Deliverable D1.2

# Project Progress Report

MATiSSE

Empower Hospitals' Reliability via TagItSmart Service platform

| Final Report on Extensions | |
|---|---|
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| | |
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# Executive Summary

MATISSE leverages on the recent advancements of Internet-of-Things (IoT), cloud computing and analytics, along with the introduction of dynamic smart tags in order to create a smart hospital ecosystem based on the TagItSmart! (TiS) platform, where unacceptable, yet preventable errors, often referred to as “never events” will be extinct; from wrong medication provided to the wrong patient, diagnosis-errors due to confusion or misordering of patients’ exams or in-surgery errors.

This deliverable targets at reporting the progress of the MATISSE project. The reporting period includes the work done throughout the whole duration of the project, from September 2017 (Month 1) to August 2018 (Month 12). The activities of the MATISSE project were divided into four work packages (WPs) according to the Description of Work (DoW). WP1 (*MATISSE Management & Impact Creation*) focused on the project management and impact creation activities. WP2 (*MATISSE System Design*) delivered the proposed MATISSE system architecture. Furthermore, the first integrated MATISSE prototype was delivered through the tasks of WP3 (*MATISSE Implementation and Testing*), and, finally, the implemented MATISSE platform was validated in a real-life pilot in the framework of WP4 (*Real-life Pilot Validation*).

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# List of Abbreviations

| | |
|---|---|
| **AM** | Access Manager |
| **API** | Application Program Interface |
| **CRUD** | Create, Read, Update, Delete |
| **DS** | Data Storage |
| **DoW** | Description of Work |
| **EC** | European Commission |
| **EHR** | Electronic Health Record |
| **GDPR** | General Data Protection Regulation |
| **GUI** | Graphical User Interface |
| **IoT** | Internet-of-Things |
| **KPI** | Key Performance Indicator |
| **PQM** | Process Quality Manager |
| **QR** | Quick Response |
| **REST** | Representational State Transfer |
| **SCM** | Smart Cart Manager |
| **SM** | Session Manager |
| **SME** | Small and medium-sized enterprise |
| **SSc** | Smart tag Scanner |
| **TiS** | TagItSmart! |
| **TTI** | Time-Temperature Indicator |
| **UM** | User Manager |
| **WP** | Work Package |
| **WSPE** | Wrong-side/wrong-site, procedure, patient events |

# A. Summary of the work performed so far

In-hospital medical errors, ofter referred to as “never events”, lead to wrong site, wrong procedure, wrong patient events (WSPEs); unacceptable, yet preventable errors which can effect complications on a hospitalized patient’s health, ranging from minor temporary injuries up to severe and permanent situations or even mortality. The so-called “never events” include wrong, expired, recalled or defected medication, wrong diagnosis due to medical exams disordering and confusion, inaccurate therapy due to lack, non-up-to-date or incorrect patients’ health records and confusion during surgical procedures. In spite of the worldwide optimizations in safety rules, “never events” have not seized to occur. The vision which supported MATISSE throughout its architectural system design, the integration of the first MATISSE prototype, its laboratory testing procedures and finally its pilot in a real hospital environment was that “never events” will never get extinct without deep exploitation of the recent advancements in Internet-of-Things (IoT), cloud computing and analytics. MATISSE aimed to significantly decrease or annihilate “never events” in the complete hospital value chain while promoting TagItSmart! (TiS) added value in a real life eHealth pilot which took place at City Clinic, Athens, Greece.

During the months 1 and 2 of the MATISSE project the initial definition of the TiS-based architecture design along with requirement specifications and analysis of the MATISSE use cases were accomplished. The proposed MATISSE architecture was divided in two layers, namely, the MATISSE Front-end and the MATISSE Knowledge Management which were further decomposed into lower level components. Additionally, the use cases of the MATISSE platform were defined, namely, Drugs’ Stocktaking, In-Hospital Medication, Smart Medical Exams, Pre-surgery Check, Patients’ Monitoring. For more details on the proposed system architecture and use cases, the interested reader should refer to D2.1 *MATISSE system architecture design* [1].

During months 3 to 8 of the MATISSE project the development and integration of the first MATISSE prototype was completed. The components integrated by the MATISSE prototype are the MATISSE Back-end, the MATISSE Dashboard, the MATISSE Mobile Application and the MATISSE Smart Cart. Additionally, the MATISSE combined tag was designed and formed. Proper test cases, setup and procedures have been defined as well as their application on the integrated prototype. A bottom-up approach has been adopted, including component as well as end-to-end integration tests in order to validate the functionality of the MATISSE platform in laboratory environment, though this was not considered entirely irrelevant to a real hospital environment. The results indicated that the developed functionalities are fully covering the outlined MATISSE requirements set during the definition of system architecture and use cases, and the MATISSE components are smoothly integrated in the prototype. For more details on the integrated prototype of the MATISSE platform and the results of the testing, the interested reader should refer to D3.1 *MATISSE prototype* [2] and D3.3 *MATISSE prototype testing evaluation* [3] correspondingly.

The implemented MATISSE platform was piloted at City Clinic, a privately-held hospital in the heart of Athens. The environment of City Clinic proved ideal for the pilot’s execution and evaluation. All the necessary hardware components were shipped to the hospital and the deployment of the MATISSE platform in this real environment followed. City Clinic participated in the pilot with 2 doctors and 2 nurses on a weekly basis. The participants were asked to fill five questionnaires, one per use case, on a weekly basis. During the pilot, they recorded suggestions for future improvements on the platform, so that it would be an even better fit for real hospital environments. All of the MATISSE use cases were successfully validated. For more details on the pilot set-up and the actual pilot validation, the interested reader should refer to D4.1 *MATISSE pilot set-up & Data Management Plan* [4] and D4.2 *MATISSE pilot validation* [5] correspondingly.

Social media and other platforms, such as LinkedIn, Twitter and Youtube have been used to raise awareness towards the project’s dissemination activities and results. Various posts were shared for the followers to observe the process through which MATISSE was formed from an idea to a real prototype system appropriate and sufficient to operate in real hospital environments. Additionally, a

video presenting two of the defined MATISSE use cases was released on Youtube and shared on *Therapaenis'* social media. Moreover, an effort has been spent to disseminate the project results by submitting papers to relevant conferences. For more details on impact creation activities that were undertaken please refer to D1.3 *Impact Creation Activities* [6].

# B. Detailed description

## B.1. Concept, Objectives, Set-up and Background

The aim of the MATISSE project is the development of a platform that will minimize or, ideally, annihilate the occurrences of "never events" in hospital environments. Introducing the innovative smart trolley utility, along with its other features, it will provide an impenetrable from errors solution that will ensure the protection of hospitalized patients from possible mistakes attributed to the human factor. MATISSE addressed the following more specific and measurable objectives.

### B.1.1 Objectives

**Technical Objectives**:

- *Design and develop a TiS-based hospital ecosystem of connected dynamic smart tagged objects*, providing secure and authorized access to patient and medicine records, along with related smart tag observations.
    - **Outcomes**: The proposed integrated MATISSE prototype system was successfully implemented, with five integrated use cases and various connected entities (patients, carts, drugs, exams etc.). From the TiS point of view, the semantic model was adopted, the suggested smart tags in the form of Time-Temperature Indicators (TTIs) were selected and the EVRYTHNG platform was employed as a back-end TiS element.

**Business Objectives**:

- *Decisively tackle in-hospital "never events"*, from patients' admission to post-surgery monitoring leveraging on the smart medication paradigm within an ecosystem of connected smart devices.
- *Promote new business models for hospitals*, claiming and proving error-proof procedures in medical activities from patients' admission to post-surgery hospitalization.
- *Validate the MATISSE solution in real-life scenarios*, demonstrating the TiS added value in a real hospital environment.
    - **Outcomes**: The MATISSE platform was successfully validated in a real-life pilot. No occurrences of never events were reported during the pilot validation phase. The Drugs' stocktaking was reported to be more time-consuming than before, yet thought to annihilate the probability of errors. The drugs' selection at the patients' location was considered faster and safer. All five MATISSE use cases were piloted and validated by a total of 12 unique doctors and 22 unique nurses for a duration of almost 6 months. Overall, the MATISSE platform was characterized as a possible solution for errors' reduction in hospital environments and reputation shaping.

**Impact Objectives**:

- *Actively promote impact creation of TiS outcomes*, leveraging on the MATISSE success story.
- *Promote commercial exploitation*, demonstrating pilot results to existing business contacts.

- **Outcomes**: The MATISSE platform was mainly disseminated though Therapaenis' social media accounts via various posts that were made throughout the project's duration, including a video presenting the most significant MATISSE use cases. Additionally, a relevant paper was accepted for publication. Moreover, on top of City Clinic, the pilot's host, attempts were made for contacts with other privately-held hospitals to commercially promote the proposed MATISSE solution.

### B.1.2 Deliverables

The deliverables that should be submitted during the whole duration of the extension according to the Description of Work are presented in the following table.

*Table 1: Table of deliverables at month 12 of the Project*

| Del. No. | Deliverable name | Work package number | Lead participant | Type | Dissem. level | Delivery date | Delivered (YES / NO) | Actual / Forecast delivery date |
|---|---|---|---|---|---|---|---|---|
| D1.1 | MATISSE web site and social media accounts | WP1 | THERA | R | PU | M01 | YES | Sept. 29th, 2017 (M01) |
| D2.1 | MATISSE system architecture & design | WP2 | THERA | R | PU | M02 | YES | Oct. 31st, 2017 (M02) |
| D4.1 | MATISSE pilot set-up & Data Management Plan | WP2 | THERA | R | PU | M06 | YES | Mar. 16th, 2018 (M07) |
| D3.1 | MATISSE prototype | WP3 | THERA | O | CO | M08 | YES | May 22nd, 2018 (M09) |
| D3.2 | MATISSE Selected Binaries | WP3 | THERA | O | PU | M08 | YES | May 28th, 2018 (M09) |
| D3.3 | MATISSE prototype testing evaluation | WP3 | THERA | R | PU | M08 | YES | May 25th, 2018 (M09) |
| D1.2 | Project progress report | WP1 | THERA | R | PU | M12 | YES | Aug. 31st, 2018 (M12) |
| D1.3 | Impact Creation Activities | WP1 | THERA | R | PU | M12 | YES | Aug. 31st, 2018 (M12) |
| D4.2 | MATISSE pilot validation | WP4 | THERA | R | PU | M12 | YES | Aug. 31st, 2018 (M12) |

Some comments on the deliverables that were delayed are as follows:

- **D4.1**: For the purposes of pilot preparation a visit to the actual hospital environment was necessary. The visit was postponed from one time to another due to some issues that arose to the hospital's end. The visit was accomplished near the end of month 6, hence D4.1 was delivered at the middle of month 7.
- **D3.1, D3.2 & D3.3**: The integration and testing overlapped with the actual validation in a real hospital environment (WP4), so some feedback were collected during the pilot and affected the overall integrated prototype that was updated accordingly, and had to be tested once again.

## B.1.3 Project Management

### B.1.3.1 Management tasks and achievements

During the reporting period, the project management has been accomplished, primarily taking into account the higher level of quality and correctness that is essential for any eHealth or medical application in general. An amount of effort was spent in order to perform all the quality checks necessary to ensure a high-quality offering.

The project management has been focused on monitoring the work done by Therapaenis' developers, while in parallel checking the progress of WP tasks and deliverables. A short internal meeting conducted on a weekly basis was a key element and supported the effective control over the project, ensuring the smooth progress of the work plan, the fulfillment of the project's contractual obligations and a final result of high-quality.

### B.1.3.2 Project meetings

This subsection discusses the project meetings during the reporting period. A TiS Project Meeting along with an Open Call Co-Creation Workshop was held in Vaasa, Finland in M01 of MATISSE, organized by UpCode Ltd. The progress of the MATISSE project was also presented in various TiS project meetings, without physical presence from Therapaenis' side.

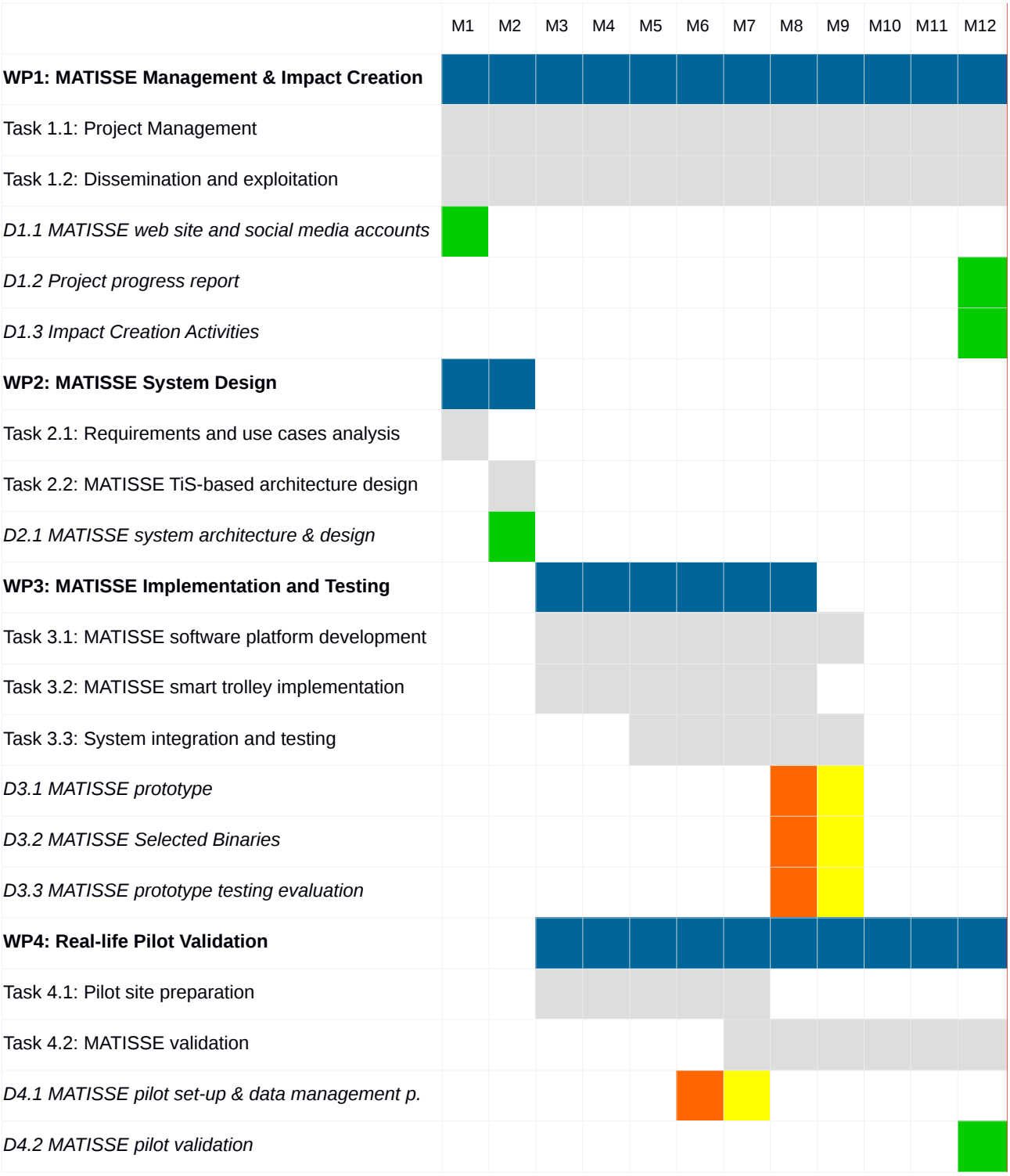
### B.1.3.3 Project planning and status

MATISSE proceeded and finished following the timetable without any significant deviations in comparison to what stated in the DoW. The advancements towards the achievement of MATISSE technical and business objectives has been constantly monitored and the tasks have been generally kept under control. The following figure illustrates the MATISSE Gantt chart along with a vertical indication bar denoting the end of the project (M12). The reader can refer to the legend reported in the table below to understand the current situation of the MATISSE project.

*Table 2: Legend for the correct interpretation of the Gantt Chart*

| Legend | |
|---|---|
| | Report expected and released in time |
| | Report released or expected to be released in delay |
| | Expected month for report's delivery |

*Table 3: MATISSE Gantt chart*



## B.2. Technical Details

The work conducted during the extension was divided into four work packages. WP1 concerned the management and impact creation activities and is discussed in paragraphs B.1 and B.2 of the present document. WP2 concerned the design of the MATISSE architecture and the supported MATISSE use cases. After WP2 was completed, the development of the first integrated MATISSE prototype followed as WP3 and the pilot preparation and data management plan as the first part of WP4, before the actual pilot deployment and validation process. Finally, the pilot in a real-hospital environment was subsequently launched as the second part of WP4.

### B.2.1 WP2 – MATISSE System Design

WP2 identified the MATISSE requirements and use cases, additionally defining the MATISSE system architecture. The use case scenarios were captured and analyzed along with the expectations from the MATISSE operation in a real-life context. Furthermore, time, system and functional requirements were collected.

#### B.2.1.1 Description of work and progress towards objectives

The tasks of WP2 which were active during the reporting period (specifically during M01-M02) included *Task 2.1 Requirements and use cases analysis* and *Task 2.2 MATISSE TiS-based architecture design*. The objectives of this WP were accomplished and can be summarized as follows:

- Derivation of the TiS-based use case and scenarios that have driven the MATISSE activities throughout the duration of the project
- Determination of MATISSE requirements and definition of the initial MATISSE architecture

Firstly, the initial task that needed to be executed was the definition of the use cases that the platform would support. These use cases were briefly defined as ideas in the DoW of the MATISSE project. During WP2 these use cases were clearly defined. Additionally, the scenarios and the actors for their execution were outlined in detail.

Given the definitions of the MATISSE use cases, the design of the MATISSE system architecture was launched. The requirements imposed by each use case were recorded and analyzed in order to define the operations of the lower level components. The points of integration with TiS were carefully considered and designed and the TiS suggested semantic model was adopted. The results of the previous processes are depicted in D2.1 *MATISSE system architecture & design* [1].

#### B.2.1.2 Significant results

- The definition of the five MATISSE use cases was accomplished during this period. In brief, the use cases that were defined are as follows:
  - *Use Case 1: Drugs' Stocktaking.* The smart trolley's tag is scanned and the patients with pending prescriptions are associated with its drawers and bins. The nurse visualizes each patient's prescriptions, collects the drugs, scans their smart tags to ensure they are correct, not expired or defected. At the same time, the smart trolley indicates the drawer and bin where the medication for a patient must be stored.
  - *Use Case 2: In-Hospital Medication*. The nurse distributing the patients' medication enters a room. The patient wears a bracelet with a QR or other code for identification. The nurse scans the patient's tag and the smart trolley's indication inform her of where the medication for this patient is stored. The nurse provides it to the patient.
  - *Use Case 3: Smart Medical Exams*. Medical exams are attached with tags in order to minimize diagnosis errors due to confusion during cross-checking in-hospital patients

and their medical exams. The clinician scans a patient or an exam and visualizes related information on the mobile device's screen.

- *Use Case 4: Pre-surgery Check*. Doctors involved in a upcoming surgical procedure scan a patient's tag and visualize information about him/her including details of a scheduled operation, avoiding possible confusions during the surgery.
- *Use Case 5: Patients' Monitoring*. A clinician enters a hospital's room periodically to check on the patients' progress of health improvement. The doctor scans the patient's tag and visualizes his electronic health record (EHR) on the mobile device's screen.

- The initial design of the MATISSE system architecture was completed during the activities of WP2. The proposed MATISSE system architecture is composed of two high-level layers which can be briefly described as follows:
  - *MATISSE Front-end*. As its name implies, this layer provides the front-end functionality. The components of this group are able to interface a number of TiS-enabled devices via their attached smart tags (Smart Tag scanner – SSc), manage the users accessing the platform (User Manager – UM), the smart medication cart (Smart Cart Manager – SCM) and the online sessions (Session Manager – SM), and finally, the required authentication and authorization services (Access Manager – AM).
  - *MATISSE Knowledge Management*. It is the back-end layer of the MATISSE architecture responsible for process quality management (PQM), data storage (DS) and communication with the TiS platform.

#### B.2.1.3 Deviations from DoW and their impact on other tasks

No deviations from the DoW occurred for WP2 as the deliverable was released in time.

#### B.2.1.4 Corrective actions

Since no deviations from DoW occurred for WP2, no corrective actions were undertaken.

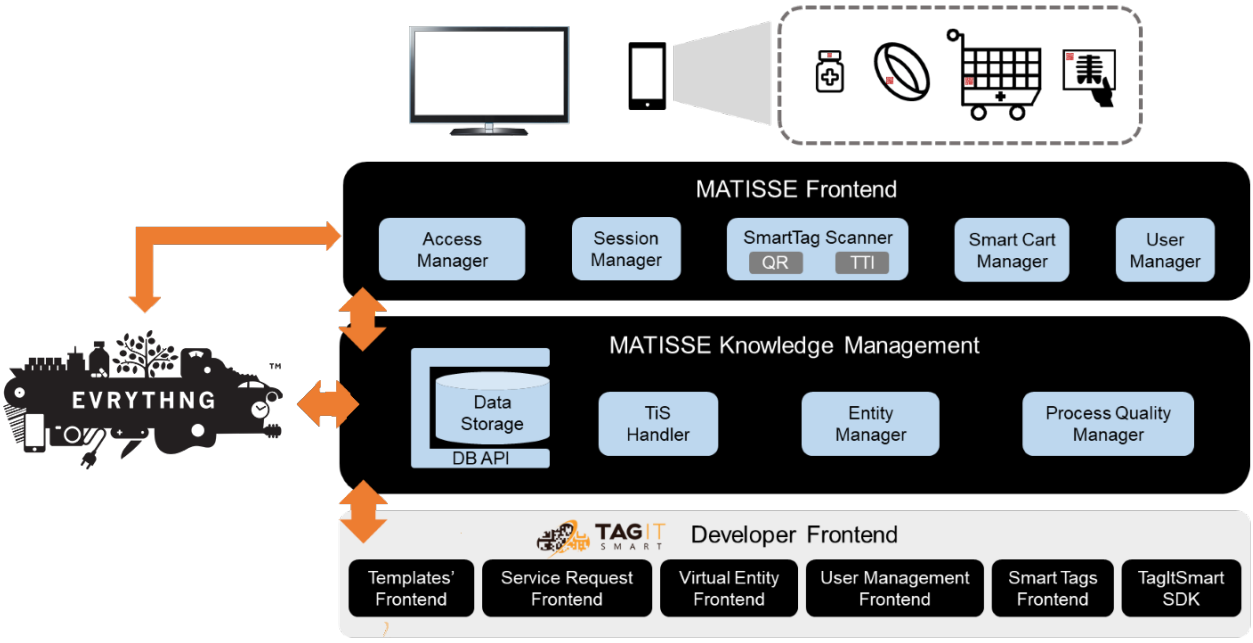



*Figure 1: The MATISSE Architecture*

### B.2.2 WP3 – MATISSE Implementation and Testing

WP3 was responsible for the implementation, integration and testing of the overall MATISSE system, following the system architecture design as defined within WP2. In this work package, the development of the software components of MATISSE was achieved, with emphasis given to their effective integration with the TiS core service platform, along with the design and construction of the MATISSE combined tag. Furthermore, the design and implementation of the MATISSE smart trolley prototype took place, followed by the integration and testing of all the components of MATISSE platform against the requirements and use cases defined in Task 2.1.

#### B.2.2.1 Description of work and progress towards objectives

The relevant to WP3 tasks active during the reporting period (from M03 to M09) were *Task 3.1 MATISSE software platform development*, *Task 3.2 MATISSE smart trolley implementation* and *Task 3.3 System Integration and Testing*. The objectives outlined for the specific work package have been reached and can be summarized as follows:

- The MATISSE integrated software and hardware components were successfully delivered
- Thorough testing of the compliance of the MATISSE system prototype against the identified requirements was conducted in laboratory environment.

During the period of WP3-related activities the composites of the proposed MATISSE architecture were analyzed and planned to be implemented. Before the beginning of the development, the smart tags that would be employed and used in the MATISSE platform were selected, as they are described in D3.1 [2]. From a development point of view, decisions were made regarding the tools that would be used for the implementation and integration of the MATISSE platform as a whole.

Firstly, the development began with the design of the DS component by the initial definition of a relational database schema with the essential associations between its entities. For a quick implementation of the Create, Read, Update, Delete (CRUD) operations, and more complex processes, a Representational State Transfer (REST) Application Program Interface (API) was implemented. Of course, the aforementioned REST API was continuously updated during the whole duration of WP3 to suit the needs of the other components. The result of these design and development procedures was the MATISSE Back-end component.

Secondly, the development was continued with the implementation of the MATISSE Mobile Application. Since a Smart Tag scanner must have been available for the execution of every MATISSE use case, there was a mandatory need for the existence of a camera module. Thus, an Android approach was adopted, which lead to a MATISSE Mobile Application compatible with most Android devices, namely smart phones and tablets. The application orchestrates the execution of the five MATISSE use cases by exploiting the formerly implemented REST API. The MATISSE Mobile Application was a point of integration with TiS. Specifically, on the drug scanning, the EVRYTHNG platform intervened between the mobile application and the back-end. Moreover, the formed MATISSE combined tag was introduced and its scanning through the MATISSE Mobile Application was implemented.

Thirdly, the implementation of the MATISSE Smart Cart followed. After an extensive market research on medical trolleys, a specific one which was considered appropriate for the transformation to a Smart Cart was selected. For the control of the cart's indications a Raspberry Pi (RPi) 3B+ was chosen and the MATISSE Back-end component managed its operation remotely. The cart was wired with LEDs and magnetic switches. Additionally, speakers and an LCD display were attached. From the RPi's side, a minimal REST API was implemented for handling of the requests sent by the MATISSE Back-end component.

The last component that was implemented during the software and hardware development phases was the MATISSE Dashboard. This component had a more administrative nature, offering the user

interfaces for creating, retrieving, updating and deleting the resources stored in the DS of the platform.

The aforementioned components where gradually integrated with the rest of the system as soon as they became available. Thorough testing was conducted to each of the components as a unit and integration end-to-end tests to ensure the smooth overall operation of the platform. The results acquired through the testing ensured that each of the components was smoothly integrated in the MATISSE prototype.

#### B.2.2.2 Significant results

- The smart tags that would be used within the MATISSE ecosystem were selected and the MATISSE Combined tag was formed as a combination of TTIs and QR codes.
- The integration of the first MATISSE prototype was accomplished. The components of the integrated prototype are as follows:
  - the *MATISSE Back-end*, which offers a REST API to other components of the platform, namely, the MATISSE Mobile Application and MATISSE Dashboard, is responsible for the data storage and remotely controls the MATISSE Smart Cart component
  - the *MATISSE Dashboard*, which was designed for administrative purposes and offers a Graphical User Interface (GUI) for creating, retrieving, editing and deleting resources, as well as managing the users of the platform, and directly communicates with the MATISSE Back-end
  - the *MATISSE Mobile Application*, which is the component that enables the execution of the five MATISSE use cases, implements the smart tag scanner of MATISSE, directly communicates with the MATISSE Back-end and with the MATISSE Smart Cart via the MATISSE Back-end
  - the *MATISSE Smart Cart*, which is the component that actively participates in two of the MATISSE use cases, namely, Drugs' Stocktaking and In-Hospital Medication, providing indications regarding the medication's storage per patient and is controlled by the MATISSE Back-end component.
- The definition of test cases, setup and procedures and their application on the integrated prototype; it included testing of components of the platform and end-to-end integration tests
- The reporting and analysis of results for the tests conducted on the MATISSE integrated prototype, which indicated that the developed functionalities cover the requirements

#### B.2.2.3 Deviations from DoW and their impact on other tasks

The deviations from DoW that were reported during WP3 are the late releases of D3.1, D3.2 and D3.3. Because of the overlapping between the integration and testing of the implemented platform and the actual validation in a real hospital environment (WP4), some feedback were collected during the pilot and affected the overall integrated prototype that was updated accordingly, and had to be tested once again.

#### B.2.2.4 Corrective actions

No particular corrective actions were undertaken regarding the slight delays on the releases of the deliverables as they technically had no impact on WP4. The MATISSE platform was already shipped and deployed in the hospital environment before they were completed and submitted.

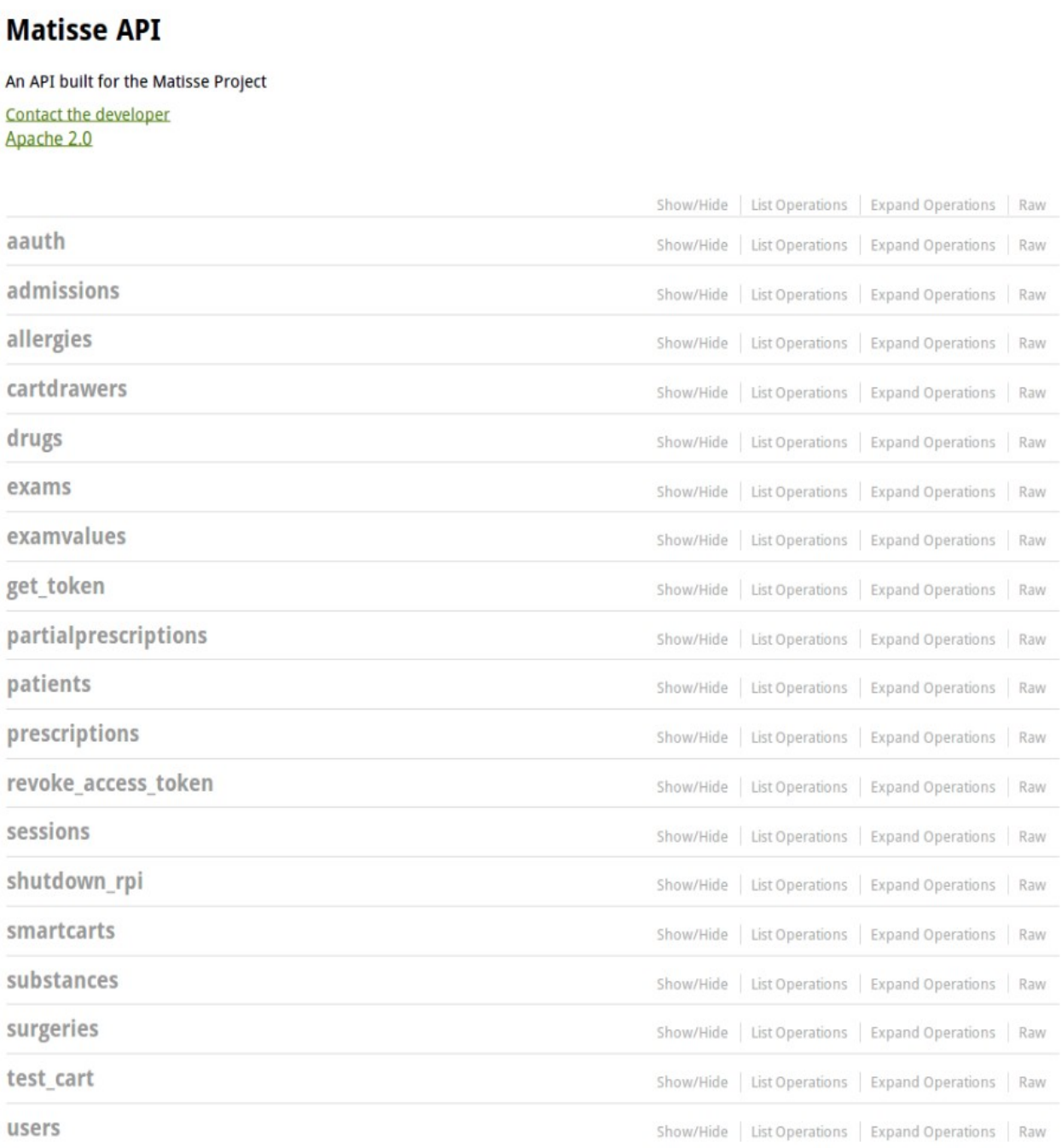



*Figure 2: The complete list of API categories exposed by the MATISSE Back-end component*

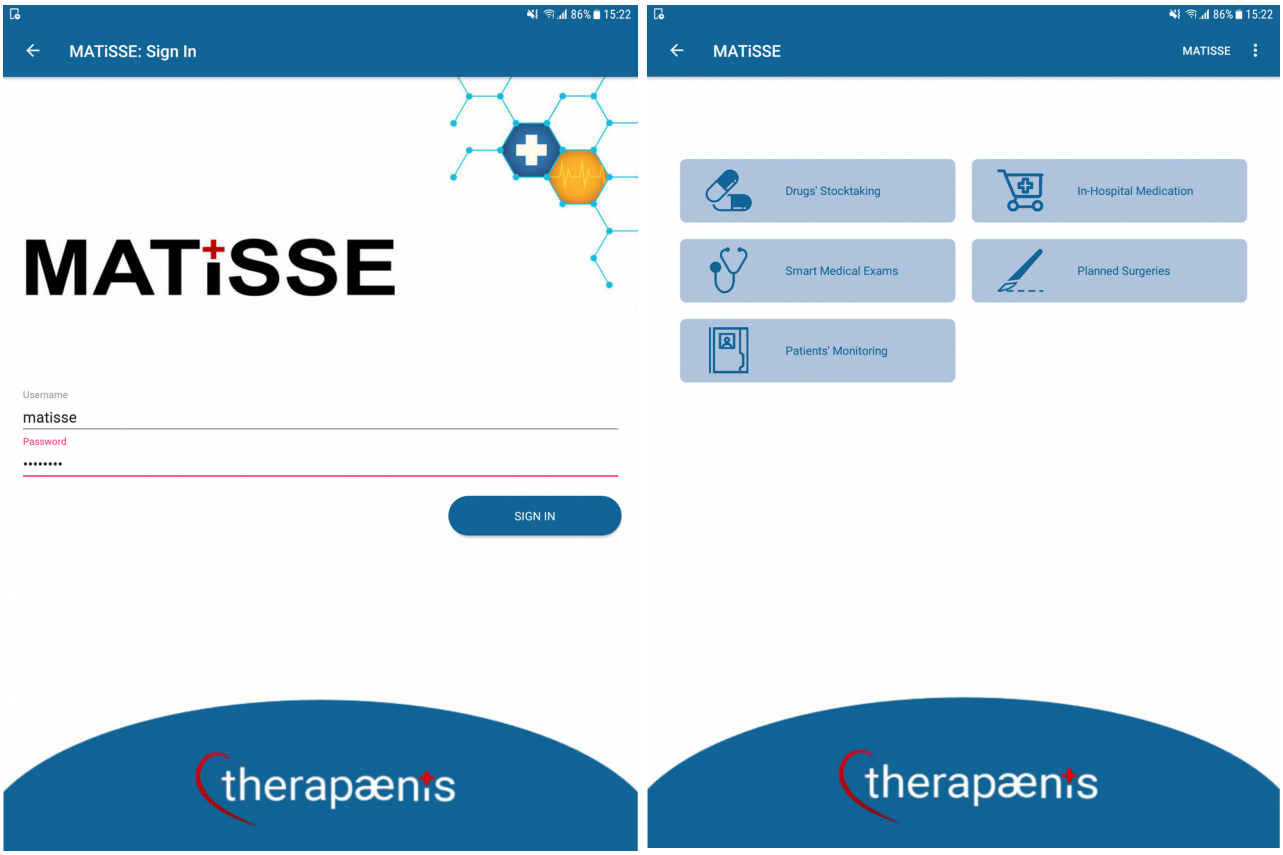



*Figure 3: The MATISSE Mobile Application*

*Figure 4: The MATISSE Smart Cart*

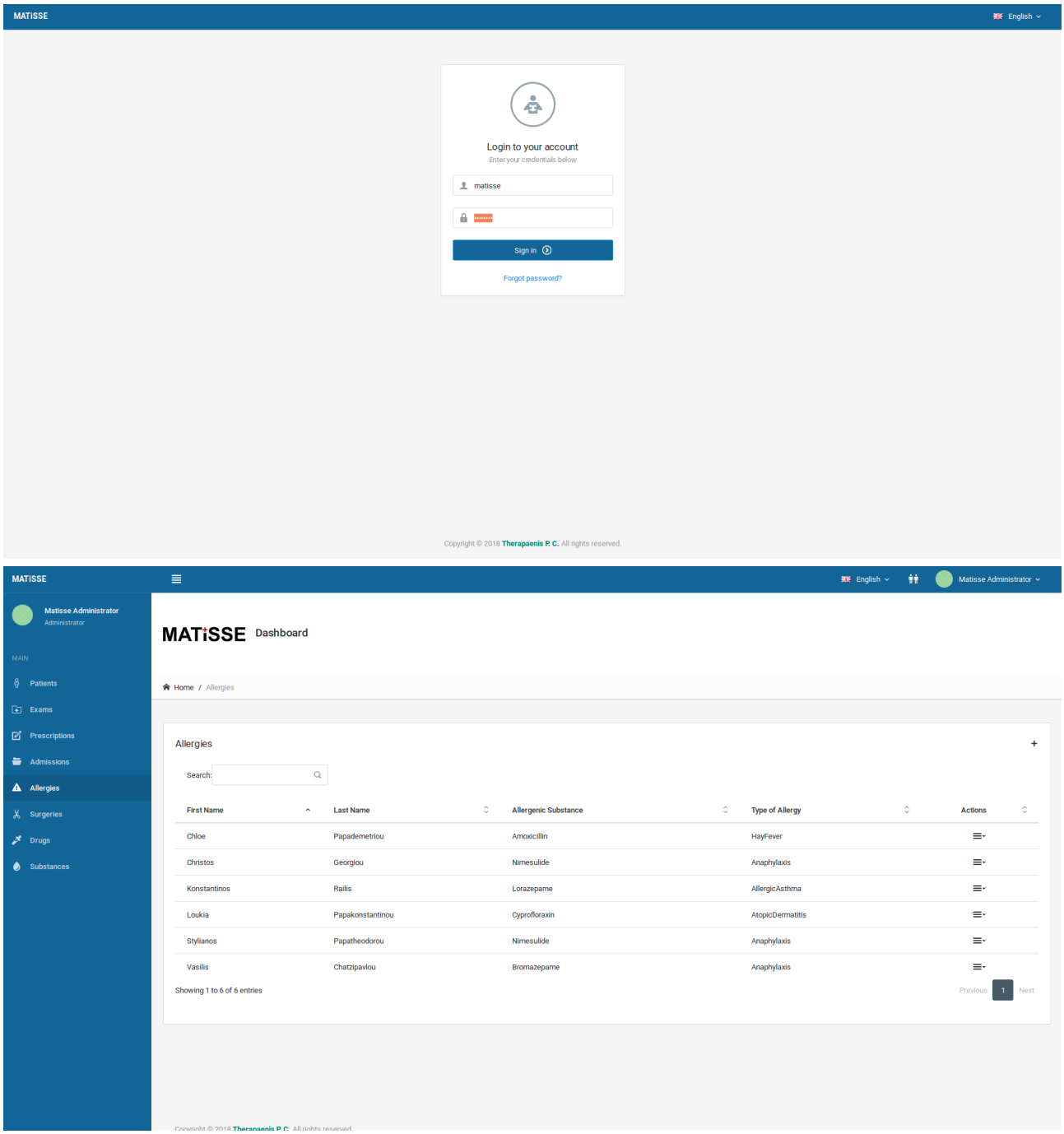



*Figure 5: The MATISSE Dashboard*

### B.2.3 WP4 – Real-life Pilot Validation

WP4 was responsible for the project's pilot actions, including both pilot preparation and validation activities. The cautious preparation of the pilot for the smooth integration of the implemented MATISSE system was a vital cogwheel for the successful validation of each of the MATISSE use cases. The preparation included the development of a set of pilot use case assessment criteria, in line with industry best practices. Based on the defined assessment criteria, the validation of MATISSE system took place.

#### B.2.3.1 Description of work and progress towards objectives

The relevant to WP4 tasks active during the reporting period (from M03 to M12) were *Task 4.1 Pilot site preparation and Task 4.2 MATISSE validation.* The objectives outlined for the specific work package have been reached and can be summarized as follows:

- The pilot site was prepared successfully for the integration with the MATISSE platform
- The MATISSE platform was piloted in a real hospital environment and the results and feedback that were collected have shown that all MATISSE use cases have been validated successfully.

The first step of WP4 was the data management plan according to the General Data Protection Regulation (GDPR). Regarding the data that were used during the pilot, they were virtual, generated for the sake of validation, with the aim of not disturbing the hospital processes and had no connection whatsoever will actual patients being hospitalized during the pilot of MATISSE. For the generation of data, the MATISSE Dashboard component was employed. Besides the virtual patients, virtual EHRs, virtual prescriptions *et cetera*, the drugs' dataset was also virtual and no real drugs were used and their names were not related in any way with actual drugs or pharmaceutical products.

The implemented MATISSE platform was piloted at City Clinic, a privately-held hospital in the heart of Athens. The environment of City Clinic proved ideal for the pilot's execution and evaluation as it offers four floors of mostly spacious two-bed rooms to a total of sixty beds, clinics diagnostic laboratories and a fully equipped surgical floor. All the necessary hardware components were shipped to the hospital and the deployment of the MATISSE platform in this real environment followed. MATISSE was initially shipped on March 5$^{th}$, 2018 and the pilot, including the medical personnel's training and minor fixes in the platform, lasted for almost 6 months, specifically until August 24$^{th}$, 2018.

Since the data processed by the components of the MATISSE platform was virtual, there was no need for a local in-hospital deployment of the MATISSE Back-End component, as the data stored and handled by this component were not sensitive. Additionally, for safety and privacy purposes, no access was granted to the hospital network. Instead of this, a Wireless LAN was established for a connection to be available. The MATISSE Smart Cart and MATISSE Mobile Application components connected to this network for the purpose of communicating with the MATISSE Back-End.

City Clinic participated in the pilot with 2 doctors and 2 nurses on a weekly basis, with the total numbers of participants reaching 12 doctors and 22 nurses. The pilot took place in the Orthopedics department. The participants were asked to fill five questionnaires, one per use case, on a weekly basis. In addition, during the pilot, they recorded suggestions for future improvements on the platform, so that it would be an even better fit for real hospital environments. The platform, and especially the smart cart, was also demonstrated to 14 patients who also gave valuable feedback.

The feedback collected and processed throughout the duration of the pilot both in the form of questionnaires and comments from the participants lead to the conclusion that the MATISSE platform was successfully validated.

#### B.2.3.2 Significant results

- The authorship of an informative document and informed consent forms for the participating personnel, along with special questionnaires for the evaluation of each use case, and the appropriate GDPR statement
- The successful preparation of the pilot in the real hospital environment from a MATISSE platform deployment point of view
- The training of the personnel of City Clinic for the execution of every use case

- The successful validation of all MATISSE use cases through the collected responses from the questionnaires and other users' feedback
- Useful comments and suggestions the participants made for future improvements on the MATISSE platform

#### B.2.3.3 Deviations from DoW and their impact on other tasks

The only deviation from DoW was the slight delay in the release of D4.1 *pilot set-up & Data Management Plan*. For the purposes of pilot preparation a visit to the actual hospital environment was essential. This visit was postponed from one time to another due to some other obligations of the hospital's manager. The visit was accomplished towards the end of month 6, hence D4.1 was delivered as soon as possible, around the middle of month 7.

#### B.2.3.4 Corrective actions

No corrective measures could be applied for the arisen situation. The start of the pilot had to be slightly delayed until March 5th, to ensure that everything would perform as expected.

*Figure 6: Training and preparing for the MATISSE pilot*

*Figure 7: MATISSE piloting at City Clinic*

## B.3. Lessons Learned

The following table presents the objectives which were active throughout the whole duration of MATISSE, along with their Key Performance Indicators (KPIs) and status.

*Table 4: MATISSE objectives and their current status*

| **Objective** | **KPI** | **Status (M12)** |
|---|---|---|
| Design and develop a TiS-based hospital ecosystem of connected dynamic smart tagged objects | At least 4 TiS components used, at least 4 types of connected entities, at least 5 integrated use cases | The MATISSE platform has almost been completely integrated with 5 use cases, more than four connected entities, such as patients, exams, drug packages, smart carts, cart drawers etc, incorporating the TiS semantic models, some of the smart tags proposed by TiS in the form of TTIs, and the EVRTHNG platform |
| Decisively tackle hospital “never events” from patients’ admission to post-surgery monitoring, | Decreament in time for Drugs’ stocktaking and drugs’ selection at patients’ location to | Through the pilot of MATISSE a significant decreament was recorded in the time needed for drugs’ selection at patients’ location, as the position of each patient’s drugs in the smart trolley is almost immediately indicated after the scanning of the |

| | | |
|---|---|---|
| leveraging the smart medication paradigm within an ecosystem of connected smart devices | 40% and 45% of the current time correspondingly. 95% reduction of never events | patient's QR code. Moreover, the exploitation of smart tags is thought to annihilate incidents of wrong or defected medication. On the other hand, the time needed for Drugs' stocktaking is slightly increased than before. According to the participants of the pilot no hypothetical never events occurred during the pilot's duration. |
| Promote new business models for hospitals, claiming and proving error-proof procedures in medical activities | 15% cost reduction through process rationalization | MATISSE actually promotes new business models, a fact that has been aknowledged by hospitals which we came in contact with, even before the pilot's start. The actual cost reduction is not a fact that can be proved arithmetically, yet, towards the end of the pilot, the participants noticed that the execution flow of everyday in hospital procedures had improved, having an impact on the personnel's efficiency. |
| Validate and pilot the MATISSE solution in real-life scenarios, demonstrating the TiS added value in a real hospital environment | More than 100 involved users/doctors, pilot duration of 6 months or more, 5 or more use cases | The MATISSE platform has been piloted and validated in a real hospital environment, in City Clinic, Athens, Greece. The operation of the platform has been presented to all the doctors and nurses of the hospital, however 12 unique doctos and 22 unique nurses actually executed the 5 supported use cases, and the platform was additionally demonstrated to 14 hospitalized patients who gave valuable feedback. The duration of the pilot was almost 6 months. |
| Actively promote impact creation of TiS outcomes, leveraging on the MATISSE success story | Conference papers, presence in workshops, industrial and trade events, project demos and videos, social media updates | The MATISSE platform has been so far mainly disseminated with updates through Therapaenis' social media, a paper submitted and accepted for presentation in a conference, MATISSE has been presented in an industrial envent, and finally a video has been shot and released in month 8 of the project. The pilot of MATISSE, beyond purposes of validation, is also considered a means of dissemination. |
| Promote commercial exploitation, demonstrating pilot results to existing business contacts | At least 2 major events to promote MATISSE for commercial exploitation | Up until now, the early ideas related to the MATISSE platform have been presented in "Innovation Night", organized in M1 by the IoT – EPI. Additionally, Therapaenis had participated in an Open Call Co-Creation Workshop in Vaasa, Finland in the framework of a TiS project meeting. |

Based on the previous table, and the general advancements in the MATISSE implementation during the first six months of the project, the successes and lessons learned have been outlined.

**Successes:**

- The first integrated MATISSE prototype has been completed, providing five integrated use cases.
- The MATISSE prototype has successfully integrated various TiS components within its architecture, such as the EVRYTHNG platform, suggested smart tags and semantic model
- A MATISSE combined tag has been designed and constructed exploiting suggested TTIs and QR codes.
- A thorough testing procedure was applied to each unit of the MATISSE platform independently, followed by end-to-end integration tests, proving the flawless operation of the overall platform
- The pilot site has been successfully prepared for the pilot's execution and validation, with informed consent forms and questionnaires for the participants.
- The medical personnel has been trained on the execution of every use case supported by the MATISSE platform.
- The pilot launched in a real hospital environment, at City Clinic, Athens, Greece and valuable feedback was collected throughout the pilot's duration, both in the form of filled questionnaires and insightful comments made by the personnel for future improvements of the platform
- Contacts have been made with various privately-held hospitals and clinics for commercial promotion purposes of the MATISSE platform.
- Updates on the development of the MATISSE platform have been shared on Therapaenis' social media and web site, along with a paper submitted in two conferences for publication
- A market analysis and exploitation plan have been laid down targeting hospitals as direct customers and insurance companies as indirect customers of MATISSE

**Lessons Learned:**

- As expected, the MATISSE Back-end was continuously updated as it offered the API for the rest of the components, and during the development phase the needs of each component were not clearly defined from the beginning.
- Connectivity and performance issues occurred during the integration of the MATISSE components, which were resolved through optimizations that were applied carefully in each of the components.
- During the construction and development of the MATISSE smart trolley, various, mainly electrical, issues occurred during the design and wiring of the trolley with LEDs and magnetic switches, yet these issues were resolved leading to a more solid hardware implementation.
- The initial estimation was that the time needed for Drugs' stocktaking would be reduced, yet after the design of the system architecture and beginning of implementation this fact was contradicted. The scanning of drugs' packages before the placement in the cart drawers induced an additional work load to the drugs' stocktaking procedure. On the other hand, the participants stated that the scanning of drugs would annihilate possible mistakes.
- TTIs could have been attached in dedicated drawers of the smart cart in order to ensure the proper condition of medicine, for which the MATISSE combined tag is not attachable.

- The statement that the number of users/doctors involved would be more than 100 proved not feasible, at least for the duration of the pilot. Although the MATISSE platform was presented to the majority of City Clinic's personnel and 14 patients, the human resources that the hospital could manage to allocate for the pilot's execution were 12 doctors and 22 nurses in total, for the whole duration of the pilot.
- The hospitals' managers are interested in the MATISSE platform as I has been validated in a real-hospital environment. The acquired results provide persuasive proofs of the MATISSE solution's value.

## B.4. Impact

It is believed that the innate nature of MATISSE will reveal and promote innovative business models as it innovates in hospitals' error prevention. The proposed MATISSE ecosystem builds an innovative medication cart. The knowledge generated from active information on trolley's dynamic smart tag usage brings a new generation of services in the proscenium, built on MATISSE quality assessment via verifying correct process execution. These assessment and verification procedures could be gradually expanded beyond the aforementioned MATISSE use cases, ensuring the correctness of every action executed within a hospital environment, spawning from the accurate conduction of a medical exam to in-surgery assistance, etc.

As thoroughly described in D1.3 *Impact Creation Activities*, MATISSE is considered a unique selling proposition, identified as a unified solution for hospitals, able to offer administration services, verification of the correctness of an executed in-hospital procedure, rationalization and real-time quality assessment. The reduction of never events will raise the hospitals' reputation and the efficiency of the personnel will increase, with a reflection in cost savings and enhanced provided healthcare services, a fact which will lead hospitals to support the MATISSE system. Furthermore, medical insurance companies are expected to push privately-held hospitals to install such a system and get lower fees in their medical insurance contracts.

There are expectations that a platform like MATISSE will enhance competitiveness and growth of the healthcare industry, as hospitals will be able to claim error-proof procedures, enhancing the quality of the provided services with a subsequent overall improvement in the health status of local people or even globally, if the MATISSE offering was adopted. Although this statement seems like a long shot, it is quite justifiable. If in-hospital procedures were completely rationalized and verified in real-time, the medical personnel would be able to focus on the health status of a patient rather than worrying about undesirable and unpleasant situations that could occur, having impact on the patient as well as the hospital's reputation. Doctors and nurses would gain confidence by their increased effectiveness having an overall impact on the provided healthcare services. The MATISSE platform could additionally have a lower but existent impact on small and medium-sized technology enterprises (SMEs) which could build upon it, extend it or even get inspired by MATISSE and develop relevant solutions for the healthcare industry. Finally, as a TiS-based platform, MATISSE will actively promote impact creation of TiS outcomes, leveraging on the MATISSE success story.

Regarding the conducted dissemination activities the project has been mainly disseminated through various updates in Therapaenis' social media accounts and web site. At the beginning (M1) of the project, Therapaenis participated in *Meetup Athens: Innovation Night*, an event organized by the IoT - European Platforms Initiative (IoT-EPI) and communicated the MATISSE vision, empowered by the TagItSmart platform. Moreover, a video was shot and released early in month 8 of the project, presenting the main MATISSE use cases and the smart trolley utility. Finally, a paper describing the MATISSE innovation has been send for publication and accepted for oral presentation in 21$^{st}$ Euromicro Conference on Digital System Design (DSD), and will be presented on August 29 – 31, 2018 in Prague, Czech Republic. Finally, MATISSE was successfully disseminated through its pilot, hosted by City Clinic, where it was validated and positively evaluated both by the medical personnel and the hospital's manager.

# C. Resources

## C.1. Resources Deployed

*Table 5: Resources deployed until the end of M12*

| Extension Costs Incurred | | | |
|---|---|---|---|
| **Cost Category** | **Budget according to the TagItSmart Standard Extension Contract** | **Costs incurred within the extension duration** | **%** |
| **1. Personnel** | 93,860.00 | 108,900.00 | 116.0 |
| **2. Travel** | 14,000.00 | 2,750.00 | 19.6 |
| **Overheads** | 26,965.00 | 27,912.50 | 103.5 |
| **3. Subcontract** | 15,000.00 | 10,000.00 | 66.7 |
| **TOTAL** | 149,825.00 | 149,562.00 | 99.8 |

The personnel costs covering the salaries of the employees working in the project has surpassed the planned total amount by 16%. This is due to the fact that during the pilot execution, the hospital participants (i.e. nurses, doctors, patients) have provided significant feedback related to the actual MATISSE medication back-end system. In more details, MATISSE initial design had to be modified to interface City Clinic's software and meet the drugs' delivery procedures of the hospital. City Clinic feedback and suggested modifications have been seriously considered, leading to two additional updates on the back-end MATISSE prototype software. This has introduced additional workload to our developing team, since, besides the alterations, the platform had to be carefully retested and training to the City Clinic personnel had to be repeated.

Moreover, in many cases, and due to very tight hospital procedures, Therapaenis' personnel had to spend additional time to the hospital running the MATISSE use cases in collaboration to the City Clinic personnel. A side effect of this was the renegotiation and reduction of the planned subcontract.

Due to the increased personnel cost, it was also decided not to charge to the project any costs associated with traveling between Therapaenis' premises and City Clinic. Instead, travel costs charged to the project cover only dissemination activities, including a publication at the 21st Euromicro DSD conference, held in Prague, Czech Republic.

## C.2. Further development and exploitation

Throughout the duration of the MATISSE project, significant results have been achieved. To begin with, the initial proposed MATISSE system architecture was outlined and depicted in the corresponding deliverable. Based on the proposed architecture, the development of the MATISSE platform was launched. Commencing with the design and development of its software components, namely, the MATISSE Back-end, the MATISSE Dashboard and the MATISSE Mobile Application, this procedure was continued and completed with the hardware and software implementation of the MATISSE Smart Cart. All components were successfully combined to form the first integrated MATISSE prototype, which passed all the extensive testing procedures. Finally, the preparation of the pilot site was conducted, as well as a designation of a management plan for the data collected throughout the pilot validation phase. The MATISSE pilot was hosted by City Clinic, a privately-held hospital in Athens, Greece. Throughout the pilot's duration, City Clinic participated with a total of 4 unique doctors and 8 unique nurses, who gave invaluable feedback and made insightful comments on possible improvements of the MATISSE platform. Through its pilot, the MATISSE system was successfully validated. In conclusion, the MATISSE project reached most of its goals and objectives as they were set in the Description of Work. The MATISSE platform is considered a TiS-based solution with real potential to minimize the attributed to the human factor errors in hospital environments and possibly lead to the annihilation of "never events".

Concerning the **further development** of the MATISSE platform, our priority is to apply the useful and insightful comments made by the medical personnel during the pilot validation phase in the next version of the prototype system. These comments are analyzed in depth in D4.2 MATISSE pilot validation. In summary the following points will be considered per component for the next version of MATISSE platform:

- MATISSE Combined Tag: The attachment of dedicated smart cart's drawer's bins with TTIs was suggested from the participants.
- MATISSE Dashboard: The participants suggested updates on the fields of the resources, a proposal which was anticipated as the initial version of the dashboard was mainly targeted to the pilot's execution, hence some additional information of the stored resources was omitted.
- MATISSE Mobile Application: Most of the participants were satisfied with the component and their suggestions mostly included visual improvements for further easing the application's comprehension and use cases' flows for an inexperienced user.
- MATISSE Smart Cart: A proposal which was considered significant for the next version of the platform was the introduction of drugs' sizes so that patients will be associated to drawers' bins accordingly and not independently of the medication they should receive.

More ideas for further development could include smart tagging of a patient's daily food, based on his/her personalized diet, tagging of patient's blood or urine samples, smart time-variant tagging of personnel's card to enter controlled areas etc.

Regarding the **exploitation** of the MATISSE platform, it will be further disseminated towards scientific, industrial and general audience in order to maximize exploitation potential via technology transfer in future research and products. MATISSE results are planned to be disseminated to AIOTI WG05 "Smart Living Environment for Aging Well" and to the ETSI eHealth activities. MATISSE will support medical business to rely on the service, bringing additional revenue streams through reputation creation. Various contacts have already been made with privately-held hospitals beyond City Clinic, and the collected feedback seems promising for the future of MATISSE. Moreover, exploitation paths also arise for individual medical experts and clinicians, claiming protection from never events through supporting and using the MATISSE platform. In addition, significant opportunities will arise for medical solution providers and manufacturers, who will be given the chance to innovate through compliance to TiS, adoption and/or extension of the MATISSE system.

# References

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