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Executive Summary

Deliverable 3.2 presents the most relevant Information and Communications Technology (ICT) trends and related emerging digital technologies with disrupting potential within the field of transportation. It focuses on the real-world applications of such technologies in mobility solutions, with the purpose of understanding how the current digital trends can ultimately fill the mobility gaps experienced by persons with disabilities.

The digital trends identified in this document, as well as their related innovative applications within the mobility sector, have been identified mainly through desktop research, and then structuring selected information with the definition and implementation of two distinct factsheets typologies: 1) Technological Domains and 2) Application Areas. By employing these two standard factsheets we highlight the most significant features of the identified digital trends, and how the related technologies are being used in real-world applications. While Technological Domains describe the trending ICT areas and the involved technologies, their related Application Areas provide a deeper insight into the use of such technologies in modern, innovative applications, especially within mobility solutions that answer disabled people's needs.

The report is structured as follows:

- Chapter 1 provides an introduction to the document.
- Chapter 2 describes the adopted methodology, focused on defining the potential impact of digital trends on future mobility solutions. The identification of the most significant ICT innovation trends has been conducted through desktop research, reporting the results in structured factsheets. In this chapter, the differences between Technological Domains and Application Areas are presented and the use of their associated factsheets is justified.
- Chapter 3 reports the factsheets for each selected Technological Domain, with the domain description, the most significant relationships with the Application Areas, the historical evolution, and the possible evolutionary scenarios.
- Chapter 4 reports the factsheets for the Application Areas, with a general description, examples of the real-world applications, the relationships with Technological Domains, and the mobility gaps that each solution can fill, especially when related to disabled people, as well as the relevant European standards and, finally, possible privacy and cybersecurity issues.
- Chapter 5 reports the conclusion.

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List of acronyms/abbreviations

Abbreviation	Explanation
AA	Application Area
ADAS	Advanced Driver-Assistance System
AI	Artificial Intelligence
AmI	Ambient Intelligence
ANN	Artificial Neural Network
AR	Augmented Reality
ASR	Automated Speech Recognition
Auto-ML	Automated Machine Learning
BLE	Bluetooth Low Energy
Car2X	Car-to-Everything
CAV	Connected Autonomous Vehicle
CCD	Charged-Coupled Device
C-ITS	Cooperative Intelligent Transport System
CMOS	Complementary Metal Oxide Semiconductor
CUI	Composite User Interface
C-V2X	Cellular-Vehicle-to-Everything
DataOps	Data Operations

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Abbreviation	Explanation
DevOps	Development and Operations
DSRC	Dedicated Short Range Communications
EC	European Commission
EGNSS	European Global Navigation Satellite System
ES	Expert System
ETC	Electronic Toll Collection
EU	European Union
FL	Fuzzy Logic
FTP	File Transfer Protocol
GA	Genetic Algorithm
GPS	Global Positioning System
GPU	Graphics Processing Unit
GUI	Graphical User Interface
H2M	Human-to-Machine
HMI	Human-Machine Interaction
ICO	Information Commissioner's Office
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
IIoT	Industrial Internet of Things
IMS	Innovative Mobility Services
IoT	Internet of Things
IoV	Internet of Vehicles
ISO	International Organization for Standardization
ITS	Intelligent Transport System
ITS-CCAM	Intelligent Transport Systems - Cooperative, Connected and Automated Mobility
IVI	In-Vehicle Infotainment

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Abbreviation	Explanation
IVR	Immersive Virtual Reality
KPI	Key Performance Indicator
LCD	Liquid-Crystal Display
LOI	Local Operator Interface
M2M	Machine-to-Machine
MANET	Mobile Ad-hoc Network
MAPS	Mobile Accessible Pedestrian Signal
MBUX	Mercedes-Benz User Experience
ML	Machine Learning
MMI	Man-Machine Interface
mPASS	Mobile Pervasive Accessibility Social Sensing
MR	Mixed Reality
NFC	Near-Field Communication
NLP	Natural Language Processing
OCR	Optical Character Recognition
OEM	Original Equipment Manufacturer
OGES	Open Graphics Library for Embedded Systems
OIT	Operator Interface Terminal
OpenVG	Open Vector Graphics
OT	Operator Terminal
PT	Public Transport
PTCV	Pre-Trip Concierge and Virtualization
QR code	Quick Response code
RFID	Radio-Frequency Identification
RSU	Road-Side Unit
RTA	Dubai Roads and Transport Authority

Abbreviation	Explanation
SIC	Safe Intersection Crossing
SMS	Short Message Service
SO	Smart Object
SPC	Smart Pedestrian Crossing
STCS	Smart Travel Concierge System
TD	Technological Domain
TFT LCD	Thin-Film-Transistor Liquid-Crystal Display
USB	Universal Serial Bus
V2H	Vehicle-to-Human
V2I	Vehicle-to-Infrastructure
V2R	Vehicle-to-Road
V2S	Vehicle-to-Sensor
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VA	Virtual Assistant
VANET	Vehicular Ad-hoc Network
VR	Virtual Reality
WCAG	Web Content Accessibility Guidelines
WiFi	Wireless Fidelity
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network
WT	Wayfinding Technologies

Table 1: List of acronyms/abbreviations

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1. Introduction

According to Eurostat, 25% of the European Union (EU) population aged 16 or over reported long-term physical, mental, intellectual, or sensory impairment. However, today's transport systems remain largely inaccessible to disabled people, and hinder them from benefitting from fundamental transport services. In addition, demographic ageing often associated with sensory, mobility or cognitive challenges, is pervasive throughout the world and for this reason, it is necessary to find mobility solutions suitable for both the elderly and people with disabilities. TRIPS aims to design, describe, and demonstrate practical steps to allow disabled people to play a central role in the design of inclusive digital mobility solutions.

Modern Information and Communication Technologies (ICT) significantly enhance products and services in different contexts, including the mobility sector; recently, ICT innovation has enabled the development of technologies that can be used to improve the travel experience, not only by increasing safety, but also by beginning to fill disabled people's mobility gaps. Since the role of ICT tools in modern transport services is increasingly relevant, it is necessary to take disabled people into consideration when evaluating factors affecting mobility gaps.

Usually, ICTs are considered tools used to communicate and access information,[1] and are therefore conceptualized as instruments.[2,3] This view does not allow us to fully grasp the profound changes to society that ICT have caused,[4] leading us to consider looking at technologies as human action systems, in order to emphasize their capability to intentionally transform concrete objects in order to efficiently produce a desired result.[5] Evaluating ICT under this perspective draws attention not only to the latest tools available, but also to how human actions are affected by such tools, and the associated newly available actions. This means that we no longer see ICTs as mere instruments, but as technologies that have a profound effect on the human capability to perform actions with a unprecedented *rang*e of impact.[6]

This transformation allows us to qualify modern society as an information or network society.[7] Like everyone else, disabled people make use of ICTs to perform everyday actions, allowing them to increase or preserve their quality of life as well as their opportunities to successfully enter the workforce and, more generally, participate in society. For instance, a blind person can rely on personal devices to know where they are currently located and to get around when they are far from home, whereas a tetraplegic individual can move around by driving a motorized wheelchair. It must be noted that disabled people do not decide whether to use or not such technologies, as these modern tools are inherently part of a disabled person's capability for action, since they constitute the very nature of a particular functioning.

[1] Toboso, Mario. "Rethinking disability in Amartya Sen's approach: ICT and equality of opportunity." Ethics and Information Technology 13.2 (2011): 107-118.
[2] Feenberg, Andrew. Critical theory of technology. Vol. 5. New York: Oxford University Press, 1991
[3] Tiles, Mary, and Hans Oberdiek. Living in a technological culture: Human tools and human values. Psychology Press, 1995
[4] Echeverría, Javier. "Apropiación social de las tecnologías de la información y la comunicación." Revista Iberoamericana de Ciencia, Tecnología y Sociedad-CTS 4.10 (2008): 171-182
[5] Quintanilla, Miguel Ángel. Tecnología: un enfoque filosófico y otros ensayos de filosofía de la tecnología. Fondo de Cultura Económica, 2017.
[6] Echeverría, Javier. "Fernando Sáez Vacas, Más allá de Internet y Javier del Arco, Ética en la sociedad red." Isegoría 34 (2006): 289-294.
[7] Castells, Manuel. La era de la información: economía, sociedad y cultura. Vol. 1. siglo XXI, 1999.

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This also means that the capability set of a disabled person can be seen as a functioning space that relies on the appropriation of the technologies that contribute to making specific actions possible.

As such, a disability is *"only actually a disability when it prevents someone from doing what they want or need to"* .[8] In the 'Digital Dividends Report' for the World Bank, Raja also states:

> *The physical inaccessibility of "brick and mortar" and "pen and paper" based educational, employment, information, and social environments has been one of the primary factors for the marginalization of persons with disabilities. Everything from being able to travel to and enter a school or work site, perceiving and understanding what is written on the blackboard, hearing, understanding, and communicating with teachers, managers, clients, and peers, accessing paper and print-based content, and recreation and socialization can become a barrier.*[9]

When comparing ICTs with more traditional tools, it becomes clear that digital technologies and services can make a real difference in a disabled person's welfare.[10] Accessibility is a crucial factor for mobility solutions, hence disabled people's user acceptance must also be included along with travel time, travel costs, comfort and convenience, safety, and security[11] when evaluating the quality of travel services.

ICTs can reduce the physical barriers to mobility, enabling the social integration of disabled people and their access to information, communication, and educational tools and processes. In addition, ICTs can facilitate the development of optimised, more accessible, less resource consuming and less emission intensive transport service, reducing the economic barriers and health concerns.

The role of public administration in this is crucial. Government departments act not only as facilitators, therefore providing guidance and information on new methods to support disabled people, and coordinating with research institutions and care services, but also make these services available and more accessible, raising the capability of disabled persons to use them.[12]

D3.2 identifies the most significant ICT innovation trends with disrupting potential within the field of transport, which can significantly facilitate or hinder disabled people's mobility. The deliverable:

i) identifies and presents the emerging digital technologies within trending "Technological Domains",
ii) presents the related "Application Areas" which include real-world solutions that make use of the technologies described in the Technological Domains, and
iii) defines major relationships between Technological Domains and Application Areas by highlighting the evolutionary scenarios of Technological Domains, and future applications on advanced mobility solutions, together with their impact on disabled people's mobility.

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[8] Khetarpal, Abha. "Information and communication technology (ICT) and disability." Review of market integration 6.1 (2014): 96-113.
[9] Raja, Deepti Samant. "Bridging the disability divide through digital technologies." Background paper for the World Development report (2016).
[10] Tsatsou, Panayiota. "Digital inclusion of people with disabilities: a qualitative study of intra-disability diversity in the digital realm." Behaviour & Information Technology (2019): 1-16.
[11] Bąk, Monika, and Przemysław Borkowski. "Applicability of ICT solutions in passenger transport-Case studies from different European backgrounds." Transport 30.3 (2015): 372-381.
[12] Curry, R. G., M. Trejo Tinoco, and D. Wardle. The use of information and communication technology (ICT) to support independent living for older and disabled people. London: Department of Health, 2002.

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Technological Domains and Application Areas have been described via standardized factsheets, which allow to easily compare them on different aspects and also allow to easily find relevant information. Since the main goal of the Deliverable 3.2 is the evaluation of ICT trends to develop future mobility solutions suitable for disabled people, in each Application Area's factsheet future applications on advanced mobility solutions and the impact on disabled people have been reported.

This report has been developed within Task 3.2, in coordination with Task 3.1, where new mobility services are researched and assessed focusing on service and operational concepts from disabled people's perspective, Task 3.3, where gaps in standardisation, legislation and certifications under a disability perspective are identified, and Task 3.4 where, referring to Technological Domains identified in Task 3.2, assistive technologies are reviewed.

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2. Methodology

To identify the most significant ICT innovation trends, it was necessary to structure our research to effectively respond to TRIPS' stated objectives: identifying digital technology trends with the final goal of shedding light on their potential impact on future mobility solutions.

The need to categorize general technologies as *enabling* technologies arose, which led us to describe trends by framing them within technological domains. This allowed to reach three objectives: i) effectively covering the state of art of the involved technologies, ii) providing information on the related *evolutionary scenarios* (a crucial aspect to discuss trends), and iii) identifying major links with application areas that leverage the technologies within a specific domain, especially focusing on mobility applications. This also means that, after a digital trend was framed, it was possible to focus on the impact of that digital trend on future mobility solutions, effectively detecting innovative real-world solutions enabled by the trend's related technologies. These selected applications leverage the reported digital trends to respond to disabled people's mobility needs, with the final aim of filling the mobility gaps which hinder disabled people's movements, and eventually leading to reach the project's goals.

On the basis of the considerations reported above, we distinguished between Technological Domains and Application Areas, which reveals the extent to which the research study was conducted with focus on real-world solutions: Technological Domains are focused on trending technologies, while Application Areas are focused on the application of trending technologies in real-world solutions and, finally, in innovative mobility solutions which fill mobility gaps to satisfy specific disabled people's needs. To this purpose, a specific approach was designed and followed, composed by the following activities:

1. **Listing of trends as identified by authoritative sources**. Since a trend can be defined as a general direction into which something is changing, developing, or veering[13], identifying a digital technology trend required to perform a general investigation on the *popularity* of existing technologies. Consequently, authoritative sources such as Gartner[14] and iMOVE[15] were first consulted, with the aim of obtaining a preliminary list of digital technology trends for the 2020s that have been evaluated as such by institutions with a widely recognized authority in the scientific community.
2. **Internal discussion on trends identified by authorative sources.** Expert judgement was then applied to the trends listed by authoritative sources, obtained within the previous step. Identified trends were scrutinized through multiple internal discussions, in order to select the most meaningful technology trends for the objectives of TRIPS (i.e. for disabled people's mobility), finally focusing on Automation, Artificial Intelligence (in particular, Machine Learning), the Internet of Things, and Intelligent Transport Systems. In parallel, trends were closely investigated to identify more meaningful categories where multiple mobility applications might be included. The realization that a more meaningful categorization was needed brought us to separately consider User Experience and User Interfaces (and thus, gamification, virtual and augmented reality, and advanced human-machine interaction techniques), Web technologies (crucial for IoT) and big data analytics, robotics (closely linked to automation, AI, and ML), machine vision, and geolocation. In parallel, experts started bringing in examples of real-world innovative mobility applications which were linked to the identified trends.

[13] https://marketbusinessnews.com/financial-glossary/trend/

[14] https://emtemp.gcom.cloud/ngw/eventassets/en/conferences/epaeu20/documents/gartner-emea-toptentrends-2020.pdf

[15] https://imoveaustralia.com/thoughtpiece/disrupting-urban-mobility/

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3. **Distinction between *Technological Domains* and *Application Areas***. As we started identifying and distinguishing between more meaningful categories for the technological trends, the need arose for devising a categorization which could ease the identification of innovative mobility applications, and, especially, their impact on disabled people's mobility gaps. A further categorization process was then initiated that, on the one hand, allowed to focus on more general trends at an higher abstraction level, and, on the other hand, ensured the necessary focus on innovative mobility applications and, in particular, their consequences for disabled people's mobility. This further categorization consisted in distinguishing between two main categories: Technological Domains (TDs), such as IoT and Machine Learning, where a general overview of the related technologies and their evolution (trends) was to be provided, and Application Areas (AAs), were special attention was to be given to innovative mobility applications, and their impact on disabled people. In other words, within AAs, an analysis at a lower abstraction level, and thus a specific focus on real-world mobility solutions, was the main reason behind the distinction between TDs and AAs. Two distinct factsheets templates were devised for the two main categories, with the appropriate sections. Clearly, TDs and AAs have many-to-many relationships, of which the most significant ones were identified, and are reported both in the diagram in Figure 1, and in each single TD and AA factsheet, in a dedicated section.
4. **Factsheets production**. The templates devised in the previous step were filled with the required information, ultimately leading to an easier overview of the identified trends and their related innovative mobility applications.

The identified 12 Technological Domains (TDs) and 11 Application Areas (AAs) are reported in Figure 1, which also highlights the most significant relationships we identified between the two categories.

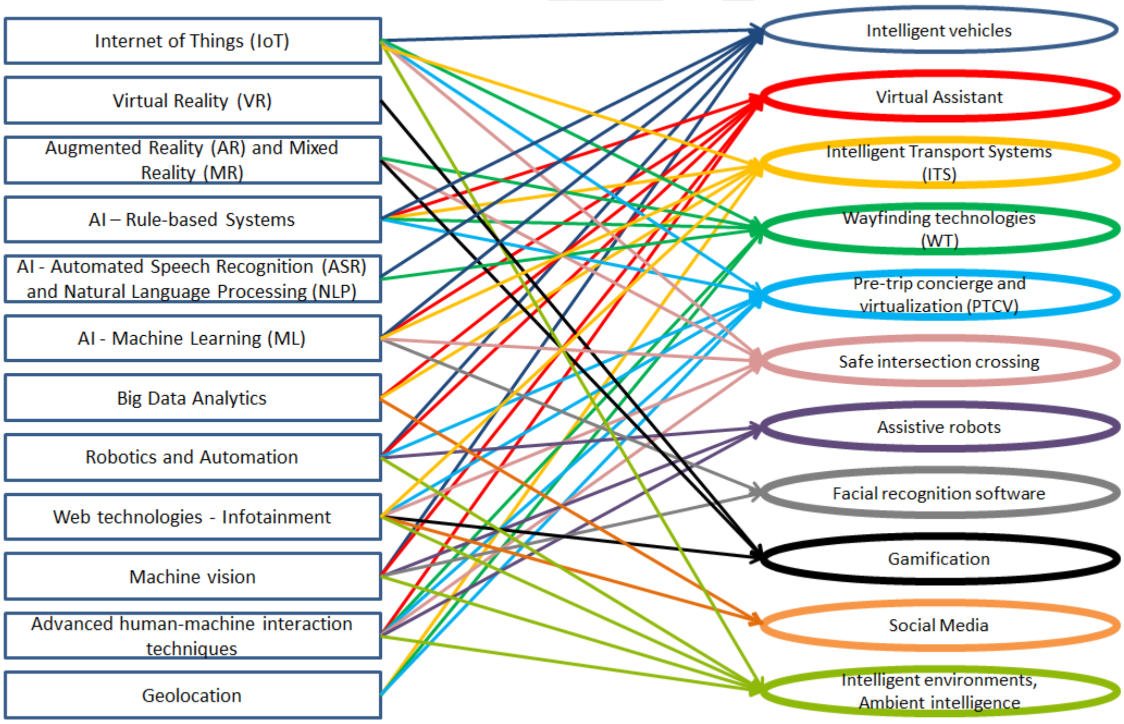

Figure 1. Technological Domains (left), Application Areas (right), and most significant relationships

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As stated above, TDs and AAs were described via dedicated factsheets with a standard structure, to better focus on similar aspects across TDs and AAs, and reach the project's objectives. In the following sections, a description of TDs and AAs templates is provided.

2.1. Technological Domains

The factsheets describing TDs were structured as follows:

1. Description. In this section, a general description of the technological domain is provided.
2. Application Areas. As per Figure 1, relationships with the most relevant AAs are reported in this section, with information on how and why each AA is related to the TD.
3. Evolutionary scenarios. In this section, the history and future evolution of the TD is detailed in order to understand possible innovative solutions within the domain.

By providing all the TD factsheets, it was easier to subsequently focus on real-world applications of such technologies, which were described with the AA factsheet. The structure of the AA factsheets is described in the following section.

2.2. Application Areas

The factsheets describing AAs were structured as follows:

1. Description. As for TDs, the Description section is used to provide general information on the AA, without focusing on specific applications.
2. Examples. The Example section reports specific real-world solutions, especially when relevant to disabled people.
3. Enabling technological domains. This section reports the most significant relationships between the AA and the identified TDs (see Figure 1). Since a proper description of each TD-AA relationship is provided within TD factsheets, this AA factsheet's section only reports the enabling TDs.
4. Impact on advanced mobility solutions (and mobility gaps). This is the most significant section of the AA factsheet, since it reports all the identified real-world mobility solutions within the AA which have a positive impact on human needs, especially when responding to disabled people's needs, and filling mobility gaps.
5. Relevant European regulatory frameworks and standards. In this section, we refer to the most significant frameworks and standard related to the described AA, with frequent references to the Rolling Plan for ICT Standardisation[16].
6. Relevant cybersecurity and privacy issues. This section reports major cybersecurity threats related to the AA.

All the TD and AA factsheets are reported in the following sections, starting from the TD factsheets.

[16] https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/rolling-plan-2020

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3. ICT trends for inclusive urban mobility

3.1. Internet of Things (IoT)

Internet of Things (IoT)	
Description	The term 'Internet of Things' (IoT) was first introduced by Kevin Ashton, and refers to uniquely identifiable objects ("things", which can be anything from planes, cars, buildings, to industries and living beings, or even parts of them) and their virtual representations in a structure similar to that of the Internet. However, a "standard" definition of the Internet of Things (IoT) has not been agreed upon[17]. Instead, multiple definitions have been used, each one focusing on one of the two fundamental aspects which characterize IoT: the "Internet" /"network" and the "things" components[18]. Initially, the focus was directed to RFID tags attached to "things" and connected to a network[19]; later, more attention was given to the interconnection of mobile devices, as sensors and actuators qualified as "things".[20] Among the various definitions, IoT has been described as i) things having identities and connected via intelligent interfaces[21], ii) an umbrella keyword related to the pervasiveness of the Internet in the physical world through identifiable sensors and actuators[22], iii) a loosely coupled, decentralized system of cooperating Smart Objects (SOs)[23], iv) a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols[24], and v) a group of infrastructures with interconnected objects, providing means for accessing the data they generate, managing them, and performing data mining.[25]

[17] https://www.tandfonline.com/doi/full/10.1080/00207543.2017.1402140
[18] https://www.sciencedirect.com/science/article/abs/pii/S1389128610001568
[19] https://www.tandfonline.com/doi/full/10.1080/00207543.2017.1402140#
[20] https://ieeexplore.ieee.org/abstract/document/6714496
[21] https://www.sciencedirect.com/science/article/pii/S1319157816300799
[22] https://www.sciencedirect.com/science/article/abs/pii/S1570870512000674
[23] https://link.springer.com/book/10.1007%2F978-3-319-00491-4
[24] https://www.tandfonline.com/doi/full/10.1080/00207543.2017.1402140#
[25] https://ieeexplore.ieee.org/abstract/document/7373221

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	An IoT network usually includes four layers:[26] 1. A *sensing layer* that results from the integration of different types of "things" such as RFID tags, sensors, and actuators; 2. A *networking layer* allowing information to flow through a wired or wireless network; 3. A *service layer* that integrates services and applications via middleware; 4. An *interface layer* to allow for interaction between the user and the system, and the display of information. According to Lee and Lee[27] the most relevant five IoT technologies are: Radio-frequency identification (RFID), for wirelessly identifying, tracking, and transmitting information within up to 100 metres distances; Wireless Sensor Networks (WSN), which are networks of sensors that track the status of different devices (e.g. location, movements, temperature etc.); middleware, that is, service-oriented software allowing to communicate with a plethora of devices such as sensors, actuators, or RFID tags; cloud computing, a computing platform which allows on-demand access and sharing of computing resources (e.g. computers, networks, software, storage); IoT applications, which enable machine-to-machine (M2M) and human-to-machine (H2M) interaction. IoT can be also described as the next step in the evolution of the Internet.[28] It can be considered as the result of the convergence of M2M, big data, and cloud computing, with increasing integration of capabilities such as identification, tracking, monitoring, metering, automation, actuation, and payment.
Application areas	**Intelligent Vehicles**. IoT connected cars are an area of particular interest for investors, but also vehicles used in public transportation, such as buses and trains, are going to be transformed by the IoT. As an example, subway cars in New York City will be equipped with chargers, built-in Wi-Fi, and security cameras.

[26] https://www.tandfonline.com/doi/full/10.1080/00207543.2017.1402140#
[27] https://www.sciencedirect.com/science/article/pii/S0007681315000373
[28] https://onestore.nokia.com/asset/190140

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	The IoT is the main responsible for the success of connected cars. Connected cars can be embedded, in case they use a built-in antenna and chipset, or tethered, if they can connect to the driver's smartphone through dedicated hardware. Internet connectivity is crucial for vehicles' manufacturers, since it allows them to release software updates in real time. In addition, this allows to gather valuable data on the vehicle's performance, and the drivers' behaviour[29]. **Intelligent Transport Systems.** Intelligent Transport Systems are smart systems that can be built with IoT. For instance, IoT allows vehicles to communicate with one another, thus leading to ITS. IoT-based Intelligent Transport System (IoT-ITS) support the automation process of any kind of transportation ways, enhancing the means to transport, track, and deliver goods, and thus also customer experience.[30] By processing and storing sensor data, and providing computational capabilities through data analytics, IoT allows for effectively assisting and managing the Traffic system. The highly-populated metropolitan areas require IoT-ITS, since smart transportation can only be achieved by deploying millions of devices equipped with IoT technology. **Wayfinding Technologies.** IoT-enabled wayfinding allows for multiple benefits: avoiding rush hour traffic, locating free parking spots, locating the hospital entrance closest to one's appointment, etc. IoT makes it possible for the user to receive relevant context-related information. Experiential wayfinding requires accurate indoor maps and wayfinding software with an open architecture, capable to collect and process data from heterogeneous IoT devices.[31] **Pre-trip concierge and virtualization.** IoT can integrate data on points of interest, infrastructure, facility amenities, and potential obstacles, and provide such information to the final user en route, via crowdsourcing. Pre-trip planning/booking

[29] https://www.businessinsider.com/iot-connected-smart-cars?IR=T
[30] https://tinyurl.com/y9qdeac9
[31] https://www.jibestream.com/blog/how-the-internet-of-things-is-delivering-experiential-wayfinding

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	services can integrate the user mobility profile with accessibility needs for intended travel and planning. Virtualization, which help passengers "see" their routes on an app, can rely on IoT technologies to dynamically display artifacts during the virtual route simulation. **Safe intersection crossing.** IoT allows for safe intersection crossing by making pedestrians' connected mobile devices communicate with traffic signals, vehicles, and other infrastructure, thus receiving context-based information related to pedestrians and man-made artifacts, helping them cross an intersection safely.[32] **Intelligent environments and Ambient Intelligence.** Ambient intelligence (AmI), being an element of pervasive computing which make environments more sensitive, adaptive, autonomous, and personalized to human needs, leans on the presence of intelligence and decision-making capabilities in IoT environments, thus qualifying IoT a precondition for AmI to exist.[33]
Evolutionary scenarios	Even if the actual idea of connected devices had been around at least since the 70s (and was described as "embedded internet" or "pervasive computing"), the term "Internet of Things" was coined by Kevin Ashton in 1999, to attract his senior management's attention to the RFID (a new technology at the time) by leveraging the growing popularity of the internet.[34] However, the term "Internet of Things" started to get widespread attention in the summer of 2010, when the Chinese government announced it would make the IoT a strategic priority in their Five-Year-Plan. In 2011, Gartner included the IoT in their list of "hype-cycle for emerging technologies". The next year, IoT was the theme for the biggest European Internet conference LeWeb, and popular tech-focused magazines such as Forbes and Wired started using the term. In 2013, IoT market was expected to reach $8.9 trillion by 2020.

[32] https://www.its.dot.gov/research_areas/attri/safe_crossing.htm
[33] https://www.springer.com/gp/book/9783030041724
[34] https://iot-analytics.com/internet-of-things-definition/

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	In the future, it has been foreseen that there will be a shift from consumer-based IoT to industrial IoT (IIoT). In addition, regulations will be issued as more and more governments recognize the security threats posed by consumer IoT devices. IoT will also be employed for automated machine learning (auto-ML), and will provide suggestions to technicians about their work environment, in addition to reports. In the more distant future, IoT will evolve to adapt to the increasing growth of the computing power at the edge of the networks. Decentralization will allow IoT to permeate into governance, financial transactions, health and other disciplines. Due to the increasing integration challenges, a unified IoT framework will be needed. Smart cities will become mainstream, and thus also IoT technologies used in such context. Finally, the trust issue which comes with welcoming dozens of smart devices in our homes, will be most likely tackled by employing the blockchain as an effective backend.

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3.2. Virtual Reality (VR)

Virtual Reality (VR)	
Description	Virtual Reality (VR) is a computer-generated three-dimensional representation of reality that allows a real-time human machine interaction. It enables users to experience a virtual 360-degree world, view it from all sides, move around in it and interact with it.[35] The user no longer perceives his real environment.[36] In some cases the user can even gain the impression that the digital world is the real world. The term Immersive Virtual Reality (IVR) describes a digital twin that is strongly adapted to the real world, which the user believes to be real.[37] VR has both entertainment and serious uses. Four technologies are crucial for VR:[38] 1. The visual (and aural and haptic) displays that immerse the user in the virtual world and that block out contradictory sensory impressions from the real world; 2. The graphics rendering system that generates the ever-changing images; 3. The tracking system that continually reports the position and orientation of the user's head and limbs; 4. The database construction and maintenance system for building and maintaining detailed and realistic models of the virtual world.
Application areas	**Gamification:** Gamification is adding gaming component into nongame environments.[39] With a Gamification approach in VR a user is enabled to explore new territories and areas and to acquire and apply new skills. Gamification boosts competition between players.[40] This competition can also raise the motivation of people.[41] With this characteristics

35 https://magic-holo.com/en/difference-between-virtual-reality-vr-and-augmented-reality-ar/
36 https://magic-holo.com/unterschied-virtual-reality-vr-und-augmented-reality-ar/
37 https://www.vrs.org.uk/virtual-reality/what-is-virtual-reality.html
38 http://sbabu.people.clemson.edu/WhatsReal.pdf

39 https://www.sciencedirect.com/topics/computer-science/gamification
40 https://tinyurl.com/y7apqhrb
41 https://www.sciencedirect.com/topics/computer-science/gamification

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	of VR it is possible to try out and play through new ideas and concepts or to analyse the interaction of humans. One example is a simulation study involving the Game Theory and concerning about decision-making. One example of a VR Gamification approach in transport sector will be safety training for passengers and road users. Especially people with reduced mobility can profit from this technology. For example, with VR and a Gamification approach, the process of becoming familiar with a new MS can be facilitated in a playful way. One example could be the training with virtual stops and stations as a preparation of in-door-navigation for trip planning. Additionally, VR and Gamification can be useful for planners and architects. By means of VR, they are able to perceive from a MS from the perspective of disabled people and to optimise MS from their perspective. If Gamification is added, this can contribute to increased motivation and thus allow new ways of thinking.
Evolutionary scenarios	The term "virtual" has been used in the computer sense of "not physically existing but made to appear by software" since 1959.[42] In 1989 the term virtual reality was coined by Jaron Lanier, a manufacturer of gloves, goggles, and other VR products.[43] The first approaches of VR systems were:[44] • Morton Heilig (1956) developed an apparatus called Sensorama, which was to become the "Cinema of the Future"; • In 1965, Harvard student Ivan Sutherland developed the concept of the "Ultimate Display", which described the basis for today's VR technology; • In 1968, Sutherland and Bob Sproull invented the first VR display, that was adapted to the user's head and was not connected to a camera but to a computer.45 It was a heavy device that was suspended from the ceiling, hence it was called Sword of Damocles;45

[42] https://www.etymonline.com/word/virtual#etymonline_v_7821
[43] https://academic.oup.com/joc/article-abstract/42/4/73/4210117?redirectedFrom=PDF
[44] http://sbabu.people.clemson.edu/WhatsReal.pdf
[45] https://www.vrs.org.uk/virtual-reality/history.html

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- Nintendo launched the "Virtual Boy" in 1995;
- In 2012, the startup Oculus VR heralded a new era in virtual reality development with the introduction of the Oculus Rift.

1994	1999
Swimming due to lags	Still a major problem for HDMs and caves, not screens
Displays: narrow field of view or poor resolution or high cost	HMD resolution of 460 by 680 real pixels now affordable Projector resolution 1280 by 1024
Limited model complexity	Rendering limited mostly by cost
Poor registration in augmented reality	Augmented reality dynamic registration still hard; 1 ms = 1 mm error
Tethered ranging	Wide-area tracking available; wireless not yet in use
Bad ergonomics	Ergonomics getting there
Tedious model building	Model engineering a major task

Progress in VR technologies

One of the limiting factors of VR is a low bandwidth, but it is foreseeable that in the future there will be a development of high-performant internet connections like 5G. This development will bring new possibilities for VR.[46]

In addition, the development of lighter, smaller and more manageable headsets will soon progress, making the use of VR more straightforward.

[46] https://tinyurl.com/yb5s7s5c

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3.3. Augmented Reality (AR) and Mixed Reality (MR)

<table>
<tr><th colspan="2">Augmented Reality (AR) and Mixed Reality (MR)</th></tr>
<tr><td>Description</td><td>
AR is a technology that overlays digital information on the real world. Rather than provide a fully immersive virtual experience, augmented reality enhances the real-world with images, text, and other virtual information via devices such as heads-up displays, smartphones, tablets, smart lenses, and AR glasses.[47]

The figure shows a simplified representation of a virtual continuum.[48]

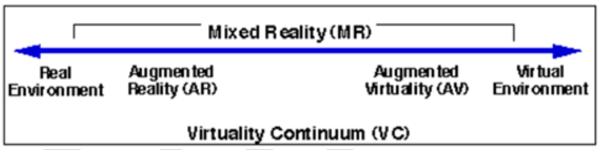

Figure 2: Simplified representation of a "Virtual Continuum"

MR (mixed or also merged Reality) is seen as a subclass of VR related technologies that involve the merging of real and virtual worlds.[49] It is an overlay of digital and real content.[50]

The picture shows the difference of VR, MR and AR.[51]

Figure 3: Differences between VR, MR and AR

VR creates a whole new, digital world where the user interacts with objects.[52] With AR, information and holograms are projected in our immediate environment, using a device like a smartphone
</td></tr>
</table>

47 https://tinyurl.com/ydaojx4q
48 https://tinyurl.com/yae2br6a
49 https://tinyurl.com/w5jufmj
50 https://www.foundry.com/insights/vr-ar-mr/vr-mr-ar-confused
51 https://www.actimage.ch/unternehmen/actimage-news/actimage-mixed-reality
52 https://magic-holo.com/unterschied-virtual-reality-vr-und-augmented-reality-ar/

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	display.[53] MR also merges the real world and digital elements and a user can manipulate both physical and virtual objects.[54] One of the main differences of MR and AR is that MR gives you a more real feeling by the use of 360-degree headsets.
Application areas	**Wayfinding technologies (WT).** AR can be used to improve orientation and enhance reality with additional information. For example, applications for indoor navigation can be used to make it easy for visitors to find their destinations with a super-imposed pathway solution through the phone's camera. The technology has a great potential for smart buildings, retail, education, and any public use facilities. In addition to visual cues, AR can also provide audible feedback.[55] **Safe intersection crossing.** AR can be used to improve the interaction between vehicles and other (vulnerable) road users like pedestrians, cyclists etc. in combination with connectivity technologies. AR could display in a vehicle the presence and location of a person who is physically not yet in sight. The advanced knowledge about the presence of these road users on the roadway is especially important when their presence is not expected or when these users are out of range of other sensor systems.[56] **Gamification.** With AR and a Gamification approach, the process of becoming familiar with a new MS can be facilitated in a playful way. One example for Gamification in combination with AR or MR could be the exploring of new vehicles or concepts by passengers as part of a research study as well as safety trainings.
Evolutionary scenarios	There have been early visions and realisations of "augmented reality" since the 1950s, like the Sensorama from Morton Heilig (1957) or the head-mounted display as a kind of window into a virtual world from Ivan Sutherland (1968). These inventions were prototypes and far from mass use.

53 https://www.actimage.ch/unternehmen/actimage-news/actimage-mixed-reality
54 https://www.intel.de/content/www/de/de/tech-tips-and-tricks/virtual-reality-vs-augmented-reality.html
55 https://www.22miles.com/digital-signage-solutions/augmented-reality-wayfinding/
56 http://safersim.nads-sc.uiowa.edu/final_reports/UW%201%20Y1%20report.pdf

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	With the increasing capabilities of digital technologies, there were many breakthroughs in augmented reality such as: • Bruce Thomas developing an outdoor mobile AR game called ARQuake in 2000; • ARToolkit (a design tool) being made available in Adobe Flash in 2009; • Google announcing its open beta of Google Glass (a project with mixed successes) in 2013; • Microsoft announcing augmented reality support and their augmented reality headset HoloLens in 2015. As the development of software and micro-technology rapidly develops, a huge variety of applications in combination with smart phones, head-up displays, glasses etc. is available.[57] One of the limiting factors of AR is a low bandwidth, especially while using mobile data, but it is foreseeable that in the future there will be a development of high-performant internet connections like 5G. This development will bring new possibilities for AR.[58] Furthermore, the development of bigger smartphone displays will progress, making the use of AR even under difficult lighting conditions and for people with impaired vision easier.

[57] https://www.interaction-design.org/literature/article/augmented-reality-the-past-the-present-and-the-future
[58] https://tinyurl.com/y88oh66r

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3.4. AI – Rule-based Systems

AI – Rule-based Systems	
Description	AI Rule-based systems (also known as production systems or expert systems) are a form of artificial intelligence, which mimics human reasoning for problem solving. Such rule-based systems encode a human expert's knowledge on how to act under certain conditions into an automated system. This knowledge is expressed in a serios of IF-THEN statements. The so-called termination criterion is determines when to stop processing since a solution is either found or that none exists. This prevents infinite loops.[59]
Application areas	**Intelligent Vehicles**. Autonomous vehicles are designed to include embedded forms of artificial intelligence to make complex risk mitigation decisions. Since AI processes are fundamentally different to human decision-making processes, we must uestion and mediate these decisions, and what they might mean in relation to others. Significant challenges remain regarding the conceptualisation of AI decisions, and the extent to which the various sourounding actors understand them. **Virtual Assistant.** Intelligent virtual or personal assistants are AI-driven programs that can process natural language and complete tasks based on spoken commands. They are designed to imitate human interaction in order to carry out particular tasks. These range from basic ommand and control systems ("lights on"/"lights off"), and more sophisticated platforms that can contextualise basic conversations. These type of systems are increasingly being proposed and developed due to their potential for emulating the problem-solving abilities of a customer service agent.[60] AI virtual assistants may restore aspects of independence simply by helping people with disabilities perform tasks they would otherwise need the help of other people for. AI-powered voice assistants can break

[59] https://link.springer.com/chapter/10.1007/978-3-642-21004-4_7
[60] https://www.businesswire.com/news/home/20180723005506/en/Global-Intelligent-Virtual-Assistant-Market-2018-2023-Market

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	down barriers and be especially useful for those with visual impairments.[61] **Intelligent Transport Systems.** Several AI-based techniques are being deployed in different areas of the transportation environment, suggesting the potential of Intelligent Transportation Systems (ITS). In particular: (i) Vehicle control, (ii) Traffic control and prediction, and (iii) Road safety and accident prediction. The combination of different AI techniques is promising, especially to manage and analyse the massive amount of data generated and handled by transportation systems.[62] **Wayfinding Technologies.** By capturing a travellers position, navigational intent and making use of contextual information from systems, state of network, and other travellers, an integrated wayfinding system can shape a journey. The data collection can be made through social, mobile, cloud and analytics technologies, and can be potentially used in conjunction with transport information systems and integrated collected traveller data (including specific requirements regarding audio, visual and mobility challenges).[63] **Pre-trip concierge and virtualization.** Pre-Trip Concierge & Virtualization systems making use of AI-based logic can provide pre-trip planning and en-route travel information to travellers with disabilities, family members and caregivers, including creating a virtual environment for users to familiarise themselves with their travel before the trip. This technology also offers the ability to peer transportation services based on user needs.[64]
Evolutionary scenarios	Artificial intelligence and decision theory take their roots in the research on systematic methods for problem solving and decision making that made significant breakthrough in the forties. Notably, in 1943 the logician Emil Post proved that mathematical or logical systems could be written as some sort of production system, building on the idea that such a system can be seen as a set of rules

[61] https://digitalhumans.com/blog/what-are-virtual-assistants/
[62] https://tinyurl.com/y8nuvsbt
[63] https://tinyurl.com/ybzabq4g
[64] https://www.its.dot.gov/presentations/2017/ATTRI_Webinar_nov2017s.pdf

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	specifying how a string of symbols can be turned into another set of symbols. In 1948, Turing writes an attempt to model the brain, and sets out some preliminary ideas on artificial neural networks. Two years later, he publishes and discusses the concept of a thinking machine and emphasizes that building a mind requires sufficient knowledge about the world to represent its states and a set of rules to model a behaviour (which cannot be as complex as human behaviour). This is perhaps one of the earliest leads of rule-based systems. A few years later, the term artificial intelligence was officially coined. Thus, the works of Alan Turing and Emil Post set out the first ideas of decision-making systems as we know them today.[65] There's virtually today no major industry bigger than AI — more specifically, "narrow AI," which performs objective functions using data-trained models and often falls into the categories of deep learning or machine learning — hasn't already affected. That's especially true in the past few years, as data collection and analysis has ramped up considerably thanks to robust IoT connectivity, the proliferation of connected devices and ever-speedier computer processing. Some sectors are at the start of their AI journey, others are veteran travellers. Both have a long way to go. Regardless, the impact artificial intelligence is having on our present day lives is hard to ignore, namely regarding transportation. Although it could take a decade or more to perfect them, autonomous cars will one day ferry us from place to place. With companies like Google, Apple, Microsoft and Amazon spending billions to create those products and services, universities making AI a more prominent part of their respective curricula, we surely can expect very soon new developments.[66]

65 https://tel.archives-ouvertes.fr/tel-01726252/document
66 https://builtin.com/artificial-intelligence/artificial-intelligence-future

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3.5. AI – Automated Speech Recognition (ASR) and Natural Language Processing (NLP)

AI - Automated Speech Recognition (ASR) and Natural Language Processing (NLP)	
Description	ASR and NLP are particular characteristics of human-machine-communication.[67] This provides the basis for the creation of voice bots.[68] **Automated speech recognition (ASR)** is a technology that enables users of information systems to pronounce the commands verbally instead of typing them into a computer or application.[69] ASR uses computer hardware and software to understand and to process human voice.[70] ASR provides the technology that is required for converting the speech signal into the corresponding words by using algorithms.[71] One challenge of ASR research and development is the construction of computers or other machines that are capable of imitating and understanding the natural ability of human communication.[72] **Natural Language Processing (NLP)** is a computer-based approach to create natural human communication.[73] NLP describes systems that can understand language.[74] NLP can be used e.g. to automate support or analyse feedback. Other examples of the everyday usage of NLP are:[75] • Spell check • Autocomplete • Voice text messaging • Spam filters • Related keywords on search engines • Siri, Alexa, or Google Assistant

[67] https://opus4.kobv.de/opus4-th-wildau/frontdoor/index/index/year/2018/docId/1034
[68] https://www.it-finanzmagazin.de/voice-bots-support-nlp-asr-105190/
[69] https://searchmobilecomputing.techtarget.com/definition/automated-speech-recognition
[70] https://tinyurl.com/yckcku8q
[71] https://tinyurl.com/y7byte5t
[72] https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1457612
[73] https://tinyurl.com/y9u2dpgy
[74] https://tinyurl.com/yckcku8q
[75] https://www.wonderflow.co/blog/natural-language-processing-examples

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	One challenge of NLP as well as of ASR is to create naturally occurring texts and to understand human talk. Since humans speak with abbreviations, pauses and emphasises, it takes extensive computer analysis to create accurate outputs.[76] Since no physical movement is necessary to use the technology of ASR and NLP, both can be useful for people with physical disabilities.[77] Also, people with visually impaired people can be supported.[78] These technologies can be used for interaction between humans and machines, but also can take over the task of speaking or hearing instead of a human being.[77] In this manner, ASR and NLP can assist people with reduced abilities in hearing and talking.
Application areas	**Intelligent vehicles.** One implementation for NLP is an In-Car Voice in driverless vehicles. The passengers of a vehicle can talk to the system to start navigation to a specific destination or to alter the route.[79] Another implementation is using NLP to call a virtual valet driver. Passengers are enabled to instruct their vehicle parked in another place to come pick them up. When a vehicle is instructed to be ready at a certain time, the vehicle can monitor local traffic conditions so that it will arrive on time. **Wayfinding technologies (WT).** ASR can be used for wayfinding applications via a voice-user-interface. The app can directly respond to spoken commands and questions. Customers can request information such as maps, paths and directories on command. This can be especially useful for disabled customers and for reducing germs on hospital touchscreen displays.[80] One everyday use of NLP in wayfinding technologies is the voice-based navigation-oriented human-machine interface of routing map apps.[81] Apps like Google Maps or TomTom give instructions about where to walk or drive and which route to take.
Evolutionary scenarios	NLP was first used as a speech recognition feature in text editors in order to simplify the writing effort.

[76] https://tinyurl.com/yckcku8q
[77] https://tinyurl.com/ybx4w6xb
[78] https://link.springer.com/chapter/10.1007/11766247_26
[79] https://tinyurl.com/ydeu84ha
[80] https://www.digitalsignagetoday.com/news/visix-delivers-voice-activated-wayfinding/
[81] https://www.sygic.com/what-is/voice-guided-navigation

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	One of the first fields of application was in clinics and hospitals to simplify the writing of medical reports. Meanwhile, NLP applications can be found in users' devices for personal applications (e.g. Alexa, Cortana, Google Assistant and Siri) as well as in form of home assistant/entertainment applications (e.g. Amazon Echo, Apple Home Pod, Google Assistant).[82] One possible future trend is the more detailed and connected development of technical and specialised languages, e.g. medical termini.[83] This enables an advanced and professionalised approach in many fields.

[82] https://tinyurl.com/ydeu84ha
[83] https://www.sciencedirect.com/science/article/pii/S1386505698001324

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3.6. AI - Machine Learning (ML)

AI - Machine Learning (ML)	
Description	ML is a method of data analysis that automates analytical model building. A sub-set of AI, ML main goal is to make machines autonomously learn from data, identify patterns, and make decisions with minimal human intervention[84]. Machines which use ML can continuously improve their performance and decision-making accuracy on a specific task through trained algorithms and neural network models. ML use statistics to find patterns in data, in massive amounts and of various types, such as numbers, words, images, sounds, etc. Every kind of data that can be translated digitally can be used by a machine-learning algorithm. ML is behind many of the most popular web services used today, such as Netflix, YouTube, Spotify, Google, Baidu, Facebook, Twitter, etc. All these services leverage the user's actions to suggest further content the user might want next. Within ML, Deep Learning is a technique that boosts the ability of ML algorithms in identifying patterns, making them capable of detecting even the less significant patterns. To do so, Deep Learning employs multiple layers of single computational nodes which collaborate to deliver a solution in the form of a prediction. Neural networks draw inspiration from the functioning of the human brain, connecting nodes (called "neurons") to form a network that resembles the structure of a brain. ML can be supervised, unsupervised, reinforcement ML. The most used kind of ML is the supervised one, where data are manually labelled to instruct the machine about which patterns are to be considered. Unsupervised ML does not require labels, since the machine can identify patterns by itself. Finally, there

[84] https://www.sas.com/en_us/insights/analytics/machine-learning.html

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	is reinforcement ML, where the machine learns by trial and error to reach a predefined objective.[85]
Application areas	**Intelligent vehicles.** Intelligent and autonomous vehicles very closely associated with emerging technologies such as machine learning, artificial intelligence, local computing that provide the essentials tools for these kinds of vehicles. Nowadays, vehicles are equipped with a lot of sensors, actuators, and controllers. These devices are managed by many software which also includes machine learning. One of the main tasks of the machine learning algorithms applied to the intelligent vehicles sector is continuous monitoring of the surrounding environment and the prediction of possible changes to those surroundings.[86] **Virtual assistant**. Virtual assistants let us interact using natural spoken language. Voice interfaces drastically simplify our interaction with technology. The technologies that power virtual assistants require massive amounts of data, which feeds artificial intelligence (AI) platforms, including machine learning, natural language processing and speech recognition platforms.[87] These technologies are necessary to cope with the breadth and ambiguity of language. Then, there are virtual assistants based on machine learning – a group of AI algorithms that learn their behaviour from data instead of being explicitly programmed. This allows assistants to learn how people speak and be able to generalize to deal with new speakers or requests. **Intelligent transport systems (ITS).** ITS encompasses a broad range of wireless and wire line communication-based information and electronics technologies and is one of the most promising methods in dealing with the traffic problems. This application requires a large amount of data: some information is obtained using traditional traffic information query operations, analysis and management of traffic information while other data require machine learning techniques which, using mathematical algorithms, they are able to extract the meaning from big data.

[85] https://tinyurl.com/y7ezrdpo
[86] https://tinyurl.com/ybucx77t
[87] https://searchcustomerexperience.techtarget.com/definition/virtual-assistant-AI-assistant

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	Safe intersection crossing. Walkways are a double-edged sword. Pedestrians are often overly confident, confident that they can cross the road. Cars, depending on the place and time of day, do not always slow down as they should. The crossroads and walkways we are used to were regulated when there was a different type of city and interaction. The new smart intersections use machine learning to make intersections safer. Smart crossings are actually the combination of an intelligent surface, machine learning software and a sensor system. This surface shows different configurations depending on the situation. For example, a pedestrian crossing appears only when it is safe for pedestrian crossing.[88] **Facial recognition software.** Facial recognition is a biometric software application capable of uniquely identifying or verifying a person. The facial recognition process begins with an application for the camera which is able to use computer vision and a deep neural network in order to find a prospective face within its stream. Facial recognition techniques are quickly evolving with new approaches such as 3D modelling. This application might become a benefit to disabled people; for example, using this technology, is it possible to scan approaching people and alert the user when someone they know is approaching.
Evolutionary scenarios	In the 1950s, a sequence of significant events made machines capable of learning. The first of these remarkable events was the development of the "Turing Test" to determine if a machine is actually capable of exhibiting an intelligent behaviour undistinguishable from that of a human being. In 1952, an application for an IBM computer was made capable of not only learn the game of checkers, but also improve the more it played. In 1957, the first neural network for computers was designed. Then, in the 1960s, Bayesian methods for probabilistic interference were introduced. In 1986, Deep Learning techniques were designed, based on artificial neural networks.

[88] https://blog.ferrovial.com/en/2019/09/welcome-smart-roads/

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	In the 1990s, ML started to analyse large quantities of data and learn from the results, shifting from a knowledge-driven to a data-driven approach. Then, in the 2000s, Kernel methods such as the Support Vector Clustering were developed. Hardware advancements in the 2000s made it possible to use GPUs in embedded systems and speed up training, leading to sophisticated deep neural networks which demonstrated the feasibility of deep learning itself. Today, ML is making the demand for GPUs to continuously grow, as more and more companies seek to derive precious information from their data. Latency is, nowadays, the main obstacle hindering ML future evolution. Cloud data storing, widely employed today by most companies, has its downsides, among them the time needed for data to travel to a central data centre, which could be located thousands of miles away, increasing latency. Edge machine learning has the objective of running ML algorithms locally, on dedicated hardware, thus enabling real-time operations and reducing overall power consumption. ML software, algorithms, and hardware are becoming more and more efficient to allow for edge machine learning. Also, unsupervised machine learning is becoming increasingly popular, considering that it has been estimated that, on an average AI project, 80% of the project time is used aggregating, cleaning, labelling, and augmenting data. Dedicated accelerators are being developed to speed up and optimize the workload involved in machine learning projects, to improve edge devices' performance. ML has a wide potential also in blockchain technology, by helping investors to make trending decisions; self-driving cars, from automatic braking, cruise, steering and acceleration control, to a fully autonomous car in every aspect, capable of driving safely in all possible scenarios; and facial recognition, by providing the right data on the face fed to the ML machine, being it extracted from social media posts, videos, or photographs.[89]

[89] https://www.imagimob.com/blog/the-past-present-and-future-of-edge-machine-learning

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3.7. Big Data Analytics

Big Data Analytics	
Description	Before defining Big Data Analytics, it is necessary to understand the meaning of Big Data. Big Data refers to data sets that cannot be easily handled by traditional relational databases because of their size or type, meaning that relational databases cannot capture, manage, or process big data with low latency. This also means that, for data to qualify as big data, it must have either one or more of the following three characteristics: 1. high volume; 2. high velocity; 3. high variety. Among the '3Vs', the volume is the most frequently associated with Big Data, but is also the most highly variable and least functional, considering that defining a volume as *large* depends on technology advancements, sector, and organization. Velocity refers to the frequency at which data is created, analysed, and stored.[90] Big data can be structured, semi-structured and unstructured, can originate from different sources, and have different sizes, from terabytes to zettabytes. The driving forces behind the growing data complexity and variety of data sources are AI, mobile, social, and IoT. Much of the most common data we are faced with on an everyday basis are currently generated in real time and at a very large scale. Big data analytics is defined as the use of advanced analytic techniques against big data[91] to derive critical information such as customer preferences, hidden data patterns and correlations, and market trends.[92] Thanks to Big Data Analytics, analysts, researchers, and business users can make better and faster decisions by leveraging previously inaccessible and/or unusable data. Organizations are increasingly aware of the importance of running analytics applications to extract value from data moving through the enterprise in different forms and silos.

[90] https://tinyurl.com/y9zvw8xu
[91] https://www.ibm.com/analytics/hadoop/big-data-analytics
[92] https://www.techfunnel.com/information-technology/big-data-analytics-guide/

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	Big Data Analytics is valuable to businesses in the form of data mining, text analytics, natural language processing, machine learning, statistics and predictive analytics, techniques which are used to gain new insights from data sources either independently or in combination with already existing enterprise data. Organizations can derive value in terms of: • New growth opportunities • Cheaper data storage • Increased operational efficiency • Fast and real-time decision-making via in-memory analytics • Enhanced go-to-market initiatives • Improved customer service • Increased competitive edge • Targeted launch of new products and services in line with customer needs Nowadays, cloud technologies are behind advanced big data analytics, allowing for the deployment of highly specialized solutions.
Application areas	**Virtual Assistant**. VAs are a distinct kind of personal assistant also thanks to their heavy reliance on new technology, such as Big Data Analytics, that can support VAs in providing to the masses the same function that is currently provided to the wealthy individuals by personal assistants.[93] Popular VAs such as Alexa and Siri are still quite limited in conversing using natural language, but, as proven by Microsoft's Project Mélange, Big Data Analytics are currently being employed as a new tactic to bridge the gap.[94] **Intelligent Transport Systems.** From their analysis on Big Data, Oussous et al.[95] stated that Big Data are used in ITS through two different processing paths: i) real-time extraction of valuable information from the processing of streaming data and ii) the analysis of historical data, aggregated on data warehouses with the objective of creating business intelligence and supporting decision making.[96] Big Data Analytics will also play a crucial role in future Cooperative ITS (C-

[93] https://www.smartdatacollective.com/how-virtual-assistants-use-data-analytics-to-save-clients-money/
[94] https://futurism.com/microsoft-is-working-to-make-virtual-assistants-more-multilingual-and-more-human
[95] https://www.sciencedirect.com/science/article/pii/S1319157817300034
[96] https://tinyurl.com/yb7l8ve4

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	ITS), as stated by Javed et al.[97] Big Data Analytics can be leveraged to provide citizens with access to faster and safer travels. City authorities can gather data and valuable insights on traffic flow, allowing them to efficiently manage urban transit. Big Data Analytics can support multiple components of an Intelligent Transportation Network (ITN): the transportation management system, the vehicle control system, as well as the electronic timetable and route information system.[98] **Social media.** Social media analytics are one of the better examples of how Big Data Analytics shapes our lives. Social networking platforms collect user information that is leveraged by marketers to understand customer behaviour, identify user groups, and engage them. Social media offer various metrics such as likes, post reactions, post replies, that help businesses shed light on the interaction between their customer base and their content.[99]
Evolutionary scenarios	In the mid-nineties, the concept of Big Data was first introduced to refer to increasing volumes of data, but it was only in the early 2000s that the term was expanded to include variety and velocity, thus identifying the three dimensions of big data: volume (amount of collected data), variety (types of collected data), and velocity (speed of data processing). These three dimensions came to be known as the 3Vs, as Gartner popularized the concept in the 2000s. In 2006, the Hadoop framework made it possible to approach Big Data more easily, since the Apache open-source, distributed framework allowed organizations to run complex big data applications on a clustered platform made from commodity hardware. Nowadays, Big Data Analytics is largely driven by automation frameworks.[100] The current trends in Big Data Analytics include: • IoT-related analytics, thanks also to the increasing adoption of digital twins, that is, digital replicas of physical objects, systems, and people. Such replicas will create new

97 https://www.sciencedirect.com/science/article/abs/pii/S221420961830192X
98 https://tinyurl.com/y6vkeccy
99 https://locowise.com/blog/what-is-big-data-analytics-on-social-media
100 https://www.techfunnel.com/information-technology/big-data-analytics-guide/

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	business opportunities which can be leveraged with advanced data platform and analytics. • Augmented analytics, powered by the deployment of AI and ML technologies applied to augmented data streams. • Deriving value from dark data, meaning that organizations will be more and more capable of untapping the potential – and monetize – the routine business information collected, processed, and recorded for compliance purposes. • Cold cloud storage, which is allowing to optimize cloud systems by reducing storage cost for historic and unused data. • DataOps, resulting from the employment of Agile Methodologies and DevOps in the Big Data Analytics lifecycle, providing automated mechanisms for testing and delivery.

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3.8. Robotics and Automation

Robotics and Automation	
Description	Automation and robotics engineering can be defined as the use of control systems and information technologies with the aim of reducing human work in the production of goods and services.[101] The term "Automation" refers to the use of software, machines or other IT technologies to perform a physical task or process that would otherwise be performed by a human worker. In this context it is possible to define many types of automation, ranging from completely mechanical to completely virtual, and from very simple to the amazing complex.[102] Instead, Robotics is a branch of interdisciplinary engineering that encompasses several disciplines for the design, construction, operation and use of robots. Through the interaction of robotics and automation it is possible to create programmable machines which are able to carry out a sequence of actions autonomously, or semi-autonomously. These robots interact with the physical world via audio, visual and tactile sensors and actuators. Robots are widely used as they are very adaptable and flexible in their applications. The main difference between robotics and automation is that robots are "intelligent" machines that can perform a variety of tasks with programming, whilst bespoke automation is a term that is used to indicate the sector that aims to automate a technological process. There are obviously overlapping functions between Robotics and Automation; to distinguish these categories it can be said that physical robots can be used in automation, but many robots are not created for automation.[103]

[101] https://www.myklassroom.com/Engineering-branches/85/ROBOTICS-AND-AUTOMATION(SS)
[102] https://medium.com/@kamila/automation-vs-robotics-whats-the-difference-97567efad2f1
[103] https://www.workfusion.com/blog/the-difference-between-robotics-and-automation/

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Application areas	**Intelligent vehicles.** In recent years, robotic vehicles, generally called intelligent vehicles, have become an important branch of robotics and automation**.** These vehicles not only offer "basic" services such as location and navigation but also provide support to the driver during normal vehicle operation. Thanks to the development of new technologies, there are many support systems nowadays that make vehicles partially autonomous; tests are already underway to fully automate the vehicles.[104] **Virtual Assistant**. A Robot Assistant can be defined as a robot that helps with day-to-day household tasks, making life easier. These types of robots will not just search the Internet and provide concrete information about the news or the weather, such as Siri and Google Now - they will probably help us make meaningful decisions about life and carry out daily physical activities.[105] **Pre-Trip concierge and virtualization (PCTV).** The concept of robotics and automation is combined with the Pre-Trip concierge and virtualization service; in fact, a person with a disability can book a trip and, depending on his request, an automated shuttle is sent that responds to his needs and can be equipped with an assistive robot that helps the customer to board the shuttle. **Assistive robots**. The development of assistive technology for the disabled and the elderly seems to be mature for new research and application.[106] An assistive robot is a device capable of detecting, processing sensory information in such a way as to assist older people and people with disabilities to carry out daily activities.[107] **Intelligent environments, Ambient intelligence.** Mobile robots can interact with devices distributed throughout the environment and to exchange information by making use of communication technologies. The main purpose of this information

[104] https://tinyurl.com/y98w8h5h
[105] https://www.businessinsider.com/personal-assistant-robots-are-the-future-2016-3?IR=T
[106] https://www.ieee-ras.org/rehabilitation-and-assistive-robotics
[107] https://tinyurl.com/ycgmqscv

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	exchange is to replace the physical interaction between robots and their environment. These devices are connected to each other via a network and, in combination with intelligent software, they are capable of creating an environment so intelligent that it can provide context-sensitive human services.[108] In this way, physical environments, using different types of sensors and actuators, become increasingly "intelligent" for the perception and manipulation of the environment.
Evolutionary scenarios	The first robot by name was built between 1937 and 1938 in; it was two metres tall and weighed 120 kilos. This robot had a humanoid appearance, could walk by voice command, talk and move its head and arms.[109] First sign of automation was introduced into the world at Ford Motor Company in 1948. Ford's then Vice President Delmar S. Harder proclaimed, "What we need is more automation!". This statement is considered as the first testimony of the word "automation" in industrial production. However, more than a decade passed before real industrial robots were marketed.[110] To see the first industrial robot one had to wait until 1961 when George Devol and Joseph Engelberger founded Unimation, Inc. and integrated the first industrial robot, the Unimate #001, into a General Motors assembly line in Trenton, New Jersey. The progress of robotics is closely linked to the emergence of cheap and powerful computers, which have given the opportunity to develop sophisticated software on board a robot. However, although the robotics sector developed quickly in the early 2000s, much of what was introduced to the market took years to develop or was not yet ready to be used in the real world. Since then, these technologies have finally become effective and affordable enough to reach the global market and are making their way into real world environments. Neil Gallant, Managing Director of Neutronic Technologies, said that the main change that has witnessed in recent years is the spread of

[108] https://link.springer.com/chapter/10.1007/978-0-387-93808-0_24
[109] https://futura-automation.com/2019/05/15/a-history-timeline-of-industrial-robotics/
[110] https://blog.voodoomfg.com/2018/04/24/a-brief-history-of-robotic-automation-in-factories/

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	the use of robots. The technology is basically unchanged, but connectivity has offered many advantages. The robotics scale is continuously growing and applications are created daily for all types of sectors and environments.[111] Some of the biggest developments in the automation world will come from the automobile industry; in fact self-driving cars are already being tested. The logical next step, in a context of aging populations, is the development of robots capable of providing assistance to older adults or assisting health workers and health workers. The new robots, taking advantage of new technologies, will be semi-intelligent and will both be safer and easier for humans to interact with. In the coming years, new technologies will increase the number of ways and places where robots can be used.

[111] https://futureofearth.online/the-future-of-robotics-and-automation/

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3.9. Web technologies - Infotainment

Web infotainment technologies	
Description	The term 'infotainment' is a composit of 'information' and 'entertainment'and is used to describe material that is intended to both inform and entertain in an effort to attract audiences (Stockwell, 2004). Infotainment applications include entertainment, information, communication, leisure, lifestyle, fashion, connectivity, and gaming activities. Instant access to communication and information is essential in such a fast-changing world. Therefore, high-performance apparel in this field normally relates to smartphone functionalities (e.g., touch pads and switches attached to the garment), display technologies, interaction technologies, communication interfaces, internet of things, and visual identity, to name a few.[112] In addition, artificial intelligence (AI), personal assistants (Amazon, Google, Microsoft and others), the cloud and 5G together with tighter integration of connectivity and functionality, are reshaping the design opportunities and increasing the appeal of infotainment systems and their integration into dynamic websites and device based systems.
Application areas	**Intelligent Transport Systems.** These systems integrate complex live system knowledge into distributed vehicles, devices and traffic systems. In cars they can be integrated directly into the manufacturers infotainment and navigation software to assist with navigation, travel advice and environmental information. In public transport, these systems may be used to give priority at traffic lights, optimize driving times and keep to timetables, and finally public transport authorities can use them to directly guide traffic, allow priority to emergency vehicles at traffic lights, and to reach victims faster.[113] **Pre-trip concierge and virtualization.** System virtualization is naturally suited to make use of

[112] https://www.sciencedirect.com/topics/engineering/infotainment
[113] https://be-mobile.com/solutions/traveler-information/cooperative-intelligent-transport-systems-c-its

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	infotainment systems. Existing systems as they are established in cars and public transport can provide tailored and up-to-date information to travellers. In cars, distribued systems can allow passengers to access personalised information about the next step of their journey making use of video screens and voice systems. This offers the ability to pair transportation services based on user needs.[114] **Safe intersection crossing**. Web infotainment technologies can be used ito promote safe intersection crossing, by providing: 1. Traffic light information. Informs road users about the time-to-red and time-to-green; 2. Dangerous situations- Warns drivers about roadworks, stationary vehicles, tail ends of traffic jams, etc. 3. Maximum speed- Displays the applicable speed limit on every stretch of road; 4. Speed advice- Makes sure that drivers can hit the brakes in time or start accelerating again; 5. Traffic lane information- Notifies drivers about which lanes are open and closed or how fast they can drive.[115] **Gamification.** The principles of gamification and digital engagement can be used to motivate users towards engaging with the a system. Some are explicit, clearly announced and demarked, encouraging users towards changes in behaviour by making use of playfull engagaments, others are implicit, part of a general system, encouraging systemic change and participation without clearly announcing its intentions. Infotainment systems are often making use of bioth types of gamification. **Social Media.** Social Media can be used to provide personalised information into already existing networks of digital imagery, video, audio and voice. It is designed to be disseminated through social interaction, using accessible and scalable publishing techniques, and offers the possibility to share social media content via digital signage channels. This for example can allow the sharing of external content

[114] https://www.sciencedirect.com/topics/engineering/infotainment
[115] https://www.swarco.com/stories/c-its-overview

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	to information screens, provide different feeds (weather, traffic, etc.). **Intelligent environments and Ambient Intelligence.** Information and communication technologies (ICT) and Internet of Things (IoT) innovations are vital for planning and maintaining smart transport infrastructure. A network of sensors, applications, devices, and services, can give cities the ability to improve traffic congestion, energy consumption, and motor safety. Smart cities can use this information to provide citizens with improved transportation services, such as efficient incident response, traffic optimization and re-routing. Internet of Vehicles (IoV) allows vehicles to exchange information, efficiency and most importantly safety with others as well as with infrastructures for safer navigation, traffic management, and pollution control.[116]
Evolutionary scenarios	The term infotainment was seemingly first used in librarianship.[117] The rise of infotainment stems from the fact that library users are no longer drawn by library collections or space alone. Infotainment is also anchored on the understanding that library services or products are not commonly consumed in isolation. Library users are social in their day-to-day lifestyles and many would like a social experience in the libraries. Library 3.0 refers to libraries using digital technologies to facilitate user-generated content and collaboration to promote and make library collections accessible. Library 3.0 enables libraries to create infotainment zones with television sets, piped music, video games, audio visual facilities, comedy shows, puppetry, instructional videos, slideshow screenshots, storytelling, 3-D animations and social meeting areas with comfortable furniture which have the potential to increase the number of visits to research and academic libraries. Library 3.0 tools can also facilitate the use of assistive technologies, such as the provision of magnifying lenses in reading areas, scanner readers for converting text to computer-generated audio, audio loops for users

[116] https://mobility.here.com/learn/smart-city-mobility/smart-city-car-connected-intelligent-integrated

[117] Kwanya, Tom, Christine Stilwell, and Peter Underwood. *Library 3.0: intelligent libraries and apomediation*. Elsevier, 2014

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	who need hearing aids, and adaptive workstations with height-adjustable furniture, which enhance the comfort of using the library materials or space.[118] By 2026, the connected vehicle market is predicted to generate $273 billion in revenue for OEMs. In-vehicle infotainment systems will be responsible for a fair share of those revenues too. By the same year, the IVI market is expected to grow to $46 billion – up from $15 billion in 2016. Such rapid market growth is fuelled by several factors: Increased customer demands for connectivity and better driving experience. Gradual commoditization of innovative technologies (AI/ML, IoT, 5G and V2X communication standard); the inevitable arrival of Level 3 and Level 4 autonomous vehicles, fostering OEMs to come up with new ways for entertaining passengers. Today, software already represents 10% of total vehicle content. By 2030, its share will increase to 30% as most OEMs take a course on "making vehicles as smart as mobile phones". Furthermore, over 125 million connected cars will be shipped to consumers worldwide between 2018 and 2022.[119]

118 https://www.sciencedirect.com/topics/social-sciences/infotainment
119 https://tinyurl.com/y7nnduxw

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3.10. Machine vision

Machine vision	
Description	Machine or Computer Vision is the use of a camera or multiple cameras to inspect and analyse objects automatically, with traditional use in manufacturing, but, machine vision systems can provide a lot more information about an object than simple absence/presence type sensors. Typical uses for machine vision include: quality assurance; robot/machine guidance; test and calibration; real-time process control; data collection; machine monitoring; and sorting/counting. Automated machine vision is well suited to repetitive inspection tasks, and provides consistent and reliable inspection results. This type of computer vision can turn data from roads and cities into usable information for third parties. By generating geospatial and social data based on media from roads or cities companies can sell data to third parties.[120]
Application areas	**Intelligent Vehicles**. Machine vision can protect drivers by monitoring attention or helmet usage through intelligent algorithms. New legislations make mobility companies responsible for their drivers and users security. By analysing video and image footage companies ensure and require security from their drivers.[121] **Intelligent Transport Systems.** Image and Video analysis solutions can keep track of roads, runways or railroads defect levels. Millions are spent every year to keep roads, railways and runways functional for every type of mobility. Intelligent computer vision solutions can significantly reduce required resources for road or railroad analysis and statistics.[122] **Pre-trip concierge and virtualization.** By collecting data through security cameras in busses or planes, companies gain valuable information about their customer's behaviour. Collecting statistics on

[120] https://tinyurl.com/y9jyaomb
[121] https://medium.com/cobblevision/computer-vision-in-the-mobility-industry-ef56263ca9c2
[122] https://medium.com/cobblevision/computer-vision-in-the-mobility-industry-ef56263ca9c2

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	customers in planes or busses requires personnel to conduct studies. With computer vision insights and information collected through automated and more effective means, can allow improved individualised services to specific needs and therefore can be better addressed specific needs of travellers for future trips.[123] **Safe intersection crossing.** In the context of traffic monitoring, important advances have been achieved in environment modelling, vehicle detection, tracking, and behaviour analysis.[124] A novel computer vision-based approach, Cross-Safe provides accurate and accessible guidance to the visually impaired as one crosses intersections, as part of a larger unified smart wearable device. Cross-Safe leverages state-of-the-art deep learning techniques for real-time pedestrian signal detection and recognition. Recognized signals are conveyed to visually impaired end user by vocal guidance, providing critical information for real-time intersection navigation.[125] **Intelligent Environments and Ambient Intelligence.** Computer vision technology allows space use to be monitored, represented, and quantified in ways not possible before, minimising errors that affect reliability and validity. The careful use of the technological potential of computer vision opens up new ways of identifying phenomena, becoming aware of systematic patterns and regularities and inquiring further into the degree of congruence between the physical organisation of layouts and patterns of space use.[126]
Evolutionary scenarios	In the late 1960s, computer vision began at universities which were pioneering artificial intelligence. It was meant to mimic the human visual system, as a stepping stone to endowing robots with intelligent behaviour.[127] Studies in the 1970s formed the early foundations for many of the computer vision algorithms that exist today. Toward the end of the 1990s, a significant change came

[123] https://medium.com/cobblevision/computer-vision-in-the-mobility-industry-ef56263ca9c
[124] https://medium.com/cobblevision/computer-vision-in-the-mobility-industry-ef56263ca9c
[125] https://medium.com/cobblevision/computer-vision-in-the-mobility-industry-ef56263ca9c
[126] https://medium.com/cobblevision/computer-vision-in-the-mobility-industry-ef56263ca9c
[127] Papert, Seymour (1966-07-01). "The Summer Vision Project". MIT AI Memos (1959 - 2004).

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	about with the increased interaction between the fields of computer graphics and computer vision. Recent work has seen the resurgence of feature-based methods, used in conjunction with machine learning techniques and complex optimization frameworks. The advancement of Deep Learning techniques has brought further life to the field of computer vision.[128] Machine vision technology has found its way into applications inside and outside of factory settings, riding a wave of progress in automation technology and growing into a sizable global industry. Quite a bit of future technology will depend on machine vision, and the market will grow accordingly. The main drivers of growth in the machine vision market are the need for quality inspection and automation inside factories, growing demand for AI and IoT integrated systems that depend on machine vision, increasing adoption of Industrial 4.0 technology that uses vision to improve the productivity of robotic automation, and government initiatives to support smart factories across the globe. Machine vision software will be one of the fastest growing segments between 2017 and 2023. The main reason for this is the expected increase in integration of AI into industrial machine vision software to enable deep learning in robotics technology. PC-based industrial machine vision products, the oldest form of industrial machine vision, will retain a large portion of machine vision market share because of their ease of use and processing power. The major identified trends on regard to the evolution of Machine Vision in the global market are: 1. From CCD (charge-coupled device) to CMOS; (Complementary metal–oxide–Semiconductor) even for high-end machine vision and defense systems; 2. Smaller pixels for industrial image sensors; 3. More image processing in the camera; 4. Lenses with improved performance at lower cost and finally;

[128] Richard Szeliski (30 September 2010). *“Computer Vision: Algorithms and Applications”.*

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	5. USB3 Vision and CoaXPress to gain market share.[129]

[129] https://www.adimec.com/top-5-predictions-for-the-future-in-machine-vision/

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3.11. Advanced human-machine interaction techniques

Advanced human-machine interaction techniques	
Description	The term Human-Machine Interaction (HMI) describes the interaction and communication between human users and a machine, most commonly a computer.[130] In its simple and original form, a user interface can also refer to analog control elements of a device, for example. The goal of user interface design is to produce an interface which makes it easy, efficient, and user-friendly to operate a machine and to obtain the desired result. In general this means that the operator should have to provide minimal input to achieve the desired output. The machine shall minimise undesired outputs to the human.[131] HMI can be found in everyday life as well as in professional environments. Common examples of the everyday usage of HMI are a radio alarm clock or sending messages via smartphone or laptop.[132] HMI is the most common term for describing this technology. However, it is sometimes referred to as Man-Machine Interface (MMI), Operator Interface Terminal (OIT), Local Operator Interface (LOI), or Operator Terminal (OT). Furthermore, HMI and Graphical User Interface (GUI) are similar but not synonymous, since GUIs are often used within HMIs for visualization.[133] In essence, a human user commands the computer to perform a certain action.[134] Thereby the user's activity consists essentially of three levels:[135] • Physical: The mechanics of interaction between human and machine; • Cognitive: The understanding of the system by the user;

130 https://www.eolss.net/sample-chapters/C18/E6-43-37-06.pdf
131 https://en.wikipedia.org/wiki/User_interface
132 http://ijstm.com/images/short_pdf/408.pdf
133 https://www.inductiveautomation.com/resources/article/what-is-hmi
134 http://ijstm.com/images/short_pdf/408.pdf
135 http://ijstm.com/images/short_pdf/408.pdf

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	• Affective: The attempt to make the user experience as positive as possible for the user. In industrial settings, HMIs can be used for example to: • Display data; • Monitor production time, trends, and tags; • Monitor KPIs; • Track machine inputs and outputs.[136] Interface layers can address one or more human sense, including: tactile (touch), visual (sight), auditory (sound), olfactory (smell), equilibria (balance) and gustatory UI (taste).[137] As advanced HMI technologies, head-up displays, touch screens or voice recognition can be seen as state of the art. There are even more sophisticated technologies under development like suits for steering telerobotic applications in space.[138]
Application areas	**Virtual Assistant.** Virtual Assistants can be steered by voice as a means of HMI. This can assist e.g. in planning a trip or gathering information about the accessibility of a means of transport. **Wayfinding Technology.** The HMI for wayfinding technologies is often the touch screen of a smart phone or navigator. Alternatively, applications can be steered via voice. It allows to select or determine the destination and to receive visual and audible information. **Pre-trip Concierge and Virtualisation (PTCV).** Advanced HMI technologies can be applied to operate specific forms of information gathering like PTCV applications. **Safe intersection crossing.** Head-up displays in connected vehicles can be used for raising awareness of the driver about approaching pedestrians and other (vulnerable) road users which are not yet physically visible.

136 https://www.inductiveautomation.com/resources/article/what-is-hmi
137 https://en.wikipedia.org/wiki/User_interface
138 https://tinyurl.com/y9yxg75q

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	Assistive Robots. Assistive robots are “humanized” devices which are designed to interact with human beings. They therefore are equipped with sensors and software to communicate with speech as HMI. **Intelligent Environments, Ambient Intelligence.** Applications for smart home like lighting, food storage, heating or the remote operation of household appliances can be operated by voice as HMI.
Evolutionary scenarios	HMI developed over the last half century from a form of interaction in which the computer is behaving like a mechanism to a more complex style of interaction in which the computer behaving as an organism.[139] In the 1950s, the first electronic computers used punched cards as an input medium to give data and commands to a machine. The first touch-based monitors were also developed. Other input devices such as the light pen, which could sense differences in brightness on the monitor, and the track ball, which originated in aircraft control and the military, were also developed in the 1950s. A decade later, text lines could already be entered via keyboards. The invention of the mouse also dates back to the 60s. The further development of the optical mouse took place in the 80's, when the first graphical user interfaces were launched. This was the first time that Xerox made entire workstations with keyboards, mice and monitors available for industrial purposes, but at prices of ten thousand dollars and more. The first consumer level computers were released by the MacIntosh company. The touch interfaces used today were also invented back in the 80s. The consequent further development from the 2000s onwards went in the direction of natural user interfaces which can handle body movement or voice commands. An increase would be the control of computers with thoughts (thought control).[140] Current development for future applications goes into the direction of more sophisticated composite user interfaces, which address the interaction with

[139] https://www.sciencedirect.com/science/article/pii/B0080430767043333
[140] https://infostory.com/2017/07/27/history-of-human-machine-interface/

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	more than one human sense. The commonly known HMI are graphical user interfaces consisting of a combination of a tactile interface and a visual display. If a further sense is addressed with audio signals, this is called a multimedia interface. An even further development includes smells, for example. These so-called Composite User Interfaces (CUI) can be subdivided in the three categories standard composite user interfaces (using devices like keyboards, mice, and computer monitors for input and output), virtual CUI (blocking out the real world and creating a virtual reality) and augmented CUI (not blocking out the real world and creating augmented reality).[141]

[141] https://en.wikipedia.org/wiki/User_interface

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3.12. Geolocation

Geolocation	
Description	Geolocation refers to any type of technology that can identify a geographic location. By locating an associated device in real time, you can locate an asset (container, trailer, pallet, etc), often making use of mobile phone technology or another kind of internet-connected device (Internet of Things). One or multiple technologies can help define the geographic location of an asset, however it is recommendable to combine different geolocation technologies:[142] • **Global Positioning System**, GPS in short, is a satellite-based radio navigation system consisting of approximately thirty satellites orbiting the Earth. It provides accurate outdoor positioning (up to five meters); works everywhere outdoors and no infrastructure is required. • **Bluetooth Low Energy** Bluetooth is a wireless short-range communications technology standard. It's mainly designed for communicating over short distances since the signals do not carry far. Its' latest version, Bluetooth Low Energy (BLE) is making big improvements in geolocation and positioning and most smartphones and devices today are equipped with Bluetooth capability. By installing BLE beacons on known locations, the beacon will broadcast their identifier to Bluetooth-enabled devices nearby, and their location can be inferred by triangulation. • **WIFI** positioning taps into wireless local area networks (WLANs), which are networks of devices that connect to a specific radio frequency, 2.4GHz or 5.0GHz. The device then transfers data over radio waves for a range up to a hundred meters, covering both indoor and outdoor sites. WiFi positioning also harnesses WiFi networks that you don't own or can't access. Your WiFi device can track public information about those networks – like IP

142 https://tinyurl.com/yb4xwnpy

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	addresses and BSSIDs – to determine location. • **Network-based geolocation** Location can also be determined by using a service provider's network infrastructure. The accuracy of network-based techniques can vary depending on the concentration of base stations and the implementation of timing methods. A technique used by different network providers is network triangulation. This means that you determine the location of a point by forming triangles to it from known points. To use a service provider's network infrastructure your tracking device will be equipped with a module of the service provider. The best strategy is combining geolocation technologies to ensure both minimal energy consumption and maximum data accuracy.[143]
Application areas	**Intelligent Vehicles**. An example of the application of geolocation technology in intelligent vehicles is Yield! that uses Bluetooth to detect drivers or pedestrians within 10 to 30 meters of a smartphone using the app and delivers an alert notifying them of the other person's presence. Another example is Drive Safely app, which uses Near Field Communication (NFC) to determine if a smartphone user is in the driver's seat of a vehicle and sends an auto-reply message to incoming calls and texts while the vehicle is moving. The app runs in the background and will not activate on public transit or when the smartphone owner is a passenger in a vehicle.[144] **Intelligent Transport Systems.** The integrity of positioning systems has become an increasingly important requirement for location-based Intelligent Transport Systems (ITS), public transport operations and traffic control services. In ITS, satellite navigation systems, such as global positioning system (GPS), are used to provide real-time vehicle positioning information including details of longitude, latitude, direction and speed.

[143] https://tinyurl.com/yb4xwnpy
[144] https://gcn.com/articles/2014/10/27/apps-traffic-pedestrian-safety.aspx

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	Map matching algorithms are used to integrate the positioning information into the digital road map. However, the navigation systems used in ITS cannot provide the high quality positioning information required by most services, and an error in the positioning information or map matching process might lead to the inaccurate determination of a vehicle location. This could have legal or economic consequences for ITS applications such as traffic law enforcement systems (e.g., speed fining). Such applications require integrity when measuring the vehicle position and speed information and in the map matching process when locating the vehicle on the correct road segment to avoid errors when charging drivers.[145] **Wayfinding Technologies.** Wayfinding technologies and geolocation technologies have the same purpose: to help locate and navigate. The first oneis used mostly indoors (large public transport stations, for example) and the second applied for itineraries outside. They are intrinsically related by providing a full perspective of location and transition (indoor/outdoor), and together they are called Geofencing. Geo-fencing adds an extra dimension to facility management of large venues such as stations or airports where GPS signals are unreliable. It acts as a virtual perimeter of a venue, giving users live data when a device enters or exits a facility. Geo-fencing technology is widely used for securing corporate campuses, healthcare centers, transportation hubs, and public parks among others.[146] **Pre-trip concierge and virtualization.** An example of the application of geolocation technology in pre-trip concierge services is the Smart Travel Concierge System (STCS), that combines different technologies, including GPS, for assessment of transportation readiness, pre-trip planning and execution, and trip virtualization activities specifically for individuals with cognitive disabilities to allow them to take fixed route transportation

145 https://www.sciencedirect.com/science/article/pii/S209575641530564X
146 https://pigeon.srisys.com/geo-fencing/

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	independently and reduce their need to use costlier paratransit services.[147] **Safe intersection crossing.** People with vision impairment rely heavily on walking and public transit for their transportation needs. A major challenge for this population is crossing intersections safely. There is the ongoing effort to develop a prototype Mobile Accessible Pedestrian Signals (MAPS) application for the blind and visually impaired. A MAPS system provides signal and intersection geometry information to smartphone users at signalized intersections. User interaction was with simple tactile input (single or double tap) and text-to-speech technology. Smartphone application may effectively provide geometry and signal timing information and thus provide decision support for visually impaired pedestrians.[148]
Evolutionary scenarios	The origin of geolocation traces back to 1933 with the introduction of the radar, and was further developed for submarines and space travel. By 1999, the first commercial use of GPS was released, it was a safety phone called the *Benefon Esc*. This allows civilians and consumer-facing services to use GPS with the same pinpoint accuracy as the military. In 2005 Google Maps officially debuts while Yelp popularizes location-based reviews leveraging geolocation technologies. Only one year later, after testing equipment, such as the handheld SkyCaddie, and being courted by the electronic industry for several years, the U.S. Golf Association permits distance-measuring GPS devices and laser range finders. In 2015, Facebook begins licensing location-based data from Factual, a geodata platform. This includes "US Places data," which includes hotels and restaurants "extended attributes," to support Facebook business pages, check-ins, and more. In 2017, Match.com reportedly enables users to see which other users they have crossed real-life paths with, while in the same year Facebook fights to represent the primary "digital presence" for local businesses. With 2.5 billion comments being added to Facebook business Pages every month, they are now competing directly with Google.[149]

[147] https://www.its.dot.gov/presentations/2017/ATTRI_Webinar_nov2017s.pdf
[148] https://tinyurl.com/y9v64lts
[149] https://www.pcworld.com/article/2000276/a-brief-history-of-gps.html

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	This rapid evolution led to 90% of all smart device apps today to be installed with geo-tracking capabilities. Besides Google Maps, there are several other applications trying to improve the connection and engagement with its users. According to Cisco, the US multinational technology giant, by this year, 2020, there are supposed to be 5.5 billion smartphone users, and research and development will move even faster than we have seen so far.[150]

[150] https://workingcapitalreview.com/2020/01/whats-hot-in-geolocation-tech-for-2020/

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4. Application Areas

4.1. Virtual Assistant

Virtual assistant	
Description	A virtual assistant, also called AI assistant or digital assistant, is an application program that understands natural language voice commands and completes tasks for the user.[151] Virtual assistants are digital co-workers which, making use of Artificial intelligence, and can interact with humans. Virtual assistants are tools: their goal is to assist some of the day-to-day responsibilities of people, not to replace them. Virtual assistants reduce the time spent on these mundane tasks so as to have more time for interesting, strategic and impactful things.[152] The technological advantages provided by new technologies, such as Machine Learning and Artificial Intelligence, allow Virtual Assistants to process customer preferences and intents, fulfil their needs and enhance performance over time by gaining new insights from each interaction.[153] They are typically cloud-based programs that require internet-connected devices and/or applications to work.
Examples	**Google Assistant.** The virtual assistant offered by Google has many functions such as searching for information on the web, planning events and alarms, adjusting the settings of connected devices and, using NLP algorithms, starting two-way conversations. Google Assistant allows you to set medication reminders, consult your doctor and even order medical supplies online. Google Assistant can offer a source of support for disabled people; for example it is possible to connect this virtual assistant with smart bulbs so that you can turn them on and off even when it is not possible to reach the light switch. **Siri**[154]. This assistant makes use of a selection of technologies to answer questions, make

[151] https://searchcustomerexperience.techtarget.com/definition/virtual-assistant-AI-assistant
[152] https://www.voicea.com/exactly-virtual-assistant/
[153] https://tinyurl.com/ydytzhtl
[154] https://tinyurl.com/y7m2mbxx

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	recommendations and perform actions by delegating requests to a range of Internet services. The software can adapt to users' uses, searches and preferences of the individual language; in this way the returned results are personalized. **Amazon Echo**[155]. Amazon's virtual assistant also has basic functionality, such as playing music, creating task lists, setting alarms; this virtual assistant also allows you to control several smart devices, acting as a home automation hub. Anyone who has difficulty with technology or physical control of their environment may benefit from Amazon Echo if they are able to speak and hear well enough. Tecla-e integrates with Amazon Alexa's voice assistant service; is an assistive device that allows disabled people to control smart devices and the environment through wheelchair driving controls and skill switches.
Enabling technology domains	AI - Rule-based Systems, AI - Machine Learning (ML), Big Data Analytics, Robotics and Automation, Advanced human-machine interaction techniques
Impact on advanced mobility solutions (and mobility gaps)	Virtual assistants can revolutionize future mobility. Using the new deep learning and machine learning technologies in virtual assistants, it is possible to develop models to predict the successive positions of a moving object given its previous positions, which can be used in various applications such as traffic flow forecasting, prediction of the intersection turning movement and personalized route recommendation.[156] The automotive industry is making leaps towards car convenience and connectivity with the help of virtual assistants. In recent years, an increasing number of consumers are already routinely using voice assistants in cars and for this reason car manufacturers continue to invest in creating better user experiences. In-car virtual assistants can be useful for everyday driving requests, such as looking for the nearest petrol station. These virtual assistants have the advantage of being programmable and therefore able to carry out practical tasks in a car such as controlling the lights and managing the temperature inside the vehicle; they are also able to warn drivers of maintenance

155 https://energysquad.com/smart-level-2/
156 https://www.jiwonkim.co/urban-mobility-prediction/

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	requirements (such as low tyre pressure) and give driving tips (such as fuel saving). There is therefore a huge opportunity for improving the car experience for consumers.[157] Leading original equipment manufacturers like Daimler, Hyundai, Honda, PSA, and BMW already have, or are actively working on, integrated infotainment systems which, by using voice instructions, allow drivers to access a wide range of services, without compromising the road safety Automotive VPAs must have a deep understanding of the vehicle in order to meet the needs and learn specific behaviours of the driver in order to guarantee the safety of passengers inside the vehicle; for instance, if a driver communicates tiredness to the smart assistant, it will trigger a "vitalising" program (such as adjusting interior lights, music, temperature) in order to make the driver feel more awake. Virtual assistants can also be installed on board public transport to provide important information to travellers while they are en route. In-vehicle information allow to help people with disabilities during their trip and reassure them that they have taken the right vehicle and route. This type of information can be printed in on-board displays and with audio formats to bridge the gaps of various kinds of disabilities.
Relevant European regulatory frameworks and standards	The European Commission has basic requirements that AI applications (such as virtual assistants) should meet in order to be considered reliable and to be used in the European market: • Human agency and oversight; • Technical robustness and safety; • Privacy and data governance; • Transparency; • Diversity, non-discrimination and fairness; • Societal and environmental wellbeing; • Accountability. Moreover, the Rolling Plan 2020's most related thematic areas and actions are the following:[158] Key enablers and security: • Public sector information, open data and big data;

[157] https://www.alphabet.com/en-ww/blog/connected-cars-car-virtual-personal-assistants
[158] https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/rolling-plan-2020

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	• Artificial Intelligence. Sustainable growth: • Smart grids and smart metering; • Robotics and autonomous systems.
Relevant cybersecurity and privacy issues	Some consumers have expressed concerns about the privacy of virtual assistants: this technology requires a large amount of personal data for machine learning to improve themselves over time. Virtual assistants are always "listening", waiting for a word to “wake up” or become activated to respond to voice commands.[159]

[159] https://searchcustomerexperience.techtarget.com/definition/virtual-assistant-AI-assistant

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4.2. Intelligent Vehicles

Intelligent Vehicles	
Description	An intelligent vehicle can be defined as a vehicle that is capable of taking information about its state and/or the surrounding environment; and are capable of processing the information acquired and making some level of decisions.[160] In the future an intelligent vehicles will be no longer limited to the functions of, or tethered down by, a smartphone accomplice. Onboard internet connection can provide information such as the traffic situation, risk of collisions and other safety warnings. These kinds of vehicles include high performance technology such as:[161] • onboard sensors; • positioning the vehicle on a digital map; • monitoring of the surrounding environment; • reception of surrounding information through wireless communications; • monitoring of the driver and the interior of the vehicle. Car manufacturers and service providers developed various connectivity solutions, such as the machine-to-machine (M2M) connectivity platform. This M2M feature in a car enables interconnectivity between two connected cars.[162]
Examples	**Audi connect** is a service developed by the German car manufacturer that allows the digital connection between driver, vehicle and infrastructure. It bundles all parts that use online connectivity within the vehicle, which becomes part of a global network with personalized services available online and via a smartphone app.[163] **BMW ConnectedDrive** integrates BMW's intelligent interfaces, smartphones and other technologies to be aware and in control of everything that happens both inside the vehicle and in everyday life. Digital services, driver-focused technologies and driver assistance systems have been developed to provide

160 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6503868/
161 https://www.sciencedirect.com/science/article/pii/B9780128128008000011
162 https://www.alliedmarketresearch.com/connected-car-market
163 https://www.audi.com/en/experience-audi/models-and-technology/digital-services/audi-connect.html

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	more comfort, more entertainment and more safety.[164] **Tesla:** The infotainment system developed by Tesla, allows you to monitor the energy consumption of the vehicle and adjust some dashboard functions such as climate, lights and windows. The system also includes a full web browser, navigation, media and voice-controlled phone. **Navya Autonom Shuttle** is a self-driving, 11-passenger electric vehicle developed for use in public transportation service which can be a solution for accessibility problems. Users can create a profile that includes information on their disability needs and therefore, at the time of the request, the system dispatches a vehicle that has the equipment the user needs.[165]
Enabling technology domains	Internet of Things (IoT), AI – Rule-based Systems, AI - Automated Speech Recognition (ASR) and Natural Language Processing (NLP), AI - Machine Learning (ML), Robotics and Automation, Machine vision, Geolocation.
Impact on advanced mobility solutions (and mobility gaps)	The challenge of innovation in the transport sector is represented by the automation of all transport sectors (road, maritime, rail and air) but the sector most affected by this challenge is the automotive sector. The mobility of the future will be characterised by an extensive use of electric Connected Autonomous Vehicles (CAV) and by roads adequately equipped to accommodate them (smart roads).[166] The development of these vehicles and infrastructures will probably also be supported by the enhancement of traditional public transport (PT) and the development of innovative mobility services (IMS) which may offer new solutions to current mobility challenges.[167] The shift to an ageing society will place significant challenges for mobility (to fit elderly transport needs), road traffic safety (to contrast their higher vulnerability as road users) and societal

164 https://tinyurl.com/y73kqvoh
165 https://navya.tech/autonomous-shuttle-benefits/
166 https://tinyurl.com/y9uawq5g
167 https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=34596&no=1

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	responsibilities (to prevent social exclusion of disabled people). IMS and CAV could improve the mobility of users with limited access (elderly or people with disabilities) and allow them to travel more comfortably and safely. Indeed, self-driving cars could revolutionize the way disabled people move into their communities and also travel away from home. Intelligent vehicle technology alone is not enough to help people become more independent, but the advances made in machine learning and artificial intelligence may eventuslly allow these vehicles to understand spoken instructions, observe the surrounding environment and communicating with people. ITS aims to improve safety levels for the road user group (especially pedestrians with physical disabilities) implementing safety enhancement measures such as: • Smart pedestrian crossing (e.g., prolonging crossing times for elderly and disabled users); • Vehicle presence detection (either to the Vehicle or from the vehicle to pedestrian); • Automatic advice to drivers by disabled users (e.g., presence of wheelchair).
Relevant European regulatory frameworks and standards	Rolling Plan 2020's related thematic areas and actions:[168] Key enablers and security: • Internet of Things; • Artificial Intelligence. Sustainable growth: • Smart grids and smart metering; • Robotics and autonomous systems; • Intelligent Transport Systems - Cooperative, Connected and Automated Mobility (ITS-CCAM) and Electromobility. Existing EU legislation is to a large extent already suitable for the placing on the market of automated

[168] https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/rolling-plan-2020

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	and connected vehicles. EU vehicle approval framework legislation, modernised in 2018, ensures a real internal market for and a special procedure is foreseen for new technologies. Despite all, new regulatory changes will have to follow in order to build a harmonised, complete and future-proof framework for automation.[169]
Relevant cybersecurity and privacy issues	In 2015 Wired showed how easy it was for a couple of legal hackers to infiltrate a AV's software; for this reason makers of intelligent vehicles began taking automotive cybersecurity seriously. Protecting the car industry from cyber-attacks is "a matter of public safety". The 2015 hacker attack aimed to reveal software vulnerabilities; future attacks, on the other hand, could be of a more damaging nature causing potentially fatal collisions but hackers could also steal personal information such as bank and social security numbers.[170]

169 https://ec.europa.eu/transport/sites/transport/files/3rd-mobility-pack/com20180283_en.pdf
170 https://builtin.com/cybersecurity/automotive-cyber-security

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4.3. Intelligent Transport Systems (ITS)

Intelligent Transport Systems (ITS)	
Description	ITS (Intelligent Transport or Transportation Systems) arise from the convergence of ICT (Information and Communication Technologies) and automation with transportation system engineering. An intelligent transportation system can be defined as an advanced application which, using various information and communication technologies, provide innovative services relating to transport and traffic management. The main purpose of Intelligent Transport System is to improve safety, mobility, and efficiency of transportation. ITS includes a wide range of application capable to manage the problems caused by traffic congestion through the integration between the new IT techniques for real-time telemonitoring, simulation, communication networks and new connection tools between users like social networks and mobile technologies.[171] Managing the amount of data from roads and vehicles is a fundamental task to ensure safety, liveability, a more efficient use of energy resources, the quality of the air. Mobility must first of all be accessible to all (including passengers with reduced mobility); unfortunately, indeed, disabled people mainly face problems in mobility.
Examples	**Cityringen** is a global sustainable project inaugurated in Copenhagen at the end of 2019. Cityringen is a 15.5 km underground railway connected with the existing metro line and with bus and train stations in order to reduce the need to travel by car. The fully automated Cityringen line is driverless and provides a 24-hour transport system. Overall, access is important. Each Cityringen station has two elevators to make the stations easier to access for passengers with reduced mobility.[172] The Ticket dispenser and validation machines are installed in such a way that they can be accessed for

[171] https://theconstructor.org/transportation/intelligent-transportation-system/1120/
[172] https://railway-news.com/copenhagen-cityringen-metro-line-opens-sunday/

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	passengers in wheelchairs. On the train, deaf deople can benefit from the information signs and telecoil systems at call points. Moreover, a SMS notification system was introduced to inform citizens of eventual extraordinary works impacting on mobility.[173] **First Glasgow[174]** launched new fleet of eco-friendly buses that offer an improved customer experience; these vehicles are equipped with Euro VI technology that offer more comfort and are more eco-friendly. Furthermore, on these vehicles there are USB charging points, free Wi-Fi and comfortable e-leather seating to improve passenger travel. The First Bus planner app gives regular information about public buses, timings, seat availability, the real-time location of the bus and an evaluation of the time taken to reach the destination.[175] **GoSutton**[176] is the brand new form of public transport has been launched in Sutton. All vehicles can seat up to 14 people, have USB charging points and free Wi-Fi on board and above all are fully accessible in fact all vehicles are able to accommodate a wheelchair). These buses will not follow a linear route but will travel in a defined area. Customers travelling on the new buses will be able to book a seat in real time using the GoSutton app.
Enabling technology domains	Internet Of Things (IoT), AI – Rule-based Systems, AI - Machine Learning (ML) , Big Data Analytics , Web technologies - Infotainment , Machine vision, Geolocation.
Impact on advanced mobility solutions (and mobility gaps)	Intelligent transport systems (ITS) are applications that aim to provide highly innovative services in relation to the various modes of transport and traffic management; their application guarantees users more information and a more coordinated and efficient use of networks. The European Commission (EC) is working to lay the foundations for the next generation of ITS solutions which will include automation in the transport sector.[177]

173 https://www.salini-impregilo.com/en/projects/cityringen
174 https://www.intelligenttransport.com/transport-news/72666/low-emission-bus-fleet-glasgow/
175 https://www.aindralabs.com/what-is-intelligent-transportation-system-its-applications-and-examples/
176 https://www.intelligenttransport.com/transport-news/80398/trial-on-demand-bus-sutton-launches/
177 https://ec.europa.eu/transport/themes/its_en

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	EC has adopted a new strategy for C-ITS (Cooperative Intelligent Transport Systems) according to which these vehicles will be integrated into a comprehensive data infrastructure. Car2x and V2X are the current keywords in terms of safety (even of vulnerable road users), efficiency and comfort in road traffic;[178] ITS must use short-range (such as Car2X) and wide-area communication technologies (such as 3G, 4G, future 5G) that allow road vehicles to communicate not only with each other (V2V: Vehicle to Vehicle) but also with traffic signals, infrastructure and other road users (V2I: Vehicle to Infrastructure).[179] Cooperative systems in vehicles analyse the data received and warn the driver against risky situations; this way, cooperative systems support foresighted driving style, display dangers not even visible to the driver and help to avoid accidents.
Relevant European regulatory frameworks and standards	Directive 2010/40 / EU (the ITS directive) represents a strategic and legal framework to accelerate the spread of innovative transport solutions across Europe. Moreover, it is necessary to list Rolling Plan 2020's most related thematic areas and actions Key enablers and security: • Internet of Things; • Public sector information, open data and big data; • Cybersecurity / network and information security; • Artificial Intelligence; • Broadband infrastructure mapping; • European Global Navigation Satellite System (EGNSS). Sustainable growth: • Intelligent Transport Systems – Cooperative, Connected and Automated Mobility (ITS-CCAM) and Electromobility; • Smart cities and communities/ technologies and services for smart and efficient energy use.

178 https://www.vector.com/int/en/know-how/technologies/automotive-connectivity/v2x/#c7426

179 https://www.car-2-car.org/about-c-its/

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Relevant cybersecurity and privacy issues	Connected vehicles communicate with other vehicles and roads wirelessly; through this interaction important information on safety and mobility is exchanged and, moreover, new data are generated on how, when and where vehicles travel. All of this have led to concerns about personal privacy which could compromise the wider deployment of Intelligent Transport Systems because privacy is a primary concern of transportation agencies when tracking people, vehicles, and goods within transportation grid. Therefore, ITS technologies must secure the integrity, confidentiality, and handling of personal and financial data to protect citizens' rights.[180]

[180] https://www.its.dot.gov/factsheets/privacy.htm

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4.4. Pre-trip Concierge and Virtualization (PTCV)

Pre-trip Concierge and Virtualization (PTCV)	
Description	Pre-trip Concierge (or Pre-trip Planning) and Virtualization (PTCV), employs ICT technologies to provide information both before (pre-trip planning) and during a trip (en route information) to not only travellers with disabilities, but also their family members and/or caregivers, with the primary objective of familiarizing the users with their travel before the trip, by focusing on the three dimensions of pre-trip assessment, training, and virtualization. Applications within this area are also capable of taking into account specific user needs and select the most appropriate transportation services accordingly.[181] PTCV applications mainly address individuals with cognitive disabilities (e.g. intellectual and developmental disability, those on the autism spectrum, individuals with traumatic brain injuries), who often do not own or use personal vehicles and rely on public transportation, friends/family, or specialized paratransit services to access employment, education, and other fundamental activities. PTCV applications aim at building cognitively accessible tools which make it possible for disabled people to leverage fixed-route transportation services, thus avoiding the use of specialized paratransit services. PTCV applications reduce the complexity of public transportation systems to lower barriers for disabled people.
Examples	**AbleLink suite.** AbleLink is a suite of assessment, self-directed learning, and trip execution technologies to support independent travel for individuals with cognitive disabilities.[182] The AbleLink suite is composed of 4 distinct subsystems[183], designed to support self-assessment of current transportation skills, general training on those skills, and personalized tools to allow for the proper completion of pre-trip preparation activities. Among these subsystems, a mobile app specifically supports disabled people in travelling safely,

[181] https://www.its.dot.gov/research_areas/attri/pretrip_concierge.htm
[182] https://www.its.dot.gov/research_areas/attri/pretrip_concierge.htm
[183] https://rosap.ntl.bts.gov/view/dot/44053/dot_44053_DS1.pdf?

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	whether by bus or on foot. The application shows pictures of different possible places of interest, on which the disabled people can tap to select their desired destination. After tapping on the picture, the app guides the user to reach it. A caregiver, support professional, or family member can create customized travel routes and activate them on the basis of the GPS location. They can also include customized, personally meaningful content, so that the disabled person is guided by proper step-by-step visual and audio instructions and cues, and is assured that they are in the right direction either by pointing out landmarks along the way or telling them "this is not your stop" when they see others departing. In addition, a support professional/caregiver can build a route through a wizard, allowing them to record audio and visual prompts, and create steps the user will experience along the way. During the travel, the caregiver can check time-stamped updates to be sure the disabled person is on the correct route.[184] **Aira app.** Aira is a service that instantly connects blind and low-vision people to highly-trained, remotely-located agents.[185] Among various use cases, Aira is also used to make blind and low-vision travellers get through Minneapolis-St. Paul International Airport. By wearing smart glasses and using the Aira app[186], travellers connect with an agent, who can then guide them by giving information on their surroundings, visible to the operator as a livestream from the perspective of the traveller. The agent can help locate their luggage, read flight boards, and arrange transportation. **Other airport apps.** Several airport apps are available to provide PTCV services to disabled people.[187] Among the features they provide, there are parking reservation and prepayment, food ordering, real-time updates on parking availability, security wait times, gate changes, flight arrival and

184 https://www.ablelinktech.com/assets/datasheets/WayFinder%20Overview.pdf
185 https://play.google.com/store/apps/details?id=io.aira.smart&hl=en
186 https://minnesota.cbslocal.com/2018/01/03/aira-app-msp/
187 https://www.nap.edu/read/25728/chapter/4#33

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	departure times, photo features that enable users to capture the location of their car and then be guided to it upon return, speech to text features for hands-free communication with airport personnel, flight tracking via boarding pass, push notifications on flight status, airport alerts, track-your-bags features that allow to even track wheelchairs and other mobility aids, airport maps specifically designed to navigate within an airport with turn-by-turn directions, estimated walking times, and a “Wheelchair Request Service” that allows travellers to ask for wheelchair service upon arrival.
Enabling technology domains	Internet of Things (IoT), AI – Rule-based Systems, Robotics and Automation, Web technologies – Infotainment, Advanced human-machine interaction techniques, Machine vision, Geolocation.
Impact on advanced mobility solutions (and mobility gaps)	Pre-trip planning was found to be especially useful when used for the implementation of an integrated framework for geospatial information of transport facilities (such as taxi, tram, bus, train) and essential services (clinics, restaurants, banks, etc.) in a graphical user interface. In the future, the ease-of-access information in pre-trip planning will be crucial for effectively enhancing the travel experience and increase its popularity among disabled people, caregivers, and support professionals.[188] PTCV is being employed consistently in air travel, thus making its impact on mobility gaps in this sector significant. Research has shown that disabled people fly less often than the general public for a plethora of reasons, and PTCV could change this general attitude.[189] In a recent research project, nearly all participants of the focus groups indicated that pre-trip planning is fundamental for a successful travel experience. In the near future, disabled people and their caregivers, immediately after booking a flight, might expect to being informed by PTCV services about how early they need to arrive at the airport, which is the departure terminal, how far the Security is with respect to the gate areas; for those planning to drive, other information is crucial, such as parking

[188] https://www.sciencedirect.com/science/article/pii/S0386111217300444
[189] https://www.nap.edu/read/25728/chapter/4

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	areas near the airport, or knowing how to reach the terminal in case they need assistance. Pre-trip planning may be useful in filling other mobility gaps such as identifying the accessible transportation options at the destination, the location of the pickup areas, and the availability of help with luggage and mobility for reaching those areas. The complexity of such pre-trip planning activities is growing, as rideshare companies, hotel shuttles, rental car companies, and taxis are being moved further away from terminals. In addition to the above-listed needs, PTCV can provide disabled people with additional information such curbside check-in, companion restrooms, and quiet areas. In some airports, print materials or other messaging is readily available and can help educate individuals who may not use the Internet, so that they are better prepared for their next trip. However, when the airport's website cannot answer a question, travellers would also need to communicate via text, or a social media platform (e.g. Twitter, Facebook, WhatsApp). This assumes that websites are accessible to individuals with hearing or vision loss, intellectual disabilities, or to individuals who cannot use common input devices such a mouse.
Relevant European regulatory frameworks and standards	Since PTCV makes use of ICT products and services including websites, software, and digital devices, EN 301 549 is certainly relevant - the standard incorporates the WCAG standards for web accessibility.[190] In addition, the Rolling Plan 2020's most related thematic areas and actions[191] are the following: Key enablers and security: • Internet of Things; • Cybersecurity / Network and information security; • Artificial Intelligence; • E-Privacy; • Accessibility of ICT products and services. Sustainable growth:

[190] https://www.etsi.org/deliver/etsi_en/301500_301599/301549/03.01.01_60/en_301549v030101p.pdf
[191] https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/rolling-plan-2020

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	• Intelligent Transport Systems – Cooperative, Connected and Automated Mobility (ITS-CCAM) and Electromobility; • Robotics and Autonomous Systems.
Relevant cybersecurity and privacy issues	As PTCV is achieved through the use of web technologies and mobile applications, cybersecurity and privacy issues are related to the security and privacy ensured by the app provider, which must be evaluated along with the sensitivity of the traveller's and caregiver's information needed to be used as input for a specific software. Such information might be almost trivial, e.g. when using informative apps which do not require to know anything private about the user, to more complex apps which require livestreaming of the surroundings of the user and the use of a personal camera and microphone, along with information about the disability of the disabled people and their GPS location. For caregivers/family members, it must be considered that, sometimes, PTCV applications can offer the possibility to include personalized cues, both audio and visuals, into their trip-building functionalities, thus requiring to provide potentially sensitive data.

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4.5. Gamification

Gamification	
Description	Gamification is adding game mechanics into non-game environments[192] and has been defined as a process of enhancing services with motivational affordances in order to invoke behavioural outcomes.[193] The idea behind gamification is to use game elements to promote "serious" purposes, whereas ambitions are increasing motivation and behavioural change.[194] Gamification can be seen to have three main parts: 1) the implemented motivational affordances, 2) the resulting psychological outcomes, and 3) the further behavioural outcomes.[195] Gamification uses game mechanics to make a context, e.g. a learning environment more pleasant and entertaining for the users. In this way, the motivation of the users could be increased. Such game mechanics are for example ownership, feedback, cooperation, status, and competition.[196] Other typical game elements are points, awards, comparisons, or specifications.[197] Research has shown that gamification works.[198] However, the beneficial effects of gamification depend on the context.[199] Game elements such as leader boards and feedback mechanisms help people feel more ownership and more engaged

[192] Deterding, S., Khaled, R., Nacke, L. E., & Dixon, D. (2011, May). Gamification: Toward a definition. In *CHI 2011 gamification workshop proceedings* (Vol. 12). Vancouver BC, Canada.
[193] J. Hamari, "Transforming Homo Economicus into Homo Ludens: A Field Experiment on Gamification in a Utilitarian Peer-To-Peer Trading Service", Electronic Commerce Research and Applications, 12(4), 2013, pp. 236- 245
[194] https://wirtschaftslexikon.gabler.de/definition/gamification-53874
[195] Hamari, J., Koivisto, J., & Sarsa, H. (2014, January). Does gamification work? – a literature review of empirical studies on gamification. In *2014 47th Hawaii international conference on system sciences* (pp. 3025-3034). IEEE.
[196] Arnab, S., Lim, T., Carvalho, M. B., Bellotti, F., De Freitas, S., Louchart, S., ... & De Gloria, A. (2015). Mapping learning and game mechanics for serious games analysis. *British Journal of Educational Technology*, *46*(2), 391-411.
[197] : https://wirtschaftslexikon.gabler.de/definition/gamification-53874
[198] Hamari, J., Koivisto, J., & Sarsa, H. (2014, January). Does gamification work? – a literature review of empirical studies on gamification. In *2014 47th Hawaii international conference on system sciences* (pp. 3025-3034). IEEE.
[199] Hamari, J., Koivisto, J., & Sarsa, H. (2014, January). Does gamification work? – a literature review of empirical studies on gamification. In *2014 47th Hawaii international conference on system sciences* (pp. 3025-3034). Ieee.

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	when carrying out tasks.[200] Studies revealed the beneficial effect of gamification on motivation.[201] The potential of gamification for the development of sustainable urban mobility and various modes of transportation is the focus of recent research.[202]
Examples	The potential to combine games and rewards with public transport travel is significant.[203] An example is a platform for managing peak demand in public transport in the city of Singapore that uses game elements like rewards, ranking and social networks. One of the most famous gamifications is "Pókemon Go", which rewards users with high-level Pókemon by walking great distances and presents an example of applying game mechanics to fitness, but also transport.[204] In the context of disability, accessibility and inclusion gamification is little used. One example is the *production game* which resembles the classic game Tetris for to enriching work for elderly or impaired persons in production.[205] A further example is *mPASS* (mobile Pervasive Accessibility Social Sensing) that used gamification and crowdsourcing to collect data on accessibility in the city.[206] Gamification has the potential to stimulate and encourage behaviour. As on example is the gamification *Beat the Street* initiative in the UK.[207] The approach aims for encouraging persons to make more trips by foot and makes it a challenge to see how far they can walk by logging their journey by tapping cards against sensors called 'Beat Boxes'. A similar approach is followed by the Australian *Healthy Active School Travel* gamification

200 Pavlus, J. "The Game of Life". *Scientific American*, 303, pp. 43-44, 2010
201 Shneiderman, B. "Designing for Fun: How Can We Design User Interfaces to Be More Fun?" *Interactions*, 11(5), pp. 48-50, 2004.
202 Stampf, D. (2016). Gameful Urban Mobility: Exploring the Potential for Gamification in Various Modes of Transport. PhD thesis. RMIT University.
203 Pluntke, C., & Prabhakar, B. (2013). INSINC: a platform for managing peak demand in public transit. JOURNEYS, Land Transport Authority Academy of Singapore, 31-39.
204 https://www.growthengineering.co.uk/definition-of-gamification/
205 Korn, O. (2012, June). Industrial playgrounds: how gamification helps to enrich work for elderly or impaired persons in production. In *Proceedings of the 4th ACM SIGCHI symposium on Engineering interactive computing systems* (pp. 313-316).
206 Prandi, C., Nisi, V., Salomoni, P., & Nunes, N. J. (2015, September). From gamification to pervasive game in mapping urban accessibility. In *Proceedings of the 11th Biannual Conference on Italian SIGCHI Chapter* (pp. 126-129).
207 http://www.intelligenthealth.co.uk/best-foot-forward-for-reading-as-beat-the-street-returns/

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	approach.[208] In the context of safe transport systems, the *SmartDriver* App is another example for the use of gamification.[209] The App aims to reward drivers for safe driving and compares the behaviour to other drivers.
Enabling technology domains	Web technologies – Infotainment, Virtual Reality, Augmented Reality (AR) and Mixed Reality (MR).
Impact on advanced mobility solutions (and mobility gaps)	Gamification can be used to improve accessibility of mobility systems and hence to reduce mobility gaps and barriers. One example is the training of web designers in adopting the Web Content Accessibility Guidelines (WCAG)[210] for accessibility design.[211] Gamification can further be applied to engage citizens in the data collection process of projects like the urban accessibility mapping system.[212] Gamification can be effectively used as an incentive to change behaviour, like mode and route choice.[213] Games and game elements can be also applied for learning purposes. An example is the serious game B.u.S. that was used to inform players about a new mobility concept in a gamified way.[214]
Relevant European regulatory frameworks and standards	No gamification specific standards, but norm for the human-machine interaction of interactive system can be applied: • Ergonomics of human-system interaction - Part 210: Human-centred design for interactive systems (ISO 9241-210:2019) • Ergonomics of human-system interaction - Part 171: Guidance on software accessibility (ISO 9241-171:2008)
Relevant cybersecurity and privacy issues	Research discusses the conflicts of users' privacy issues and data security in the context of gamification.[215] Accordingly, some game elements,

[208] https://tinyurl.com/y9qqg7eu
[209] https://www.tower.co.nz/car-insurance/smartdriver
[210] https://www.w3.org/WAI/intro/wcag.php
[211] Spyridonis, F., Daylamani-Zad, D., & Paraskevopoulos, I. T. (2017, September). The gamification of accessibility design: A proposed framework. In *2017 9th international conference on virtual worlds and games for serious applications (vs-games)* (pp. 233-236). IEEE.
[212] Prandi, C., Nisi, V., Salomoni, P., & Nunes, N. J. (2015, September). From gamification to pervasive game in mapping urban accessibility. In *Proceedings of the 11th Biannual Conference on Italian SIGCHI Chapter* (pp. 126-129).
[213] Pluntke, C., & Prabhakar, B. (2013). INSINC: a platform for managing peak demand in public transit. JOURNEYS, Land Transport Authority Academy of Singapore, 31-39.
[214] König, A., Kowala, N., Wegener, J., & Grippenkoven, J. (2019). Introducing a mobility on demand system to prospective users with the help of a serious game. *Transportation Research Interdisciplinary Perspectives*, *3*, 100079.
[215] Mavroeidi, A. G., Kitsiou, A., Kalloniatis, C., & Gritzalis, S. (2019). Gamification vs. Privacy: Identifying and Analysing the Major Concerns. *Future Internet*, *11*(3), 67.

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	like competition and communication with other players can lead to privacy violations of pseudonymity, unobservability among others and should be considered in the game design process. Privacy gaps have been reported elsewhere in relation to gamification.[216] Especially the monitoring of data collected on both the activity performed and the employee performing the activity are likely to breech privacy rights.[217] Thus, individual data should only be used in an aggregated form. On the other hand, there are approaches to use gamification for raising cyber security awareness.[218] The role-playing quiz application was designed to educate payers on password security and thus aims to make online interactions more secure. Another educational game is the Cybersecurity Lab, designed to teach young people basic cyber security skills.[219]

[216] Thiebes, S.; Lins, S.; Basten, D. Gamifying Information Systems—A Synthesis of Gamification Mechanics and Dynamics. In Proceedings of the 2014 Conference on European Conference on Information Systems, Helsinki, Finland, 9–11 June 2014

[217] Reeves, B. and Read, J.L. (2009). Total Engagement. Using Games and Virtual Worlds to Change the Way People Work and Businesses Compete. 1st Edition. Harvard Business Review Press, Boston, USA.

[218] Scholefield, S., & Shepherd, L. A. (2019, July). Gamification techniques for raising cyber security awareness. In *International Conference on Human-Computer Interaction* (pp. 191-203). Springer, Cham.

[219] https://www.pbs.org/wgbh/nova/labs/lab/cyber/

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4.6. Social Media

Social Media	
Description	Online communication has become a multi-way channel network that facilitates the sharing of information, ideas, photos and opinions in virtual communities and networks.[220] Social media multiplies content among millions of users, who feed their opinion back and through their network quickly, efficiently and in real-time.[221] Thus, recipients are an active part of the media and shape the content and scope. Social media has many functions for its users. Literature defines seven functionalities of social media: presence, sharing, relationships, identity, conversations, groups and reputation.[222] Social media are interactive Web 2.0 Internet-based applications that can be accessed by any internet communication tool and are generated mainly by users. Social media facilitates the development of virtual social networks. A key feature of social media is its potential for content posted there to spread *virally* over social networks by resharing content. Social media differ in type strongly, as there are social networks, media networks, discussion networks or review networks, which though can overlap.[223] In business, social media is used to market products, promote brands, connect to current customers and foster new business. In 2020 there were about 3 billion social media users.[224] The most popular social networks worldwide in 2020 were Facebook, YouTube and WhatsApp.[225] Social media has many proved and expected effects on the life of its users, like

[220] Kietzmann, J. H., Hermkens, K., McCarthy, I. P., & Silvestre, B. S. (2011). Social media? Get serious! Understanding the functional building blocks of social media. *Business horizons*, *54*(3), 241-251.
[221] https://www.thebalancesmb.com/what-is-social-media-2890301
[222] Kietzmann, J. H., Hermkens, K., McCarthy, I. P., & Silvestre, B. S. (2011). Social media? Get serious! Understanding the functional building blocks of social media. *Business horizons*, *54*(3), 241-251.
[223] https://www.thebalancesmb.com/what-is-social-media-2890301
[224] https://www.statista.com/statistics/278414/number-of-worldwide-social-network-users/
[225] https://www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/

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	interpersonal relationships[226], self-presentation[227], physical and mental health[228,229]. Social media is also influencing society, like political polarization[230,231].
Examples	**Facebook.** With 2.5 billion users, Facebook is the most popular social network.[232] The number of daily active Facebook users worldwide was 1.7 billion in the first months of 2020.[233] Facebook Inc. was founded in 2004 by Mark Zuckerberg. It is now considered on of the Big Five technology firms among Microsoft, Amazon, Apple and Google.[234] Facebook has acquired Instagram and WhatsApp. **Twitter.** Twitter is a social networking service used by approximately 386 million users in 2020.[235] The company was founded in 2006. Registered users can post, like, and retweet tweets. The number of characters for tweets is limited to 280. Twitter messages are public, but users can also send private direct messages. **Pinterest.** Pinterest was founded in 2009 with the aim of providing a platform for enable saving and discovery of information. Pinterest uses images and

[226] Chan, TH (2014). "Facebook and its Effects on Users' Empathic Social Skills and Life Satisfaction: A Double Edged Sword Effect". Cyberpsychology, Behavior, and Social Networking. 17 (5): 276–280. doi:10.1089/cyber.2013.0466

[227] Chua, Trudy Hui Hui; Chang, Leanne (2016). "Follow me and like my beautiful selfies: Singapore teenage girls' engagement in self-presentation and peer comparison on social media". Computers in Human Behavior. 55: 190–7. doi:10.1016/j.chb.2015.09.011

[228] Kontos, Emily Z.; Emmons, Karen M.; Puleo, Elaine; Viswanath, K. (2010). "Communication Inequalities and Public Health Implications of Adult Social Networking Site Use in the United States". Journal of Health Communication. 15 (Suppl 3): 216–235.

[229] Holmberg, Christopher; Berg, Christina; Dahlgren, Jovanna; Lissner, Lauren; Chaplin, John Eric (2018). "Health literacy in a complex digital media landscape: Pediatric obesity patients' experiences with online weight, food, and health information". Health Informatics Journal. 25 (4): 1343–1357. doi:10.1177/1460458218759699

[230] Hayat, Tsahi; Samuel-Azran, Tal (April 3, 2017). ""You too, Second Screeners?" Second Screeners' Echo Chambers During the 2016 U.S. Elections Primaries". Journal of Broadcasting & Electronic Media. 61 (2): 291–308. doi:10.1080/08838151.2017.1309417

[231] Volfovsky, Alexander; Merhout, Friedolin; Mann, Marcus; Lee, Jaemin; Hunzaker, M. B. Fallin; Chen, Haohan; Bumpus, John P.; Brown, Taylor W.; Argyle, Lisa P. (September 11, 2018). "Exposure to opposing views on social media can increase political polarization". Proceedings of the National Academy of Sciences. 115 (37): 9216–9221. doi:10.1073/pnas.1804840115

[232] Statista (2020). Most popular social networks worldwide as of April 2020. https://www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/

[233] The company Statista (2020). Number of daily active Facebook users worldwide as of 1st quarter 2020. https://www.statista.com/statistics/346167/facebook-global-dau/

[234] https://en.wikipedia.org/wiki/Big_Tech

[235] Statista (2020). Most popular social networks worldwide as of April 2020. https://www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/

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	videos in the form of pinboards. Pinterest defines itself not as a social network bus as a "catalogue of ideas".[236] Pinterest is used by approximately 366 million users in 2020.[237] **WhatsApp.** WhatsApp is a cross-platform messaging service owned by Facebook, Inc. It was launched in 2009 and is used by approximately 2 billion users in 2020.[238] The application runs on mobile devices but is also accessible from desktop computers. **TikTok.** TikTok is an American video-sharing social networking service owned by a Chinese internet technology company. It became available in 2016 in China and 2018 in the United States. The service is used to create short videos of private dance scenes among others. TikTok is used by approximately 800 million users in 2020.[239]
Enabling technology domains	Big Data Analytics, Web technologies – Infotainment.
Impact on advanced mobility solutions (and mobility gaps)	Social media is being used for: • Tracking mobility and activity patterns[240] and detecting and describing traffic anomalies;[241] • Creating community-based platform for sustainable and inclusive urban design and thus facilitating participatory approaches;[242] • Emergency management and informing people about emergencies. There is also an ISO norm for the use of social media for emergency purposes (ISO/CD 22329). The amount of data on social platforms allows scientists to extract insights based on machine

[236] *Nusca, A. (2015). "Pinterest CEO Ben Silbermann: We're not a social network". Fortune. R*
[237] https://www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/
[238] https://www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/
[239] https://www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/
[240] Hasan, S., Zhan, X., & Ukkusuri, S. V. (2013, August). Understanding urban human activity and mobility patterns using large-scale location-based data from online social media. In *Proceedings of the 2nd ACM SIGKDD international workshop on urban computing* (pp. 1-8).
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[242] Liang, X., Lopez, M., Aiello, J., Langone, N., Vottari, S., & Ardesi, Y. (2019). Public engagement in urban innovation: towards the concept of inclusive mobility. *CERN IdeaSquare Journal of Experimental Innovation*, *3*(1), 16-21.

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	learning.[243] Social media has also an effect on the diffusion of sustainable mobility opinions and behaviour change[244] and used to study mobility and interactions.[245] Social media analytics uses Big Data to collect and analyse user data and to understand user behaviour.[246] Social media can be used for raising awareness and inform about sustainable travel behaviour.[247]
Relevant European regulatory frameworks and standards	Above all other, media freedom and pluralism are part of the rights and principles enshrined in the European Charter on Fundamental Rights and in the European Convention of Human Rights[248,249]. The European Union's approach social media privacy gives users more rights to remove themselves entirely from social media permanently (General Data Protection Regulation, Article 17, 2012) International regulations: • ISO/IEC 30071-1:2019: Information technology — Development of user interface accessibility — Part 1: Code of practice for creating accessible ICT products and services National regulations: • In April 2019, the UK Information Commissioner's Office (ICO) issued a proposed code of practice for social networking services when used by minors, enforceable under GDPR, which also includes restrictions on "like" and "streak" mechanisms in order to discourage social

[243] Sumbaly, R., Kreps, J., & Shah, S. (2013, June). The big data ecosystem at linkedin. In *Proceedings of the 2013 ACM SIGMOD International Conference on Management of Data* (pp. 1125-1134).
[244] Borowski, E., Chen, Y., & Mahmassani, H. (2020). Social media effects on sustainable mobility opinion diffusion: Model framework and implications for behavior change. *Travel Behaviour and Society*, *19*, 170-183.
[245] Grabowicz, P. A., Ramasco, J. J., Gonçalves, B., & Eguiluz, V. M. (2014). Entangling mobility and interactions in social media. *PloS one*, *9*(3).
[246] Rashidi, T. H., Abbasi, A., Maghrebi, M., Hasan, S., & Waller, T. S. (2017). Exploring the capacity of social media data for modelling travel behaviour: Opportunities and challenges. *Transportation Research Part C: Emerging Technologies*, *75*, 197-211.
[247] Groth, A., Buchauer, R., & Schlögl, S. (2018). Influence of Social Media Engagement on Sustainable Mobility Behaviour in Alpine Regions. In *Information and Communication Technologies in Tourism 2018* (pp. 186-199). Springer, Cham.
[248] European Parliament, Resolution of 21 May 2013 on the EU Charter: standard settings for media freedom across the EU, 2011/2246(INI)
[249] European Parliament, Resolution of 3 May 2018 on Media pluralism and media freedom in the European Union, 2017/2209(INI)

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	media addiction, and use of this data for processing interests[250] • Germany is trying to bind diversity obligations on social media platforms for forcing social media platforms to incorporate diversity into their algorithms[251] • See also a book regarding *Social media communication*[252]
Relevant cybersecurity and privacy issues	Cybersecurity and privacy issues are addressed in Art. 9 GDPR – Processing of special categories of personal data, but the subject is discussed broadly across many arenas: • The exploitation of the internet prosumer commodity[253] • The right to be forgotten[254] • Privacy settings for virtual identity[255] • Social media services as a common goal for cyber attacks[256] • Social media as gateways for malware[257] • "Fake tweets" and other misleading content in social media[258] • Racisms and other types of bias and exclusion, including the suppression of videos from persons with disabilities[259].

[250] BBC (2019). Under-18s face 'like' and 'streaks' limits on social media. Retrieved online: https://www.bbc.com/news/technology-47933521

[251] LSE (2019). Germany proposes Europe's first diversity rules for social media platforms. Retrieved online: https://blogs.lse.ac.uk/medialse/2019/05/29/germany-proposes-europes-first-diversity-rules-for-social-media-platforms/

[252] Lipschultz, J. H. (2017). *Social media communication: Concepts, practices, data, law and ethics*. Taylor & Francis.

[253] Fuchs, C. (2012). The political economy of privacy on Facebook. *Television & New Media*, *13*(2), 139-159.

[254] General Data Protection Regulation, Article 17, 2012

[255] https://ec.europa.eu/info/sites/info/files/virtual_idenitity_en.pdf

[256] Kunwar, R. S., & Sharma, P. (2016, April). Social media: A new vector for cyber attack. In *2016 International Conference on Advances in Computing, Communication, & Automation (ICACCA)(Spring)* (pp. 1-5). IEEE.

[257] Zurkus, K. (2016). Social media, the gateway for malware. Available online: https://www.csoonline.com/article/3106292/social-media-the-gateway-for-malware.html

[258] *Carroll, R. (2012). "Fake Twitter accounts may be driving up Mitt Romney's follower number | World news | guardian.co.uk". Guardian. London.*

[259] Lao, D. (2019). TikTok admits to suppressing videos from some persons with disabilities, LGBTQ2 community. https://globalnews.ca/news/6250923/tiktok-policy-suppressing-persons-lgbtq-disabilities/

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4.7. Wayfinding technologies (WT)

Wayfinding technologies (WT)	
Description	Wayfinding technologies facilitate pedestrians' and/or motorists' understanding and navigation through complex built environments such as urban centres, healthcare and educational campuses, and transportation facilities. Sites, such as campuses present a unique set of navigational challenges, for example, as such environments have developed over time into complex clusters of buildings and routes. In other settings, such as airports, pathfinding efficiency is key. Travellers need information to guide them from the roadway to the airport and through the terminal complex in the most efficient way. Wayfinding systems provide physical or electronic maps, signage, directions, and other visual cues to minimise stress and simplify navigation. As such they can help build wellbeing, safety and security. Theis effectiveness relies on giving directional guidance through a carefully planned sequence that delivers information to users at key decision points in their journey. Comprehensive wayfinding systems often combine signage, maps, symbols, colours, and other communications. Increasingly, they integrate mobile applications, digital displays, RFID, and other wireless technologies.[260]
Examples	Augmented Reality (AR) has long been indicated as a promising technology for navigation, providing a more intuitive experience and potentially delivering navigational clarity that's more forgiving than current technologies. Even so, AR has faced a couple of significant constrains: First, it requires a level of data transmission that generally is not available. Second, it requires the user to understand how to employ it. Like all navigational technologies, AR requires acurate information to provide benefits to users. It needs to know where the user is, where they are going, which way they are facing and the best route to the destination. Like other

[260] https://segd.org/whatwayfinding#:~:text=Wayfindingrefers%20to%20information%20systems,and%20experience%20of%20the%20space.&text=These%20information%20systems%20help%20people,routes%20to%20the%20extent%20possibl

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	geolocation-based technologies, it also faces technological hurdles to realize the promise. Indoor positioning technology isn't accurate to the level required for most applications. Currently Augmented Reality still seems to be a concept in trial rather than a practical application. Google is at the forefront of AR technology and has yet to release AR at scale. The main challenge has been to find a use-case that shows AR to be more effective than current technologies. While there are certain situations where AR is effective, it comes with safety concerns and user-experience failures that have prevented AR from being worthy of implementation.[261] With relation to Geolocation, Geo-fencing technology is widely used for securing buildings and areas. A practical example of the commercial use of geofencing is provided by the company Pigeon. Its services include customized to support large recreational centres such as zoo parks, resorts or theme parks. Pigeon acts as a virtual perimeter of a venue, giving users live data when a device enters or exits a facility. Geo-fencing technology is widely used for securing corporate campuses, healthcare centres, transportation hubs, and public parks among others.[262] With regard to Machine Learning, as server power increases, this technology area will become more integrated, and allow great advances, also in assisting the mobility of the disabled. Soon, we my imagine an app that will be able to predict an individual's travel intent, based on search patterns, digital communication, and an appointment in your phone calendar; crowdsource traffic data for the best route, adjusted on the fly; change directions based on the closest open door to where you are going; suggests the location of a parking spot; and calculate an indoor route that goes only through ramps and elevators. The technology for all of these steps already exists. It just needs to be put together for one continual, seamless, automated operation.

[261] https://www.iotforall.com/augmented-reality-indoor-geolocation-and-the-future-of-navigation-experiences/
[262] https://pigeon.srisys.com/geo-fencing/

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	That requires server power, and a company innovative to put it all together. In 2016, Advertising Age called this concept wayknowing, defined as integrating all available information in real-time to allow for human queries based on behaviour, not just knowledge of a software. As Apple, Google, Microsoft, Facebook and Amazon develop competing conversational interfaces, Siri's original inventors have started a new company (Viv), aimed at breaking the silos of apps and enable open sharing of data. Add to that the rising potential of in-ear technologies, and the promise of a heads-up, conversational assistant to help navigate our world becomes more reality.[263]
Enabling technology domains	Internet of Things (IoT), Augmented Reality (AR) and Virtual Reality (VR); AI Speech Recognition (ASR) and Natural Language Processing (NLP); AI Based Ruled Systems; Advanced human-machines interaction techniques.
Impact on advanced mobility solutions (and mobility gaps)	Considering that people with disabilities routinely are faced with unique mobility challenges, understanding how accessible the traveling environment (outdoor, indoor) is and how people with disabilities usually find ways through these environments is of great importance. Once ontologies that reflect the wayfinding and navigation needs of people with disabilities are developed, they can be used to design and develop databases that include accessibility of the environment for the purpose of wayfinding and navigation of people with disabilities. The scheme of these databases is designed such that a wide range of queries related to finding points of interest and wayfinding and navigation activities can be answered. Most existing map databases with accessibility, some designed based on developed ontologies, are intended for all communities, while others are focused on a specific community, for example, wheelchair users. For people with disabilities, it is imperative to know whether the places (e.g., parks or buildings) to which they want

[263] https://www.concept3d.com/blog/digital-wayfinding/the-present-and-future-of-wayfinding-in-2019

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	to travel have accessible entrances/exits before they make decision for their trip. Considering people's mobility is usually from places to places, accessible points of interest play an important role in places where people with disabilities can go and in what activities they can participate. This implies that points of interest are a starting point for people with disabilities to make decision on the places they can go, before they can make any plans for their daily activities. Accessible points of interest must be compliant to a given set of standards. At the community level, models must address the specific needs of each disability community (e.g., wheelchair users, people who are blind or visually impaired). At the individual level, models must address the specific preferences of each individual with disabilities (e.g., an individual who is blind or visually impaired). Databases with accessible sidewalk networks (outdoor), accessible hallway networks (indoor), and accessible points of interest and accessible sidewalk wayfinding and navigation techniques, can be incorporated into existing wayfinding and navigation services to assist people with disabilities with their daily mobility. When incorporated into existing wayfinding services, the services must provide directions using consecutive cues that are themselves accessible. When incorporated into navigation services, in addition to accessible routes and directions, the services must provide real-time guidance by taking into account dynamic changes (e.g., traffic) that would impact either the route or the directions.[264]
Relevant European regulatory frameworks and standards	• 2012 Assistive products for blind and vision-impaired persons -- Tactile walking surface indicators Standards. • Accessibility requirements for products and services, Legislative Observatory (OEIL), European Parliament (2015/0278). • Directive 2000/78/EC of 27 November 2000 establishing a general framework for equal treatment in employment and occupation, OJ L 303, 2.12.2000. • Directive 2000/43/EC of 29 June 2000 implementing the principle of equal

[264] https://www.hindawi.com/journals/misy/2015/520572/

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	treatment between persons irrespective of racial or ethnic origin, OJ L 180, 19.7.2000. • Directive 2000/78/EC of 27 November 2000 establishing a general framework for equal treatment in employment and occupation, OJ L 303, 2.12.2000. • Directive 2004/113/EC of 13 December 2004 implementing the principle of equal treatment between men and women in the access to and supply of goods and services, OJ L 373, 21.12.2004 • Commission Regulation (EU) No 651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty Text with EEA relevance, OJ L 187, 26.6.2014. • Directive 2006/54/EC of 5 July 2006 on the implementation of the principle of equal opportunities and equal treatment of men and women in matters of employment and occupation (recast), OJ L 204, 26.7.2006. • European Disability Forum, 'Ten years on: practical impact of the Employment Directive on persons with disabilities in employment – EDF analysis of Council Directive 2000/78/EC', 2010. • European Disability Strategy 2010-2020: A Renewed Commitment to a Barrier-Free Europe, COM (2010) 636 final, European Commission, 2010. • Assistive products for persons with disability — Classification and terminology-ISO 9999:2016 • UN Convention on the Rights of People with Disabilities
Relevant cybersecurity and privacy issues	Ubiquitous and pervasive computing is the emerging communication development towards embedding microprocessors in everyday objects so they can communicate information. Ubiquitous computing is changing daily behaviours of people in a variety of ways such as; people tend to: 1) communicate in different ways; 2) be more active; 3) conceive and use geographical and temporal; 4) spaces differently; 5) have more control. This computing architecture relies on the convergence of wireless technologies, advanced electronics and

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	the Internet. The developers of this technology aim to create intelligence products that able to communicate continuously so that the data generated can be easily accessible. According to a research from L. Barkuus and A. Dey, "Location-based services for mobile telephony: A study of users' privacy concerns," privacy is related to keeping personal data safe and protecting people's identity in terms of name, social security, and purchase behaviour. From the viewpoint of law, privacy protection rules stipulate that users' privacy data must be consumed under a few conditions[265]. Generally, when using the technology people are concerned more about the exposure of their personal information to the third party. Therefore, in order to persuade people to perform the behaviour that relates to ubiquitous technology, the privacy factor is important. The governments play a stimulating role in this development by means of including privacy and security requirements in its purchase conditions. Creating a culture of privacy and security, and continue to raise privacy awareness to all users, are key initiatives to further improve cyber security.

[265] M. Shahrom, E. S. Kassim, N. Humaidi, and N. H. Zamzuri. *"A Captology Study on Behavior Model for Persuasive Ubiquitous Technology."* Published at the International Journal of Machine Learning and Computing, Vol. 7, No. 5, October 2017.

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4.8. Safe intersection crossing

Safe intersection crossing	
Description	Safe Intersection Crossings (SICs) enable pedestrians to use connected mobile devices to interface with the traffic and environmental infrastructure to cross an intersection safely. SIC aim to address the lack of visibility in pedestrian crossings and by improving it, increase traffic safety for pedestrians and reduce the number of urban accidents. Communications technologies are critical to the safe, secure, and efficient operations of transportation systems. As ITS capabilities improve and become more widespread, the transportation industry continues to develop new ways to utilize these emerging technologies and the data they produce. Transportation agencies have incorporated communications into their operational environments (i.e., field systems, management centres, and public fleets), and Vehicle manufacturers are increasingly including multiple types of communications in their vehicles. While much research has been conducted with Wi-Fi, Dedicated Short Range Communications (DSRC), cellular, and satellite communications, there are emerging communications technologies such as Cellular-Vehicle-to-Everything (C-V2X) and 5G that could also have significant impacts on transportation systems. For example, C-V2X is being developed as a potential replacement for the DSRC system used by many ITS communications technologies today, and the capabilities of 5G are not yet clearly defined. 5G technology could also drastically increase the speed at which information is communicated between vehicles and other entities, like roadside infrastructure, other vehicles, or even pedestrians with smartphone applications. For the existing communications technologies in use in transportation today, modal partners and stakeholder partners have invested in a wide range of research and analyses including: Development of a band plan for the 5.9 GHz part of the spectrum; Comparison of cellular, Wi-Fi, and satellite

	capabilities and costs to deliver interoperable, low-latency messages; Assessment of out-of-band and adjacent channel interference in the 5.9 GHz spectrum.[266]
Examples	**Smart pedestrian signal** - **Dubai smart city initiative**. The Dubai Roads and Transport Authority (RTA) installed the Smart Pedestrian Signal as part of Dubai's Smart City initiative. The Smart Pedestrian Signal becomes activated by sensors connected between the ground and the traffic light. The pedestrian traffic will be measured (e.g., the number of pedestrians waiting and time needed to cross the path) by the smart signal. Based on the waiting time and the size of the pedestrian traffic, the signal time will adjust for the safer and smoother pedestrian crossing with adequate consideration given to traffic.[267] **Hong Kong north point.** With a single tap of a card, elderly pedestrians and those with disabilities can now get a few extra seconds to make their way across Hong Kong's busy roads. The device is attached to a traffic pole. When someone taps it with an Octopus card for the elderly or a personalised Octopus card registered with the "Persons with Disabilities Status", the blinking green light will flash for 16 seconds, up from the usual 12 at the North Point location. A new countdown display next to the green man shows how much time left for pedestrians at the crossing. The extension of the blinking green light is to give the elderly – with an average walking speed of 0.9 meters per second – enough extra time to cross one car lane. The extra-time will vary between three to four seconds or a third of the usual time. Such, depending on the location and the size of the crossing.[268] **Bercman Smart Pedestrian Crosswalk (SPC)**. SPC is a multifunctional C-ITS device, which improves traffic safety on unregulated pedestrian crosswalks. It warns road users located nearby and notifies road users of the probable traffic hazard. The system is adaptive, reacting accordingly to the situation. SPC

[266] https://www.its.dot.gov/research_areas/attri/safe_crossing.htm
[267] https://cdmsmith.com/en-ME/Client-Solutions/Insights/Smart-Solutions-for-Pedestrians-in-Smart-Cities
[268] https://www.todayonline.com/world/smart-device-gives-elderly-and-disabled-more-time-cross-hong-kongs-busy-streets

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	monitors the traffic lanes and sidewalks with cameras and sensors, including different safety and notification functions, for the detection of traffic hazards. Narrow- artificial intelligence algorithms predict the moving trajectories of road users and warn them: Audio warnings for pedestrians, and rapidly blinking LED lights for vehicle drivers.[269] **Continental intelligent intercrossing**. Continental presents its first comprehensive Intelligent Intersection pilot that is operating in the heart of Walnut Creek, California. A three-dimensional view of the intersection, displayed using augmented reality, will let visitors experience data feeds from traffic at the junction and talk first hand with experts about the value intelligent intersections can bring to smart cities. First introduced as a concept at CES 2018, Continental's Intelligent Intersection is a real-world, end-to-end solution comprising a sensor set, powerful sensor fusion algorithms to generate a comprehensive environmental model and Dedicated Short-Range Communication (DSRC) to transfer valuable information between the intersection and connected vehicles.[270]
Enabling technology domains	Internet of Things (IoT); Augmented Reality (AR) and Mixed Reality (MR); AI- Machine Learning (ML); Web technologies-Infotainment; Machine vision, Advanced human-machine interaction techniques, Geolocation.
Impact on advanced mobility solutions (and mobility gaps)	As research from the EU's Safety Cube project indicates, certain driver behaviours increase the likelihood of accidents occurring: distractions are prevalent causes amongst these. Yet there exist knowledge gaps, particularly regarding psychological factors, observational errors, and certain distractions. Most accidents result from simple errors of judgment or perception, filling these is vitally important. 25,100 people lost their lives on EU roads in 2018. 21% of all traffic fatalities in the EU are pedestrians. The largest share of these are 65 or over. Also, the proportion of disability people in the elderly also is higher. The environments in which Vulnerable Road Users navigate and interact with traffic also influence their safety. New road safety

[269] https://www.bercman.com/products/spc

[270] https://www.continental.com/en/press/press-releases/2018-12-17-ces-2019-smart-cities-156184

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	innovations based around Intelligent Transport Systems can be integrated into road infrastructure. Voice Response Units can alert cyclists and drivers of potential collisions. Similar warning systems for pedestrians, as well as active pedestrian safety systems which perform autonomous emergency braking in critical traffic situations, offer great potential. ITS applications have assisted in reducing the number of accidents in Europe, but the development has mainly been vehicle-centric. The decrease in casualties of Vulnerable Road Users, such as pedestrians, cyclists, and Powered Two-Wheelers (PTWs), has been much less prominent. In the longer term the technology can also serve to improve inner-city traffic flow, thereby reducing travel time and vehicle emissions.[271]
Relevant European regulatory frameworks and standards	EU Valletta Declaration on road safety of March 2017 set a target for reducing serious injuries, namely, to halve the number of serious injuries in the EU by 2030. A new approach is set out in the Europe on the Move" Communication. The legislative initiative is part of a bigger effort to secure a competitive advantage and to increase public and private investment in AI to €20 billion per year. A key challenge will be to grow investment, data, and talent required to develop AI and accelerate its adoption, and to create an innovation-friendly regulatory environment across the EU. The EU progressively improved the Vehicle General Safety Regulation and the Pedestrian Safety Regulation. The Commission is proposing to revise these Regulations to make some important safety features mandatory, such as Intelligent Speed Assistance, Autonomous Emergency Braking (including in relation to pedestrians and cyclists) or improved direct vision for trucks. As a follow-up, it will be important to prioritise the work of the EU in developing new vehicle safety regulations (for example Autonomous Emergency Braking for trucks including pedestrian and cyclist detection and direct vision standards). The 2020 EU Rolling Plan areas and actions include Key enablers and security (Internet of Things; Artificial Intelligence; 5G) and Sustainable growth (Smart grids and smart metering; Robotics and autonomous systems; Intelligent Transport Systems - Cooperative,

[271] https://www.eltis.org/content/vulnerable-road-users-and-road-safety-europe

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	Connected and Automated Mobility (ITS-CCAM) and Electro-mobility[272]. EU References to consider: - EU regulation 78/2009 – vehicle approval / protection of vulnerable road users - EU regulation 631/2009 – implementing vehicle approval to protect vulnerable road users - EU Road safety policy framework for the decade 2021 to 2030 - EU White Paper on Artificial Intelligence - Safe vehicles Regulation crossed with Pedestrian Safety Regulation
Relevant cybersecurity and privacy issues	As modern vehicles are capable to connect to an external infrastructure and Vehicle-to-Everything (V2X) the necessity to secure communications becomes apparent. There is a very real risk that today's vehicles are subjected to cyber-attacks that target vehicular communications. The sensing layer is made up of vehicle dynamics and environmental sensors, which are vulnerable to eavesdropping, jamming, and spoofing attacks. The communication layer is comprised of both in-vehicle and V2X communications and is susceptible to eavesdropping, spoofing, man-in-the-middle, and sybil attacks. Attacks targeting the sensing and communication layers can propagate upward and affect the functionality and can compromise the security of the control layer.[273]

[272] https://ec.europa.eu/transport/road_safety/what-we-do_en
[273] https://www.sciencedirect.com/science/article/pii/S221420961930261X

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4.9. Assistive robots

Assistive Robots	
Description	Since assistive robots represent a very powerful assistance technology with many different application possibilities, they are also addressed in deliverable D3.4. and for this reason, they are briefly described in this factsheet. A detailed consideration of the characteristics and possible applications is given in the dedicated Deliverable mentioned above. An assistive robot is a device that can take actions, perceive the surroundings and thereby can support people with disabilities. Assistive robots interact directly with humans.[274] They use sensors and algorithms to perceive the environment and the individuals.[274] They are able to make decisions and are characterised in particular by navigation, cognition, multimodal interaction and safety.[274] Through these abilities, the robot can strongly support people with disabilities in everyday life.[275] This allows the robot to perform tasks that would otherwise have to be performed by a human assistant.
Examples	**Pepper:** Pepper is a 1,20 m tall robot with humanized appearance and sophisticated technology, presented 2014 by Aldebaran Robotics SAS and SoftBank Mobile Corp. It is characterized by advanced mechanics and language technology.[276] The assistive robot **ANNIE** is a developed at the Fraunhofer IFF. It is a mobile manipulator for future use for tasks in industry and business. The main focus is on logistical tasks or the operation and interconnection of machinery. It can also handle assistive tasks or inspection and monitoring. Besides state-of-the-art hardware and software, the robot integrates key technologies developed at the Fraunhofer IFF in the field of perception, navigation, safety, software architecture and interaction. The aim is to develop an advanced robot which is

274 https://www.iff.fraunhofer.de/en/business-units/robotic-systems/research/assistive-robotics.html
275 https://web.stanford.edu/class/engr110/2012/04b-Jaffe.pdf
276 https://www.robot-world.at/serviceroboter/pepper

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	capable to handle efficiently the varied scenarios from the sectors.[277] The humanoid robot **"Russels"** was developed as learning environment to engage children with autism. The robot teaches learning skills to autistic children and measures their response in real time. The robot has some human characteristics, but not so complex that it will overstimulate or overstrain autistic children. The room where the robot interacts with the children is equipped with cameras and sensors that tracks the child's movements. This information provides feedback to the robot in order to make him understand how well the child is performing and even how much it enjoys the activity.[278]
Enabling technology domains	Robotics and Automation, Advanced human-machine interaction techniques.
Impact on advanced mobility solutions (and mobility gaps)	The main advantage of assistive robots is that, in addition to artificial intelligence, they also can move or relocate themselves. In terms of assistance systems for handicapped people, this opens up possibilities that can otherwise only be created by human assistance such as care personnel. For example, an assistive robot could help disabled people with sensory or mental disabilities to travel by processing the necessary information, guiding them through the transport system and even handle special situations, thus contributing to participation and inclusion.
Relevant European regulatory frameworks and standards	• ISO/TC 184 - Automation systems and integration • ISO 13482:2014 - Robots and robotic devices — Safety requirements for personal care robots
Relevant cybersecurity and privacy issues	Since assistive robots are observing their environment and the humans around them to react to it, everything that happens around them is recorded and analysed.

[277] https://www.iff.fraunhofer.de/en/business-units/robotic-systems/research-platform-annie.html
[278] https://www.brainfacts.org/archives/2014/humanoid-robot-russell-engages-children-with-autism

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4.10. Facial recognition software

Facial recognition software	
Description	Facial recognition is a category of biometric software that maps an individual's facial features and stores the data as a face print. This technology is independent of human processing or monitoring. The software uses deep learning algorithms to compare a digital image to the stored face print in order to verify an individual's identity. The software identifies 80 nodal points on a human face. In this context, nodal points are endpoints used to measure variables of a person's face, such as the length or width of the nose, the depth of the eye sockets and the shape of the cheekbones. However, if the subject's face is partially obscured or in profile rather than facing forward, this type of software is less reliable. According to the United States National Institute of Standards and Technology (NIST), the incidence of false positives in facial recognition systems has been halved every two years since 1993.[279] Simply put, the technology scans a person's face and then verifies it. In particular, it works in three basic steps that you will find in all facial recognition technologies: 1. **Face Detection**: This is the first step where the human face is located and detected in the form of images and videos; 2. **Face Capture**: Then, the process moves towards capturing facial features. Facial biometrics, which is a 2D or 3D sensors, capture the face, which transforms the facial information captured into digital information by the application of an algorithm; 3. **Matching and Verification**: Lastly, the facial information gathered is then matched with the information (other faces) present in the database to check if there is any match.

[279] https://searchenterpriseai.techtarget.com/definition/facialrecognition#:~:text=Facial%20recognition%20is%20a%20category,to%20verify%20an%20individual's%20identity

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	Facial Recognition has already coupled with AI and Deep Learning has become the benchmark for the biometric identification process for many industries that include: airports, mobile manufacturing industries, home security, and appliance manufacturers, schools, and more.[280]
Examples	Growing numbers of applications are using face recognition as the initial step toward interpreting human actions, intentions, and behaviour based on the idea that many actions and behaviours can only be interpreted if you also know the identities of the individuals and the people around them. Examples are a valued repeat customer entering a store, behaviour monitoring in an elder care or child care facility, and command-and-control interfaces in a military or an industrial setting. In each of these applications, identity information is crucial to providing machines with the background knowledge needed to interpret measurements and observations of human actions. A key goal is to give machines perceptual abilities that allow them to function naturally with people; to recognize people and remember their preferences and peculiarities, to know what they are looking at, and to interpret their words, gestures, and unconscious cues, such as vocal prosody and body language. An example of AI Machine Learning as an enabling technology regarding Facial Recognition is what is already being implemented to vehicles allowing safer driving and safer intersection crossing: the Anti-Sleep Alarm that uses a Samsung Gear 2 smartwatch and a smartphone to detect drowsiness in drivers from hand gestures and facial recognition. The app prompts the driver to pull over and rest and sets off an alarm if it determines the driver is falling asleep at the wheel. Personalised itineraries and travel options can be further personalised when resourcing to facial recognition. High-quality cameras in mobile devices have made facial recognition a viable option for authentication as well as identification. Apple's iPhone X and Xs, for example, include Face ID technology that lets users unlock their phones with a face print mapped by the phone's camera. The

280 http://www.m2sys.com/blog/guest-blog-posts/evolution-of-facial-recognition-technology/

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	phone's software, which is designed with 3-D modelling to resist being spoofed by photos or masks, captures and compares over 30,000 variables. Face ID can be used to authenticate purchases with Apple Pay and in the iTunes Store, App Store and iBooks Store. Apple encrypts and stores face print data in the cloud, but authentication takes place directly on the device. Existing payment of services using Facial recognition include Amazon, MasterCard and Alibaba, who have rolled out facial recognition payment methods commonly referred to as selfie pay. The Google Arts & Culture app uses facial recognition to identify museum doppelgangers by matching a real person's face print with a portrait's face print. The same can be applied in Public Transport and Mobility providers. This technology can overthrow the obstacle for motor and mental disabled, once doesn't require any end-user interaction or a 'handler' to verify.[281]
Enabling technology domains	AI Machine Learning
Impact on advanced mobility solutions (and mobility gaps)	Researchers are exploring applications for these perceptually aware devices in health care, entertainment, and collaborative work. Recently, much effort has gone into creating a person-independent expression recognition capability. Facial-expression research has so far been limited to recognition of a few discrete expressions rather than addressing the entire spectrum of expressions along with their subtle variations. Before a system can achieve a useful expression analysis capability, it must be able to recognize and tune its parameters to a specific person. Wearable recognition systems where we build computers, cameras, microphones, and other sensors into a person's clothes, allows the computer's view to move from a passive third-person to an active first-person vantage point. These wearable devices can adapt to a specific user and be more intimately and actively involved in the user's activities. Consequently, we can expect to see rapidly growing interest in the largely unexplored area of first-person image interpretation. Face recognition is an integral part of wearable systems like memory aids

[281] https://tinyurl.com/y2e78tos

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	and context-aware systems. Thus, developers will integrate many future recognition systems with clothing and accessories.[282] Next-generation recognition systems will need to recognize people in real time and in much less constrained situations. Identification systems that are robust in natural environments cannot rely on a single modality; fusion with other modalities is essential. Technology used in smart environments has to be unobtrusive and allow users to act freely. Wearable systems in particular require the sensing technology to be small, low power, and easily integrated with clothing. Considering all the requirements, systems that use face and voice identification seem to have the most potential for widespread application. Cameras and microphones have been successfully integrated with wearable systems. Audio and video based recognition systems have the critical advantage of using the modalities humans use for recognition. Finally, researchers are beginning to demonstrate that unobtrusive audio and video-based personal identification systems can achieve high recognition rates without requiring the user to be in a highly controlled environment.[283]
Relevant European regulatory frameworks and standards	In a number of European countries, facial recognition technologies are being tested or used in different contexts in both private and public spheres. To date, there are few examples of national law enforcement authorities using live facial recognition technology in Europe. EU law regulates the processing of facial images under the EU data protection acquis. Below the main EU Legislation references: • Law Enforcement Directive (Dir. (EU) 2016/680); • General Data Protection Regulation (Reg. (EU) 2016/679); • Directive on privacy and electronic communications (Dir. 2002/58/EC, as amended by Dir. 2009/136/EC).

282 https://www.urmc.rochester.edu/biochemistry-biophysics.aspx
283 http://alumni.media.mit.edu/~tanzeem/computer2000_biometrics.pdf

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	In the field of police and judicial cooperation in criminal matters, the Law Enforcement Directive (Directive (EU) 2016/680)21 is the most relevant instrument. It establishes a comprehensive system of personal data protection in the context of law enforcement. The Law Enforcement Directive specifically refers to facial images as 'biometric data' when used for biometric matching for the purposes of the unique identification or authentication of a natural person. The sectorial EU instruments governing large-scale EU information systems in the field of migration and security, complement the EU data protection acquis. Biometric data is defined as "personal data resulting from specific technical processing relating to the physical, physiological or behavioural characteristics Below, the listed Legal sources, regarding the collection and processing of facial images by the EU IT systems for migration and security. • Regulation (EU) 2018/1862, 28 Nov. 2018-SIS II Police ; • Regulation (EU) 2018/1861, 28 Nov. 2018 - SIS II- Border Checks; • Reg. (EU) 2018/1860, 28 Nov. 2018- SIS II Boarders-Return; • Reg. (EU) 2017/2226, 30 Nov. 2017-Entry-Exit System (EES); • Reg. (EC) 767/2008, 9 July 2008- VIS; • Proposal for revision COM(2018) 302 final, 16 May 2018- VIS Proposal; • Reg. (EU) 2019/817 – bordes & visa, 20 May 2019; • Reg. (EU) 2019/818 – police & judicial cooperation, asylum & migration, 20 May 2019; • Proposal for revision COM(2016) 272 final, 4 May 2016 on the use of fingerprints and facial images to improve immigration irregularities; Reg. (EU) 603/2013, 26 June 2013-EURODAC-Determines Member State responsible to examine an application for international protection
Relevant cybersecurity and privacy issues	On the 28th of October 2019, the European Data Protection Supervisor (EDPS) published various observations regarding facial recognition technology on the under Wojciech Wiewiórowski:

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	"Facial recognition: A solution in search of a problem?" The EDPS regards the data protection and privacy issues associated with facial recognition as relatively clear-cut. EU data protection rules clearly cover the processing of biometric data. The General Data Protection Regulation (Regulation (EU) 2016/679) ('GDPR') prohibit the processing of biometric data for the purpose of uniquely identifying a natural person, unless in specific cases. The processing of biometric data, including facial images, is considered to be especially sensitive for the purposes of the GDPR and is subject to more stringent rules as one of the 'special categories of data.' The EDPS questions whether facial recognition technology is necessary at all, or whether other, less intrusive methods could arrive at the same result. EDS questions whether there can be a valid legal basis for the use of facial recognition technology. Consent would have to meet the standards set out in the GDPR, therefore be explicit, freely given, informed, and specific, but individuals cannot opt in or out to the use of such technology when they require access to public areas covered by such surveillance. The EDPS explores the issues of transparency and accountability in respect of facial recognition, pointing out that little is known regarding the use of the technology, how the captured personal data is used, who can access it, and who it is sent to, as well as its retention period, how profiling operates, and who is ultimately responsible for automated decision making based on such data. Also to note that EDS considers that it is extremely difficult to identify the source of the input data, as facial recognition systems are uploaded with many images collected without consent, meaning that any individual could be subjected to the technology and categorised, and thus often discriminated against. The EDPS concludes that the technology is not completely accurate, resulting in significant consequences for individuals who are incorrectly identified, whether as criminals or not, and suggests that, although the quest for accuracy may result in an increasing collection of data, the data collected will never be sufficient in eliminating bias and the risk of false negative or positive results. The EDPS calls for the EU to decide when, if ever, facial recognition technology should be allowed in a democratic

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	society. Only if the answer is that it should be allowed, will consideration be given to the issues of how it is to be permitted, and how accountability and safeguards should be implemented.[284]

[284] Facial recognition: A solution in search of a problem? Wojciech Wiewiórowski (28 October 2019).

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4.11. Intelligent environments, Ambient intelligence

Intelligent Environments, Ambient intelligence	
Description	Ambient intelligence (AmI) is a discipline that integrates intelligence to environments and creates an interaction between humans and their environments.[285] AmI is a concept in which people are surrounded by networked devices that adapt to their needs.[286] The objective of AmI to make the places where people live and work more beneficial for them.[287] Ambient intelligence devices are divided into stationary, nomadic, and autonomous devices[288] and can be beneficial in terms of security, healthcare and comfort.[289] AmI thus is based on an electronic and digital environment which is aware of the presence of a human being and reacts sensitively and responsively to the needs, habits, gestures and emotions.
Examples	One example is Smart Homes, where a building or an environment where people live or work, provides context-aware services and allows remote home control.[290] Examples of this can be: • the opening of doors when a person approaches; • the adjustment or adaptation of furniture (e.g. also healthcare bed); • recognize the sensation of heat and regulate the room temperature; • reaction to gestures (e.g. adjustment of volume or speed of media content); • Detection of tiredness and darkening of the room or switching off appliances (e.g. TV). This requires an environment in which all objects, clothing, infrastructure etc. are equipped with sensor technology. Actuators are necessary to make objects move or change. Furthermore, a networking of all objects is required in order to communicate

285 https://www.sciencedirect.com/science/article/abs/pii/S157411920900025X?via%3Dihub
286 https://www.itwissen.info/AmI-ambient-intelligence.html
287 https://link.springer.com/chapter/10.1007/978-3-540-70621-2_2
288 https://www.itwissen.info/AmI-ambient-intelligence.html
289 https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6177682
290 https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6177682

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	with each other and with the user. Artificial intelligence is required to interpret situations or signals and to act appropriately according to user habits and the situation. AmI can be used in various environments such as in private households, hospitals, PT or factories. [291]
Enabling technology domains	Internet of Things, Robotics and Automation, Web technologies – infotainment, Machine vision, Advanced human-machine interaction techniques.
Impact on advanced mobility solutions (and mobility gaps)	People with limited cognitive abilities often have – depending on the severity of the disability - difficulties in orientating themselves in unfamiliar environments or are overwhelmed by unexpected events. Here AmI can offer support with sensor technology and artificial intelligence. In addition, sensor technology and networking can be used to monitor the state of health of people and, if necessary, to initiate appropriate measures, for example if certain values are exceeded or symptoms occur. AmI can be used for indoor navigation. For example, sensor technology and the internet of things in combination with assistive robots can become an integrated solution for orientation within buildings where, for example, satellite navigation based on GPS does not work reliably.[292] Inside a private vehicle, AmI can supply and retrieve heterogeneous information. Those can be e.g. driver's health information (physiological, psychological, emotional and medical conditions), environmental Information (analysis of the situation outside the car, e.g. conflict records or road conditions) as well as car Information (e.g. car's movement and available internal services).[293] The principles of ambient intelligence such as context sensing and the sharing of context information are an essential prerequisite for the further development of automated driving up to autonomous vehicles. Completely autonomous vehicles without a necessary (back-up) driver would

[291] https://link.springer.com/chapter/10.1007/978-3-540-70621-2_2
[292] https://tinyurl.com/yac8b4d6
[293] https://ieeexplore.ieee.org/document/1398977

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	offer completely new possibilities of mobility and participation for disabled people of all kinds.
Relevant European regulatory frameworks and standards	• ISO/IEC JTC 1/SC 7 Software and systems engineering; • ISO/IEC (1999-2001) ISO/IEC 14598 Information technology –Software product evaluation, Part 1 to 6. Especially ISO/IEC 14598-3:2000 Software engineering — Product evaluation — Part 3: Process for developers; • ISO 13407: Human Centred Design Process for Interactive Systems.
Relevant cybersecurity and privacy issues	Privacy issues are especially relevant in terms of AmI because AmI systems require record user's private information.[294] A high degree of privacy is one of the main factors of success of AmI.[295] The most threatening privacy issues regarding AmI are:[296] • Perceptual interfaces for several devices and applications will record personal information about users; • Learning systems and an AI that offers personalized services to the users will record users' everyday activities and habits.[297]

[294] https://tinyurl.com/y95k2cgw
[295] http://publica.fraunhofer.de/dokumente/N-48353.html
[296] Ackerman, M. S., 2004. Privacy in pervasive environments: Next generation labelling protocols. Personal and Ubiquitous Computing 8 (6), 430–439

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5. Conclusion

Using technology to improve the lives of people with disabilities, by studying strategies (and devices) to simplify daily actions, is the goal of many challenges looking to the future.

In this deliverable, digital technologies have been presented and identified within trending "Technological Domains", and real-world solutions leveraging related technologies have been described within "Application Areas", thanks to the identification of the major relationships between such domains and areas. The history and evolution of each Technological Domain has been presented, including possible future evolution and their impact on disabled people's mobility. The use of standardized factsheets has allowed to easily focus on different aspects across technologies and applications belonging to distinct but interrelated domains and areas.

On-board virtual assistants are an example of the application of ICTs such as machine learning and big data analytics to public transport, and were reported to be especially useful to help passengers with various types of disabilities, for instance, for them to receive real-time information while travelling. One of the most significant challenges in the field of transportation is the development of autonomous vehicles that, using technologies such as machine learning and artificial intelligence, will be able to understand voice instructions, observe the surrounding environment, communicate with people, and improve road safety, especially for disabled people. In particular, completely autonomous vehicles without a necessary (back-up) driver would offer completely new possibilities of mobility and participation for disabled people of all kinds. Not only cars, but also trains are being fully automated, as in the case of the Cityringen project, which features a driverless metro line, provided with elevators to allow easier access to disabled people, and also ticket dispensers and validation machines installed in such a way as to allow wheelchairs users to access them easily.

With respect to safety, ITS and CAVs are being designed taking into consideration that all road users are human and, although driving can be a monotonous activity, constant focus is required. Solutions within the area of Safe Intersection Crossings, by using connected mobile devices to interface with vehicles and other infrastructure, can alert cyclists, drivers, or pedestrian about potential collisions. As a result, innovative solutions to increase safety are being integrated both within transport services and vehicles, such as smart pedestrian crossings that can prolong crossing times for disabled people, and collision detection systems that can alert both vehicle's drivers as well as pedestrians.

Our study also showed that disabled people do not only need assistance during the trip but already before starting the trip; with this regard, Pre-trip Concierge and Virtualization (PTCV) aims to provide all the necessary information to disabled people and/or their caregivers both before and during a trip. Caregivers, who can identify the most personally meaningful content for the disabled people they care for, are allowed to upload such meaningful content to PTCV apps to provide proper step-by-step visual instructions and cues, and assure the disabled person that they are on the right way. Time-stamped updates can also be checked for the caregiver to be sure the disabled person is on the correct route. Such applications could be enhanced by leveraging facial recognition capabilities to know whether the disabled person looks impatient—because information is being presented too slowly—or confused because it is coming too fast. Among PTCV services there also several airport services for disabled people, such as parking reservation and prepayment, food ordering, and real-time updates on parking availability, security wait times, gate changes, flight arrival and departure times. The Aira app allows to guide blind and low-vision people within an airport by instantly connecting them to

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highly-trained, remotely-located agents, via the video and audio input/output of the disabled person's smartphone.

The increasing usage of social media must also be considered among the main digital trends; these tools are part of our life today and, if used correctly, can improve the disabled people's quality of life. In fact, social media can be used to track mobility patterns and to detect and describe traffic anomalies; social media are also used for emergency management and, by leveraging big data analytics, they can be used to collect and analyse user data, and to understand user behaviour.

Finally, assistive robots could help disabled people with sensory or mental disabilities to travel by processing the necessary information, guiding them through the transport system and even handling special situations, thus contributing to participation and inclusion.

We have created this overview in order to provide the TRIPS project with a detailed and up to date background understanding of ICT trends and the related emerging digital technologies. This forms a part of the landscape, against which we will be able to construct strategies to facilitate persons with disabilities to take control of their travel challenges.

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