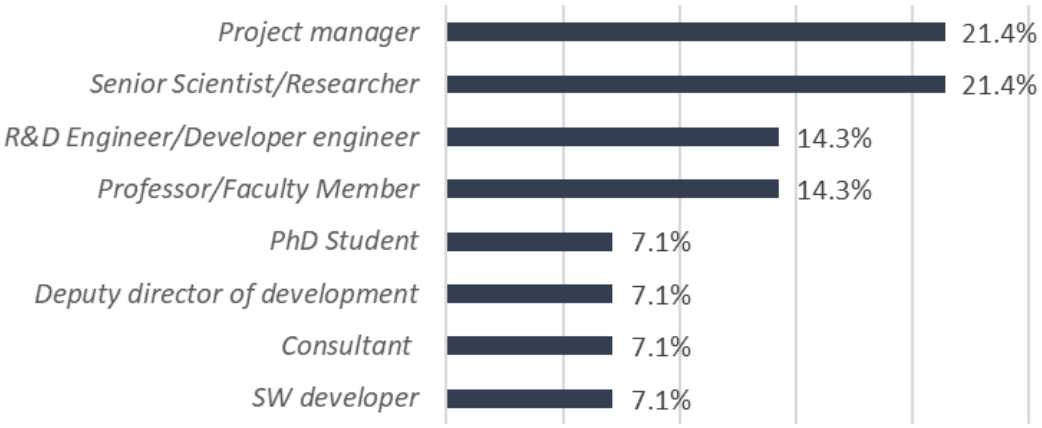


Figure 17: Respondents organizational role

SW/HW usage: Figure 18 indicates, the largest number of respondents use hardware platforms appx. 61%, followed by utilization of IoT and ML/DL libraries/toolkits appx. 56 and 50% respectively. Sensors for hardware, human and software monitoring (33%, 33% and appx. 17%) are also among the selected answers. The respondents also demand consultation services appx. 28% while appx. 33% of the participants use solutions not mentioned within any category, and hence were categorized as "other".

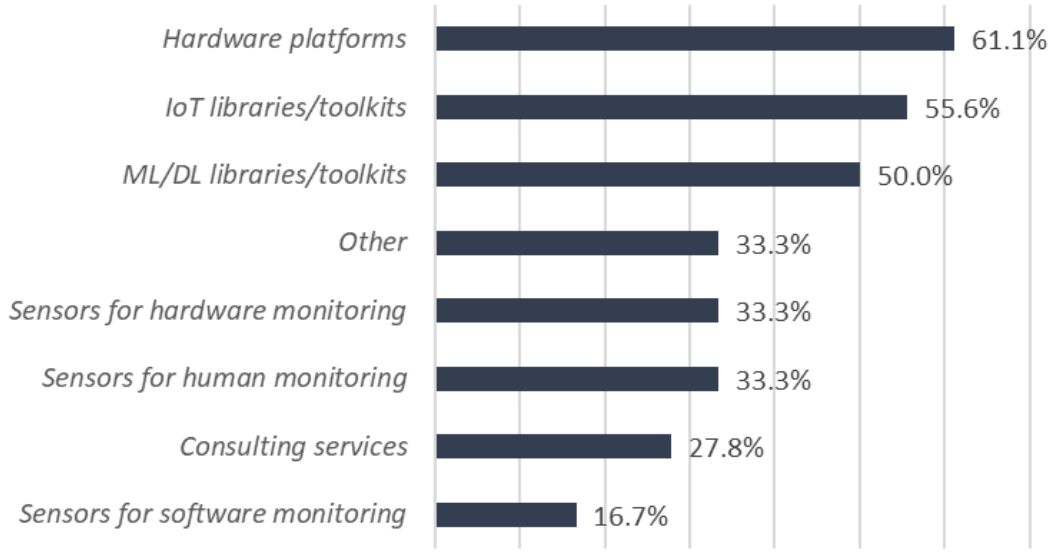


Figure 18: SW/HW/other devices usage by the respondents

The participants mentioned a variety of answers with respect to SW/HW tools and devices used within their organization. Some of the TEACHING relevant HW and SW products that are being utilized by the survey respondents are listed below:

- RaspberryPi
- CAN analysing tools
- Mathematica, Matlab/Simulink and other simulation tools
- dSpace system - hw and sw
- Dymola
- Siemens SIMATIC controllers
- Beckhoff automation systems
- REXYGEN
- Tanner Tools
- Cadence automotive solutions
- Quartus Prime design software
- CUDA parallel computing platform-NVIDIA
- HW – NVIDIA
- TensorFlow software library for machine learning
- Xilinx processing platforms
- Infineon Altera, Intel, Aurix tools
- Lauterbach microprocessor development tools

License type: Figure 19 shows the distribution of the type of licences used within the organisations, and it can be seen that most of the participants use free and open-source solutions (72%). Annual and Perpetual license types were also selected by majority of respondents (56% and 50% respectively) showing the high usage of software solutions with monthly or yearly subscription together with open-source solutions. Finally, appx. 22% of the answers did not fit within any category, and hence were categorized as "other".

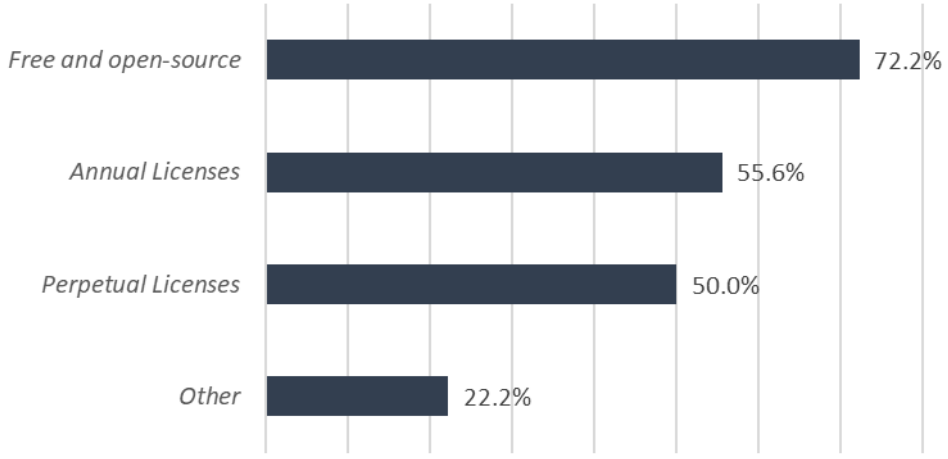


Figure 19: License type

Approximately, how much does your company spend on software/hardware tools or services (yearly)?

Min	**~0.3K euro**
Max	**200K euro**

Interests in knowing more about TEACHING offerings: As a final step in this analysis, the survey participants' interests in knowing more about the TEACHING offerings were assessed via a five-point Likert scale with 1 = "Not at all interested" and 5 = "Highly interested". It is revealed that the participants are highly interested in AIaaS (7 respondents), Autonomous

Driving Application (6 respondents), Dependability engineering (best practices and recommendations-5 respondents) as well as Hardware Boards (4 respondents). Furthermore, the respondents expressed mainly moderate interests about the HPC2I component (9 answers), the TEACHING platform as a whole (7 answers) and the METriCS measurement environment (4 answers). Interestingly, very few participants (≤ 3) selected the "not at all interest" answer which may be due to the fact that the period of releasing was in parallel with the technical development of the TEACHING offerings thus the respondents could face lack of deep technical information. This obstacle will be resolved in the next stakeholder engagement activities (D6.3 Section 4).

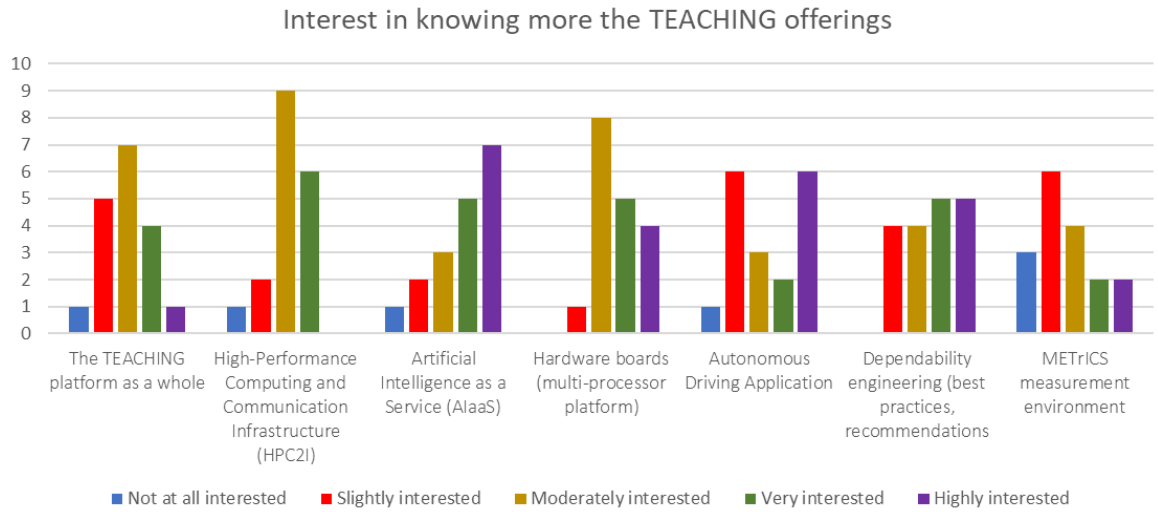


Figure 20: Assessment of the respondents' interests in knowing more about the TEACHING offerings

3.3 Marketing strategy

The TEACHING marketing strategy is based on the dissemination and communication activities that aim to create visibility of the project and promote the exploitation of the TEACHING's outcome by establishing effective communication channels and gaining TEACHING recognition among relevant stakeholders. By creating awareness about the project outcomes and promoting their adoption, the company exploiting the platform will foster a culture of cooperation in the context of related services and applications. Several communication tools have been already realising the communication strategy towards the relevant, targeted audiences or market stakeholders. Here it is worth mentioning, that each stakeholder group should be approached with specific means of communication tools and a relevant message to achieve an optimal impact of the TEACHING's outcome.

General information about the TEACHING platform, incorporated toolkits and its benefits have been disseminated by different reports, scientific articles, promotional materials such as presentations videos, newsletters via various online tools and channels (website, social media, virtual events). Following the same paradigm, the TEACHING's promotion strategy will continue involving the following tools and means their relevant indicators for measuring results throughout the project duration and beyond.

TEACHING marketing tools and channels	Brief Description	
Website, social media channels	General information via website (access to reports, deliverables, promotional material etc) about the	Website: Number of visitors, return visits, clicks

	TEACHING offerings and its benefits for those wishing to become users of the project outcome. Regular posts, messages, news, short clips about the TEACHING offerings through the most popular online channels: LinkedIn, Twitter YouTube	Social media: Number of followers Impressions/reactions & engagement
Promotional material • *Brochures* • *Newsletters/Press releases* • *Presentations*	Regular promotional materials offered to all interested parties including key TEACHING stakeholders.	Number of promotional materials prepared and released
Academic/scientific communication • *Training sessions* • *Educational workshops* • *Conferences*	Sharing information about the TEACHING offerings through participation in workshops/conferences and organization of educational workshops.	Number of educational workshops/training sessions
B2B/B2C communication • *Mini demos* • *Webinars/workshops*	Arranging a stand to present and demonstrate the TEACHING offerings to the relevant stakeholders. Organising B2B meetings/workshops with the potential stakeholders.	Number of event/workshops

3.4 Business model for future commercialization

The selection of the optimal business model will support the establishment of a viable business which will commercialise the results from the TEACHING project, following productization projects and will disseminate the concept of service-based engineering design tools.

Regarding the exploitation of the TEACHING platform and the associated toolkits, several options have been separated that will be further discussed as the project come to its closure:

- **Establishing new start-up company:** Partners jointly set up a company to be representative for the TEACHING platform
- **Ownership by one of the partners:** A strategic partner will be selected to carry out the exploitation and business plan of the platform after the project accomplishment
- **Exploitation by different partners separately** – This model can confuse the market if there is cross-selling from different partners of the project

3.5 Pricing strategy

Multiple options are being considered by the project partners regarding the pricing strategy of the TEACHING products and services. Below are presented some of these choices that are still subject of discussion between the partners.

- **Fee per module:** An estimation of a fee per module used for various tools provided in the TEACHING platform

- **Fee per product/services:** A price list for different products and services integrated in the TEACHING platform
- **Fee for the TEACHING platform:** An estimation of a fee for the full version of the TEACHING platform and its associated toolkits.
- **Freemium:** Offering both free (simple and basic features of the TEACHING platform) and premium/paid (more advanced and additional features of the platform) product and services.
- **Free Trial:** Offering the full version of the TEACHING platform for a period of time (e.g. 30 days) to let users get an idea of the full range of features of the platform and 'hook' customers to commit to TEACHING. In most cases, after the 30 days free trial period, the subscription to the application will be renewed automatically if the user did not cancel the subscription during the first 30 days.
- **Free of charge:** The TEACHING outcome is offered free of charge

The final pricing strategy of the TEACHING project will be selected based on the competition in the market as well as the financial targets set by the TEACHING partners. Thus, this is a topic for further discussion as the project comes to its closure.

3.6 Plan for financial forecast

At the current stage, given also the relatively early project phase (M20), we can only propose the project's financial assessment plan that will be used to conduct the final financial analysis of the project (to be reported in D6.5). Depending on the pricing strategy that will be selected by the TEACHING partners (Sec. 3.5), the TEACHING financial analysis will involve an evaluation of financial profitability of the project, the determination of the appropriate contribution from the funds, and finally, the assessment of the project's long-term sustainability from the financial perspective. To conduct the desired financial forecast several important assumptions may include but not limited to:

- All cash-flow generated by the proposed project during the observed period has been stated in Euros (EUR)
- The agreed period of forecast will include both the development/implementation and the operational intervals.
- The development/implementation period will be the project running interval between January 2020 and July 2023.
- The operational period will be defined as the period between July 2023 and inclusive of July 2038, (at least 15 years) which is in accordance with the European Commission's recommendation [107]. Within this operating period, costs and benefits (project cash flows) for each year will be determined.
- 4% discount rate will be used according to the European Commission's recommendation [107].

The TEACHING financial forecast will be mainly based on fundamental financial decision-making indicators such as, **Net present value (NPV)**, I**nternal rate of return (IRR)** and **Return of Investment (ROI).** More specifically,

- NPV will be used to determine the present value of the TEACHING investment by the discounted sum of all future cash flows.

$$NPV = \sum \frac{CF_n}{(1+i)^n} - Initial\ investment$$

Where CFn is the cash flow in the n^{th} period, i is the discount rate, n the total time of the investment [108].

- IRR will be used to measure and compare the profitability of the TEACHING investment and will show the rate of return of the initial capital invested. It will be estimated by using the NPV formula (above presented) by assuming the NPV value equal to 0 and solving for discount rate, which is the IRR [109].

$$NPV = \sum \frac{CF_n}{(1 + IRR)^n} - Initial\ investment = 0$$

- Finally, ROI will be applied to evaluate the efficiency of the TEACHING investment. It measures the amount of return on an investment relative to the investment's cost. To calculate ROI, the return of an investment is divided by the cost of the investment, and the result is expressed as a percentage [110].

$$ROI = \frac{Return\ of\ Investment}{Cost\ of\ Investment} \times 100\%$$

4 Conclusion

This deliverable illustrates the work performed in WP6, Task6.2 "Exploitation, Sustainability management and Business continuity", by defining the TEACHING market context with the objective of identifying suitable hardware platforms, sensors, technologies and available software tools. In this context, the conducted market analysis shows that the general CPS/CPSoS market will grow at a CAGR of more than 10% for the next 5 years, by reaching $12720 M by the end of 2026. The disruptive technologies emerging from combining the cyber and physical worlds seems to provide an innovation engine for a broad range of industries, creating entirely new markets and platforms for growth. This trend is an obvious prospect for the TEACHING project to take advantage the revealed key challenges and market drivers towards a holistic customer value approach by establishing capabilities to support business modelling for the market. In addition, the market growth of different key technologies (such as IoT, WSN, AI, etc.) interconnected with CPS/CPSoS have been accurately described.

The document also analyses important CPS/CPSoS application domains underscoring the essential role of CPS/CPSoS in different industrial fields. Furthermore, the TEACHING related platforms and associated toolkits have been surveyed and analysed by trying to formulate TEACHING's competitors' landscape. The analysis of the survey reveals a multitude of diverse platforms and toolkits with a variety of scopes and objectives.

In addition, first insights from the key stakeholders have been implemented via the 1st TEACHING stakeholder engagement questionnaire referring to several questions regarding the current preferences in using hardware platforms and software toolkits similar to TEACHING as well as revealing their potential interest regarding the TEACHING platform and associated toolkits.

Finally, based on PEST and SWOT analysis a preliminary business plan has been formulated while the Business Model Canvas previously presented in D6.1 has been updated visualizing the updated TEACHING value proposition together with the TEACHING description.

To align future activities and potential trade-offs several business models for future commercialization as well as marketing and pricing strategies together with a plan for financial forecast have been proposed. It is worth mentioning that these aspects will be revised, feeding with updated market dynamics, the final business model to be adopted based on the partners' desires and exploitation perspectives. Such updates will be finalised as the project comes to its closure and will be reported in D6.5 (a special section will be dedicated to cover the topic).

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APPENDICES

APPENDIX I- 1st Stakeholder engagement questionnaire

TEACHING: A Computing Toolkit for Building Efficient Autonomous Applications Leveraging Humanistic Intelligence

TEACHING is an EU-funded project that designs a computing platform and the associated software toolkits supporting the development and deployment of autonomous, adaptive and dependable Cyber-Physical System of System (CPSoS) applications. To set the project's business plan we would highly appreciate your assistance in answering a couple of questions regarding the current usage of similar tools. The survey is anonymous and your participation is voluntary.

Please note, that for your future reference, we will share some important insights from this campaign in our website (https://www.teaching-h2020.eu/deliverables/).

We thank you for devoting 5 minutes of your time to our survey.

* Required

1. Organization name (Optional)

2. Your position in your organization (Optional)

3. Country *

4. The type of your organization *

Check all that apply.

- [ ] Automotive industry
- [ ] Aviation industry
- [ ] Hardware suppliers
- [ ] Software suppliers
- [ ] Academic/Research institution
- [ ] Other

5. My organization demands/uses *

Check all that apply.

- [ ] Hardware platforms
- [ ] Sensors for software monitoring
- [ ] Sensors for human monitoring
- [ ] Sensors for hardware monitoring
- [ ] ML/DL libraries/toolkits
- [ ] IoT libraries/toolkits
- [ ] Consulting services
- [ ] Other

6. Please specify which hardware or software tool your organization currently purchases *

7. Please specify the license type for software tools *

Check all that apply.

- [ ] Perpetual Licenses
- [ ] Annual Licenses
- [ ] Free and open-source
- [ ] Other

8. Approximately, how much does your company spend on software/hardware tools or services (yearly)? *

9. In TEACHING we develop a computing platform and associated components listed below. Which of these technologies would your organization be interested in knowing more about?

Mark only one oval per row.

	Not at all interested	Slightly interested	Moderately interested	Very interested	Highly interested
The TEACHING platform as a whole	◯	◯	◯	◯	◯
High-Performance Computing and Communication Infrastructure (HPC2I)	◯	◯	◯	◯	◯
Artificial Intelligence as a Service (AIaaS)	◯	◯	◯	◯	◯
Hardware boards (multi-processor platform)	◯	◯	◯	◯	◯
Autonomous Driving Application	◯	◯	◯	◯	◯
METrICS measurement environment	◯	◯	◯	◯	◯
Dependability engineering (best practices, recommendations)	◯	◯	◯	◯	◯

10. If you have comments, please leave your notes *