Within this central deliverable of the ACCEPT project the overall project vision in terms of its general positioning, the project’s business and its research and technological objectives will be revealed. For that, a story is utilized to demonstrate typical use cases where different user groups can benefit; the logical structure as well as a high-level architecture of the ACCEPT System is described providing information from different perspectives.
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## Note

*This deliverable is subject to final acceptance by the European Commission.*

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### Project Partners

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Executive Summary

Within this central deliverable of the ACCEPT project the overall project vision in terms of its general positioning, the project’s business and its research and technological objectives will be revealed. For that, a story is utilized to demonstrate typical use cases where different user groups can benefit; the logical structure as well as a high-level architecture of the ACCEPT System is described providing information from different perspectives.

For the ACCEPT Story, ten different personas where identified to reflect the major stakeholders of a construction project. These personas have a life with a background, helping to put a face to the different user of the ACCEPT System in order to a simpler identification with the roles instead of just a technical description. This will enable not only the consortium of the ACCEPT project but also the target user of the projects dissemination to follow and understand the implications to a user throughout the project. During the twelve identify use cases the reader accompany the personas, allowing a deep understanding of the requirements for solving day to day issues on the construction site.

The logical structure of the task planed over the course of the project is explained by presenting the ACCEPT Project as a house, with a foundation and three pillars to support a roof. These analogies are used to explain the logical structure, where the whole ACCEPT System will be built on top of the work done in the fundament, while each pillar focuses on a specific domain for the envisioned goals of the project. Moreover, the roof will cover this house, making the house – so to speak – habitable. This reflects the piloting along the project, which ensures that the results will have an actual impact.

The concrete goals of the ACCEPT System are explained by providing a first version of a high-level architecture for the system. The major components and building blocks are identified and described. Providing already a very clear method allowing the envisioned functionalities as described not only in the DoA but also in the use cases of this document.
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1 Introduction

The following text needs to be adapted and used in every single ACCEPT deliverable. Its purpose is to give a general introduction to the project for those people knowing little or nothing about the project. The following introduction of chapter 1 (without the last clause) as well as the subchapter 0 can be directly copied to your own deliverable, the remaining subchapter need to be altered or extended. The following example is taken from D2.1.

ACCEPT – Assistant for Quality Check during Construction Execution Processes for Energy-efficient buildings – is a project funded by the Horizon 2020 Framework Programme of the European Commission under Grant Agreement No. 636895. The ACCEPT system will run on Smart Glasses and unobtrusively guide workers during the construction on site. This provides a standardized and coordinated process for all workers, ensuring that all benefits of energy-efficient building components are maintained.

The ACCEPT system consists of three pillars:

- **Advanced Knowledge Transfer for Energy-efficient Construction**
- **Agile Project Coordination for Bridging Heterogeneities**
- **Adaptive Quality Assurance with Self Inspection-Features**

Within this central deliverable of the ACCEPT project the overall project vision in terms of its general positioning, the project’s business and its research and technological objectives will be revealed. For that, a story is utilized to demonstrate typical use cases where different user groups can benefit; the logical structure as well as a high-level architecture of the ACCEPT System is described providing information from different perspectives.

1.1 ACCEPT Project Overview

One of the major problems in the construction sector today is the potential loss of benefits of energy-efficient building components because of the lack of knowledge or bad implementation during the construction processes. The outcomes of the ACCEPT project will help to overcome this problem with the following applications as a holistic platform:

- The Construction Operator Assistant App (CoOpApp) running on Smart Glasses, which passively collects data and actively provides guidance to the worker on site during the building process. (Pillar I: Advanced Knowledge Transfer for Energy-efficient Construction)
- A Site Manager App (SiMaApp) running on a mobile device, which allows to remotely coordinate the working process as well as collect additional data on site by different sensors. (Pillar II: Agile Project Coordination for Bridging Heterogeneity)
- An interactive web-based Dashboard as a monitoring and quality assurance solution. The Dashboard will use self-inspection methods to determine important characteristics such as U-Values. (Pillar III: Adaptive Quality Assurance with Self-Inspection Features)

To achieve its goals, the project ACCEPT conducts original research from a user centred perspective and applies technologies from the fields of Ubiquitous Computing, Big Data, Cyber Physical Systems, the Internet of Services, and Human-Computer Interaction. For more information, please refer to the project website at [http://www.accept-project.com](http://www.accept-project.com).
1.2 Deliverable Purpose, Scope and Context

The purpose of this deliverable is to act as a guideline along the project. It will be used by all partners to stay focused on the main ideas and goals of the project even in complex and technical phases of the project. To achieve this, the Project Vision Consensus Document provides information about the general positioning of ACCEPT, its stakeholders, the underlying vision, and some preliminary application scenarios.

The Strategy Consensus Document provides information on a rather high level. In order to get a deeper insight into the project, please refer to the upcoming deliverables D2.6 (User Stories and Requirements Analysis), D2.7 (Architecture Definition and Functional Specification) and D2.8 (Technical Specification and Mock-ups), which are providing more details.

1.3 Document Status and Target Audience

This document is listed in the Description-of-Action (DoA) as “public”, as it provides general information about the goals and scope of the ACCEPT project and can therefore be used by external parties in order to get according insight into the project activities.

While the document mainly aims at the project’s contributing partners, this public deliverable can also be useful for the wider scientific and industrial community. This includes other publicly funded research and development projects, which may be interested in collaboration activities.

1.4 Abbreviations and Glossary

A definition of common terms and roles related to the realization of the ACCEPT project as well as a list of abbreviations is available in the supplementary document “Supplement: Abbreviations and Glossary”, which is provided in addition to this deliverable. Further information can be found at http://www.accept-project.com.
1.5 Document Structure

This deliverable is broken down into the following sections:

- Chapter 1 provides an introduction for this deliverable including a general overview of the project, and outlines the purpose, scope, context, status, and target audience of this deliverable.

- Chapter 2 provides the ACCEPT Story. This story consists of an introduction to the overall goals and stakeholders of the envisioned product: The ACCEPT System. Afterwards so called Personas are defined, which aims to bring specific user profiles to life with a character description. These personas are than used to describe in a story-like approach the use cases of ACCEPT; providing a framework, which acts as guideline throughout the project. The ACCEPT Story will be the basis for the User Stories and Requirements Analysis in D2.6.

- Chapter 3 follows the logical structure of the DoA, summarizing the different building blocks for the project.

- Chapter 4 contains a first high-level architecture of the envisioned ACCEPT System. This will be the basis for the Architecture Definition and Functional Specification provided in D2.7.

- Chapter 5 positions the project in regards to the market and the research domain. It also defines some rough out of scope areas.
2 The ACCEPT Story

This chapter illustrates typical situations where the ACCEPT system can be used. For this, a story is created and brought to life with characters (represented by so called personas). This ACCEPT story demonstrates a sample of the various possibilities that are offered to the different user groups. They are intended to describe the current processes, problems and issues arising on a typical construction site and how ACCEPT can assist and provide solutions.

2.1 Introduction

The main target audience for ACCEPT is those who work on construction sites. These are amongst others; site managers, foremen and construction workers. These people are in the focus of the ACCEPT System because, by helping them, the biggest gains with the least efforts are foreseen to improve the overall work processes on a construction site.

For site managers the main interaction point with the ACCEPT System is through the SiMaApp which allows workflow analysis, profile generation and site construction overview with a mobile (e.g. tablet) device. Construction workers use CoOpApp on the construction site via smart glasses. The CoOpApp receives instructions from the ACCEPT System identifying work tasks. It also provides an interaction overlay using augmented reality (AR) allowing an improved workflow environment whilst also helping to ensure quality assurance (QA). A key component the CoOpApp functionality is the ability to communicate with other workers via the use of virtual “post-it’s”.

Of course, site workers are not the only stakeholders who will interact with the ACCEPT System. A variety of secondary users include architects, engineers, and manufacturers will feed information into the system and gain knowledge by interacting with profiles through the Dashboard. Their inputs range from providing 3D models which will be used by workers on CoOpApp to component data sheets which will be used by site managers when selecting materials through SiMaApp.

Tertiary users of the ACCEPT System include those who may not use the system directly but are still likely to benefit from it. These include clients, scientists and end users (occupiers). Clients can interact directly with the process of the construction project using the Dashboard but also have the benefit of an improved and faster construction process as well as a quality assured completed building. This means they are likely to get a more cost effective and better quality product. Scientists and researchers will be able to access data from ACCEPT that may not be available through other means, they can use this data to improve the quality of buildings and feed into future legislation.

The Use Cases each follow a typical scenario on a construction site. They show how the ACCEPT System interacts with the construction processes and helps to improve the workflow environment. In the ACCEPT Story, Sam the Site Manager and his team (led by Tom the Foreman) benefit from improved site management. This means that errors are reduced and when unexpected scenarios occur on site they can be dealt with in an efficient manner. Their interaction with the ACCEPT System also helps to improve the working environment by upskilling the workers and improving communication amongst the workforce. Their interaction with consultants is also improved as they benefit from fewer errors on site through reduced re-design requirements. Again, where problems do occur,
ACCEPT assists the process, helping to reduce errors in communication by providing visual and location based information on where and why the defect has occurred. With this improved flow of information, any issue can be rectified much more effectively. With the improved workflow and QA during the construction process a superior overall product will be created – The building itself is likely to be much better performing in terms of energy and acoustics because the workers installing systems will have undertaken quality checks during the construction process. The ACCEPT System will, therefore, contribute to reducing the gap between the designed and actual performance of buildings, (which is typically attributed to issues arising on the construction site).

2.2 Personas

Personas represent archetypes of persons, reflecting typical users by describing their biography, home or work situation, preferences and interests. These personas will serve as a reference throughout the course of the ACCEPT project. Each persona will interact with the ACCEPT System from different needs and in their own ways, as will be observed in this section.

2.2.1 Alice the Construction Worker

Alice is a 45 year old worker in a construction company. She has been working in this company for 20 years. During this time she gained significant experience in performing tasks in building construction such as structural works, window and insulation installation as well as knowledge of most common materials, techniques, and tools used in building construction. Alice is valued by her site manager because she always performs her tasks effectively and professionally.

Recently, Alice’s company decided to increase its competences in the fields of service engineering and historical building renovation. Therefore, Alice’s site manager has now also scheduled her to be a part of both HVAC installation and renovation crew in an upcoming project. Until now, Alice has only installed two ventilation systems and carried out a single renovation of building façade designed in Art Nouveau style. Although she is a skilled worker, she encountered a lot of difficulties to accomplish these relatively new tasks respecting time and quality requirements. Alice has asked for an opportunity to acquire more insight into these two fields.

Technology usage: Alice is fairly tech savvy however is not up to date with all the latest gadgetry. Her phone is usually a couple of years out of date.

2.2.2 Bob the Construction Worker

Bob is a construction worker aged 23. He is generally inexperienced on construction sites but his primary skill is bricklaying. Bob arrived in the country only 3 years ago and still struggles with the language barrier. He generally compensates this gap by working hard.

His friends and family describe Bob as a very willing man. He started working at the age of 16 to help his father in the family company and learned the profession from him. Despite his desire to work, Bob never took the time to enlarge his scope to the new requirements of more energy efficiency-buildings. He has always worked on traditional builds and never on modern construction projects. He is not really afraid to learn but does not believe he is
capable of learning new skills by himself and remains a little bit sceptical of all those new regulations and requirements.

**Technology usage:** Bob has a smartphone on the construction site to communicate with a foreman and a site manager. He has limited skills of reading more complex text instructions, but he is quite capable of understanding visual information such as 3D images or videos. Apart from his smartphone, Bob is quite unfamiliar using ICT though, and generally quite reserved about changing his working style.

### 2.2.3 Sam the Site Manager

Sam is a site manager of 32. He is one of the youngest site managers of his company. He quickly arrived at this position by his willing and perfectionist nature. He is very appreciated by his superiors because of his easy contact with all the stakeholders of a construction project whatever their status.

As a young man he still has a lot more ambitions and wants to prove more of his abilities. He always moved forward in life by challenging himself and tried to never stay in his comfort zone. Recently he decided that he could specialize in the efficiency-buildings. The older site managers do not seem to be interested in those new challenges so he will take the opportunity and accept to take in charge these kinds of projects.

**Technology usage:** Sam is curious by nature and is really familiar of new technologies. He loves all of the new gadgets. He is also really interested in science innovations and especially in the construction sector. He believes that a lot of progress can be done in the energy efficiency of buildings thanks to those innovations and stays aware of the construction new developments.

### 2.2.4 Tom the Site Foreman

Tom is a 35 year old qualified construction worker. He was an employee of a multinational construction company that performed large-scale construction works such as airports, bridges, and highways. Since the construction sites were located around the world, he stayed away from home for long periods. 5 years ago Tom got married and decided to settle down. As a result he left his company and started working in a smaller domestic construction company. Given his project experience and organisational skills the site manager appointed him for a foreman position. Now he is leading a six-people crew planning and coordinating their construction tasks. Over the years, Tom has gained significant experience in scheduling materials, equipment and personnel, monitoring progress, enforcing code and safety regulations as well as supervising staff and subcontractors.

As part of a strategic reorganisation, Tom’s company recently decided to widen their service offer in the field of service engineering and historical building renovation. In order to keep up the required rate of productivity and quality, the company also decided to invest money in research and development initiatives regarding BIM and ICT support. Tom loves information technologies, so he is excited about gaining a new experience.

**Technology usage:** Tom is already familiar with smartphone and tablet on construction site and he uses them for coordinating work and communicating with a site manager. At home, he uses a laptop to manage his blog: ‘Safety on the Construction Site’.
2.2.5 Paul the Engineer

Paul is an engineer of 37. He has been working in building rehabilitation for more than 15 years. Actually he began working for his old professor when he was 22 and obtained great academic knowledge. Due to his scholarship, he could work on different (and amazing) projects related to historic building restoration. He studied for a master’s degree in energy-efficiency; however, a construction company hired him before finishing his studies. He worked for the company for 8 years and gained something he considers extremely important; professional expertise.

Then he made an important decision. Leaving the company was difficult though Paul doesn’t regret it. Currently Paul is a freelance consultant and his work is valued by different companies and other organizations.

**Technology usage:** Paul is interested in new technologies and uses his smartphone constantly. Besides he continues collaborating with the university. Actually, Paul and his former professor have developed an app to get an initial evaluation of building damage occurring due to weathering.

2.2.6 Simona the Architect

Simona qualified as an architect in 2001 and after receiving her Master’s degree in Sustainable Building design, she joined a medium size architectural firm as an associate.

Simona works in close liaison with client, consultant and contracting teams. She prides herself on creating designs that meet the individual needs and aspirations of her clients, whilst delivering her schemes according to the project programme. Alongside her significant body of experience, Simona has utilised her MSc to support her passion for designing low energy, sustainable buildings, particularly with regard to the integration of innovative components and technologies into the design. Simona has always tried to exploit the use of technology to improve her work and also to establish a structured and efficient way to conduct Quality Control both during construction as well as commissioning.

When the legendary German architect Ludwig Mies van der Rohe coined the now famous phrase “God is in the Details”, he encouraged his audience to live and work in a thorough manner and to take note of details. This became Simona’s moto from the early years of her career. For this purpose, she spends a lot of her time out in the field, trying to achieve the best possible outcome from the construction. However, Simona would prefer to spend more time in the office, developing her designs to a more advanced and detail level, without losing touch with the on-site work. In fact, she is currently researching new ways to use innovative technology in order to achieve this aim.

**Technology usage:**

Simona is very open for new technologies. She uses her Smartphone for work as well as privately. The also owns a tablet private and has a notebook at work. She constantly checks new software to not only improving her design work but also to check a construction site without losing to much time on the actual site.
2.2.7 Peter the Client

Peter is a 55 year old Chartered Accountant, working for a large international company in the financial domain. His position as Head of the Financial Advisory Services department requires that he travels a lot, in order to meet his own clients, both inland as well as abroad.

During his career in various well paid positions, Peter managed to gather a significant amount of money, which would allow him to invest in real estates. His ambition became feasible with the support of a special funding scheme for improving the Energy Performance of existing buildings. Therefore, he decided to buy an existing residential building and renovate it, aiming to creating revenue for himself by renting the new flats.

**Technology usage:** Peter has a strong relationship with technology and in fact most of his work relies on his “mobile office”, as he calls his laptop and smartphone. Peter pays a lot of attention to details and would like everything and everyone around him to be as ‘nit-picking’ as he is. He is concerned about his job as well as his personal investments and wants to be constantly informed about what is going on.

2.2.8 Mika (and Elsa) the Manufacturer

Mika can be defined with one single word; entrepreneur. She is 63 years old and has her own company. Her husband and other relatives consider her a workaholic. Mika doesn’t deny she loves working but she thinks her relatives exaggerate. However she avoids talking about her retirement. Mika doesn’t consider herself as an old woman. She is convinced there are still many important things to do.

Mika’s company has produced high quality building components such as windows and doorsets since 1984. Mika worked for other companies before founding her own factory. She was always valued by her bosses and had diverse responsibilities. Nevertheless, in spite of her successful career, she felt it was not enough. Mika wanted to make his own decisions and face new challenges. Her daughter Elsa works with Mika in the office. She believes her mother is a bit stubborn and is used to arguing with her. Nevertheless they share their passion for innovation.

**Technology usage:** Elsa and Mika agree the company must invest more in research projects. Currently they are developing new eco-friendly components in order to reduce her company’s carbon footprint along with systems that enhance their quality assurance procedures.
2.2.9 Michelle the End User (Occupier)

Michelle lives in her brand new home with her family who consist of her husband, Juan and their 2 year old son, James. They also have a pet dog, Michael.

Michelle is a live-at-home mother, providing childcare for her son whilst Juan is at work during the day. She spends a large proportion of her time in the house but occasionally takes James down to the park with the dog. Michelle looks after all aspects of the home including finance, bills and DIY

**Technology usage:** Michelle is not very technically minded. She has a mobile phone however doesn’t know how to use it other than to make calls. She doesn’t really understand her energy bills when they come through and doesn’t really keep track on energy use in the home even though it has been provided with utility monitors.

2.2.10 Dave the Scientist

Dave is a thinker; he likes nothing better than solving problems. After his distinguished career in building physics he has specialised in energy profiling and building user surveys. He is a well-respected member of the scientific community. He uses data collected to publish peer reviewed research papers and seminar presentations on the use of homes and ways in which to improve the design and occupation of buildings.

**Technology usage:** Dave is an expert; he uses technology frequently and always keeps up to date with the latest trends in hardware and software especially when it comes to data collection.

2.3 Use Cases

The use cases will describe in small stories how a persona might interact with the ACCEPT System by using one of the following applications: SiMaApp, CoOpApp and Dashboard. These use cases also create a common understanding of the functionalities of the ACCEPT System. The following use cases are initial use cases, which will be validated and improved during task 2.4 with the involvement of end-users in focus groups. From the focus groups and the use cases, user stories will be derived that represent specific interactions or expectations of a person using the ACCEPT System. They will act as functional and non-functional requirements during the ACCEPT Project.

2.3.1 Use Case 1: Work Rescheduling

**Involved Personas:** Alice the Construction Worker, Bob the Construction Worker, Sam the Site Manager

Construction worker Alice has a specific profile, which mirrors her expertise as well as the current construction tasks she is working on. Her profile is also linked indirectly to a workflow profile. Alice calls sick for today.

Site Manager Sam, updates this information using SiMaApp, he then uses SiMaApp to evaluate the workflow profile. He realises that Alice’s tasks lie on the critical path, i.e. her task is crucial for the time schedule of the overall project. The system shows that construction worker Bob has similar expertise in Alice’s current work tasks. In addition, Bob’s work for that day is not marked as crucial to the overall project schedule. Sam
selects Bob as a temporary replacement for Alice’s work task. Bob gets informed about the changes to his work tasks including what kind of task he has to perform today, through the CoOpApp.

The seamless continuation of the construction works is assured through the use of the ACCEPT System.

2.3.2 Use Case 2: Construction Error Detection

**Involved Personas:** Alice the Construction Worker, Sam the Site Manager, Paul the Engineer

Construction worker Alice has to install a HVAC system. While Alice has done this before she is not fully confident in the execution of every single step. In order to ensure the quality of work execution and avoid construction errors she is using the CoOpApp as a support system.

Alice is using smart glasses and augmented reality (AR) to display a 3D BIM model of the HVAC project with assigned metadata. The metadata consists of assembly instructions, specification, technical data, etc. While Alice is working, CoOpApp informs her that some part of the BIM model and real objects on construction site do not match. Due to the error detection she gets informed and can interrupt her task to solve the problem before continuing.

By using the CoOpApp, Alice takes a photo of this situation and attaches it to a location on site which is mirrored to a virtual location in the building model. She sends an alert to Sam containing this information. Sam the Site Manager receives the alert on his Dashboard and he contacts Paul the Engineer using the telephone information provided on the SiMaApp profile. Because of the photo taken by Alice, which shows the on-site situation with the overlapped 3D model of the project, Paul can understand the problem immediately. After an hour Paul adjusts the 3D model and uploads it to the ACCEPT System using the Dashboard. Alice has instant access to the updated version and can proceed with her task. When the task is completed Alice makes a 3D scan of the whole HVAC system using (3D) sensing technologies (e.g. laser scanner and/or photogrammetry), she sends it to Paul to provide the updated version of the 3D model (as-built).

Although Alice met some problems during the installation due to design errors, she was able to accomplish her task successfully within the given time and guarantee high level of work execution. In a traditional process, Alice would notice problems during HVAC installation and she would go to Sam to report the problem. Sam would consult project’s drawings and would ask Alice to take the measurements on site. Afterwards, Sam would compare Alice’s measurements to the measurement in the project and he would call Paul the engineer to describe him the problem. According to this information Paul’s studio would have to identify the problem (it can take often days). As a result, the problem identification and solution can take a huge expenditure of time and cause delays on site. ACCEPT has streamlined this process and has allowed the construction project to continue without major delays.
2.3.3 Use Case 3: Safe-Guarding Energy Efficiency

Involved Personas: Bob the Construction Worker, Sam the Site Manager

Bob the Construction Worker has the task to construct a new wall on site, which is specified as an External Thermal Insulation Composite System on masonry brick wall.

To ensure that the specified thermal insulation properties of the system are maintained, Sam the Site Manager installs infrared (thermal imaging) cameras which gather images on a daily basis from the construction site. Using the passively gathered time-lapse photos from the CoOpApp as well as his daily collected data from the SiMaApp, Sam can see that the wall has not been installed as designed. He can see this through the thermal imaging camera that thermal bridges have been caused by bad joints between the rigid insulation panels. Therefore, he sends instructions to Bob with the CoOpApp to repair the defaulting part.

By using the ACCEPT System, Sam could identify that there was an error during the construction in due time, thereby allowing the problem to be corrected before finalising the job. After executing the repair works, the performance of the system can be checked again and assurance can be made that the detail will perform as designed. The ACCEPT System has, therefore, helped Sam to pick up the issue on time. It has also allowed the workers to fix the problem in order ensuring the energy efficiency of the building is maintained through construction.

2.3.4 Use Case 4: Quality Assurance

Involved Personas: Sam the Site Manager, Bob the Construction Worker

The construction company, in which Sam the Site Manager works, has been commissioned to construct a small single family house. During the construction of the roof, a deviation from the specified workmanship is picked-up from onsite sensors. Sam needs to communicate this problem to Bob the Construction Worker -who is assigned to the construction site -so that Bob can remove and reinsert the defaulting components, before moving on with the work. Sam knows from Bob’s profile (which he can see on his SiMaApp) that he has limited skills for reading instructions in the form of text. Bob is, however, quite capable of understanding 3D images, videos and other visual information. Sam chooses to send a visual representation of the technical requirements for the correct methodology of the installation to Bob. Through instructions displayed as a visual overlay on the CoOpApp. Bob can unobtrusively follow the instructions presented as AR. At the same time, Sam can supervise the procedure on his SiMaApp through Bob’s glasses, thus ensuring that the instructions are followed and the quality of the construction is maintained.

Although there was a mismatch with the specifications, this was evident immediately and therefore could be corrected within less time, thus reducing any negative impact on the critical path of the project.

2.3.5 Use Case 5: Quality Assurance through Effective Site Controls

Involved Personas: Simona the Architect, Sam the Site Manager, Tom the Foreman, Mika the Manufacturer and Peter the Client
Simona the Architect has specified a special type of thermal window manufactured by Mika the Manufacturer, to be used in the construction of the office building that her team has designed and is currently under construction. Mika has attached a QR code on the windows, which can be read by the CoOpApp on site. This is linked to a set of metadata for the specific element. The same QR code is also scanned by Mika, as part of the logistics procedure, to ensure that the shipment includes all the items ordered.

After receiving the windows on site, Sam the Site Manager scans the QR codes of the windows and confirms that they comply with the specifications required. He can also confirm that all the units needed for the specific phase of the building construction have been delivered on time. This information is visualised in the Dashboard. The work tasks required for the integration of the windows are automatically unlocked and workflows are initiated.

The team of Tom the Foreman receive a notification through the CoOpApp that they can now start installing the windows, but because they are new to the site they don’t have a clear understanding about the location of each window. Using CoOpApp, Tom scans the QR code attached to each window and the intended installation location of each component is highlighted on a digital representation of the floor plan linked to the BIM model. Furthermore, to ensure that the thermal characteristics of the windows are maintained, Tom is able to display a short installation instruction video on his CoOpApp. This was prepared by Mika as part of the metadata linked to the QR code in order to ensure the proper implementation of the components. After installing each window, the QR code generates a sign-off checklist ensuring the proper installation of the component has taken place.

Simona checks the progress of the installation with the Dashboard and is informed that the installation has been completed. She is also supplied with the completed installation checklists giving her confidence that the windows have been installed as per her design specifications. This information is also made available to Peter the Client, who is informed through a special gadget in the Dashboard about this outcome.

2.3.6 Use Case 6: Inclement Weather

**Involved Personas:** Sam the Site Manager, Bob the Construction Worker

It is spring, Sam the Site Manager arrives on site and it is unseasonably cold. Sam checks the weather forecast which shows that the temperature over the next 2 days is going to be below $2^\circ C$. He checks the temperature from thermal sensors on site collected actively with the help of the SiMaApp. The sensors show that the temperature is currently $0^\circ C$.

Sam uses the SiMaApp to automatically identify temperature dependant tasks scheduled for the next 2 days. SiMaApp highlights that Bob the Construction Worker is scheduled to lay bricks; a task which cannot be undertaken in temperature less than $4^\circ C$. He is reassigned an alternative task, according to his work profile, which can be completed in the current weather conditions.

The following day, the weather forecast still shows that the temperature is still below $4^\circ C$. Sam checks the temperature from thermal sensors on site, and they now show that the current temperature is actually $6^\circ C$. Based on this information, he makes the decision that temperature dependant tasks can resume. Bob is assigned to undertake brick laying for
the day. Sam monitors the local temperature throughout the day using SiMaApp in order to identify temperature fluctuations.

The ACCEPT System has assisted in enhancing the quality of construction by identifying the optimum conditions for carrying out tasks. When these conditions were not met, the ACCEPT System was used to reassign work tasks to maintain construction progress on site. Using local data, the ACCEPT System can assist the Site Manager to reduce time lost to inclement weather.

2.3.7 Use Case 7: Procurement of Materials

Involved Personas: Sam the Site Manager, Simona the Architect, Mika the Manufacturer

Sam the Site Manager is ordering a replacement window for delivery to the construction site because of a breakage that has occurred. Due to surrounding residential occupants, the site has restrictions in place that prohibit deliveries outside of the hours of 10am to 4 pm on weekdays. The site also has a tight access that prevents large articulated vehicles approaching site. He has previously assigned profiles for each supplier and a list of preferred suppliers is displayed.

Sam uses SiMaApp to order placement window from Mika the Manufacturer. The SiMaApp alerts Sam after checking the material profiles that Mika usually delivers windows using large articulated vehicles by default. It also reminds Sam that time restrictions are in place for deliveries. Sam informs Mika of the time restrictions for the site and requests delivery on a small flatbed truck. When the replacement window arrives, it is delivered at the correct time, and is able to approach site unhindered.

The ACCEPT System has assisted in the smooth and effective procurement of materials, helping to reduce time lost on site due to errors in communication.

2.3.8 Use Case 8: Variations to Construction

Involved Personas: Sam the Site Manager, Peter the Client, Alice the Construction Worker, Simona the Architect

Sam the Site Manager is in a design team meeting with Peter the Client and Simona the Architect; the project is on site and well progressed, however Peter has requested that the layout is amended to incorporate a new door into a wall that has already been partially constructed. Alice the Construction Worker is currently dry-lining the wall.

Whilst still in the meeting, Sam uses the SiMaApp to log that a design change is occurring to the wall and notes that all current work should stop until a resolved layout is created. The ACCEPT System checks the work schedules for the day and discontinues any work tasks involving the wall and proposes alternative tasks for workers through the SiMaApp to Sam, who accepts all suggestions. Based on this, Alice receives a notification via the CoOpApp telling her that the dry-lining of the wall task has been discontinued and that she has been assigned a new task. She stops her work and moves on to her newly assigned task. Sam receives the updated plans from Simona; fed to the ACCEPT System by an upload via the Dashboard. He is then able to reengage work tasks on the attached wall with the new specifications in place via SiMaApp.

ACCEPT has speedily and efficiently managed a variation to the construction saving potentially abortive work and costs involved in retrofitting components.
2.3.9 Use Case 9: Managing Complex Construction Tasks

**Involved Personas:** Sam the Site Manager, Peter the Client, Tom the Foreman

The rehabilitation of a historic building is being carried out in order to enhance its energy-efficiency. Due to the works, part of the main façade must be removed temporarily. The façade was originally coated with ornamental tiles forming a sort of intricate mosaic and other iconic images.

Peter the Client has insisted the building must keep its original essence as this will increase the saleability of the flats. In fact, this aspect is one of the key requirements of the contract. Sam the Site Manager has contacted a restoration specialist, who has designed step by step the way to remove, classify, encode, store and restore the tiles. Sam has uploaded the methodology to the ACCEPT System with a special widget on the Dashboard, including drawings, models, descriptions and tips.

Tom the Foreman has the responsibility to carry out the work. He is a seasoned professional although he cannot be considered as a restoration specialist. Nevertheless, by using the CoOpApp, Tom is able to consult every step of the process as the entire methodology is available in the app.

Once the activities regarding the enhancement of the building have been finished, it is time to reconstruct the façade as it was originally built. As this is an extremely complex activity, where accuracy is essential, every single tile has been classified and encoded and the database has been fed into the ACCEPT System. The team of Tom the Site Foreman uses the CoOpApp to verify the order, sequence, location and position of every tile. He also requests an image of the original tile mosaic and a 3D model of the different stages of the work.

Thereby, the ACCEPT System provides an inestimable support when highly complex tasks are involved.

2.3.10 Use Case 10: Knowledge Transfer

**Involved Personas:** Alice the Construction Worker, Bob the Construction Worker, Tom the Site Foreman

Alice the Construction Worker is in charge of installing all the airtightness membranes on the wall/floor junctions as well as the airtightness joints around the frames. Bob the Construction worker has been tasked to plaster all the walls.

Alice uses the CoOpApp to request execution details. She sees a small video or a 3D model and then takes the specific precautions to ensure the correct installation of the component. Later Bob has to plaster all the walls but Alice has not yet finished installing all the airtightness membranes. Bob is inexperienced at this task and as such he would not notice the lack of membranes on a construction site. However by using the CoOpApp Alice is reminded that there is a sequence of work following her task, she has therefore attached a virtual note mentioning that the installation of the membranes is not yet finished. Bob wouldn’t normally understand a note from Alice, as he doesn’t speak her language fluently, but the CoOpApp presents a translated version of Alice’s note. He therefore understands that the task cannot yet be undertaken here and starts his work in a different location.
In the traditional construction process, Alice would undertake her task but may forget that there may be different trades working after her, even though she intends to finish the work later she would not think to communicate that the task is not completely finished. Bob would also have started his work as planned without noticing the lack of membranes. The absence of airtightness membranes is however one of the most impacting mistakes on the energy-efficiency of the building. Moreover it becomes almost impossible to install properly the membranes after the plastering. Bob’s misunderstanding would involve a loss of time in the construction process and a loss of efficiency.

ACCEPT has allowed in both cases a gain of time and an energy-efficiency closer to the design intent.

2.3.11 Use Case 11: Equipment Problems

**Involved Personas:** Tom the Site Foreman, Sam the Site Manager, Paul the Engineer

Sam the Site Manager can see that his workers have enough expertise to install the shading system on the glass façade, which should be done by another crew during the next 2 weeks. Using the SiMaApp Sam checked that the components required for performing this task are already present on site, so he decides to assign this task to the team of Tom the Site Foreman. Sam is providing specific execution information and construction details for the successful installation of shading elements to Tom. Tom is using CoOpApp on his smart glasses to identify the building elements and display visual information on top of real objects on site using AR. Tom’s team starts the installation. On Thursday, Tom’s team is reassigned to another task, so they stop the installation of the shading elements. Tom uses CoOpApp to communicate to Sam the progress of this task during these days and to attach a virtual note for another team highlighting that the installation of the last element is not finished and it should be done before starting the installation of a new shading element.

To provide the current conditions on site, Tom performs a 3D scan of the façades with the installed shading system using the SiMaApp. He uses an external GPS positioning system and 3D sensing technology (e.g. laser scanner and/or photogrammetry) to provide spatial characteristics of installed shading system for an automated construction progress tracking system. The ACCEPT System has access to the BIM 4D models of the project (3D CAD model combined with schedule information). Tom’s 3D scanning (registered with the same coordinates as the BIM models) generates as-built objects that can be recognized by BIM through object recognition. This built information is provided to Paul the Engineer through the Dashboard, which Paul uses to check and verify against his specification.

ACCEPT has improved the productivity on site through an automatic estimation of the construction progress. Eventual discrepancies between actual and as-planned performances, as well as more efficient and effective feedback control loops for project control tasks, are ensured.
2.3.12 Use Case 12: Post Occupancy Feedback

Involved Personas: Sam the Site Manager, Michelle the Occupier, Dave the Scientist, Mika the Manufacturer

Sam the Site Manager attends the flat of Michelle the Occupier to inspect her boiler as part of the 12 months defect inspections. Michelle has previously complained that her energy bills are very high and that she thinks there is something wrong with her boiler.

Sam is able to pull up the commissioning certificates and original installation schematics for the boiler using SiMaApp, as it recognises the boiler’s unique identification number. He undertakes an inspection and finds no fault with the system or the installation. There is nothing physically wrong with the system, so Sam suggests to Michelle that he brings in a specialist to look into the reason behind her high energy bills.

Sam does, however, identify a problem with a window that has condensation within the panes. Using the SiMaApp he makes a virtual defects note linked to the window, which is also logged within the Defects Profile for the home. The defects note is automatically forwarded to Mika the Manufacturer via the Defects Profile, so that she can arrange for a repair team to visit Michelle’s home and fix the window.

Back at the office, Sam uses the Dashboard to review the defects notes and notices that the window issue is a common trend. Using the SiMaApp he logs a note against the component profile that there may be a potential issue with the supplier. This note will appear on all of the Contractor’s sites where this window supplier profile is selected. The ACCEPT System has helped to feed data back into the supply chain to help improve the procurement of suitable materials. Having design and commissioning data available to hand through ACCEPT whilst inspections are being carried out; defects inspections can be streamlined for all parties and reducing the number of visitations required to rectify faults.

Meanwhile, Dave the Scientist undertakes a building user survey at Michelle’s home. During his visit, Dave noticed that the windows are wide open and the boiler is on a high setting. Utilising energy meter data provided to him through the Dashboard, he identified a pattern that points to the home not being run efficiently. He communicates this to Michelle with recommendations to reduce her energy bills. By linking to energy consumption data available in the home, ACCEPT can be utilised by researchers and scientists to close the performance gap between design and occupied energy usage. Such data is valuable in supporting research that can be used in the design of sustainable new homes.
3 Logical Structure of ACCEPT

3.1 Introduction

The logical structure of the ACCEPT project is the management structure for the coordination of the work to be done over the course of the project. The structure is linked directly to the different Work Packages (WPs) of the project and helps to reach the goals of the project by providing a clear working framework to the project consortium.

Figure 1 depicts this logical structure of the project. The five core WP’s are represented in that figure:

- The ACCEPT Fundament represents the work of WP3. This work is the technical groundwork for the whole ACCEPT System. The technical developments done will be the basis for the whole ACCEP System.
- ACCEPT Pillar I represents the work of WP4. The work will enhance the capabilities of the ACCEPT System to show information on the different end user application, but will focus on the CoOp App. The information provided to the different end user of the ACCEPT System is accumulated from other end user of the ACCEPT System. This sharing of information is the basis for the knowledge transfer. As the end user will be from different categories as architects and construction worker this will lead to a direct interaction between different stakeholders of a construction site project. This vertical and horizontal sharing of knowledge will be a clear advantage, which will in the end improve the energy efficiency of a building constructed with the help of the ACCEPT system.
- ACCEPT Pillar II represents the work of WP5. This work is focused on the coordination of construction projects. In order to coordinate a construction project a lot of data is to be considered. For this, different profiles will be created. These profiles will store information structured in project, workflow, user and quality profiles. Changes in one profile will cause changes in other profiles. These agile changes will be utilized to provide guidance as well as alert the different stakeholders of the ACCEPT System. The information of the profiles will be shown to the end users filtered. Based on the background of the end user they will get exactly the information they need to know, bridging in the process the heterogeneities between different stakeholders of the ACCEPT System. While all end user contact points will interact with the profiles the most visible results will be fed to the SiMa App.
- ACCEPT Pillar III represents the work of WP6. This work is focused on the quality assurance of construction projects. The main target platform for the visualisation of the quality assurance is the Dashboard. The input for the quality assurance will be gathered by multiple sensors. The setup and requirements for the sensors is adapted to the needs of the construction site and the construction project in general. Data will be collected passively and actively by different sensors connected to the ACCEPT System. The quality assurance will monitor on the one hand the results of the workflow (what was done?) while on the other hand monitor the results (who good was it done?) of the execution.
- ACCEPT Roof represents the work in WP7. This work will evaluate the work of the ACCEPT project with the help of pilots of the different prototypes. For each pillar of
the project a distinctive pilot setup is foreseen. The continues running pilots will feedback information directly from all end user of the project to improve the results of the project as well as allowing for a feedback channel to adjust the focus to the actual user needs.

![Diagram of the ACCEPT Project structure]

Figure 1: Infographic – Logical Structure of the ACCEPT Project

3.2 Fundament

The ACCEPT Fundament is the base for the whole ACCEPT System. It represents the work of WP3. This covers the core research and development activities as well as the providing of the ICT infrastructure for the ACCEPT System. Specific objectives for the Fundament include:

- establish an approach to store information in a central point
- providing the base version of the app for the smart glasses platform (see subchapter 4.2)
- providing the base version of the app for the mobile platform (see subchapter 4.3)
- providing the base for the Autonomous Messaging Framework (see subchapter 4.5)
- providing the base for the Service Market Place (see subchapter 4.6)
- providing the base for the Sensor Abstraction Framework (see subchapter 4.5)

As opposed to the Pillars of the ACCEPT System the Fundament does not have a distinct focus the work in the Fundament will impact the Pillars strongly. Beside tangible results,
best practices will be developed, which can act as a guideline for the work over the course of the whole project.

The outcomes of the work on the smart glasses and mobile platform are essentially the first minor versions of the Site Manager App (SiMaApp) and Construction Operator App (CoOpApp). These first versions will provide core functionalities such as integrating the communication framework to access the ACCEPT Services in the distributed server architecture.

3.3 Pillar I – Knowledge Transfer

Pillar I – **Advanced Knowledge Transfer for Energy-efficient Construction** – of the project defines a series of objectives on how the transfer of knowledge will be achieved. This knowledge will be utilized to reduce the potential loss of benefits of energy-efficient building as it is common that the lack of knowledge during the construction processes is a major reason for the loss of benefits of energy-efficient building components. The focus thereby is the transfer of knowledge between the different users during the building construction process.

The information gathered at different points from different stakeholders will be used to create knowledge, which will be provided to a construction worker to assist him by his day to day work. The information for this knowledge transfer will be displayed on visual or audio format using smart glasses.

During this pillar the focus will be two-folder. On the one hand the extension of the functionality of the CoOpApp (see subchapter 4.2) is pushed. This is the interaction (creating, visualising, sharing, etc.) with the two different types of information:

- **Execution Detail Assets (EDA):** EDA is focused on complex execution details, which can be accessed on demand. This information can be reused by different construction projects, e.g. for helping in the installation of a specific construction component
- **Extended Visual Annotations (EVA):** EVA is focused on simple information presented as virtual post-its attached to real world objects. This information is for a specific construction project, which allows different stakeholders of the construction project to share small bits of information relevant only to that specific project.

As a basis for the interaction with the two types of information, the CoOpApp needs basic functionalities to “select” objects in the real world actively as passively for the different use cases. For this, different algorithms and libraries from the field of image processing will be evaluated and integrated.

On the other hand, a server application has to be developed, which will act as a repository for the two types of information: This Visual Wiki (see subchapter 4.6). In order to distribute the data the AMF (see subchapter 4.9) will be extended to handle the special requirements for handling the EVA and EDA data.

Last but not least, EDA and EVA support will be brought to the Dashboard (see subchapter 4.4) by creating widgets allowing interacting with the workers on site from e.g. the office. Allowing not only the transfer of knowledge between the colleagues on site but extending the knowledge transfer to all stakeholders of a construction project.
3.4 Pillar II – Project Coordination

The main objective of the Pillar II – Agile Project Coordination for Bridging Heterogeneities – is to provide an holistic event driven data basis, which will be manipulated and visualised in the different clients of the ACCEPT system. The services around this data basis aim to:

- improve coordination of a construction project by providing guidelines and methodologies
- increasing the efficiency, reliability and productivity of construction processes by monitoring and controlling of the entire project execution process in terms of time, resources, budget management and delays control
- reduce the mismatch of energy performance between as-planned and as-built through interaction with sensors for the Quality Assurance (QA)

Pillar II represents the work of WP5, which covers the development of the templates for profiles needed to coordinate the construction site and services to ensure interaction between these profiles as well as within the whole ACCEPT system. In order to guarantee an agile, flexible and efficient coordination of the construction process as well as ensuring high quality of work execution (i.e. reaching the planned energy efficiency performance), Pillar II focuses on the following activities:

- generation of templates for the different profiles:
  - Profile for a construction project which provides information such as: plans, sections, description of technologies, materials, involved sub-contractors, etc.
  - Profile for workflows (technical and descriptive), e.g. the technical workflow provides information about installation process of a building component which should be performed by workers; the descriptive workflow provides metadata information to ensure interaction between sub-contractors.
  - Profile for quality attributes, describing parameters to measure and monitor the quality of construction works, e.g. in terms of energy-efficiency values (as-planned vs. as-built) or the efficiency of the construction process (e.g. on basis of KPIs from Lean Management perspective to reduce waste).
  - Profile for the user of the ACCEPT System to describe the different users, their skills, availability, tasks/crew assignments, role and duties, etc., e.g. profiles for worker, foreman, engineer, site manager, architect, etc.;

- Implementation of services to access and modify profiles
- Creating an event-driven formalism for the interaction between profiles
- Implementation of services and filters to translate the profile information from one domain to another
- Implementation of an abstraction to incorporate different data sources as legacy systems or BIM/IFC/COBIE

The hierarchical organization of the ACCEPT System from the point of view of the Pillar II is depicted in the following figure (see Figure 2):
All results of the work in Pillar II will feed to the creation of a distributed server application; the Profile Nexus (see subchapter 4.7). The Profile Nexus will be the central mediator for all interaction with the different profile information and is thereby the second source for data beside the Viki (see subchapter 3.3 and 4.6).

At the beginning, the groundwork for the whole WP5 is made (task T5.1). This will be on the one hand the general idea of how the different profiles will be defined, while on the other hand a framework for the sever application is created. The basis for all profiles will be a methodology for an event-based. Based on this all other tasks focus on one specific profile:

- The second task (T5.2) will result in definition of template for construction project profiles as well as in the interaction of this with other profile types. The first action will identify and analysed all information that profiles should contain as well as technical needs for each profile according to the type of project, standards, workflows, level of expertise and other parameters. Information from this profile can be utilised for example to:
  - Worker using CoOpApp will be informed on which working site to work at the start of the day
  - Site manager using SiMaApp will receive the alert about a worker absence due to the illness and will suggest another worker to take over considering its availability and requested skills to perform a task
  - Site manager using Dashboard is able to have an overview over the progress of a project and verify a quality of construction works with data gathered via sensors.

- During the third task (T5.3) the template for workflow profile will be developed containing information to describe both technical and descriptive workflows. Technical workflows will contain information about an actual workflow, which has to

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**Figure 2:** Hierarchy Schema of the ACCEPT System from the Point of View of Pillar II

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**ACCEPT SYSTEM**

**NEXUS SERVICE**
- Automatic algorithms
- Event reaction data mining system
- Client library, context-aware mechanism, database abstraction layer, syndication and/or ontology
- Technical interface between BIM and ACCEPT system

**PROFILE**
- Access service
  - Visualize information on mobile system
  - Modify manually/automatically information via mobile system

**PROFILE’S INTERACTION**
- Event-based interaction between different profiles
- Algorithm for profile interaction
- Technical interface BIM-profiles

**PROFILES**
- User requirements
- Technological requirements
- User interface and software requirements

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**HOW?**

**BIM**
be executed by a construction operator. Descriptive workflows (metadata) will be important to support interaction between different profiles during the construction project, e.g. how different subcontractors will work together. Therefore, the workflow profiles will provide information on the level of working tasks (and sub-tasks) to describe and monitor the task, such as working content, construction area, real effort (as-planned/as-built), working crew (as-planned/as-built), construction materials/elements, tools/machines as well as interdependencies between tasks. The workflow profile and its interaction with other profiles/target platform of the ACCEPT system and BIM software will allow for an automatic estimation of the construction progress, eventual discrepancies between actual and as-planned performances as well as more efficient and effective feedback control loops for project control tasks. Information from this profile can be utilised for example to:

- Worker using CoOpApp will be able to visualize information how to install a construction component according to the rules of the trade
- Site manager using SiMaApp will be able to reschedule task in an efficient way due to an unexpected event without losing the general productivity on site.
- Site manager using Dashboard will receive alert if a subcontractor is likely not be able to finish with his workflow in time allowing him to reschedule works in advance.

- The fourth task (T5.4) will result in the development of the template for quality profile, specifying types and format of information (parameters) that will be used to describe and monitor the quality of work execution for QA purposes, e.g. KPIs from Lean perspective to reduce waste. Information from this profile can be utilised for example to:
  - Worker using CoOpApp will be informed if the finished installation of a component has been done in a proper way according to the installation instruction;
  - Site manager using SiMaApp will be able to collect QA relevant data via sensors on-site;
  - Architect/Engineer using Dashboard will be able to compare as-planned vs. as-built of QA relevant data.

- The main output of the last task (T5.5) will be a template for user profiles to represent the different stakeholders participating in construction projects as well as the interaction between those profiles. A user profile will contain all information important to a construction project such as expertise, role and duties, availability, crew assignment, etc. Information from this profile can be utilised for example to:
  - Worker using CoOpApp will be able to communicate his illness
  - Site manager using SiMaApp will be able to choose a construction worker as a temporary replacement for a sick worker matching similar expertise of other available workers
  - Site manager using Dashboard will gather and display data regarding user expertise based on the task they have already performed

Last but not least, efforts of every task will be spent to tackle the important issue is to translate the information of a profile from one domain to another. This will be solved with business logic methods and a mixture of automatic algorithms and redundant information saved as data for the specific domain. Moreover, a context-aware mechanism will enable
the nexus service to provide the information for the specific domain of each user. This domain translation service might have some functionalities, e.g. delivery of installation instructions of a building component as a text in different languages based on a user profile; delivery of a 3D CAD model (BIM) of a complex building details with assigned metadata and/or sequence of work execution according to the rules of the trade.

3.5 Pillar III – Quality Assurance

Pillar III – Adaptive Quality Assurance with Self Inspection-Features – of the project defines a series of objectives on how data from different sources can be accumulated and processed automatically in order to allow quality assurance (QA) in a variety of environments.

In order to implement the QA and the self-inspection features on the construction project. The information from different sources will be gathered and analysed in order to adapt the current context. Specific objectives are:

- Conducting a study, which concentrate on actors in the construction project, with the focus on the workers and the site project and workflow manager. This will be the basis for the services, which will provide the monitoring of the workflow in general, but especially the monitoring of the workflow profiles. The monitor service will be a central point to interact with real-time information containing in the profile information of the PN (see subchapter 4.7), e.g. the status of specific workflows as well as context information relevant to specific workflows. Based on the analysis of the profiles the QA for the different phases of the construction project can be conducted. As a starting point, critical aspects of a construction project will be identified and specified regarding required information to be provided online to construction workers. For all aspects identified as being crucial on a construction site, necessary information will be assembled and prepared to be used by the different construction workers. Specifying quality thresholds for the quality monitoring. Thresholds are to be defined precisely as soon as the construction quality domains are identified. In construction, one can seek quality in different domains: energy, HVAC, acoustic, hydrothermal, lighting, architectural, etc. For each major, the most important quality assurance indicators will be defined.

- Creating an approach for CPS integration and sensors. First, research has to be conducted to investigate existing technologies for collecting information from a construction project site. This will be closed link to the task 2.2 of the project.

- Creating a methodology to gather data by visual means to adapt the QA to the context of the specific construction project with its unique characteristics. The gathering of data will focus on visual information based on recording of the construction site environment while using the CoOpApp. Especially during the installation of building components, which are critical for the energy-efficiency.

- Providing methodology for self-inspection of components. The QA in the construction domain is especially complex. As reference to control the quality in the construction domains, different documents have to be considered:
  - plans, sections, elevations, 3D models
  - precise requirements on Materials, on technical’s, on site management
  - details of plans: techniques for assemblies, fixing (Replacing, dismantling, recovery)
- specifications: Requirements of suppliers (bulk materials, packaging instructions, resume falls)
- technical (foundations): of water quality test to the output of the treatment system, the resolution details plans for thermal transmission, care guide

Defining these quality indicators will be based on the following approach:
To react and always adjust in time if there is a problem on the site, to prevent errors and make sure to reach the objective predefined, to control and reduce the merge of error. Quality indicators can also be integrated to checklists; they can be short and simple and they will help focus on critical steps needed to prevent common mistakes. Following some examples of guidelines:

- using task checks for simple but critical stuff
- using communication checks for complex stuff. These checks help people to coordinate and to distribute responsibilities in an easier way.
- picking the right type of list. Using ‘read-do’ checklists when users have limited experience with the process. Using ‘do-confirme’ checklists when users have memorized most of the steps.

For the quality assurance (QA), the strategy will be defining actors, tools, inputs, workflow events, quality repository, technical references and post evaluation service. The schema depicted in Figure 3 gives guidelines for the approach for the QA.
3.6 Roof – Pilots

3.6.1 Introduction

The ACCEPT system will be tested through a series of Pilots which will enable the project to reach technology readiness level 6 by the end of year 3. This means that the system will be tested and verified against the ACCEPT key objectives, consequentially bringing it much closer to market readiness by the conclusion of the project. The key objective of the piloting tasks is, therefore, to provide the ACCEPT project with a foundation to make a strong impact in the industry by the provision of real tested results.

Figure 3: General Schema of the Quality Assurance Approach of Pillar III
During the course of the project there will be 7 Pilots which will be conducted across 3 pilot groups, each of which focus on testing one of the 3 applications, CoOpApp, SiMaApp and the Dashboard. These pilots will be real world use scenarios with the systems being tested on live building sites. This has advantages over artificially lab-tested systems as learning from the Pilots can be incorporated at an early stage of production.

Each of the 3 pilot groups will consist of 2 pilots focused on testing ACCEPT. Additionally, included within Pilot Group II is a control pilot which will be used to generate base data for verification against the project objectives. Further details about the individual pilot groups can be found in the sections below. Focus groups will be utilised (e.g. by using a paper prototype or plain interviews) to bring feedback right from the start to the first prototypes.

Prototype I is used within the first on-site pilot to obtain qualitative data which will be used to develop Prototype II of the application. Prototype II is used for the second pilot in the respective pilot group to obtain qualitative and quantitative data where available. This iterative design process will help ensure the ACCEPT System is developed that is both useable and applicable for the end user.

Before starting the pilots, a pilot plan will be developed, which will include the pilot’s objectives; scope; tools; implementation details; resources; support; team members profiles and responsibilities; budget; schedule and risks. It will also include the monitoring and evaluation plan and all the indicators and define the methodologies of their measurement.

Once the pilot-planning document is ready, the resources are in place, and some candidate projects have been selected, the execution of the pilot will begin. During the execution all the specified indicators will be measured and all the relevant data will be collected. In addition, all the necessary support will be provided to the users as needed.

The Data mining procedure will be executed with various methodologies, depending on the specifics of the project and the type of indicators being measured. Indicators will be recorded daily, weekly or per case results, according to their type. The data mining methodologies will be divided in categories, based on the collection strategy, as follows:

- **Automatic**: it is possible to have automatic tools that will collect numeric data like number of hours a system was used, exactly when and by whom (if each worker is given a username for instance). This way data does not have to be collected from users directly.
- **External**: One or several observers from the team can be present during execution on site. This can be done with or without interfering with the normal construction process.
- **Subjective**: Participants can document their impressions, experiences and ideas through several tools like journals or diaries, questionnaires, tables or forms. The frequency of documenting must be pre-defined. This type of feedback gathering is useful for quality metrics. In addition to free-text comments that could enrich the conclusions, this type of feedback can be tabulated and analysed as well.
- **Environmental**: Data can also be gathered by questioning workers, site managers, contractors and also the Architects and Engineers about the pilot results and their perceptions.
3.6.2 Pilot Group I

The first piloting group will focus on the knowledge transfer between construction workers using the Smart Glasses platform. FER and EJD will manage the first pilot group (Figure 4 depicts the sequence of action in the pilot group) which will run simultaneously and respectively in the countries of Belgium and Spain. Different sequential activities are planned to be carried out during the process which will start with the creation of at least two focus groups.

![Infographic - Sequence of Action in Pilot Group I](image)

The feedback expected in each stage as depicted in the infographic in Figure 4 is explained in the following subsections.

### 3.6.2.1 Focus Groups

The focus groups will consist of at least 6 construction workers and should reflect the heterogeneity of the construction domain. The focus group sessions will be designed in order to provide clear and unequivocal answers for the following questions:

1) How can the acceptance of smart glasses on construction sites be maximized?
   - What kind of physical attributes are needed for the smart glasses?
   - Are special incentives needed, if so, what kind?
   - What are the main concerns about using smart glasses?

2) What kind of interaction with the smart glasses is feasible?
   - How can information be displayed without distraction (user safety)?
   - What kind of user input would be preferable?

### 3.6.2.2 Pilot I

The gathered feedback, from real-world workers and their day-to-day working habits, will feed into the first prototype, Prototype I. FER and EJD will each run pilot schemes simultaneously and respectively in the countries of Belgium and Spain. During the pilots, workers will be equipped with smart glasses which will be used on site for at least a working day. The feedback gathered from the workers will be gathered from interviews and structured feedback forms as well as on data gathered by the CoOpApp during its usage.
The results of the evaluation will be used as direct feedback for the technical partner to improve the CoOpApp

3.6.2.3 Pilot II

The gathered feedback and subsequent development of the application to Prototype II will be used for Pilot IV. Those results will be crucial for the development of the second prototype. In the second prototype all envisioned functionalities should be implemented and tested. As per Pilot I, this pilot will be held simultaneously at two construction sites. FER and EJD will equip workers with smart glasses who will test the prototype for a whole day. Data will be gathered by interview and through the CoOpApp during the day.

In summary, the results obtained from the Pilots I and II will allow the ACCEPT consortium to validate the significance of the CoOpApp

3.6.3 Pilot Group II

Pilot Group II focuses on the second pillar and coordination of a construction project utilising SiMaApp running on a smart tablet.

This pilot group will be managed by consortium partner INGL. The format of the pilot group will follow the basic principle using feedback data to inform the ongoing development of the associated application, which in this case is the SiMaApp. The pilots will focus on the intended end user, site managers. INGL will work in conjunction with a local housing association to provide access to suitable sites for piloting purposes. Figure 5 depicts the sequence of action in the pilot group.

Figure 5: Infographic – Sequence of Action in Pilot Group II

The feedback expected in each stage as depicted in the infographic in Figure 5 is explained in the following subsections.
3.6.3.1 Focus Group

The focus groups will involve at least 6 site managers and be based on the paper prototype of SiMaApp. This user group will help inform the direction of the development of Prototype I of the SiMaApp by answering questions based around the functionality, user interface and implications of the use of technology on site.

3.6.3.2 Pilot III

The first pilot will be run on a UK construction site assisted by a local housing association. Due to the expected rudimental development at this stage it is expected that only the basic systems will be available to evaluate. Data extracted is likely to be qualitative and will be used to inform the second prototype of SiMaApp.

3.6.3.3 Pilot IV

Following the feedback from Pilot III and the simultaneous development of the wider ACCEPT system through the other Pilot studies, the SiMaApp will be much more developed for testing in Pilot IV providing to provide into the wider ACCEPT System, as well as showing interactions on site. It is intended that this pilot will test the ACCEPT System throughout a construction project which will be used to validate the objectives of the ACCEPT project against Pilot V (Control). Data extracted should therefore be both qualitative and quantitative.

3.6.3.4 Pilot V

Pilot V will run alongside Pilot IV and will be as similar as possible in terms of the construction methodology and site management, without compromising the control through the use of ACCEPT. It is therefore likely that the Control will slightly proceed Pilot IV in order to mitigate against any learning the construction workers gain from the use of ACCEPT on other sites. The same set of data will be extracted for Pilot V as for Pilot IV and will be used to validate the effect that the ACCEPT system has had against Key Performance Indicators in the project.

3.6.4 Pilot Group III

During the third pilot group EPI will cooperate with a third party, which could be a local contractor or a subcontractor company, in order to test the whole ACCEPT System in situ. During this Piloting group, two pilots will be conducted, Pilot VI and Pilot VII, which will bring the whole ACCEPT System to the construction site. The pilots will focus on pillar III of the ACCEPT project, the Adaptive Quality Assurance with Self-Inspection Features with special attention to the desktop application, which is the web-based Dashboard. In order to assess whether the objectives of the corresponding task have been satisfied, a list of case specific key-performance indicators for the ACCEPT System will be defined. Figure 6 depicts the sequence of action in the pilot group.
The feedback expected in each stage as depicted in the infographic in Figure 6 is explained in the following subsections.

### 3.6.4.1 Focus Groups

The focus groups for Pilot Group III differ in that formal focus groups will not be undertaken; this is due to the well-known use of a Dashboard like interface. In lieu of focus groups, the consortium will provide feedback and expertise which will help inform the formation of Prototype I of the Dashboard.

### 3.6.4.2 Pilot VI

The first pilot (Pilot VI) will be used to gather general feedback, for evaluating the different components and services of the ACCEPT system, as well as specific feedback for the Dashboard. This will lead to the development of the second Dashboard prototype.

### 3.6.4.3 Pilot VII

The second pilot (Pilot VII) will measure the success indicators of the project, validate the results and measure its impact. In addition to the Dashboard, the two pilots during this task will also use the CoOpApp and the SiMaApp, to validate ACCEPT as a whole system.
4 High-level Architecture

4.1 Overview

The ACCEPT System is envisioned as a distributed system with three end user contact points as well as a contact point for Cyber Physical Systems (CPS).

Figure 7 depicts the high-level architecture of the whole ACCEPT System. The four corner of the architecture are the four interaction points: SiMaApp, CoOpApp, Dashboard and the Sensor Abstraction Framework (SAF) for the interaction with CPS.

In the centre of the architecture are the distributed server applications which will provide the different ACCEPT Services. Every component of the ACCEPT System is connected through the Autonomous Messaging Framework.

![High-level Architecture of the ACCEPT System](image)

Each component identified in the high-level architecture is explained in more detail in one of the following subchapters.

4.2 Site Manager App – SiMaApp

The Site Manager App (SiMaApp) will run on a mobile device. The main target user will be a site manager but based on the Use Cases (see subchapter 2.3) additional user of the ACCEPT system are already identified as secondary target user.

The SiMaApp will be used to check the progress of a construction site, as well as managing the day-to-day work. The SiMaApp will allow to connect hardware sensors to actively collect data, which will be fed to the ACCEPT System.

The following requirements for the SiMaApp are already apparent:
• Allow the integration of third party services deployed in the Service Market Place (see SMP subchapter 4.6)
• Provide a runtime for third party services, with access control list to control the access to data as well as to functionalities of the ACCEPT System
• Provide a Sensor Abstraction Layer (SAL) by using the Sensor Abstraction Framework (see SAF subchapter 4.5). The SiMaApp will use the SAL to integrate external sensors.
• Provide Augmented Reality (AR) feature to visualize EVA and EDA information
• Provide AR features to allow limited interaction functionality to manipulate EVA and EDA information

4.3 Construction Operator App – CoOpApp

The Construction Operator Assistant App (CoOpApp) will run on smart glasses. The main target user will be a construction worker on site, but based on the Use Cases (see subchapter 2.3) additional user of the ACCEPT System are already identified as secondary target user. The CoOpApp will unobtrusively visualise information regarding the construction, providing guidance to the worker on site during the building process. In addition, it passively collects data.

The application will be used by stakeholders, who directly access the construction site and allow them to generate virtual notes on real elements with augmented reality. Another feature of the application is to allow displaying information relating to an object that is displayed to assist in the installation of the object or improving energy efficiency in construction. CoOpApp will use libraries for augmented reality functionality, and use project libraries to interact with the ACCEPT Services. That is to develop a framework focused on the server side and a server abstraction layer. Also is to develop a framework focused on the user side for inputs and interactions. Additional functionalities can be integrated via the Service Market Place (see SMP subchapter 4.6).

CoOpApp is focused for the knowledge transfer by utilising the Extended Visual Annotations (EVA) and Execution Details Assets (EDA) information:

• EVA is focused on simple information presented as virtual post-its attached to real world objects. This can be pictured as post-its sticking to any object on the construction side. A specific gesture of the wearer of smart glasses running the ACCEPT app will start a visual user interface enabling the user to select real world objects. These objects will be highlighted. The object which is currently “selected” will be highlighted differently, for example with a different colour lining the edges of the object. With additional gestures the selection can be targeted to different objects or to selected parts of the object. After selecting an object, information can be attached to that object. Different options will be developed to add additional usage. Other user running the ACCEPT app on smart glasses will see that information was attached to an object as soon as the object is recognized. The visual annotations will not be limited to only the construction worker. Notes can also be utilized to transfer information between other stakeholders of the construction building process. Even before an object is created in the real world, a visual annotation could be attached to specific objects.
EDA is focused on complex execution details, which can be accessed on demand. This is a system for the distribution and provisioning of special assets providing guidance for specific tasks and processes. The possibilities to use EDA as guidance for specific tasks and processes. This could be a video overlay or a complex CAD model which will be shown above real world objects in order to highlight specific information regarding a component. For this, the assets will be show on the CoOpApp.

Last but not least, the application will be mine for visual information to fed additional data to the system.

### 4.4 Dashboard

The Dashboard will be the desktop client for the ACCEPT System. The main target user will be the site manager, but based on the Use Cases (see subchapter 2.3) additional user of the ACCEPT System are already identified as secondary target user. The Dashboard will be built as a web application, which will be the framework for so called widgets. These widgets will provide the actual end user functionality. The framework of the Dashboard will manage the interaction with the rest of the ACCEPT System.

The widgets will provide functionalities in order to monitor or interact with different profile information from the Profile Nexus (see subchapter 4.7) as well as interact with the EVA and EDA information provided by the Viki (see subchapter 4.6). A role-based access will allow access to different functionalities and services. All users of the ACCEPT System will be able to provide, modify and access information relevant to them.

The framework of the Dashboard will provide core functionalities such as accessing the Autonomous Messaging Framework (see AMF subchapter 4.9) in order to access the ACCEPT Services.

The Dashboard will have a number of widgets for the self-inspection mechanism in order to provide Quality Assurance (QA) functionalities. For this, a sample of quality indicators will be provided allowing tracking the results and the deviations from the reference values (goals, internal or external standards, statistical references). Based on the data used for the different visualisation, real-time information can be displayed. For a manager the Dashboard should help by the following objectives:

- evaluate performance
- help make a diagnosis of the situation
- communicate, inform, motivate employees advancing continuously

The interaction style for this web application will provide various levels of usability, and support different types of users, these could include: Batch, Question-answer, Command language, Function keys, Form fill-in, Menus, Direct manipulation, Non-command.
The interface design characteristic of this dashboard can be represented in general by its structure which describes the organisation of the information space presented by the widgets; its navigation function which enables moving through this information space; its presentation module which describes the interaction styles used to present the information and behaviour of the application. In general, the Dashboard should be help by:

- registration of site plans and related references
- identification of buildings, areas, floors, local and providers
- management reserves observed and followed up reserves lifted finding the request for assistance on reservations to subcontractors
- table Incremental board actions on reserves
- the history of actions and stakeholders
- on the site, make a statement of plan, if necessary with photos
- check, correct and generate a PV

The following figures (see Figure 8, Figure 9 and Figure 10) showing examples how a visualization of data could look like in different widgets of the Dashboard.
Figure 8: Example (1/3) for Visualization of a Widget in the Dashboard

Figure 9: Example (2/3) for Visualization of a Widget in the Dashboard

Figure 10: Example (3/3) for Visualization of a Widget in the Dashboard
4.5 Sensor Abstraction Framework – SAF

The Sensor Abstraction Framework (SAF) will be the basic environment for the communication with Cyber Physical Systems (CPS). It will encapsulate the logic for managing driver for specific sensors and how these sensors can communicate their data to the ACCEPT System.

The challenge for the SAF is the managing of previous unknown sensors. The SAF has to load specific drivers for any given sensor to integrate them in the ACCEPT System at runtime. This is required as new functionalities will be added as services to the three applications of the ACCEPT System with the help of the Service Market Place (see SMP subchapter 4.6). These services could add functionalities, which is depended on a new type of sensor. If such a service is deployed in the SMP, the binaries for this service must also include the drivers for the sensors compatible to the requirement of the SAF.

The first type of such a driver can be seen in the Sensor Abstraction Layer (SAL). While not a classical driver for a specific sensor, the SAL will be an API wrapper, which can be used by the SiMaApp and the CoOpApp to feed data to the system by acting as a sensor.

In the SAF two kinds of sensors has to be distinguished:

- **Active Sensors** – sensors which will record a snapshot of data only at a specific point in time, only if they are actively asked to do so
- **Passive Sensors** – sensors which will record data continuously in a certain interval.

These sensors will be agents in the system, directly feeding the information to the system.

4.6 Visual Wiki – Viki

The Visual Wiki (Viki) is a server application which will provide different services for the managing and interaction with information types EDA and EVA. These services are the basis to allow linking information to real world objects. The Viki will be the repository for all data used for the augmented reality (AR).

The main consumer of the services in the Viki is obviously the SiMaApp as this client will have the best usability to interact with the AR but the other clients of the ACCEPT System will use the services of the Viki as well. The CoOpApp should for example also be usable as an AR client but will also just allow to access and manipulate information of the Viki for different use cases.

The repository of data will be filled by all the stakeholder of the ACCEPT System with all clients involved. First, they SiMaApp and CoOpApp will use the EVA for direct communication between the different end user but this is also extended to the Dashboard, enabling the entire user base of the ACCEPT System to share messages and tidbits of information regarding to one specific construction site. Second, the Dashboard will be the main contributor to add EDA to the ACCEPT System. Specific widgets, which will allow the transfer of legacy data formats to Viki. For these legacy data formats a meta-information format must be created to describe how to use this data as EDA.

Last but not least, the Viki will be responsible to implement some sort of access control list to provide one hand privacy capabilities and on the other hand intellectual property right management for the owner of the data.
4.7 Profile Nexus – PN

The Profile Nexus (PN) is the third and last server application in the distributed server architecture of the ACCEPT System. It provides different services for the interaction with the four profile types, as well as the business logic, which will provide the interaction between the profiles in an event-driven environment. The PN will guarantees the translation of information between different domains and different levels of expertise. Moreover, it is envisioned that the PN will interface between the ACCEPT System and BIM allowing communication with other existing tools via IFC standards.

The central responsibility of the PN is to handle the four different profiles: user, Workflow, Project, Quality. Each profile has its own requirements, working with specific data and even language but there are connection points between all of them. This will be utilised for the simulation process and construction management.

The different profiles will interact and modify each other. For this, the PN will implement an event-reaction data mining system to extract information from a data set and transform it into an understandable structure for further use. This system is based on a data mining algorithm that creates a data mining model from available data. To create a model, the algorithm first analyses the provided data to search specific types of patterns or trends. The algorithm uses the results of this analysis to define the optimal parameters for creating the mining model. These parameters are then applied across the entire data set to extract actionable patterns and knowledge from different domain of the ACCEPT system.

The following requirements for the ON are already apparent:

- client library to interact easily with the server component
- context-aware mechanism to provide information for the specific domain of each user;
- database abstraction layer (DAL) to easily interact with database
- interoperability BIM-ACCEPT (IFC/COBIE) to allow for information exchange
- syndication and/or ontology to compartmentalizes the variables needed for set of computations and establishes the relationships between them

4.8 Service Market Place – SMP

The Service Market Place (SMP) will be a server application and repository for third party services. These services can add functionalities to one, two or all end user applications (see subchapters 4.2, 4.3 and 4.4).

A pattern will be defined which enables these services to work in a Plug and Play fashion. In this way a simplistic marketplace can be used to distribute services to the ACCEPT System by third parties to third parties. This will act as a multiplier to the impact of the project as it allows the adoption of ACCEPT to arbitrary business processes. Experiences in other app markets have shown that this can lead to a huge set of new ideas and creative solutions for a platform.

While this task will not focusing to provide a market place in the scope of the App Store of Apple, this approach ensures that an adaptation to the work processes of different businesses is possible. Making sure that the results of the ACCEPT project can be used by every company in the construction sector.
In order to provide the envisioned functionalities the SMP must not only be a server application but must also have branches which reach into the three end user applications. In these platforms the SMP will act as runtime for the services as provides functionalities to manage the services.

### 4.9 Autonomous Messaging Framework – AMF

Instead of “building everything by yourself” approach, which typically leads to an overstraining of company’s capabilities, ACCEPT is taking a “build a platform that others can build on to create value” approach, which is successfully employed by enterprises such as Amazon, Google, Apple, to name just a few. In this respect integration and communication issues have to be analysed and clearly postulated at this early stage of the project lifecycle.

ACCEPT is built within the realm of Internet of Everything (IoE = IoT + Knowledge + Multimedia) and thus consists of many independent services and data sources that reside on various systems spanning from sensors to smartphones, wearables (such as smart glasses, watches) and further to tablets, notebooks, work stations, and powerful servers. Cooperation via interaction of all those agents (hardware and software) is the intrinsic characteristic of the ACCEPT System. This will be supported by the Autonomous Messaging Framework (AMF).

Consider the following scenario: Sam the Site Manager wants to connect to multiple applications and data sources via the Dashboard. Some of them, i.e. legacy systems, do not have a REST API but still need to be accessed remotely. Integration with legacy and off-the-shelf monolith systems is important because tones of valuable data are already there and those systems are tightly integrated into the enterprise business processes and they will not be replaced any soon. Legacy nature of those systems such as CAD, CRM, HR, ERP, etc. also means that those systems most of the times do not have Web Service enabled interface and cannot communicate via HTTP protocol. They also need transformation of their messages since they often talk in iDoc, XML, XLS, SQL vernacular.

Sam is using a tablet PC on a construction site and he has to combine the data from legacy systems (e.g. architectural drawings) with data from local sensors, smart glasses, along with his comments. As an AMF provider ACCEPT has to factor in the limited bandwidth of the mobile communication channels and work on techniques to optimise those communications on the level of the framework.

Due to the requirements induced by the ACCEPT project the AMF has to support traditional SOA style with the service/message bus in the middle and REST Web Services integration. AMF has to fit in and support hexagonal and λ-architecture. Please, note that AMF also will supports a pure ROA (Resource-based architecture) style but ACCEPT recommends it only for integration of data sources. Both of the approaches facilitates the loose coupling (time and availability aspects, location transparency, asynchronous calls) of communicating agents if done right but SOA with the message bus can outreach sources and services outside of HTTP boundaries that is not possible for REST Web Services because RESTful integration is done using HTTP as a transport and application protocol. Thus, it cannot communicate over other protocols such as TCP, SMTP, JMS, IIOP, etc.

Following the above scenario, AMF has to facilitate push messages as well as pull data requests. It also supports clients in defining tasks, which will be executed when specific criteria are met (e.g. a location is transmitted every minute; a sensor sends an update
when a certain threshold is reached). For this functionality it is fruitful to look in the direction of rule-based engines for their ease of use and expressive power, knowledge driven and flexibility. On the next steps the consortium will perform a more thorough analysis and selection of the best available solution to fill in this position within ACCEPT platform. Autonomous is also defined by its availability by all agents and light-weight support of required integration patterns (1-1 (a)synchronous, broadcast, full-duplex, streaming sensor data or audio/video content, etc.). Autonomous also means that agents are able to exchange information seamlessly, i.e. sending and retrieving data using the granularity and vocabulary they need in the formats they feel the most comfortable with, e.g. XML, iDoc, JSON, BSON, etc. A summary of the key features of the ACCEPT AMF is foreseen as:

- **Messaging** – A combination of RESTful and SOA web services for communication with legacy systems and effective microservices communications with a support of event driven reactive behaviour (push messages).
- **Choreography** – Task delegation and distribution, support of task composition via workflows and active triggers.
- **Transformation** – RESTful web services usually communicate in JSON/BSON when legacy systems use SOAP/XML, iDoc, XSL, etc. formats. However even if agents are talking in one format it does not mean that their structures and semantics are consistent and mutually understandable. Although the modern architectures quite often sacrifice complexity in the middle layer in favour of scalability (“dummy pipes with smart services” principle) it is not always optimal especially when legacy systems are in the equation.
- **Cross-cutting-concerns** – This set of requirements covers generic issues such as security, logging, monitoring and management of runtime agents, deployment, etc. TIE Smart Bridge provides functionality to satisfy most of these requirements.
- **Mediation** – In the operational mode ACCEPT platform will require a support for multiple versions of various services and to mediate between different integration styles such as SOAP – RESTful / XML-JSOn.

### 4.10 Knowledge and Information Storage – KIS

In the ACCEPT System, very different kind of data needs to be stored. This can be data passively mined through the classes, or actively gathered by sensors or similar actors of the CPS domain. Additionally, complex profiles are needed for the ACCEPT System managed by the PN (see subchapter 4.7) as well a storage solution for EDA and EVA managed by the Viki (see subchapter 4.6). Relational databases such as Oracle, MSSQL or MySQL could be used for storing the data. However, their data model is fixed. Schema updates would be necessary for each new sensor and for each alteration or adaption of a profile. That is why the Knowledge and Information Storage (KIS) aims to provide a generic data storage solution as an ACCEPT Service to the rest of the system.
5 Positioning

5.1 Business Opportunities and Objectives

5.1.1 Primary Objective

It is a primary aim of the ACCEPT project to deliver a product that is relevant to the construction industry so that it is highly marketable and offers good potential for creating new income revenue for the Consortium.

5.1.2 Overview of Business Case

The Business Model Canvas will help define the business opportunities by evaluating the potential marketability and influence of the ACCEPT app in the construction sector. The BMC will be reviewed quarterly to ensure it is responding to any changes in the market scenario and will serve to guide the prioritisation of system functionalities and target audiences as the project progresses.

The primary opportunities and ambitions for developing ACCEPT as a marketable product is set out below as follows:

- Over 90% of the construction sector is comprised of SMEs, but many advanced ICT solutions are not adopted by this group because of their associated costs and complexity in use. ACCEPT will Target SMEs in the construction industry by providing an affordable solution that can be easily used by the construction workers without special knowledge or training.
- ACCEPT will introduce new ICT technologies and open up a new area of optimization potential by disrupting the current construction process with a new technology and IT-based solution. This would also serve to increase competitiveness and efficiency of EU SME’s within the construction domain.
- There is an opportunity to establish links with large scale manufacturers such as Google and Android software developers who, until now, have had little direct association with the Construction domain. This would secure accessibility to the ACCEPT System and immediately enhance the credibility of the System within the industry.
- Many individual functionalities of the ACCEPT system already exist as software tools, but they work in isolation and not as fully collaborative tools. Accept will take advantage of the fact that no other similar product is in the market as a complete system, and offer a solution to bring together both new and established QA/Communication/Design tools into one System.
- High costs of energy have created a public awareness towards quality control and energy efficiency within construction projects, and ACCEPT will align with this by improving construction quality and safeguarding energy efficiency by reducing the gap between predicted and actual building performance.
- Global awareness for reducing CO₂ footprint creates a “market-friendly” environment for tools and software that reduce the energy consumption and carbon load of Buildings. The ACCEPT System will directly contribute to this social
ambition by helping to reduce carbon emissions in both the construction process and through occupancy of more energy-efficient building.

- ACCEPT will integrate with established construction design and management tools. Vast suites of software are used within the industry, and whilst there are standard file types in place to assist with knowledge transfer of major data elements, there remains a general separation between most partner’s digital profiles within the construction domain.

- Various European directives for Energy Efficiency in Buildings place an onus on Contractors to deliver high performance buildings but, in many instances, these developers are not adequately supported within the QA process to ensure that long term energy and carbon targets will be met. The ACCEPT System will provide comprehensive support to contractors to ensure that they can actually achieve the performance levels envisaged and approved design stage.

- Availability of intelligent 3D models of materials is becoming a more decisive factor in choosing one construction component over another, and the development of new, advanced high performance building components creates the need for effective quality control. ACCEPT will improve access to 3D information and support the quality design and integration of components into the construction project.

5.1.3 Ambitions

- To have the ACCEPT System and resulting technologies validated and accepted in an industrial relevant environment.
- Become a Quality Control indicator for accreditation bodies such as LEED or BREAAM.
- Ensure that either compliance to existing standards is given, or work towards standardization of achieved results by participation in standardization bodies.
- Use widely accepted standards with small or no license fees, in order to be affordable to SMEs.
- Create a product as close as possible to higher TRL in order to be ready for a commercial entry after evaluation of the prototypes, with less effort.
- Gain the support and commitment of key stakeholders of the construction domain and other similar markets.
- To have an established and relevant user-following by the point of commercial release of the ACCEPT System, to streamline growth of the business.

5.1.4 Ongoing factors likely to impact the Business Opportunities

We will provide further detailed analysis within D2.3 and D2.5 and the business case and opportunities are likely to change throughout the project, however, the key ongoing factors likely to impact the Business opportunities of the ACCEPT System include:

- **Legislative Changes:** EU Energy-Efficiency Directives and National polices could change in a manner that affects the appeal and interest in adoption of the ACCEPT system. Comprehensive post-occupancy testing of newly constructed buildings would place significant pressure on developers to safeguard their energy performance through robust quality control measures. Such changes are best monitored through both a Market Watch and ongoing awareness of European legislation.
• **Technological Competitors:** The delivery of a comprehensive Quality Control tool is very appealing to the Construction sector, and it is likely that competitors of sorts will emerge within the duration of the ACCEPT project. This factor will be best monitored through a Market & Technology Watch.

• **Technological Take-up & Availability:** At present, smart glasses are not widely available and current prices are not conducive to widespread take-up of the technology. It is anticipated that unit prices for smart glasses will fall dramatically through the duration of the ACCEPT Project, which will increase appeal for the System.

• **Consortium Competency:** The current Consortium is well placed to deliver the ACCEPT System, as it is currently envisaged. However, market expectations and technological advances may require the ACCEPT system to consider issues not currently within the Consortium’s expertise. This factor will be managed through Market & Technology watches in the first instance, which would forewarn of new trends etc. Each Consortium Partner, nonetheless, currently demonstrates good industry awareness and will continue to ensure that their professional skills and services align with market expectations.

• **Economic Conditions:** The market conditions may impact the development of the ACCEPT project by limiting access to commercially valuable opinions and feedback (if Contractor’s etc. become unwilling to share information or give time). A severe change in European economies would also require a change to the ACCEPT business approach, either to ensure the System remained affordable or relevant.

### 5.1.5 Overview of the Market Watch Strategy

The Market Watch will monitor the market in order to identify and record State-of-the-Art existing products relevant to the ACCEPT system as well as Research projects in the field, which are likely to develop similar or competitive components. Other products, which may have been developed well during research but could not land on the market, will also be investigated and evaluated. This process will be based on an iterative procedure, throughout the whole project duration, in order to ensure that new technologies with a high impact potential will be picked-up and appraised against ACCEPT. In this way the project will remain in-sync with the outside world and will be able to adjust in a disruptive way, in order to react to important changes in the Market.

Market Watch, consists of three deliverables. The first one defines the Market Watch Strategy, in a structured and streamlined way in order to ensure that there is a continuous flow of research and input of new information during the project duration. The second and third deliverable will be updates of the monitoring and their scope would be to pick-up new developments in the market or update the information included in the first deliverable, which may have changed in the meantime.
5.2 Research and Technological Objectives

It is a primary aim of the ACCEPT project to deliver a system that comprises of 3 applications working cross-platform on 3 systems. In order to achieve this, it is necessary to undertake comprehensive research tasks –both on the topic of the technical system infrastructure itself and also on the likely functionality the system needs to provide to end users.

The first stage of research will focus on determining the key risks associated with the delivery of high quality and energy efficient building across Europe. This will establish a benchmark of industry-wide problems that can be addressed by the Accept System.

Second stage research will consider how such highlighted common problems can be resolved. This will initially involve focus groups with relevant users and reviews of post-construction data/design information for existing buildings to assist with establishing how such repetitive problems have come about. Further analysis and testing will then seek to resolve what additional knowledge transfer, support and collaboration is needed within a construction project to overcome these problems.

Following confirmation of the problem and tools required to rectify it, the Accept technology will be developed to provide the new functionality.

5.2.1 TRL

ACCEPT will be developed to Technology Readiness Level 6 by the end of the formal H2020 research programme. In reaching TRL 6, the ACCEPT system will have proven functionality and relevance with the construction sector, having been successfully demonstrated on at least one live construction site.

Targeting of TRL 6 by late 2017 is based upon a commitment to rigorously develop and improve the prototype ACCEPT systems through an iterative design and feedback process.

At this point, the functionalities and associated architecture required to deliver them will be established, and the ability for ACCEPT to contribute to the improvement of quality and energy efficiency within construction projects will be proven.

5.2.2 Ongoing factors likely to impact the Product

We will provide further detailed analysis within D8.1 on the innovative technologies that may either assist in the production of ACCEPT or may indeed be a threat to it. Industry awareness will be prioritised as part of the work undertaken in WP8, with a clear focus on assessing those existing technologies that may offer potential for added functionality within the ACCEPT system, or that are in some manner threatening any of ACCEPT’s USPs. In particular, wearable technologies are currently being released on an almost weekly basis. It will be necessary to monitor the direct hardware capabilities of this sector alongside any accompanying opportunities for furthering the impact of ACCEPT as new technologies become available.
5.2.3 Overview of the Technology Watch Strategy

The Technology Watch will help define the product opportunities and threats by primarily analysing existing Market conditions on a Technical level. This will ensure that the project has an understanding of both the driving forces and the barriers, which may influence the potential of its success. This approach will be based on the same structure as the Market Watch strategy, already explained briefly earlier and will ensure that ACCEPT’s positioning will have a clear and distinctive objective.

Existing approaches and technologies will be appraised against ACCEPT features, in order to ensure that the results of the project will go beyond the state-of-the-Art. This will be achieved by addressing the weaknesses of existing products and providing better solutions or filling the gaps that other applications may have. The scope of the strategy will be to ensure that ACCEPT is distinguished from competing alternatives and drive the development of a comprehensive tool for the holistic monitoring of the construction process, in order to reduce rework and become a benchmark in the field.

5.2.4 Overview of Scientific Dissemination Strategy

The Scientific Dissemination will help define research objectives and help ACCEPT reach a variety of audiences. The aim of this dissemination is to ensure public disclosure of the Project results, develop a User following for Accept and encourage wider research engagement. The strategy will focus on 3 strands of dissemination, and places an emphasis on ensuring the suitability of content to the chosen distribution method, alongside a careful consideration of timing for publication.

- **Strand 1 – Paper:** Covering press releases, commentaries, news items, literary review and full research papers. The weighting of impact and suitability will vary, with initial publications in this strand likely to occur in trade journals and periodical newsletters before robust research results facilitate submissions into specialised journals, academic reviews and books.

- **Strand 2 – People:** Covering focus groups, conferences, lectures and expos. The programme of dissemination in this strand is likely to begin with focus groups and informal discussions, before progressing to expos, conferences and lectures.

- **Strand 3 – PCs:** Covering websites, emails, blogs and forums. This strand will cover an array of content levels, ranging from incidental project updates on the website and emails to detailed evaluations and appraisals of testing results via blogs and forums. Databases will be developed for each strand so that publication can be prioritised and programmed for maximum impact and outreach.

To summarise the consortium’s positioning, ACCEPT will target an array of end users and strategic partnerships, but will focus development of core functionalities, pricing and integration of 3rd party components clearly to ensure a clear relevance to SMEs within the construction sector. The consortium also holds ambitions for a robust and assured ACCEPT System by completion of the project, which will appeal to Accreditation bodies and key stakeholders through validation as a meaningful and applicable System for improving construction quality and programming.

Whilst there will be various ongoing factors to challenge the potential viability and impact of the ACCEPT System, the consortium will establish Market and Technology Watch programmes to allow such threats and opportunities to be properly picked up and
reviewed. Within this context of heightened market awareness, the consortium will also enact a strategy of scientific and industrial dissemination, through hard-copy and online publications and peer-to-peer discussions, conferencing and lectures. This approach will expand as the project develops, seeking to establish a clear following of potential end-users by the close of the project and, thereby, secure a strong business position for the ACCEPT System within industry.

5.3 Out of Scope Areas

The ACCEPT System has clear target functionalities and users, but to add further definition to the scope of the Project, various areas deemed outside of the scope of the project are listed below. These may fall adjacent to the Project deliverables or may be consequential outcomes to the research and development of the ACCEPT System, however, they in no way form the focus or aim of the Project.

Functionalities:

- We will not develop new algorithms for augmented reality, neither for the visual data recognition nor for the placement of virtual objects on real surfaces
- ACCEPT will not provide specific functionality configurations for every EU country. The system will be developed to ensure compatibility with the legislation, design processes and languages of all countries, but will only be tested and demonstrated against a sample.
- It will not define a new evaluation system for the efficiency of buildings. ACCEPT will not serve to re-determine the as-built performance but will limit the traditional mistake that impacting it.
- We will not enter in the financial aspects of the building projects. ACCEPT will not allow to follow the evolution of the costs of the construction.

Technology:

- We will not create any hardware (sensors, mobile device, smart glasses)
- We will not develop any new 3D modelling or 2D drafting software
- We will not develop any new push message and notification system software.

Interoperability:

- Design content will not be developed for the envisaged libraries and databases of best practice/industry standard design solutions, beyond that needed to demonstrate functionality of the System.
- We will not research or create new thermal insulation materials; on the other hand, we will work with state-of-the-art building components that already used in the construction.
- We will not develop new construction methodologies but we will use existing ones as a foundation for the execution of the pilots.
- We will not develop any new standards to provide interoperability with the BIM methodology. The ACCEPT System will work with industry recognised definitions and standard
- We will not develop any new methodology for construction management process