The Framework Programme for Research & Innovation
Innovation actions (IA)

Project Title:

Autonomous self powered miniaturized intelligent sensor for environmental sensing and asset tracking in smart IoT environments

AMANDA

Grant Agreement No: 825464

[H2020-ICT-2018-2020] Autonomous self powered miniaturized intelligent sensor for environmental sensing and asset tracking in smart IoT environments

Deliverable

D1.4 AMANDA Operational Scenarios Definition v2

Deliverable No.		**D1.4**	
Workpackage No.	**WP1**	Workpackage Title and task type	**System Specification, Requirements and Use Cases**
Task No.	**T1.3**	Task Title	**Trial Scenarios Definition and Evolution**
Lead beneficiary		**PENTA**	
Dissemination level		**PU**	
Nature of Deliverable		**R**	
Delivery date		**31 December 2020**	
Status		**Final**	
File Name:		**AMANDA_D1.4_Operational_Scenarios_Definition-v2.0**	
Project start date, duration		**02 January 2019, 36 Months**	

This project has received funding from the European Union's Horizon 2020 Research and innovation programme under Grant Agreement n°825464

Authors List

Leading Author (Editor)			
Surname	**Initials**	**Beneficiary Name**	**Contact email**
Vujičić	OV	PENTA	oskar.vujicic@penta.hr

Co-authors (in alphabetic order)				
#	**Surname**	**Initials**	**Beneficiary Name**	**Contact email**
1	Bellanger	MB	Lightricity	mathieu.bellanger@lightricity.co.uk
2	Bembnowicz	PB	IMEC	pawel.bembnowicz@imec.nl
3	Govaerts	JG	EPEAS	julien.govaerts@e-peas.com
4	Karanassos	DK	CERTH	dkaranassos@iti.gr
5	Kouzinopoulos	CS	CERTH	kouzinopoulos@iti.gr
6	Marti	CM	EPEAS	cyril.marti@e-peas.com
7	Meli	MM	ZHAW	mema@zhaw.ch
8	Schellenberg	MS	Microdul	martin.schellenberg@microdul.com
9	Verikios	PV	CERTH	panos_verikios@iti.gr
10	Vian	CV	ILIKA	chris.vian@ilika.com
11	Vis	PV	IMEC	peter.vis@imec.nl

Reviewers List

List of Reviewers (in alphabetic order)				
#	**Surname**	**Initials**	**Beneficiary Name**	**Contact email**
1	Kauer	MK	Lightricity	matthias.kauer@lightricity.co.uk
2	Bembnowicz	PB	IMEC	pawel.bembnowicz@imec.nl

Document history			
Version	**Date**	**Status**	**Modifications made by**
V0.1	15/11/2019	ToC	PENTA
V0.2	05/12/2019	Contribution from Penta	PENTA
V0.3	7/12/2019	Contribution by IMEC	IMEC
V0.4	10/12/2019	Additional input, Conclusion	PENTA
V0.7	14/12/2019	Additional operational scenarios	CERTH
V1.0	23/12/2019	Document consolidation, accepted changes by reviewers	PENTA, Lightricity, ILIKA
V1.1	10/11/2020	Additional inputs	PENTA
V1.3	17/12/2020	Additional inputs	CERTH, PENTA
V2.0	29/12/2000	Final version, ready for submission	PENTA

List of definitions & abbreviations

Abbreviation	Definition
ASSC	Autonomous Smart Sensing Card
BLE	Bluetooth Low Energy
ESS	Electronic Smart System
FRAM	Ferroelectric Random-Access memory
LED	Light Emitting Diode
LoRa	LPWAN system from Semtech
LPWAN	Low-Power Wide-Area Network
MCU	Microcontroller Unit
NFC	Near Field Communication
PMIC	Power Management Integrated Circuit
PV	Photovoltaic
RTC	Real Time Clock
SF	LoRa Spreading Factor

Executive Summary

The objective of the AMANDA project is to create an autonomous multisensory platform, in the size and dimensions of a credit card and with a thickness not exceeding 3mm. This document discusses typical scenarios for deploying such an autonomous multisensory card, based on a number of derived use cases. These scenarios are narrative descriptions that explore the way end users might utilize the ASSC. They are based on an analysis of the use cases of the project. The use cases were first defined in **Deliverable D1.3 - Voice-of-the Customer completed** based on surveys to understand the needs of end users and manage their expectations. The use cases were subsequently refined in **Deliverable D1.7 – Architecture design of the AMANDA system delivered (for both breadboard and integrated/miniaturised system)** to better meet the architectural design of the AMANDA card. The final, consolidated list of the AMANDA use cases is presented in this Deliverable. The document provides a developing process and will help the system development team to design a variety of future practical demonstrators.

Version V2.0 of this Deliverable updates the use cases and scenarios of the project and presents an insight on the marketing position of the final integrated ASSC as well as a comparison with similar products on the market.

Table of Contents

List of tables

1 Introduction

1.1 Purpose, Context and Scope of this Deliverable

The purpose of this document is to describe in a narrative form the final, consolidated list of the AMANDA use case scenarios for use by the AMANDA ASSC. The workflow in defining the scenarios as well as the methodological approach are also presented. The Deliverable outlines six different scenarios under three different use cases. A list of stakeholders and actors is also provided with a description of their role.

1.2 Methodology of use cases and scenarios definition

As part of **WP1 – System specifications, Requirements and Use Cases** and especially within **Task T1.2 – System Requirements and Needs**, the consortium members conducted an intensive survey to determine the needs and expectations of end users across different sectors related to the ASSC. Responses from 15 potential users were received and use cases were described in **Deliverable D1.3 - Voice-of-the Customer completed** with 25 different use cases. The use cases cover three primary versions of the ASSC: indoor, outdoor and wearable. By further research and consideration of solutions, the use cases have been reduced to three. In each of the use cases, two scenarios have been described. Use case UC3 - Mitigating the effects of the current pandemic, is our contribution to solving the problems that arose from the conditions of the pandemic. This document describes the scenarios of each different ASSC version.

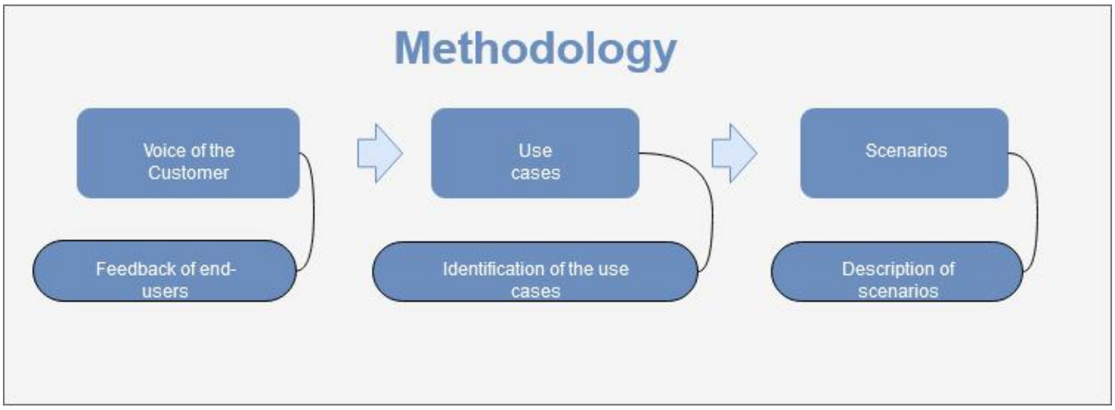

Figure 1 Use cases and scenarios methodology

Figure 1 depicts the methodology followed for the definition of the different use cases and scenarios. In order to define the use cases and scenarios, a three-step methodology has been followed. Initially, the voice of the customer was gathered and the use cases were selected. Subsequently, the operational scenarios were designed in order to prove the usability of the ASSC in each application area. The different steps of the methodology are as follows:

- **Voice of the customer.** In order to accurately identify the needs of stakeholders, such as the scientific community, business partners or end users, a research plan for the voice of the customer was developed. Different users were contacted, including industrial partners, local governments as well as different academic members. Initially, the respondents were made familiar with the key concepts and objectives of the AMANDA project as well as the potential technical features of the AMANDA ASSC. Then, surveys and interviews were conducted and the respondents answered specific questions related to their needs in IoT/IIoT solutions. The next step involved the collection of the customer needs and their categorization into groups with common characteristics. Finally, the needs and issues of the stakeholders were translated into user and business requirements

- **Use cases.** The extrapolated information from questionnaires and workshops was combined in order to ensure that the specifications and the applications of the AMANDA ASSC will successfully satisfy the end-users' needs. The consortium designed five different use cases with the intention to cover the three possible application areas; indoor, outdoor and wearable. Significant emphasis was given to the usage of all the ASSC's components and to the implementation of State-of-the-Art data fusion, edge intelligence and cyber security algorithms
- **Scenarios.** In order to prove the usability and the functionality of the ASSC, different operational scenarios were designed in each use case. An operational scenario defines a specific task of a use case and contains a combination of events which cover a particular application area of the AMANDA ASSC

2 Use cases and scenarios

2.1 Use cases

After analysing and reviewing **Deliverables D1.1 - SoA and Gap analysis/ recommendation on ESS features report, D1.2 - Initial system requirements specified, D1.3 - Voice-of-the customer completed** as well as **D1.7 - Architecture design of the AMANDA system delivered**, the Consortium revised and consolidated the use cases. As a next step, during 2020, further research underwent on the original six use cases and were subsequently consolidated into three primary use cases, as presented in Table 1 below.

Use Case	Description	Version
UC1	Environment monitoring and reporting	Indoor/Outdoor/ Wearable
UC2	Assets tracking and occupancy monitoring	Indoor/Outdoor/ Wearable
UC3	Mitigating the effects of the current pandemic	Indoor

Table 1 Definition of the use cases

All three Use Cases display the potential of a multi-sensor autonomous card. The final list of use cases is as follows:

- **Use case *UC1 - Environment monitoring and reporting.*** It utilises all three variants of the ASSC, indoor, outdoor and wearable. UC1 covers the monitoring and reporting of environmental conditions. With integrated multi-sensors and connection to a personal smartphone, the ASSC can become a mobile weather station. The ability to detect changes in temperature, air pressure and humidity can provide early information on possible sudden and unexpected upcoming changes in the state of the environment
- **Use case *UC2 - Assets tracking and occupancy monitoring.*** It covers usage of all three versions of the ASSC. Detection of the presence of an object in an open or closed space is covered by UC2. The use case also includes tracking and localization of human movements. Finally, UC2 covers the ability of the ASSC to control access to a restricted part of a building or other indoor space
- Use case ***UC3 - Mitigating the effects of the current pandemic***. It is the result of research on both the current and also future pandemics. Contact monitoring and control of the number of people in an indoor area is covered and described by scenarios that are an integral part of UC3

2.2 Scenarios

The use cases consist of two associated scenarios each. The scenarios cover one of the areas of application of the ASSC. Described outline the capabilities that ASSC has as part of the scenarios. The description is in narrative form, written in from the perspective of the end-user. Table 2 below shows the defined scenarios, the respective version of ASSC associated with the scenario and the connection to the use cases.

Label	Name	Version	Relation to Use Cases
SC01	Environment and thermal comfort monitoring	Indoor / Outdoor / Wearable	UC1

SC02	Fire monitoring	Indoor / Outdoor	
SC03	Continuous occupancy monitoring in a parking lot	Indoor / Outdoor	UC2
SC04	Asset and people localization with access control	Indoor / Wearable	
SC05	Monitor transportation conditions of medicines/vaccines	Indoor	UC3
SC06	Crowd counting for social distancing	Indoor	

Table 2 Defined scenarios

2.2.1 SC01 - Environment and thermal comfort monitoring

The ASSC is installed outdoors, or in a room or is a wearable. After the initial configuration by the system administrator, it can provide measurements related to heating, ventilation and air conditioning. The ASSC can also serve as a weather monitoring station. Moreover, the wearable version is used for thermal comfort monitoring. The ASSC automatically informs a room controlling system to adjust the heating, ventilation or air conditioning in order to achieve the optimal environmental conditions as predefined by the user. Moreover, an application installed in an end-user's smartphone, projects the room's or outer environmental conditions in real time as well as the thermal comfort levels of the users.

Generic Description	
Scenario name	Environment and thermal comfort monitoring
Version	2.0
Authors	AMANDA
Last Update	December 2020
Relationship with Use Cases	UC1
Stakeholders	End users
ASSC version	☒ Indoor ☒ Outdoor ☒ Wearable
Components used	☐ Acceleration sensor ☐ Acoustic sensor ☒ Atmospheric pressure sensor ☒ Battery ☒ BLE ☐ CO_2 sensor ☒ FRAM ☒ Humidity sensor ☐ Image sensor ☒ Light sensor ☒ LoRa ☐ Magnetic sensor ☒ MCU ☐ NFC ☒ PMIC ☒ RGB LED ☒ RTC

	☒ Solar Harvester ☒ Temperature sensor ☒ Touch sensor ☐ VOC sensor
Main flow	1) The system wakes up based on current configuration: • via the touch sensor • via the RTC 2) Data acquisition 3) Data fusion 4) Intelligent processing 5) Wireless communication security 6) Wireless transmission of the data to the main room controller 7) Wireless transmission of the data to the end-user's smartphone application 8) System sleep/power-off

Table 3 SC01 - Environment and thermal comfort monitoring

2.2.1.1 Energy requirements

Measurement of temperature, humidity and air pressure are the basic parameters that provide information about the state of the environment. Temperature, humidity, air pressure, light and touch sensors are engaged in SC01. Table 4 below shows the required measurement intervals and advertising intervals concerning the amount of light available. The card holder can also request an instant reading of the data by pressing the touch sensor. During each data transfer, the data on the availability of accumulated energy is transmitted. The sensors measure the data simultaneously. Every 15 minutes the card measures CO_2 levels, temperature, humidity, atmospheric pressure and light intensity. It subsequently transmits the results to a user's smartphone or to the room controller using BLE ADV events. Data is transmitted after each measurement in a train of 20 ADV events. In each event, data is advertised in the 3 ADV channels. A train of ADV is used to increase the probability of reception of the data by a gateway or smartphone. Energy required for MCU processing and for data acquisition is low. In one variation, one LoRa frame is transmitted every cycle (e.g. every cycle) to the control gateway in the building. The range provided by SF7 is enough for small buildings.

Parameter	Minimum	Typical	Maximum
Illumination levels	100 lux	200 lux	500 lux
Measuring Interval	15 minutes	30 minutes	1 hour
Advertising Interval	15 minutes	30 minutes	1 hour

Table 4 Operational parameters for SC01

2.2.2 SC02 - Fire monitoring

The ASSC is installed in a room or outdoors. After the initial configuration by the system administrator, it can provide measurements related to the temperature, humidity, atmospheric pressure, CO2 and VOC levels. The ASSC will be able to detect through the use of data fusion and edge intelligence algorithms the presence of fire and will alert in real time the occupants and the building's management office or the owner of the outdoors space. The card will transmit details about the incident to the building's control system, via BLE and to the closest fire department, via LoRa.

Generic Description	
Scenario name	Fire monitoring
Version	2.0
Authors	AMANDA
Last Update	December 2020
Relationship with Use Cases	UC1
Stakeholders	End users, SMEs
ASSC version	☒ Indoor ☒ Outdoor ☐ Wearable
Components used	☐ Acceleration sensor ☐ Acoustic sensor ☒ Atmospheric pressure sensor ☒ Battery ☒ BLE ☒ CO_2 sensor ☒ FRAM ☒ Humidity sensor ☒ Image sensor ☒ Light sensor ☒ LoRa ☐ Magnetic sensor ☒ MCU ☐ NFC ☒ PMIC ☒ RGB LED ☒ RTC ☒ Solar Harvester ☒ Temperature sensor ☒ Touch sensor ☒ VOC sensor
Main flow	1) The system wakes up based on current configuration: • via the RTC 2) Data acquisition 3) Data processing 4) Intelligent processing 5) Wireless communication security 6) Wireless transmission of the data to the main building controller and closest fire department via LoRa 7) System sleep/power-off

Table 5 SC02 - Fire monitoring

2.2.2.1 Energy requirements

Scenario SC02 is an example of an application of the AMANDA ASSC in fire monitoring. The goal of the scenario is to recognize the signs of a fire as early as possible and transmit a timely warning of a potential fire, by acquiring measurements from the CO_2 and VOC sensors. The

ASSC is not included in a fire-fighting system, but instead it is a separate monitoring IoT device which detects the possible occurrence of fire. Table 6 shows the required intervals for measuring and transmission of data to a central monitoring system. At any time, the system needs to provide enough energy for transmission in the event of a sudden fire. Every 2 minutes, the card measures temperature, humidity, CO_2 levels and captures a picture in order to check for the presence of fire using sophisticated edge intelligence algorithms. In the case of fire, data is transmitted using several LoRa and BLE frames to increase the probability of getting the important message through. The use of edge intelligence, image capturing and CO_2 measurements requires additional energy. However, data is transmitted only in the presence of fire. It means that the energy consumption of the wireless part is reduced, since no transmission is required in normal cycles when no fire is detected. In this case, the energy requirements are dominated by the sensors and data processing. In the case of fire, the energy in the storage of the ASSC will be used to transmit data with 5 LoRa SF11 and 60 BLE ADV frames. SF11 frames give a better range than lower SFx. Due to the high energy requirements, the AMANDA cards should be placed in well-lit places, such as near a window or a lamp or alternatively outdoors. After an alarm condition, cards may need to be recharged. The cycle duration can be increased if several cards are in use, because of the overlap, which leads to an improvement of the energy performance. The future reduction of the energy requirements of the CO_2 sensor will further reduce the energy requirements of the scenario.

Parameter	**Minimum**	**Typical**	**Maximum**
Illumination levels	100 lux	200 lux	500 lux
CO_2 concentration	300ppm	400ppm	3000ppm
Humidity	20%	50%	80%
Measuring interval	2 minutes	5 minutes	10 minutes
Advertising interval	1 hour	2 hours	3 hours

Table 6 Operational parameters for SC02

2.2.3 SC03 - Continuous occupancy monitoring in a parking lot

The ASSC is installed in an indoors or outdoors parking area. After the initial ASSC configuration by the system administrator, the control system can provide information about the occupancy status of a parking spot. Potential vehicles are detected using the magnetic sensor in combination with the light sensor. The metallic frame of the car will affect the magnetic field near the sensor. Furthermore, the light intensity will be reduced if the card is placed under the incoming vehicle. When a change in magnetic field is detected, the data from the light sensor will be used in order to confirm or not the presence of a vehicle. Additionally, the measuring of local vibrations, during a car arrival, will be investigated as a method for vehicle detection. Moreover, the CO_2 level within the parking lot will be gathered to monitor the slots occupancy. Subsequently, the ASSC will transmit the collected data to the city's parking control system via LoRa wireless communication. Informative displays around the city will present the number of free parking spots in each car park.

Generic Description	
Scenario name	Continuous occupancy monitoring in a parking lot
Version	2.0
Authors	AMANDA
Last Update	December 2020
Relationship with Use Cases	UC2
Stakeholders	End-users, SMEs

ASSC version	☒ Indoor ☒ Outdoor ☐ Wearable
Components used	☒ Acceleration sensor ☒ Acoustic sensor ☐ Atmospheric pressure sensor ☒ Battery ☒ BLE ☒ CO_2 sensor ☒ FRAM ☒ Humidity sensor ☐ Image sensor ☒ Light sensor ☒ LoRa ☒ Magnetic sensor ☒ MCU ☐ NFC ☒ PMIC ☒ RGB LED ☒ RTC ☒ Solar Harvester ☐ Temperature sensor ☒ Touch sensor ☒ VOC sensor
Main flow	1) The system wakes up based on current configuration: • via the RTC 2) Data acquisition 3) Data fusion 4) Data processing 5) Intelligent processing 6) Wireless communication security 7) Wireless transmission via BLE to the light indicator 8) Wireless transmission of the data to the parking control system via LoRa 9) System sleep/power-off

Table 7 SC03 - Continuous occupancy monitoring in a parking lot

2.2.3.1 Energy requirements

Vehicle presence detection in a parking space is an event where the arrival or departure of vehicles at a parking spot is detected. The consequence of that request is that at least one sensor should be active almost continuously. This request certainly sets significant conditions for providing the necessary energy. The ASSC has a competitive advantage over other detectors, since it can use a primary detection sensor (e.g. an accelerometer) without at the same time utilising additional sensors. After measurements have been obtained from the primary sensor, additional sensors can be switched on and the arrival or departure of the vehicle from the parking spot can be detected by edge intelligence algorithms. Advertising is required only in the event of a changed condition of the parking spot. When sufficient power is available, data can be transmitted using LoRa or BLE. Then, the ASSC satisfies the functions described in

UC01. Table 8 shows the predicted measurement values and the interval for notifications of the changes in a parking space. The magnetic and vibration sensors (accelerometer) are activated for 1 second every 10 seconds to detect changes that signal the presence/arrival/departure of a vehicle. If a vehicle is detected continuously for a given time, an occupancy message is sent using LoRa in SF11 and +14dBm. Similarly, if the absence of the car is detected (e.g the car has left the space) a LoRa message is sent, informing that the space is free. The acknowledge message from the gateway is important, as it helps tune the energy required for sending. If it does not arrive, the device might send a second frame, assuming a collision or loss of the first frame.

Parameter	**Minimum**	**Typical**	**Maximum**
Illumination levels	200 lux	500 lux	800 lux
CO_2 concentration	300ppm	400ppm	3000ppm
Magnetic field	0 gauss	2 gauss	16 gauss
Acceleration	0g	2g	16g
Measuring interval	10 seconds	1 minute	3 minutes
Advertising interval	30 minutes	1 hour	1.5 hours

Table 8 Operational parameters for SC03

2.2.4 SC04 - Asset and people localization with access control

The ASSC is carried by the employees of a company. When an employee wishes to enter the building, he can touch the ASSC on a card reader. The NFC connection transmits the cardholder's information to a central control system and either the door opens or access is denied. The ASSC also gives permission for access in different offices according to the employee's clearance. The same as entry procedure is repeated to exit the building when the employees shift is over. Moreover, the ASSC captures the location of the worker either in indoor or outdoor environments and continuously monitors the applied acceleration. The employees can use the touch sensor to change their availability status. Moreover, in jobs with a high risk of accident (e.g. miners), the accurate positioning of a worker is critical as it enhances the safety. By utilising the accelerometer along with machine-learning algorithms, the ASSC can detect if a person has fell and is unconscious or injured. The ASSC transmits the proper information to a local terminal which projects the status of all employees.

Generic Description	
Scenario name	Asset and people localization with access control
Version	2.0
Authors	AMANDA
Last Update	December 2020
Relationship with Use Cases	UC2
Stakeholders	End-users, SMEs, Fire departments
ASSC version	☒ Indoor ☐ Outdoor ☒ Wearable
Components used	☒ Acceleration sensor ☐ Acoustic sensor ☒ Atmospheric pressure sensor ☒ Battery ☒ BLE

	☐ CO_2 sensor ☒ FRAM ☒ Humidity sensor ☐ Image sensor ☒ Light sensor ☒ LoRa ☐ Magnetic sensor ☒ MCU ☒ NFC ☒ PMIC ☒ RGB LED ☒ RTC ☒ Solar Harvester ☒ Temperature sensor ☒ Touch sensor ☐ VOC sensor
Main flow	1) The system wakes up based on current configuration: • via the touch sensor 2) Data acquisition 3) Data processing 4) Intelligent processing 5) Wireless communication security 6) Wireless transmission via LoRa and BLE to local or remote monitoring system 7) System sleep/power-off

Table 9 SC04 - Asset and people localization with access control

2.2.4.1 Energy requirements

Tracking the movement of individuals requires continuous access to receivers. Receivers forward the data to a positioning system that calculates the position in space. The accelerometer reads the speed of movement. If the object does not move, there is no need to send the position continuously. In sudden situations, such as the fall of workers, immediate advertising of the appropriate event is required. Table 10 shows operational parameters for SC04. The tracking is performed by using BLE gateways with AoA features. The card regularly broadcasts BLE frames that are received by the locators and forwarded to the positioning engine for calculation of the position. The use of NFC is energy neutral because the NFC reader simultaneously powers the card via its magnetic field. The AMANDA card is designed in such a way that it can also harvest energy from the NFC field. A broadcasting frequency of 5 ADV events per second is used. It allows the objects to be continuously tracked. A higher rate can also be used in case of fast-moving objects. A lower transmission rate, every 1 minute, can be used when objects are not moving, based on accelerometer data. In the case of object or equipment, the card can be placed in a way that it faces the ceiling, allowing harvesting to be carried out. In the case of workers, the card will sometimes rely on the energy in the storage. This should not be an issue as long as the workers regularly place the card face up, when they are not in use, such as before leaving.

Parameter	Minimum	Typical	Maximum

Illumination levels	100 lux	200 lux	500 lux
Acceleration	0 g	2 g	16 g
Measuring Interval	1 minute	3 minutes	5 minutes
Advertising Interval	1 minute	3 minutes	5 minutes

Table 10 Operational parameters for SC04

2.2.5 SC05 - Monitor transportation conditions of medicines/vaccines

The ASSC is configured by the system administrator and is placed in containers which contain sensitive medical supplies such as medicines or vaccines. The ASSC collects environmental data and the movement profile during delivery. Edge intelligence algorithms are then used to estimate the supplies' condition during shipping. The shipping evaluation data will be sent to the supply manager's smartphone via BLE

Generic Description	
Scenario name	Monitor transportation conditions of medicines/vaccines
Version	2.0
Authors	AMANDA
Last Update	December 2020
Relationship with Use Cases	UC3
Stakeholders	Hospitals, Municipality
ASSC version	☒ Indoor ☐ Outdoor ☐ Wearable
Components used	☒ Acceleration sensor ☐ Acoustic sensor ☒ Atmospheric pressure sensor ☒ Battery ☒ BLE ☐ CO_2 sensor ☒ FRAM ☒ Humidity sensor ☐ Image sensor ☒ Light sensor ☐ LoRa ☐ Magnetic sensor ☒ MCU ☐ NFC ☒ PMIC ☒ RGB LED ☒ RTC ☒ Solar Harvester ☒ Temperature sensor ☒ Touch sensor ☒ VOC sensor

Main flow	1) The system wakes up based on current configuration: • via the touch sensor 2) Data acquisition 3) Data processing 4) Intelligent processing 5) Wireless communication security 6) Information to end-user via wireless communication 7) System sleep/power-off

Table 11 SC05 - Monitor transportation conditions of medicines/vaccines

2.2.5.1 Energy requirements

During monitoring, the system would mostly consume energy from the battery. Every 10 minutes, the card wakes up and measures temperature, humidity, VOC, light intensity and acceleration. The measurements and time stamps are saved in FRAM. When the shipment is at destination, the data in the card can be read using NFC or BLE. The storage in the card can be recharged using NFC (fastest) or by placing the card in an environment with enough light. Required here are low-power sensors and minimal processing. Variations: During transportation in small parcels, the card can be programmed to broadcast an alert to a gateway (say a smartphone or a device built in the transport vehicle), if some of the parameters monitored are outside the safety zone. If the transport box is a hindrance for the communication of the wireless signal, LoRa can be used, with the SF adapted to the transport environment. It can be assumed that there will be little light and that the card will rely on the stored energy. It can also be safely assumed that the wireless communication (used only to inform of problems) will not be often activated. An average of 1 LoRa frame (SF11) every 2 hours is assumed. In case BLE is used, 20 ADV events are transmitted every 2 hours.

Parameter	Minimum	Typical	Maximum
Illumination levels	0 lux	0 lux	0 lux
Measuring Interval	10 minutes	15 minutes	20 minutes
Advertising Interval	12 hours	24 hours	48 hours

Table 12 Operational parameters for SC05

2.2.6 SC06 - Crowd counting for social distancing

The ASSC will be pre-configured by the System Administrator. Subsequently, the AMANDA card will be distributed to the end-users in order to monitor any potential contact with an infected person. In that case the end-user will be informed accordingly to perform a test and self-quarantine will be suggested to avoid further spreading of the disease. The BLE module will be used as the main tracking mechanism of the system. Utilisation of the AMANDA card as a physical token for contact tracing in epidemics, ensures the anonymity of the users.

Generic Description	
Scenario name	Crowd counting for social distancing
Version	2.0
Authors	AMANDA
Last Update	December 2020
Relationship with Use Cases	UC3
Stakeholders	SME, shopping mall owners

ASSC version	☒ Indoor ☐ Outdoor ☐ Wearable
Components used	☒ Acceleration sensor ☐ Acoustic sensor ☐ Atmospheric pressure sensor ☒ Battery ☒ BLE ☐ CO_2 sensor ☒ FRAM ☒ Humidity sensor ☐ Image sensor ☒ Light sensor ☐ LoRa ☐ Magnetic sensor ☒ MCU ☐ NFC ☒ PMIC ☒ RGB LED ☒ RTC ☒ Solar Harvester ☐ Temperature sensor ☒ Touch sensor ☐ VOC sensor
Main flow	1) The system wakes up based on current configuration: • via the touch sensor 2) Data acquisition 3) Store the collected data in FRAM 4) Data processing 5) Intelligent processing 6) Wireless communication security 7) Information to end-user using Wireless transmission 8) System sleep/power-off

Table 13 SC06 - Crowd counting for social distancing

2.2.6.1 Energy requirements

Information is transmitted preferably with LoRa SF7 to a gateway in order to inform the main controller about areas with potential issues. Regular messages are broadcasted with BLE in ADV mode (a train of 10 ADV events per minute) for users that have a smartphone and an appropriate app. Those messages can be used to warn users about crowded areas that should be avoided. The active parts of the embedded system are: the imaging sensor, the processor running a simple detection and crowd counting algorithm with edge intelligence algorithms as well as the LoRa communication. The communication with LoRa takes place only when critical situations are detected. Assumption is an average of 1 frame every 10 minutes.

Parameter	Minimum	Typical	Maximum
Illumination levels	100 lux	200 lux	500 lux

Measuring interval	1 minute	3 minutes	5 minutes
Advertising interval	5 minutes	10 minutes	15 minutes

Table 14 Operational parameters for SCO6

2.3 Stakeholders

In the scenarios described in this document, different stakeholders have been defined. The table below details the stakeholders that are interested to use the AMANDA multi-sensing autonomous card.

Name	Description	Relation to scenarios
End-users / customers	An end-user is typically someone who purchases the AMANDA ASSC for personal use	SC01, SC02, SC03, SC04
Municipality	Local authority involved in air quality, traffic regulation, environmental measurements	SC01, SC04, SC06
Parking providers	Private parking provider owning a parking lot, interested to provide better services	SC01, SC02, SC03
SMEs	Small or medium businesses which use ASSC in various cases. This could be related to worker's comfort	SC01, SC04, SC06
Fire departments	Involved in scenarios where safety measures against fire are taking place	SC01, SC02
Universities	Involved in scenarios where research interest is applicable	SC01, SC02, SC03, SC04, SC05, SC06
Logistics / delivery companies	Tracking and monitoring product delivery, optimisation of delivery time	SC01, SC04
Medical facilities	Tracking and monitoring medical equipment	SC01, SC05, SC06

Table 15 List of stakeholders

2.4 Components

The AMANDA ASSC is developed in three different versions: indoor, outdoor and wearable. All three versions will consist of a core system which will incorporate the main components as defined in **Deliverable D1.6 - Full System Specification and BOM delivered**. Depending on the version and the use case scenario, the ASSC will include the appropriate additional components in order to be functional. Table 16 below presents all the components that are utilized as part of the AMANDA ASSC.

Name	Description	Use case
Solar harvester	Absorbs sunlight and converts it to electricity	All
Battery	Device for energy storage	All
PMIC	Power Management	All
MCU	Main processing unit of the system	All

RTC	Real Time Clock in order to control specific processes	All
LoRa	RF Module for Long range communications	All
BLE	Low power Bluetooth	All
FRAM	Non-volatile memory	All
NFC	Near field wireless communication	All
Capacitive sensor	Human interaction: inputs by users	All
Temperature sensor	Temperature measurement: collects environmental data	UC1, UC2, UC3
Humidity sensor	Humidity measurement: collects environmental data	UC1, UC2, UC3
Pressure sensor	Pressure measurement: collects atmospheric data	UC1, UC2, UC3
Accelerometer sensor	Measures acceleration on movement	UC2, UC3
Acoustic Sensor	Samples sound from the environment	UC1
Light Sensor	Measures light's intensity	UC1, UC2, UC3
Magnetic Sensor	Detects changes in the surrounding magnetic field	UC2
CO_2 sensor	Measures CO_2 levels	UC1
VOC sensor	Measures volatile organic compounds (e.g. alcohols, aldehydes etc)	UC1
Image sensor	Capable of capturing pictures	UC1, UC2
LED	Human interaction: optical indication	UC1, UC2, UC3

Table 16 List of ASSC components

3 Marketing position, system reliability, comparison with a current similar product

The market today offers a wide range of autonomous devices. There are also multi-sensor devices on the market but rarely devices are both autonomous and multisensory. Such devices find their application in all aspects of human activity. Some examples are solutions in the field of air quality control or the application in the field of smart cities. The AMANDA ASSC has a significant potential in solution on mitigating the effects of current and future pandemics. A possible implementation is in the area of contact tracing, as well as in monitoring the position and transportation conditions of medical equipment. The ASCC can be either a standalone end-user autonomous multi-sensor device or integrated into more complex user applications. An example of using the ASSC as a product intended for an end-user is the use of the ASSC as a personal autonomous multi-sensor device connected to a smartphone. At any time, it can provide to the owner useful information about the area conditions. An example of the use the ASSC as a product integrated into user solution is the detection of occupancy in a parking spot. Vehicle arrival and departure detection is just one part of a much more complex traffic management system in the area of smart cities. The criteria that the ASSC needs to meet are timeliness and accuracy of measurements. Note however that the ASSC is not, or should not be a measuring instrument with laboratory measurement accuracy. Devices on the market meet the accuracy of +/- 2% in temperature measurement, 1.5% deviation in the field of air pressure measurement or +/- 5% in the area of humidity measurement [1], [2]. Satisfactory accuracy for OCR cameras is greater than 95% [3] while vehicle presence sensors in the parking lot satisfy a measurement accuracy is 96% [4].

The ASSC should meet existing market standards in the areas of timeliness of notification and accuracy of measurements. The card has a comparative advantage over existing products on the market in its declared autonomy of 10 years of operation. Furthermore, a significant advantage of a multi-sensor card is the ability to measure multiple sensors simultaneously. Multi sensing, data fusion and edge intelligence should give the ASSC a considerable advantage over single-sensor systems on the market. Innovative solutions implemented in ASSC will provide a significant market advantage over other similar devices.

The price of the ASSC should not be the deciding factor for the willingness of the end-user to purchase it. The AMANDA card provides functionalities that are innovative in the market. For example, the today's price of a vehicle presence sensor in a parking spot, technically satisfactory product, a market-competitive product, averages approximately 100€ [5]. In addition to its advantages of functionality and innovation, the ASSC will undoubtedly be price competitive in the market.

The ASSC provides new functionalities, increases measurement accuracy, provides extended autonomy and can be easily integrated into existing solutions. The ASSC has market opportunities in few different aspects:

- Society is favourable toward the use of alternative and renewable energy source
- Small card is easy to carry and easy to mount
- Long-range communications capabilities add a degree of independence
- Sensor fusion will open up new application opportunities
- Air quality sensing in a smart city environment is growing due to the importance of monitoring and controlling of the pollution level in the atmosphere
- The modularity aspect of the ASSC will offer platform great degrees of flexibility

With its properties and predicted market price, it is an attractive and outstanding product that will find its wide application.

3.1 UC1 and a similar IoT device

The device with its concept and characteristics is close to the AMANDA card is a product of Aeotec (www.aeotec.com/z-wave-sensor/). The table shows the essential technical features of the device compared with the AMANDA card:

Name	**MultiSensor 6**	**AMANDA ASSC**
Energy harvester	-	√
Battery	√	√
PMIC	√	√
MCU	√	√
RTC	-	√
RF Module for Long range communications	Z-wave	LoRa
BLE	-	√
FRAM	-	√
NFC	-	√
Capacitive sensor	-	√
Temperature sensor	√	√
Humidity sensor	√	√
Pressure sensor	-	√
Accelerometer sensor	√	√
Acoustic Sensor	-	√
Light Sensor	√	√
Magnetic Sensor	-	√
CO_2 sensor	-	√
VOC sensor	-	√
Image sensor	-	√
LED	-	√
UV Sensor	√	-
Infrared	√	-
Dimensions	42 x 42 x 42mm	86 x 54 x 3mm

Table 17 Comparison of MultiSensor 6 and the AMANDA ASSC

These two devices can be compared if both are applied in *UC1 - Environment monitoring and reporting*. The main difference is in the number of sensors as well as in the ability to harvest

energy. Multisensor 6 has two ways to be powered: with 2 x CR123A batteries OR via USB cable. Its battery life is 1-3 years while the proclaimed battery life of the AMANDA card is approximately ten years. The AMANDA ASSC has a solar harvester and integrated innovative film batteries from ILIKA. MultiSensor 6 cannot detect early fires and as such cannot be used to report fire incidents. The Multisensor 6 is not portable but is intended for wall mounting.
The AMANDA card has several more sensors, which gives it the advantage of the functionality and much greater simultaneous use. Multisensor 6 has an infrared sensor which opens the possibility of detecting the presence of people. It certainly gives it an advantage as an alarm sensor in a smart home environment. Multisensory 6 uses the Z-wave standard of communication. Connecting to other devices requires an accessory (gateway). The AMANDA card has several different communication options, which gives it an advantage in a quick and easy connection to smartphones (via BLE). Both products are small products that do not require special installation conditions due to their size. MultiSensor 6 is a product intended for use in smart home environments. It certainly has the advantage of more straightforward detection of the presence of people. The AMANDA card covers indoor, outdoor and wearable at the same time, while the multisensory is a product only for the indoor variant. The market price of Multisensor 6 is 59$.

3.2 UC2 and a similar IoT device

Competitive product covering UC2 is undoubtedly the vehicle presence detector P01 Smart Parking Sensor. It is a product of Nietzsche Enterprise Co., Ltd from Taiwan (https://nhr.com.tw). The product has won several innovation awards. The table shows the essential characteristics of the P01 Smart Parking Sensor compared to the AMANDA card:

Name	P01 Smart Parking Sensor	AMANDA card
Energy harvester	-	√
Battery	√	√
PMIC	√	√
MCU	√	√
RTC	-	√
RF Module for Long range communications	LoRa/ZegBee	LoRa
BLE	-	√
FRAM	-	√
NFC	-	√
Capacitive sensor	-	√
Temperature sensor	-	√
Humidity sensor	-	√
Pressure sensor	-	√
Accelerometer sensor	-	√
Acoustic Sensor	-	√

Light Sensor	-	√
Magnetic Sensor	√	√
CO_2 sensor	-	√
VOC sensor	-	√
Image sensor	-	√
LED	-	√
microWave sensor	√	-
Dimensions	150 x 39mm	86 x 54 x 3mm

Table 18 Comparison of P01 and the AMANDA card

The P01 vehicle presence detector has two sensors, a magnetic and a microwave detector. Vehicle detection with a microwave sensor is generally considered to be the most accurate method of detection. In combination with the magnetic sensor, it gives an accuracy of reading the presence of a vehicle of > 99%. Such precision is a big challenge for the AMANDA card. To compensate for the lack of microwave sensors in the AMANDA card configuration, it is necessary for the detecting with additional sensors and the utilisation of data fusion as well as AI algorithms. The P01 enclosure is according to the IP68 standard. The P01 maximum load on the surface is approximately 5000kg. All of the above indicators can be a significant advantage of detecting the presence of a vehicle in outdoor parking lots. The significantly larger size and weight of PO1 however do not represent a disadvantage in comparison with the AMANDA card. A right choice of installation location can reduce the lack of mechanical properties of the AMANDA card compared to P01. The disadvantage of P01 is that it must be bathed in the road, which contributes to higher installation costs. The declared battery life for the product is 1-3 years. A significant advantage of using the AMANDA card in parking garages. In addition to the vehicle presence detector, the AMANDA card can simultaneously satisfy all the functions provided by UC1 and gives AMANDA card advantage over a narrowly specialized sensor such as the P01. The P01 battery is not rechargeable which can cause high operating and maintenance costs. In integrated Smart City projects, the AMANDA card can satisfy and cover other usage scenarios in addition to presence detection. The market price for P01 is 97$.

3.3 UC3 and a similar IoT device

Human passage detection and crowd counting are scenarios covered in UC3. Today's modern trends in the detection and counting the passages are based on the recognition of a person's thermal imprint. An example of a modern solution is the TD-2000 product from TD-intelligence (http://www.tdintelligence.com). Table 19 shows a comparison of TD-2000 and the AMANDA card:

Name	**TD-2000**	**AMANDA card**
Energy harvester	-	√
Battery		√
PMIC	√	√
MCU	√	√
RTC	√	√

RF Module for Long range communications	-	LoRa
BLE	-	√
FRAM	-	√
NFC	-	√
Capacitive sensor	-	√
Temperature sensor	√	√
Humidity sensor	√	√
Pressure sensor	-	√
Accelerometer sensor	-	√
Acoustic Sensor	-	√
Light Sensor	-	√
Magnetic Sensor	-	√
CO_2 sensor	-	√
VOC sensor	-	√
Image sensor	√	√
LED	-	√
Dimensions	150 x 52 x 24mm	86 x 54 x 3mm

Table 19 Comparison of TD-2000 and the AMANDA card

The TD-2000 has a thermal image, temperature and humidity sensor. It is powered by a USB cable only and does not have a wireless connection. Vertical mounting at the height of 2.5m to 5m is mandatory. The AMANDA card has more sensors, which certainly gives greater functionality. The cost of installing the TD-2000 is significantly higher than installing the AMANDA card. For the AMANDA card to be competitive in the field of counting human passages, innovative edge intelligence solutions are required. Independence from a separate power source, easy installation, predicted lower market price, as well as the possibility of temporary dislocation of the device, gives the AMANDA card advantage over TD-2000. The market price of the TD-2000 is 350$.

4 Conclusions

The described operational scenarios present a realistic picture usage of the smart autonomous card with multiple sensors. This Deliverable is the result of the conducted research and defining the needs of the end-user. All members of the Consortium are involved in research and definition described in D4.1. The described scenarios are a realistic reflection of the needs of end-users and the possible use of the ASSC. Operation scenarios described in Deliverable D1.4 currently have a real application in practice. Deliverable D1.4 represent a significant stronghold for developers in the further development process. The document defines the energy needs in each scenario presented. Comparing the AMANDA card with the currently most technologically innovative solutions provides guidelines for further development and research. From the described comparisons, it is clear that end-users will accept the AMANDA card.

5 References

[1] “https://www.warioweather.com/,” [Online].
[2] “http://www.fao.org/3/X0490E/x0490e00.htm#Contents,” [Online].
[3] “http://www.bosch-connectivity.com/products/connected-mobility/parking-lot-sensor,” [Online].
[4] “https://www.parkdroid.com,” [Online].
[5] “https://www.tattile.com/vision-solutions/vega-basic/,” [Online].