RINNO

RINNO PROJECT

Report

An augmented intelligence-enabled stimulating framework for deep energy renovation delivering occupant-centred innovations

Deliverable 1.9:

Architecture of RINNO Suite along with its Functional Technical Specifications (V2)

Work Package 1: RINNO Augmented Intelligence Renovation Framework

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Executive Summary

RINNO suite is an augmented intelligence framework for deep energy renovation with user-centric focussed approach. RINNO will streamline and facilitate all phases of building renovation (planning-design, retrofitting, monitoring). RINNO combines a set of cost-attractive, environmentally friendly, multi-functional and easily applicable building-related solutions, along with innovative retrofitting processes, methods, and tools. This deliverable is an overview of the second version of RINNO Suite architecture that will be described along with its components and sub-components, their interfaces, and the connections with external systems. The next updated and final version will be released at M36.

The document describes the way and the procedure used to develop the architecture. The documentation of the architecture follows the standard IEEE 42010 "Systems and software engineering — Architecture description". Specifically, the design process of the architecture is divided in four phases namely, the elicitation of use cases, stakeholders' requirements and market needs, the conceptual architecture definition, system's structural view and finally the specification of architectural elements. In Chapter 3 there is a detailed identification of stakeholders and their concerns. Subsequently, the conceptual architecture of the RINNO Suite is depicted in Chapter 4. The designing process that this standard implies is based on different architecture viewpoints. For the RINNO architecture three architecture viewpoints have been used, namely functional view, deployment view and information view.

The functional view defines the components, their functionality, and their interactions. The main identified architecture components are described in the previous version of this deliverable D1.8. In this deliverable there is the definition of which components are used by the different groups of RINNO's stakeholders. Furthermore, regarding the list of KPIs, there is an update regarding which component is used for each KPI and what is the required input to perform.

The information view describes the flow and the distribution of the information, as well as the application domain models.

In the Technical Use Cases Instantiation, there are five use cases regarding RINNO components:

- RINNO Transaction Manager
- RINNO Operational Interface with Augmented Intelligence – Building Performance Dashboard
- RINNO Planning & Design Assistant
- RINNO Retrofitting Manager – AR Assistance & AR Training & BIM Viewer
- RINNO Operational Interface with Augmented Intelligence – AR UI (BIM viewer)

RINNO suite is deployed under real conditions at three large demo sites (pilot buildings) so far, that cover different market needs and use cases located in France, Greece, and Poland. Deployment in Denmark will be finalized and reported in the next version of the deliverable in M36.

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Abbreviations List

AEC	Architecture, Engineering & Construction
AHP	Analytical Hierarchy Process
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
BEMS	Building Energy Management System
BIM	Building Information Model
BLRM	Building Lifecycle Renovation Manager
BoQ	Bill of Quantities
BRPs	Building Renovation Passports
CAD	Computer-Aided design
CIM	Common Information Model
CIT	Common Information Translator
CPU	Central Processing Unit
CSS	Cascading Style Sheet
DLT	Distributed Ledger Technologies
DoPW	Digital Plan of Work
DRIP	Deep Renovation Digital Plan
EU	European Union
GB	Giga Byte
GHG	Greenhouse Gases
GPU	Graphics Processing Unit
HMI	Human Machine Interface
HTML	Hyper-Text Markup Language
IAI	International Alliance for Interoperability

IAM	Identity and Access Management
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
PC	Personal Computer
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluations
PV	Photo Voltaic
RAM	Random Access Memory
RES	Renewable Energy Source
RMCP	RINNO Marketplace & Collaboration Platform
ROM	Read-Only Memory
RPDA	RINNO Planning & Design Assistant
RRM	RINNO Retrofitting Manager
RRR	RINNO Renovation Repository
RWM	Renovation Workflow Manager
RWTM	Renovation Workflow & Transactions Manager
SCB	Smart Connected Buildings
S-LCA	Social Life Cycle Assessment
SQL	Standardized Query Language
TEA	Techno-economical Assessment
UI	User Interface
UML	Unified Modelling Language

USB	Universal Serial Bus
VR	Virtual Reality
WP	Work Package

1 Introduction

RINNO aims to deliver a framework solution for deep energy renovation. The prime goal is to develop an occupant-centered operational interface with augmented intelligence for all the phases of building renovation (planning-design, retrofitting, monitoring). RINNO consists of modular and ease to install building solutions both environmentally friendly and cost attractive. RINNO combines these solutions along with efficient (off/on-site) construction strategies, on-the-job AR facilitating environment and multi-stakeholder collaboration. The novel retrofitting methods of the system will achieve low tenants' disturbance. These will also decrease the cost and time required for deep building renovation and will improve the performance of the building.

Below is a brief description of the objectives, the context, and the structure of the deliverable. It also outlines its background and its interaction with other Tasks and Work Packages.

1.1 Scope, Context and Structure of this deliverable

This deliverable introduces the second version of RINNO's architecture. Some components of the architecture will be verified during the development of the project, in this framework it is reasonable that some of the system requirements will be updated. This deliverable specifies a set of hardware and software requirements and describes the features of main components. Moreover, the architecture of the system includes the interfaces of the components and the way they should interact among them.

Within Chapter 2 of the deliverable the design approach, the methodology and the design principles that was followed to design the architecture has been defined. Chapter 3 contains a brief identification of the stakeholders and their concerns. Chapter 4 provides the conceptual architecture. In the four following chapters, the views of the architecture are presented, namely functional view (Chapter 5), deployment view (Chapter 6) information view (Chapter 7) and the dynamic view with technical use cases (Chapter 8) respectively. In the final chapter, the conclusions of the document are depicted.

1.2 Background

RINNO gathers the requirements of the stakeholders, as well as the features of the building, and provides a set of efficient solutions, from its Renovation Repository. During the design phase, a range of applicable scenarios are generated upon a virtual representation of the building (Digital-Twin). RINNO introduces a Decision Support System to assist users choosing the optimal scenarios, according to Key Performance Indicators. During the retrofitting phase, the system proposes a variety of tools and methods to reduce installation time and cost, and occupant's disturbance. Those tools and methods include novel construction offsite and onsite strategies to optimize logistics and installation processes, as well as AR devices to facilitate on-the-job training for the workers. Furthermore, the system provides an operational platform with augmented intelligence for the monitoring phase. Through a Multi-sensorial network installed at the buildings, the system collects data related to the building performance, thus the Renovation Manager can compare the actual and the designed performance. To exchange the knowledge, the information, and the solutions of the system, RINNO introduces the Marketplace and Social Collaboration Platform. In that way, all the participants, including workers, engineers, tenants, as well as investors can exchange their experiences and their practices and provide each other assistance at all renovation phases. Finally, RINNO framework, during the whole lifecycle of the renovation process, utilizes the Renovation Workflow and Transactions Manager to optimize the supervision and the management of the project, and to ensure the speed up and the transparency of the transactions. The solutions developed by RINNO will be demonstrated at four large scale pilot sites covering different EU climatic zones and markets in France, Denmark, Greece, and Poland.

1.3 Interaction with other Tasks and Work Packages

This section describes the interaction between the Tasks, the Work Packages, and the architecture documentation. Task 1.1 defines the stakeholder's requirements and the market needs. More particularly, the elicitation of the stakeholder's requirements has been carried out along two axes. Firstly, an online questionnaire submitted to the RINNO partners along with a deep analysis of the literature and a review of the most relevant H2020 project from a technical, economic and social aspect. Secondly, T1.1 defines specific tables concerning the innovation content that will be updated through the lifetime of the project. These tables are part of RINNO Renovation Repository and they represent an initial step of the development of the technology roadmap and the commercial potential of the project (e.g. Table 1). Accordingly, stakeholder's requirements are inputs of T1.3 in terms of building renovation expectations from Task1.1. Task 1.3 collects the requirements of stakeholders, identifies the demo users and their necessities, according to the questionnaire results, as well as the existing conditions of the building from an energy, architectural and structural point of view. Finally, after the assessment of RINNO solutions and technologies, Task 1.3 defines the scenarios use cases for each demo. The outputs of Task 1.3 will help the formation of the architecture and define the connection between the use cases and platform modules of the present Task (T1.5).

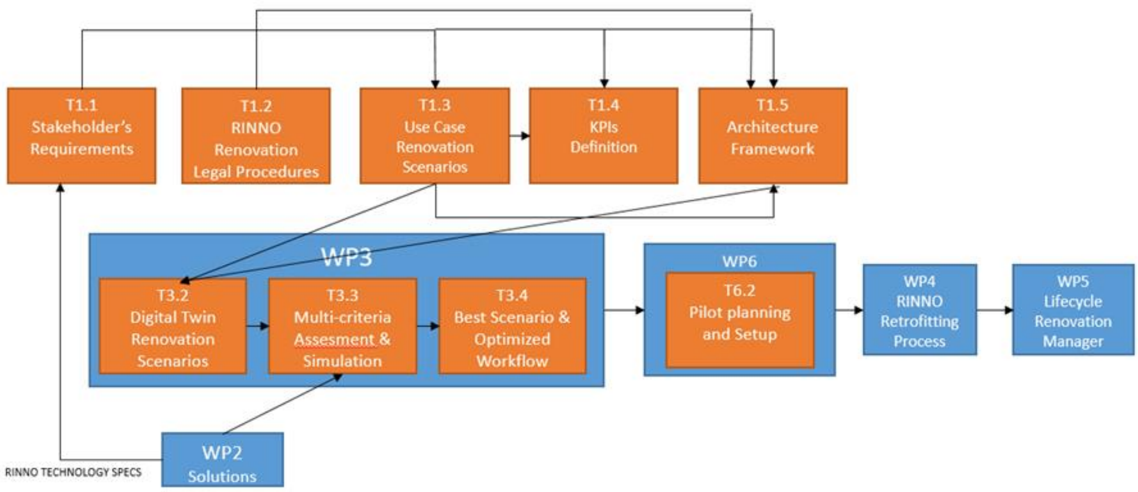

Figure 1 - Interaction with other Tasks and Work Packages

2 Architecture Design Approach & Methodology

This section describes the Architectural Design Approach for the RINNO project. The descriptions in this report include the design methodology and the design principles of the system architecture. The overall design process is divided into four phases, firstly the stakeholder's requirements and market need as well as the use case scenarios, moving to the conceptual architecture that describes the workflow of the renovation of the RINNO project, towards the structural view of the system and finally the detailed architectural elements specification. Each phase is based on the previous one, but the design approach for the System Architecture is an iterative procedure, as new requirements and needs can be identified throughout the project. An overview of the approach is depicted in the figure below.

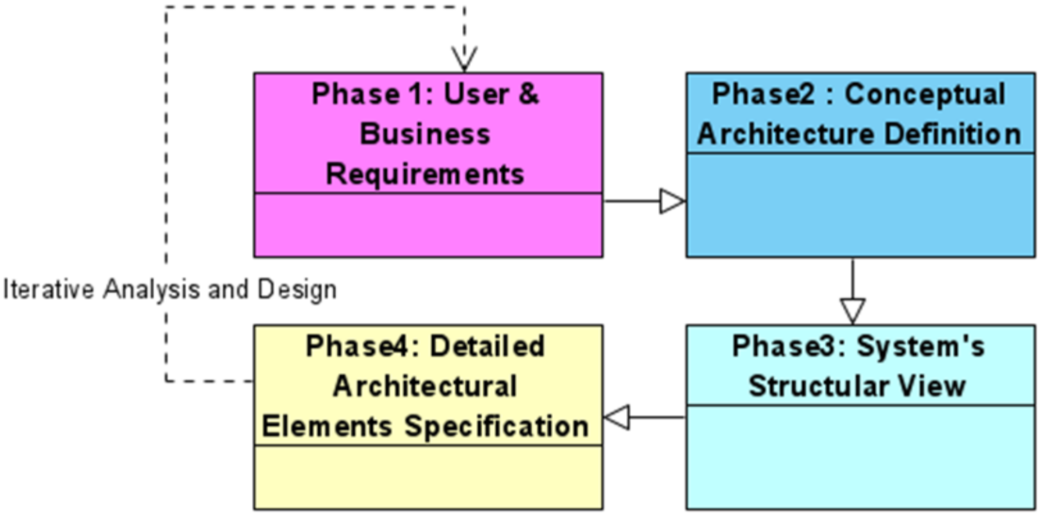

Figure 2 - Design Approach for System Architecture

2.1 Design principles

The architecture of the system should be open and modular, in that way suppliers, vendors, users and other potential actors of the project could capitalize on the distinct functionalities of the system. The architecture should be as technology independent as possible, and should include generic solutions when key technologies (open source or commercial) are available. The following principles have been specified in order to ensure that the implemented architecture will promote cost efficiency, extendibility and modularity:

- <u>Separation of concerns</u>: The system should be divided into distinct features, and each one will address different concern. The prime goal is to minimize interaction points and increase cohesion and low coupling.
- <u>Single Responsibility</u>: Each module of the system should only answer a specific question and should be responsible for a single functionality or even aggregation of cohesive functionality.
- <u>Least Knowledge</u>: Each architectural component should have limited knowledge about other components.

- Don't repeat yourself: According to this principle, a specific functionality or intent should be implemented in only one component.
- Minimize upfront design: In the first steps of the architecture implementation, only the necessary functionalities and methods should be designed, because the design of the architecture is possible to change throughout the time.

2.2 Architectural Design Process

As mentioned before, the Design Process consists of four phases. Each phase feeds the next one, but the whole process is an iterative procedure, as new stakeholder's requirements or market needs may occur throughout the project.

2.2.1 Phase 1: User & Business Requirements Definition

The first phase of the architectural design contains the elicitation of stakeholder's requirements and market needs (within Task T1.1) as well as the use case renovation scenarios (within Task T1.3). Based on the context of the above-mentioned Tasks (T1.1 and T1.3) will deliver in detail the technical description of the overall RINNO Suite and the specifications for each of its key components, modules and their functionalities.

2.2.2 Phase 2: Conceptual Architecture Definition

Throughout the second phase, a high-level conceptual view of the overall system is defined. The major components are identified along with their high-level requirements, providing the concept behind the implementation of the system. RINNO will organize its core components into the proposed conceptual/technical architecture. Conceptual architecture is described in detail in Chapter 4.

2.2.3 Phase 3: System's Structural View

The designing approach of the architecture follows the standard IEEE 42010 "Systems and software engineering — Architecture description". This procedure is suitable for the architectural description of software intensive systems. This technique defines a set of patterns, rules, and templates on how to construct a type of view. Thus, throughout the third phase, the system is further analysed, following a static and dynamic view analysis, based on three architecture viewpoints and on Use cases. In particular:

- Within the **Static View**, a detailed analysis of the system architecture in distinct components will be presented, which will define their interconnection from a functional view (Chapter 5). Also, a detailed deployment view of the system along with its deployment will be presented (Chapter 6).
- Within the **Dynamic View**, based on the Uses Cases that will be identified (Chapter 8), the dynamic behaviour of the system will be defined. Furthermore, the information flow between the components will be presented from an informational view (Chapter 7).

2.2.4 Phase 4: Detailed Architectural Elements Specification

In this fourth and final step, all the key elements of RINNO suite will be described in detail to provide a deep view on the system and to ensure interoperability between the components. Moreover, an analysis of the components along with their modules and their sub-modules is performed in Chapter 5. More specifically, at the Functional View there is a detailed presentation of the internals of the components, the interfaces, the data types and as well as their components diagrams with their inputs and outputs. Finally, the table depicted below contains the full list of main components brought by individual partners and a brief definition of all of them, along with the modules, the sub-modules, and the background technologies.

Furthermore, the following Table illustrates the detailed components and their submodules that together they comprised of the RINNO framework.

Table 1 – List of Components

<table>
<tr><th>Main component</th><th>Module</th><th>Sub-module</th><th>Name of Background Technology</th><th>Input</th><th>Output</th><th>Responsible partner</th></tr>
<tr><td rowspan="4">RINNO Renovation Repository (RRR)</td><td>Modular Building Envelope Solutions</td><td>N/A</td><td>1) Bio-based double layer panels
2) Bio-based pipes and sheets
3) Isocell Cellulose Insulation
4) Thermochromic Glass
5) K-BOX bio-based insulating system for parts of energy systems</td><td rowspan="4">• Time saved [h] in comparison to the market reference conventional solutions
• % of biobased materials in the technology
• Weight of technology solution considered in the renovation process (not considering ancillary materials)
• % of recycled materials in the solution
• Solutions waste reduction ratio in comparison to the reference</td><td rowspan="4">• Design and installation time saved
• Cost savings in design
• Reduction of cost overruns
• Use of bio-based materials
• Use of recyclable materials
• Use of recycled materials
• Waste reduction
• Material use avoided</td><td>K-FLEX</td></tr>
<tr><td>RES Harvesting Solutions</td><td>N/A</td><td>1) Building integrated photovoltaic glass
2) MicroVent sustainable Ventilation system</td><td>GREENSTRUCT</td></tr>
<tr><td>Storage Solutions</td><td>N/A</td><td>1) De-centralized domestic hot water preparation</td><td>PINK</td></tr>
<tr><td>Multi-functional</td><td>N/A</td><td>1) Climate Cover PV -</td><td>EKOLAB</td></tr>
</table>

	Hybrid Retrofitting Solutions		Roof and - Facade solutions	conventional system.		
Middleware Infrastructure	IoT Sensorial Network & Control System	Automation systems	N/A	• Time series from installed devices per pilot site • BIM information	• Time outside thermal comfort range • Time outside indoor air quality range • Acoustic characteristics • Visual Comfort (building) • Visual comfort (user and control system) • Energy consumption	MOTIVIAN
		Sensors & actuators	N/A			MOTIVIAN
		Energy monitoring devices – Performance Dashboard	N/A			MOTIVIAN
		IoT Device Managers	N/A			MOTIVIAN
	Common Information Translator (CIT)	Common Information Model (CIM) - BIM models (icf)	N/A	*(contributes to the integration of the system)*	*(contributes to the integration of the system)*	CERTH
	Middleware	Middleware engine	N/A	*(contributes to the integration of the system)*	*(contributes to the integration of the system)*	MOTIVIAN
RINNO Planning & Design Assistant (RPDA)	Renovation Modelling	Building Capturing & Mapping	COCKPIT platform for automated progress, quality &	-	-	BOUYGUES

			security control by drones			
		Digital Twin	Renovation Digital-Twin	• BIM model • Qualitative scenarios • Technology specifications	• Quantitative scenarios • Initial estimations of building energy performance	VTT
	Renovation Simulation & Assessment toolbox	Energy Assessmnt tool	INTEMA.Building	• BIM model • Technology specifications • Renovation Scenarios (quantitative)	• Decrease in Energy Consumption • Savings in Final Energy consumption for heating • Savings in Final Energy consumption for cooling • Savings in Final Energy consumption for DHW • Increase in RES based electricity production • Increase in RES based heating production	CERTH
		Environment, Cost	VERIFY and S-LCA	• Renovation	• Yearly Primary	CERTH, CIRCE

		and Social Assessment tool	assessment toolkits	Scenario • Technology specifications • Energy data series from INTEMA	energy savings • Yearly Energy Self-Supply by RES • Yearly Lifecycle Life Cycle Global Warming Potential savings • Yearly Embodied Energy • Yearly Water Footprint • Yearly Lifecycle Cost Savings • Initial Investment (CAPEX) • Annual O&M Costs • Payback Period • Return on Investment	
		Techno-economical assessment tool	Sustainable and cost-effective renovation evaluation toolkit	• Data from simulation during design stage and monitoring during the operation	• Waste production • Duration of works • Disruption Levels	RINA, UNN
	Renovation Optimizer & Planner	Dynamic decision-making toolkit	Renovation Scenario DSS	• Renovation scenarios • Inputs from	• Optimum Renovation Scenario	CERTH

		Dynamic decision-making toolkit		energy, LCA/LCC and technoeconomic assessment toolkits • CERTH's post-processing		
			Job Scheduling Optimiser	• Input from technoeconomic assessment tool • CERTH's post-processing	• Optimum Renovation Workflow	CERTH
RINNO Retrofitting Manager (RRM)	Process Industrialization	Recommendation Engine	On-site & Off-site assembling of prefab solutions by Cobots/Robots - Construction 4.0 Suite	• Lifecycle Cost Savings calculated in WP3 • Life Cycle Assessment calculated in WP3 • Information from technology providers • CERTH's post-processing • *E-Cockpit monitoring calculations during the retrofitting*	• Waste production • Duration of works • Disruption Levels • Return on investment • Payback period – EPP • *Safety* • *Quality* • *Scheduling* • *Environmental* • *Services and benefits* • *Logistics*	BOUYGUES
		"Cockpit"	COCKPIT platform for automated progress, quality & security control by drones - Construction 4.0 Suite			BOUYGUES
		"3D printing"	3D-printing - Construction 4.0 Suite			BOUYGUES

	Process Optimization	Process Optimization tool	VIA-PROCESS Business Process Management - BPM	*process performed in WP4*	**E-cockpit KPI's from D1.7*	BOUYGUES
		"e-logistics"	E-LOGISTICS platform for optimized logistics			BOUYGUES
	On-the-Job AR Environment	AR Assistance tool	AR/VR suite (AR Database, AR Manager, AR Viewer & AR Interfaces) – AR/VR enabled training and assistance	-	-	CERTH
		AR Training tool	AR/VR suite (AR Database, AR Manager, AR Viewer & AR Interfaces) – AR/VR enabled training and assistance	-	-	CERTH
	RRM Engine	RRM engine	SCB (Smart Connected Buildings)	-	-	UNN
Building Lifecycle Renovation Manager (BLRM)	Intelligent Renovation Assistant	Renovation Validation and Benchmarking tool	N/A	-	-	CERTH
		Building	N/A	-	-	EKOLAB

		Renovation Passports (BRPs)				
		Renovation Roadmap tool	N/A	-	-	EKOLAB
		Logbook tool	N/A	-	-	EKOLAB
Renovation Workflow & Transactions Manager (RWTM)	Renovation workflow tool	N/A	1) DPoW & xbimXplorer to be adapted into DRIP 2) VIA PROCESS	-	-	UNN
	Transaction manager toolkit	N/A	Smart Contracts for Multi-stakeholder Transaction Automation	-	-	CERTH
RINNO Operational Interface with Augmented Intelligence	RINNO Marketplace & Collaboration Platform (RMCP)	RINNO Marketplace	N/A	-	-	CERTH
		RINNO Collaboration Platform	Social Collaboration-Knowledge Sharing platform	• Tenants' impact during maintenance activities	• Frequency and duration of routine maintenance • Frequency and duration of repairs • Frequency and duration of replacements	CERTH
	Building	N/A	1) mSense tool	• Data from	• Integration and	MOTIVIAN

	Monitoring System (IoT Platform)		for IoT management 2) Building Monitoring System	simulation during design stage and monitoring during the operation	visualization of all involved KPI's	
	Central Dashboard	Building Performance Toolkit & Dashboard	Building Performance Evaluation toolkit SCB (Smart Connected Buildings) Decision Support System	• Data from simulations during design stage, and from monitoring during operation (D1.7)	• Integration and visualization of all involved KPI's	CERTH
		AR/VR UI	AR/VR suite – AR/VR enabled training and assistance	-	-	CERTH

3 Identification of stakeholders and their concerns

There is a wide range of stakeholders that participate in RINNO, during all the phases of the project. In Deliverable D1.1 "RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (v1)" a detailed identification of stakeholders was made. According to D1.1, six (6) stakeholders' groups have been defined, namely Designers, Contractor and Subcontractors, Building owner and/or residents, public bodies & administration, Industrial Stakeholders and Others. The classification of stakeholders' groups will assist the definition of their requirements, challenges, and concerns. For the completeness of this document, a detailed table from D1.1 that defines the stakeholders classified in each group is depicted below.

Table 2 - Definition of Stakeholders in the Stakeholders Map

Stakeholders Group	Roles
Designer • Project Manager • Architect • Structural Engineer • Survey and data gathering • Services Engineer • Work controller	The designer has main responsibilities for the design and the consolidation of designs by other designers. Other designers as like engineers are responsible for the Design discrete and technical subsystems, such as HVAC, structural, electricity, and automation
Contractor and Subcontractor • Data gathering (scanner 3D, inspection, on-site measures, material tests.,) • On site worker • Cost controller • Quality controller • Installer • Security manager • Site manager	The main contractor responsibility for the construction activities. Sub-contractors work for the main contractor and are responsible the main contractor. Perform small, straightforward and discrete functions, such as painting, ceiling contracting, wallpapering, and floor tiling.
Building owner and/or resident • Homeowner • Housing associations (as an owner) • Resident/Occupants/tenants • Property owners (social housing association) • Building's manager • Building's administrator • Facility manager/ Maintenance	Residents or neighbours they may express some requirements or requests for the project. Several configurations can be allowed for the customers, some private, as condominium, building owners or single houses owners and others public, such as social housing organizations, public administrations as building owners etc… In the case of social housing the main initiator of the renovation project is the public administrator and the benefit accrues to the community. They are

	responsible of the final decision maker in the project. They define the project's purpose and the end user's constraints. They usually have the most comprehensive knowledge about the property and understanding of the actions to be carried out.
Public bodies & administration • Council/local authority • Security authority • Waste manager • Fire service • Planning authority • Health authority	Representatives of local and public authorities supervise the project and may set constraints on its execution of the following: supervision of construction, planning division, fire authority, and health authority. The government takes the lead in terms of formulating and maintaining regulations, polices and monitoring the adherence to these. They set the standard relating to the delivery of renovation projects.
Industrial • Supplier • Manufacturer • ESCOs	Material suppliers: Supply material and equipment, such as concrete, windows, furnishings, and research instruments. They can be the same as the manufacturers. Material manufacturers: they take over the manufacturing of Components, elements or materials according to the specifications defined in the Project.
Others • Software developer or consultant • External certificatory • Funders • Education and training on renovation value chain	Software developer & external consultant: they support the Designer Team in the design and assessment of the building trough the specific use of tools or software for the purpose required. The external consultants provide the consultancy advice for the projects on designing, evaluating the cost, technical issues/advice. External certificatory is responsible of validating the project regarding different criteria set by the end users (i.e. energy classification). They are able to provide standard labels for the final product or the process.

	Financial entities: They act as sponsor of the project, funding the budget. They usually have no requirements or personal interest on the project

In the sub-sections below there is a brief presentation of the concerns of the stakeholders depending on the group they belong to. This analysis is based on the surveys performed on the D1.1.

3.1 Designers Stakeholders' Concerns

According to survey analysis, the key concerns for designers are the reduction of project development time and the accurate data gathering of the existing building. Moreover, designers should concern about the integration of requests and management of complaints from residents. Finally, other key requirements of designers are the justification of the decision making, the easy replication, the accurate prediction for the performance of the building and establishment a degree of interaction between the occupant and the building.

3.2 Contractors and Subcontractors Stakeholders' Concerns

According to the survey analysis, the key concerns for contractors and subcontractors are the reduction of accidents in the workspace and the improvement of the company's reputation. Following, the main economic concern for contractors and subcontractors is the reduction of energy consumption.

3.3 Public bodies and administration Stakeholders' Concerns

As reported by the surveys for the public bodies and administration, their key concerns are the energy savings and reductions of CO_2 and other pollutant emissions. Moreover, another key concern of public bodies and administration is the reduction of accidents on site.

3.4 Building Owner and/or Resident Stakeholders' Concerns

Based on the survey analysis of the D1.1, the concerns of this group of stakeholders are divided in three categories namely environmental, economic and health, comfort, and safety. Firstly, as regard to the environmental category, the key concerns are the reduction energy consumption and total CO2 and other pollutants emissions. Secondly, the key economic concerns for owners or residents are also the reduction of the technology maintenance cost and length of the payback time. Finally, when it comes to health, comfort, and safety concerns, the most important are the improvement of thermal comfort and air quality and no need for the owner or the resident to leave the building during the works.

3.5 Industrial Stakeholders' Concerns

According to the survey analysis for the industrial stakeholders, their prime concern is the easy interaction with the contractors and the designers. Other key concerns for the industrial stakeholders are the reduction of cost and construction time as well as the integration of requests from residents and the validation of standards compliance.

3.6 Other Stakeholders' Concerns

Based on the survey analysis for the other stakeholders, their key concerns are the reduction of cost, delivery time and CO2 and other pollutant emissions. Other key concern for this group of stakeholders is the access to financial subsidies.
In Table 3, the correspondence between the main components and groups of stakeholders is presented based on the requirements that arose from the surveys' analysis that are presented in D1.1.

Table 3 - Definition of the components used by the different stakeholders

Stakeholders Group	Main Concerns
Designer	• RINNO Planning & Design Assistant (RPDA) • RINNO Retrofitting Manager (RRM) • Building Lifecycle Renovation Manager (BLRM) • RINNO Operational Interface with Augmented Intelligence
Contractor and Subcontractor	• RINNO Retrofitting Manager (RRM) • Renovation Workflow & Transactions Manager (RWTM) • RINNO Operational Interface with Augmented Intelligence • Multi-Sensorial Network • Middleware Infrastructure • IoT Sensorial Network & Control System
Building owner and/or resident	• Middleware Infrastructure • RINNO Operational Interface with Augmented Intelligence
Public bodies & administration	• RINNO Planning & Design Assistant (RPDA) • RINNO Retrofitting Manager (RRM) • RINNO Operational Interface with Augmented Intelligence
Industrial	• RINNO Renovation Repository (RRR) • Renovation Workflow & Transactions Manager (RWTM) • RINNO Retrofitting Manager (RRM) • RINNO Operational Interface with Augmented Intelligence
Others	• RINNO Planning & Design Assistant (RPDA) • RINNO Operational Interface with Augmented Intelligence

4 Conceptual Architecture

This chapter describes the conceptual architecture of the RINNO system. It provides a high-level view of the technical architecture of the system, along with its renovation workflow. Furthermore, this chapter organizes the system in four layers, namely Interaction, Services, Physical and Horizontal Layer, depending on the functionality of its individual components:

- **Interaction Layer**: It contains all the necessary modules needed for the interaction/ communication between users/ stakeholders and the system as well as the communication among the system's modules. It also provides AR/VR interfaces, a Marketplace platform for commercial uses and a Social Collaboration Platform for the optimal cooperation of the involved actors of the project.
- **Services Layer**: This layer provides the envisioned services which will assist users to make decision during the project operation, as well as to improve their everyday life. It consists of all the necessary components like planning and renovation assistance, optimization, and industrialization of the renovation process as well as creation of an AR environment among others.
- **Physical Layer**: This layer contains all the physical devices installed in the buildings, which provides the necessary information from the physical world (buildings) to the RINNO framework. Moreover, it contains the necessary renovation solutions through the **Renovation Repository**.
- **Horizontal Layer**: It is responsible for the interaction of the rest layers on its basis. More specifically, it contains tools to ensure the secure transactions between the users and the proper functioning of the renovation workflow. It also provides the **Middleware** that constitutes the glue of the system.

The conceptual architecture of the RINNO platform, organized in four layers as mentioned above, along with the workflow of the renovation is depicted in the Figure below.

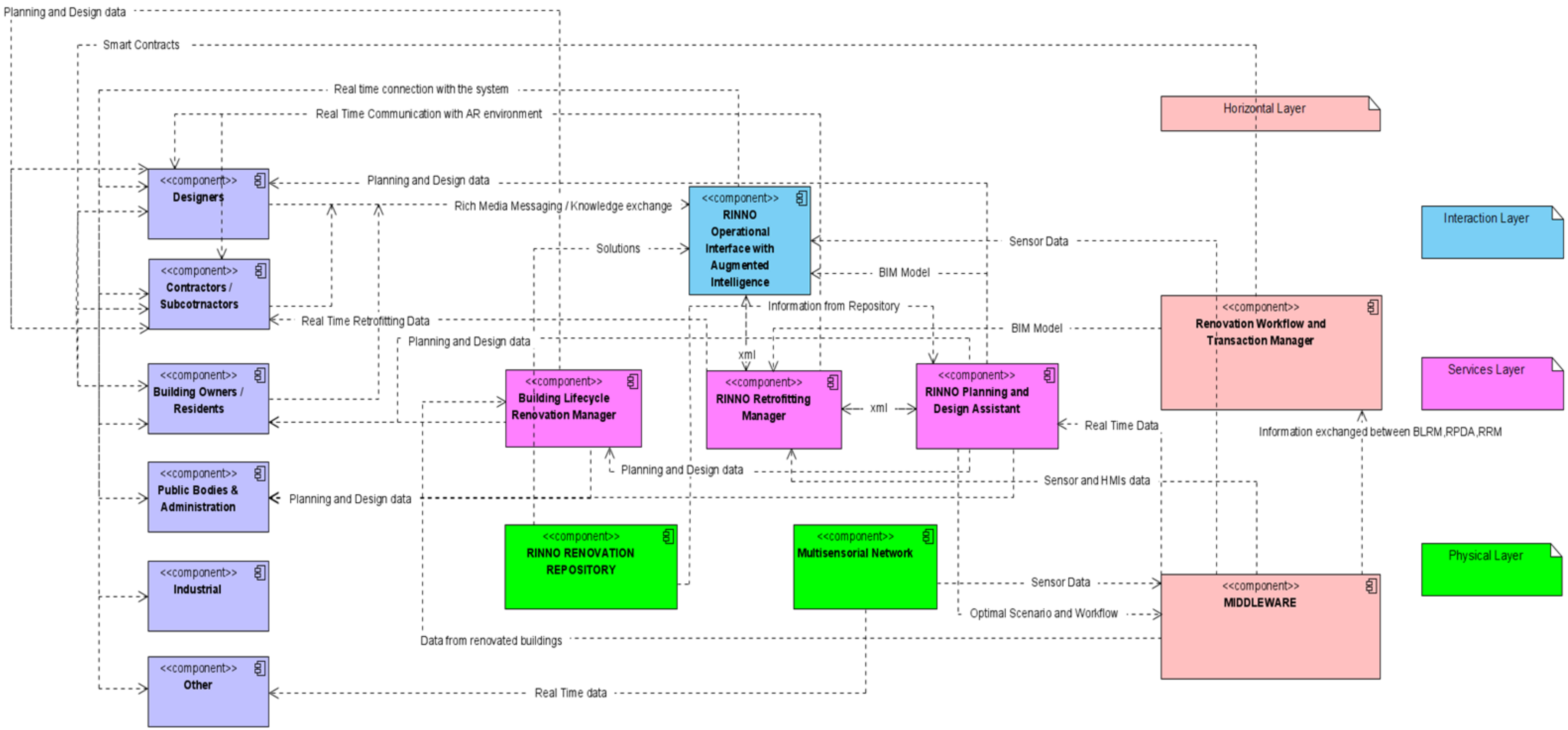

Figure 3 - Conceptual Architecture organized in layers

4.1 RINNO Interaction Layer

4.1.1 RINNO Operational Interface with Augmented Intelligence

RINNO Operational Interface with Augmented Intelligence contains a central dashboard, a Building Monitoring System, Human Machines Interfaces and the RINNO Marketplace & Social Collaboration Platform (RMCP). Dashboard consists of AR/VR interfaces as well as customized dashboard for each user based on the information is interested in. The Collaboration platform supports real time assistance to workers, communication between stakeholders, events and social networking. Designers, Contractors and Building owners or tenants exchange rich media messages through the collaboration platform of this component. They also share with this component their knowledge. **Rinno Renovation Repository** provides the Operational Interface with solutions and gets crowd populated with third parties technologies from the marketplace of this key component. **Rinno Planning and Designing Assistant** also provides the Operational Interface with the BIM model. Finally, **RINNO Operational Interface with Augmented Intelligence** gets sensor data collected at the buildings from the **Middleware**.

4.2 RINNO Services Layer

4.2.1 RINNO Building Lifecycle Renovation Manager

The **Building Lifecycle Renovation Manager** (BLRM) will follow the project in all its phases. In particular, it integrates the Intelligent Renovation Assistant. The Assistant integrates a renovation validation and benchmarking tool. The Assistant gathers renovation data from the buildings from the **Middleware** infrastructure and also gets planning and design data from the **Planning and Design Assistant** in order to optimize available renovation scenarios. In that way **Renovation Manager** generates the logbook and the roadmap of the renovation in order to allow key stakeholders to monitor and validate the renovation process. **Renovation Manager** will assist Designers and Contractors to recognize any performance gap between actual and design data and will also achieve visual and thermal comfort for the Owners or Residents of the building after the end of renovation.

4.2.2 RINNO Retrofitting Manager

The **Retrofitting Manager** combines a group of modules to make the retrofitting process easier for the stakeholders of the system by reducing the operation time and the disturbance of occupants. **Workflow Manager** provides **Retrofitting Manager** with the BIM model. Additionally, an on-the-job AR environment is generated, in order to promote real time communication between engineers and constructors. Retrofitting Manager assists designers, contractors and subcontractors, public bodies and administrators of the system with optimization, industrialization and monitoring of the renovation process. Finally, **Retrofitting Manager** exchanges data (scenarios, services, warning, notifications etc.) with other key components in xml form.

4.2.3 RINNO Planning and Design Assistant

Planning and Design Assistant is a key component of the system that helps owners or tenants, designers and contractors to make decisions in the planning/designing phase of the renovation. The Assistant is responsible for capturing the virtual model of the building and for the generation of the renovation scenarios. RPDA also uses its modules to simulate and evaluate all the available renovation scenarios and then to select the more attractive between them.

4.3 RINNO Physical Layer

4.3.1 RINNO Renovation Repository

RINNO Renovation Repository provides access to novel building innovative and energy renovation technologies and also to suitable business models.

4.3.2 RINNO Multi-Sensorial Network

Multi-Sensorial Network includes the physical devices installed in the buildings, such as smart sensors and monitoring equipment for both energy and environmental conditions. More specifically, it consists of heterogeneous devices that allow the interaction between the physical world (Buildings) and the RINNO platform.

4.4 RINNO Horizontal Layer

4.4.1 Middleware

Middleware, as mentioned above, is the glue of the system. It handles the heterogeneity of physical devices and allows messages and events to be exchanged among the components of RINNO.

4.4.2 RINNO Renovation Workflow and Transaction Manager

The **Renovation Workflow Manager** is responsible for the supervision of the whole lifecycle of the building renovation and for the interaction and interoperability between the components of the services layer (RPDA, RRM, BLRM). Moreover, the **Transaction Manager** will offer next generation, blockchain-enabled applications in order to provide secure and automated contracts between the Owners or Residents and the other stakeholders of the project. More specifically, **Transaction Manager** will convert human readable conventional contracts into smart contracts.

5 Functional View

In the current chapter, the overall functional architecture of the RINNO framework is presented along with a short description of its main components, modules, and sub-modules along with their functionalities and interactions.

5.1 RINNO Functional Architecture

The overall functional viewpoint of architecture is depicted in the figure below.

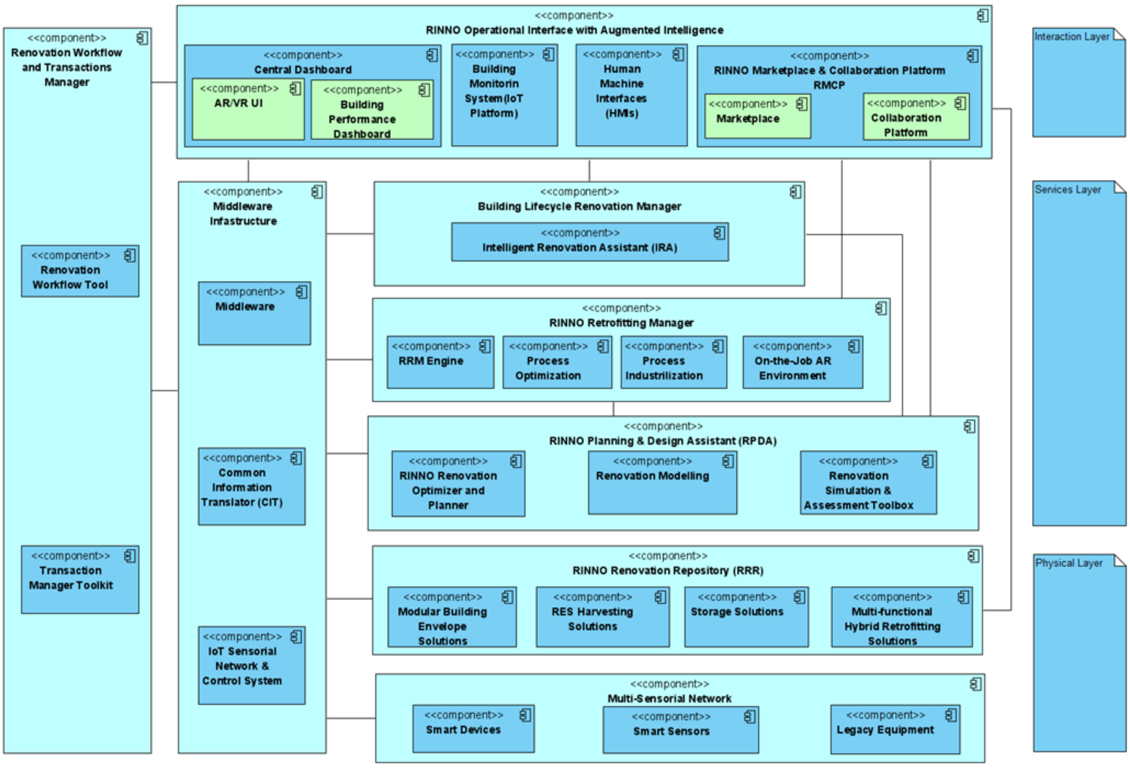

Figure 4 - Overall Functional View

5.2 Overview of the main components, modules, and sub-modules

This section presents the key components, modules, and sub-modules of the RINNO platform and their main functionalities, and interactions.

5.2.1 RINNO Operational Interface with Augmented Intelligence

5.2.1.1 Social Collaboration Platform

This sub-module is part of **RINNO Operational Interface with Augmented Intelligence** component. It creates a knowledge base that will be used for better control and coordination of the renovation workflow and real time training of workers ("on-the-job" assistance). Communication among workers, managers, engineers and building owners will be available through an application (also in the form of a Mobile App). In addition, best practices for the renovation process and best practices and suggestions for energy efficiency for tenants will be provided.

Third parties will have the opportunity to include their technologies, ideas and best practices through this platform that will feed the knowledge base.

Finally, events and social networking will be supported for a better-connected work environment.

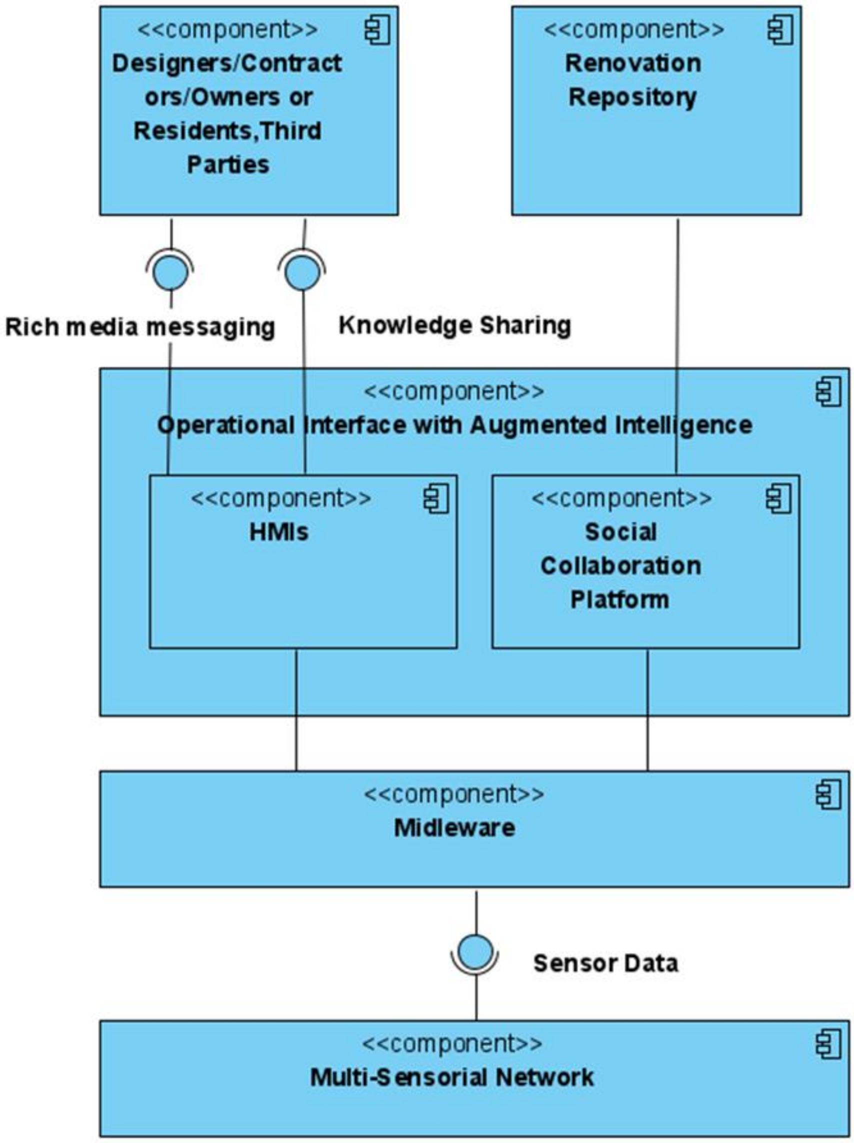

Figure 5 - Social Collaboration platform's Component Diagram

The following tables explains in detail the main interfaces and their interconnection with the other components.

Table 4 - Social Collaboration Platform - Inputs

Social Collaboration Platform	Input Description
Rich media messaging	Information, knowledge, and experiences are exchanged (through the platform or through a Mobile App) among workers, managers, engineers and building owners. Ideas, technologies, and best practices, from third parties are also transferred data.
On-Site Information	Sharing information on-site, during the renovation activities
Information during real-time training	Data collected from Smart phones and tablets (location-based services) and smart helmets (further information)

Table 5 - Social Collaboration Platform - Outputs

Social Collaboration Platform	Output Description
Social Collaboration-Knowledge Sharing platform	Communication among workers, managers, engineers and building owners is available. Tenants are supported with best practices and suggestions for energy efficiency. Also, best practices in renovation activities are provided.
Suggestions/ Solutions to support workers	Direct communication tools to assist workers in the planning, scheduling, coordination, and optimization of work effort as well as real time training, significantly supports the renovation effectiveness.

5.2.1.2 Marketplace

This sub-module is part of **RINNO Operational Interface with Augmented Intelligence** component, along with the Collaboration Platform they form the RINNO Marketplace and Social Collaboration Platform. RINNO Marketplace aims to capitalize the solutions from the **RINNO Renovation Repository** (RRR) as well as RINNO ICT tools. Moreover, 3rd parties will crowd-populate the RRR, through the RINNO Marketplace, to optimize each renovation solution with the support of the **RINNO Planning and Design Assistant** and the **RINNO Retrofitting Manager**. In addition, the technical tools of the RINNO suite feeds the Marketplace with inputs. That way ensures that the RINNO Suite will not be outdated and will continuously provide updated optimized solutions and 3rd parties technologies to the **RINNO Renovation Repository**. The RRR will also be able to generate automatic databases of materials and renovation products (e.g., EPD, ELCD, etc.), allowing its configuration. The Marketplace sub-module continuously introduces 3rd party technologies through point-to-point protocols to the RRR and achieves the sales of not only RINNO, but also 3rd party technologies along with the ICT products that RINNO Suite provides.

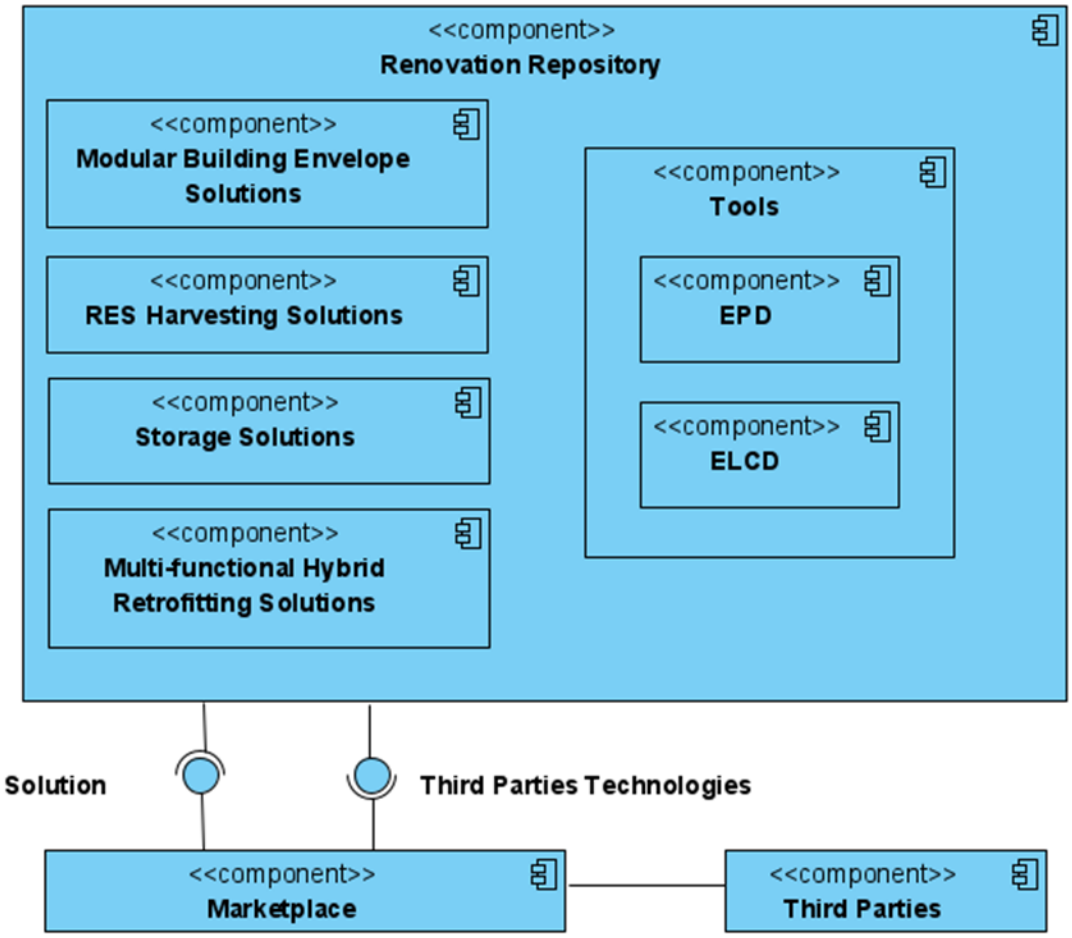

Figure 6 - Marketplace Component Diagram

Table 6 - Marketplace - Inputs

Marketplace	Inputs Description
Solutions provided by the RINNO Renovation Repository	The solutions of the Repository include: • Envelope retrofitting solutions • Energy systems (RES harvesting, hybrid & Storage Solutions) • Retrofitting process improvement techniques • Business Models

Table 7 - Marketplace - Outputs

Marketplace	Outputs Description
Third parties' technologies	**RINNO Renovation Repository** will be crowd-populated through the Marketplace by third parties to facilitate its natural expansion and ensure that both novel and conventional solutions are included and can be used for optimising each renovation case.

5.2.1.3 Building Monitoring System (IoT Platform)

The Building Monitoring System (BMS) is a module of **RINNO Operational Interface with Augmented Intelligence** component. BMS connects in-use performance data with BIM context and provides usable advice to property owners and tenants. This module will take BIM models in the form of Industry Foundation Classes (IFC) and enables users to link sensors and other data, such as tenant profile data to spaces within buildings. BMS will relate to the IoT sensorial middleware to understand the behavioural profile of users. BMS will be able to monitor any IoT device. It can receive information from any kind of device installed in the buildings under any kind of protocol. Finally, depending on the type of IoT sensors installed, the IoT Platform can generate different functionalities about the renovation process (e.g., the monitoring of parameters, advancements…) and the operation of the building.

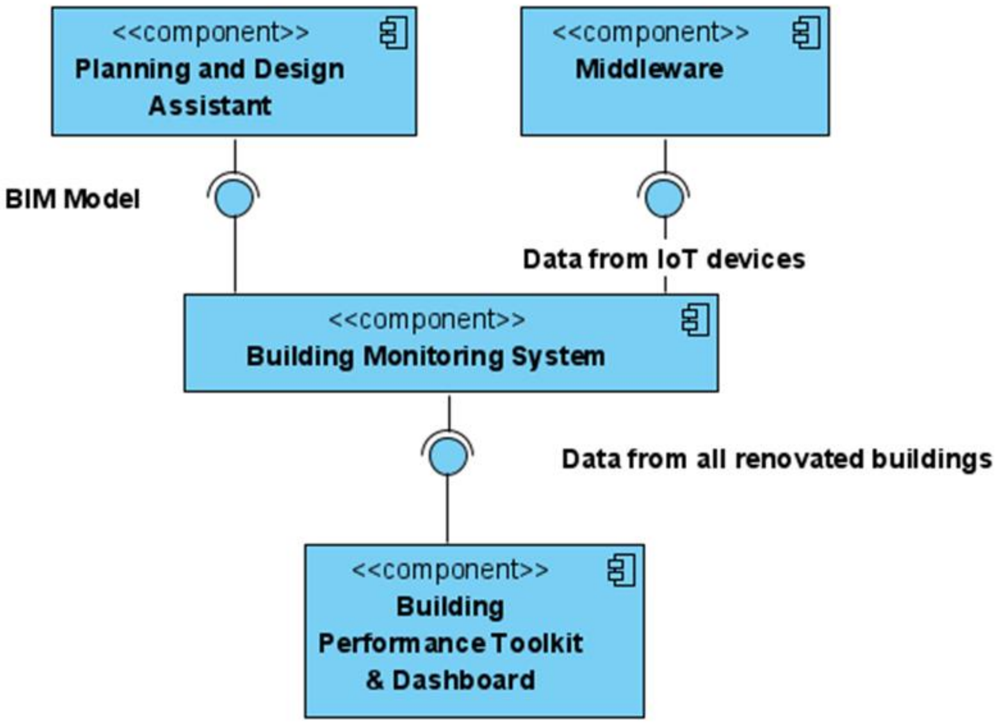

Figure 7 - Building Monitoring System Component Diagram

Table 8 - Building Monitoring System – Inputs

Building Monitoring System	Inputs Description
BIM models	The Building Monitoring System gets a BIM model in the form of Industry Foundation Classes (IFC).
Data from IoT devices in the buildings	The Building Monitoring System gets information from any kind of device installed in the buildings (e.g. energy, environmental meters) under any kind of protocol (e.g. TCP/IP, Bluetooth, ZigBee, Z-Wave).

Table 9 - Building Monitoring System - Outputs

Building Monitoring System	Inputs Description
Data from all available (renovated) buildings during the phase of renovation and operation.	The Building Monitoring System can extract useful information such as e.g., short-term energy consumption predictions, data correlations, comparisons, reports.

5.2.1.4 Central Dashboard

5.2.1.4.1 Building Performance Toolkit & Dashboard

Building Performance Toolkit & Dashboard is a sub-module of **RINNO Operational Interface with Augmented Intelligence**. Along with AR/VR User Interface they form the Central Dashboard of Operational Interface. This toolkit will allow users to create personalized dashboards based on the information they are interested in. The dashboard will enable the facility manager and the occupants to monitor building operations and decide optimal strategies. Users will also be able to set up custom alerts in order to receive notifications under certain circumstances (e.g., humidity). This sub-module utilizes visual and data analytics techniques for the analysis of the data through a spatiotemporal analysis and correlations between building parameters and various KPIs at different domains (e.g., geometric, energy consumption, usage, etc.). The dashboard will be fed with data through the Building Monitoring System (i.e., IoT platform).

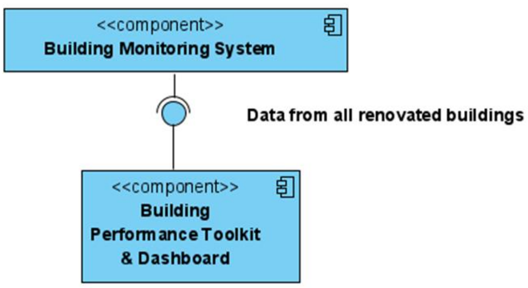

Figure 8 - Building Performance Toolkit & Dashboard Components Diagram

Table 10 - Building Performance Toolkit & Dashboard - Inputs

Building Performance Toolkit & Dashboard	Inputs Description
Data from all available (renovated) buildings during the phase of renovation and operation.	Useful information such as e.g., short-term energy consumption predictions, data correlations, comparisons, reports.

5.2.1.4.2 AR/ VR User Interfaces (UIs)

This Section is referred to the User Interfaces (UIs), which will be delivered by the AR on-the-job training toolkit (Section 3.2.3.1).

5.2.2 RINNO Planning & Design Assistant (RPDA)

5.2.2.1 Renovation Modelling

5.2.2.1.1 Building Capturing and Mapping

This sub-module belongs to the **RINNO Planning and Design Assistant** component. RINNO will capture and align the basic existing geometrical information of the building features under renovation, while considering any required structural repairs, leading to the necessary BIM. The building-as-is capturing will be firstly achieved via a questionnaire, which will be circulated to the demo sites. Then both conventional (accelerometers, gyroscopes, GPS), and very innovative devices (Ars's scanners and drones) will be also deployed for the building-as-is capturing and reconstructing the 3D geometry of the existing buildings and model them in BIM.

On top of these devices, RINNO will deliver a multiplatform software technology allowing:

- immersive environment for additive/corrective scanning/reconstructing of existing building data with design drafting/review and BoQ (Bill of Quantities) functionalities,
- the sharing of building data among other stakeholders (located locally or remotely).

These conventional and innovative devices will gather onsite data by creating a cloud of points that will form the building shape. On the other hand, some algorithms will be developed to map these points together and create a BIM model. This creation will allow us to differentiate between the main components of the envelope: windows, doors, roof, concrete, etc.

The output of this task will be an IFC BIM model. The result will be connected to the Renovation Digital Twin and the Renovation Assessment Toolbox.

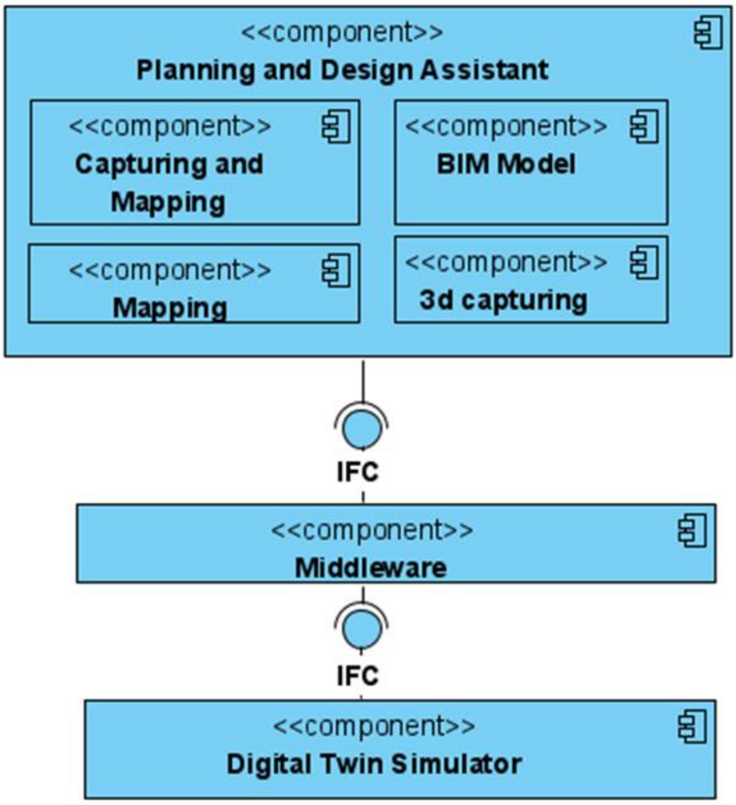

Figure 9 - Building Capturing and Mapping Component Diagram

The following table explains in detail the main interfaces, and their interconnection with this component.

Table 11 - Building Capturing and Mapping - Inputs

Building Capturing and Mapping	Inputs Description
Cloud of points	Drones are often used to collect a series of RGB images which can be later processed on a computer vision algorithm platform such as on AgiSoft Photoscan, Pix4D or DroneDeploy to create RGB point clouds from where distances and volumetric estimations can be made.

Table 12 - Building Capturing and Mapping - Outputs

(Καλύτερα θα είναι: Building Capturing and Mapping)	Output Description
IFC BIM Model	The Industry Foundation Classes (IFC) data model is intended to describe architectural, building and construction industry data. It is a platform neutral, open file format

	specification that is not controlled by a single vendor or group of vendors. It is an object-based file format with a data model developed by building SMART (formerly the International Alliance for Interoperability, IAI) to facilitate interoperability in the architecture, engineering, and construction (AEC) industry, and is a commonly used collaboration format in Building information modelling (BIM) based projects.

5.2.2.1.2 Digital-Twin

Renovation buildings Digital-Twin sub module subject to energy efficient renovation plan, to make the renovation offer more attractive and less time-consuming to all relevant stakeholders by assessing different renovation solutions with an automatized building modelling approach (Machine Learning based). Its primary advantage over other approaches lies on being simpler in terms of formulation and application compared to conventional modelling approaches, without the requirement of dedicated experts' involvement.

The VTT Digital-Twin model is created based on a mix of existing mathematical & physical model of the building and info pulled from extensive databases, where either aggregated data (e.g., energy bills) or historical data (delivered by IoT middleware) are stored. The Digital-Twin building model is trained based on a) either hourly measurement data (indoor temperature, energy consumption of single consumption points – heating/cooling elements and/or electrical equipment (ventilation fans, home/office appliances) or b) building consumption point, building automation data, IoT sensors data and weather data) and, if available, geometry of the building (from CAD data file) and thermal properties of building envelope elements.

This module success is interconnected with the interaction with multiple components as depicted in the scheme below.

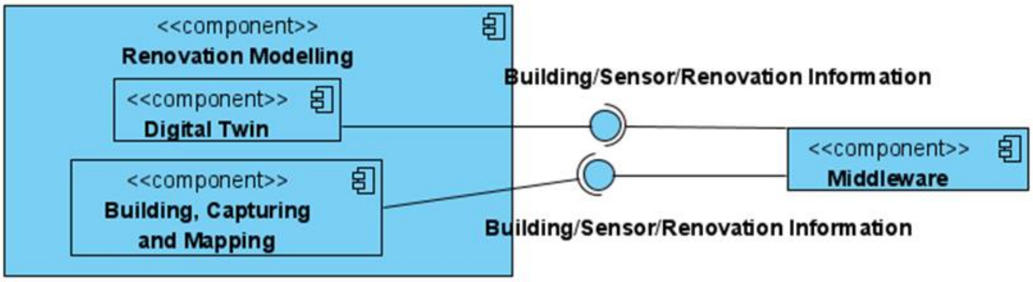

Figure 10 - Renovation Digital-Twin Component Diagram

This tool is part of the RINNO Renovation Modelling module. The following table explains in detail the main interfaces, and their interconnection with Renovation Digital-Twin sub-module.

Table 13 - Renovation Digital-Twin - Inputs

Renovation Digital-Twin – Tool	Inputs Description
Building sensor information	• IoT sensor data • BEMS data • Weather data
Basic building information	• Country • Building type • Construction year • Weather data • Cooling set point • Heating set point. • Space heating/cooling type • Conditioned floor area • Number of floors • Floor height • Number of residents
Renovation options	Measures to improve: • the building airtightness • the thermal insulation of the windows/outside walls/base floor/roof • the solar shading of the windows. • the mechanical ventilation system by adding heat recovery for the ventilation system • the energy efficiency of the hot water system • energy efficiency and/or CO_2-emission efficiency of the heating/cooling system • the space heating efficiency by adding an auxiliary space heating system

Table 14 - Renovation Digital-Twin - Outputs

Renovation Digital-Twin - Tool	Output Description
Space heating and hot water	(Before, After and Savings information)
Appliance electricity	(Before, After and Savings information)
Space cooling	(Before, After and Savings information)
Carbon footprint	(Before, After and Savings information)
Energy cost	(Before, After and Savings information)
Investment cost	(Before, After and Savings information)
Payback time	(Before, After and Savings information)

5.2.2.2 Renovation Simulation & Assessment tool

5.2.2.2.1 Energy Assessment

This submodule belongs to the RINNO Simulation and Assessment toolbox module which in turn belongs to the **RINNO Planning and Design Assistant** component. The Energy Assessment tool (subtask 3.3.1) will assess the energy performance of the various renovation scenarios considering the specifications of the building envelope, the various thermal zones, the building systems, Renewable Energy Systems (RES) production systems, weather data and user behaviour. The dynamic energy demand (thermal and electrical) of the buildings will be investigated along with the RES production, potential and own-use utilization through assessing possible RES harvesting synergies combined with storage solutions.

Finally, it is envisaged that the tool will additionally have responsive capabilities offering recommendations to the users and will support control and actuations functionalities. This is a development that goes beyond the requirements of the RINNO project and if this goal is realized it will offer the potential for more energy efficient operation of the building by minimizing energy consumptions and losses and optimizing RES own use.

The Energy Assessment tool receives input on the building geometry, the thermophysical properties of the building elements as well as the various combinations of building and RES systems for all potential renovation scenarios through the Renovation Modelling Toolkit (BIM, Digital Twin) (T3.1, T3.2). Additional input for the technologies will be received from the **RINNO Renovation Repository** component (WP2).

The output will be used by the RINNO Renovation Optimizer and Planner (T3.4) to determine the optimum renovation scenario. In addition, the output of the Energy Assessment tool will partly feed the Environmental, Cost and Social Assessment tool (subtask 3.3.1).

This component success is interconnected with the interaction with multiple components as depicted in the schema below.

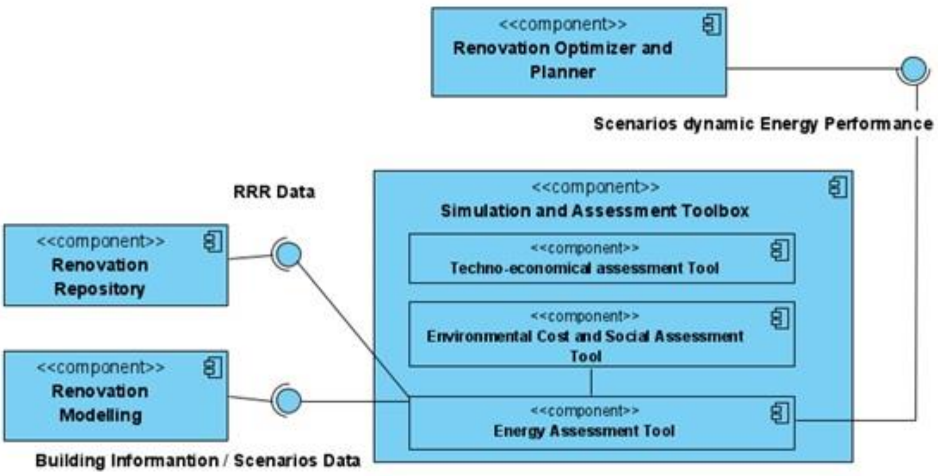

Figure 11 - Energy Assessment tool Component Diagram

The following table explains in detail the main interfaces, and their interconnection with the Energy Assessment tool component.

Table 15 - Energy Assessment tool - Inputs

Energy Assessment tool	Inputs Description
Building information from the Renovation Modelling toolkit (BIM, Digital Twin)	The Energy Assessment tool will receive inputs on the building geometry, the thermophysical properties of the building elements as well as the existing building systems and RES systems that produce thermal or electrical energy from the Renovation modelling toolkit so that the dynamic energy performance (demand and production) of the existing building will be assessed. Furthermore, the proposed renovation scenarios, considering the various technological solutions and their integrations and synergies, will also be provided to determine their energy performance
Information and data on the technologies used from the RINNO Renovation Repository (RRR)	The specifications of the technologies used on a renovation scenario will be taken by the RINNO Renovation Repository. These specifications (such as power, capacity factor, maximum and minimal voltage and current etc. for an electricity production system) are required for the modelling the technologies and their integration on the buildings as well as the energy assessment of the various scenarios

Table 16 - Energy Assessment tool - Component outputs

Energy Assessment tool	Outputs Description
Energy performance data to the RINNO Optimizer and Planner	Results of the analysis on the energy assessment of the various scenarios will be fed to the RINNO Renovation Optimizer and Planner to rank them in terms of energy performance based on appropriate KPIs.
Operational data for the Environmental, Cost and Social assessment tool	Specific output data (such as the forecasted power production for RES systems etc.) will be fed to the Environmental, Cost and Social assessment tool (3.3.2) to conduct the LCA/LCC/s-LCA analysis of the renovation scenarios.

5.2.2.2.2 Environmental, Cost and Social Assessment

This sub-module belongs to the RINNO Simulation and Assessment toolbox module which in turn belongs to the **RINNO Planning and Design Assistant** component. The Environmental, Cost and Social Assessment tool will conduct the analysis of the proposed renovation scenarios of each demo site regarding:

- The Lifecycle Assessment of the renovation scenarios, where the evaluation of parameters such as:
    a) embodied energy of the renovation components
    b) primary energy savings
    c) CO_2 emissions per kWh produced
    d) Lifetime GHG emissions
    e) Water footprint of the renovation measures.
- The Lifecycle Cost assessment of the renovation scenarios where the direct, indirect, internal, and external costs incurred will be evaluated for all stages during a project's lifetime (capital, operation and maintenance and end-of-life costs).
- The assessment of social life cycle assessment (S-LCA) aspects concerning the residents' welfare during the building renovation process.

The evaluation of the renovation scenarios will be conducted based on the KPIs defined in T1.4. The tool receives input from the Energy Assessment tool regarding some operational parameters of the renovation scenarios. Additional input for the technologies will be received from the **RINNO Renovation Repository** component (WP2).

The output will be fed into the RINNO Renovation Optimizer and Planner (T3.4) to determine the optimum renovation scenario. In addition, the output of the LCC assessment will assist the business modelling tasks in WP7 that will be customer focused guided by circular renovation principles.

This component success is interconnected with the interaction with multiple components as depicted in the schema below.

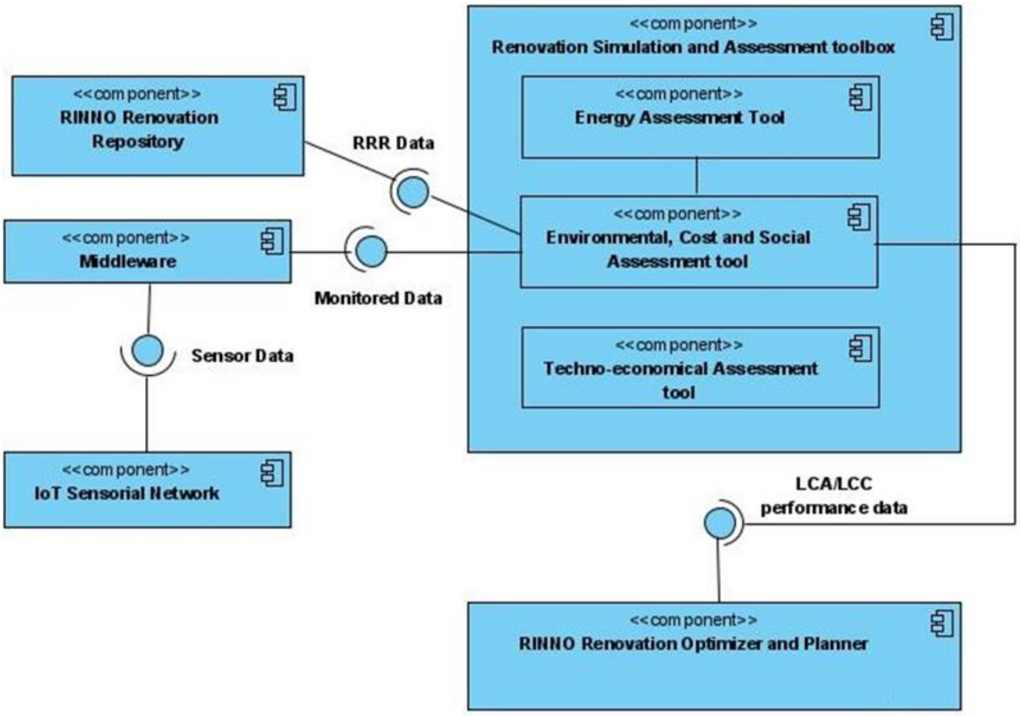

Figure 12 - Environmental, Cost and Social Assessment tool Component Diagram

The following table explains in detail the main interfaces, and their interconnection with the Environmental, Cost and Social Assessment tool component.

Table 17 - Environmental, Cost and Social Assessment tool - Inputs

Environmental, Cost and Social Assessment tool	Inputs Description
Operational data from the Energy Assessment tool	The Environmental, Cost and Social Assessment tool will receive inputs on certain operational parameters (such as capacity and energy production of RES systems, building energy consumption etc.) from the output of the Energy Assessment tool. This input is required to estimate the environmental impact as well as the cost during the operational phase of the renovated building.
RINNO Renovation Repository (RRR)	Specifications of the technologies used on a renovation scenario will be taken by the RINNO Renovation Repository. These specifications are required for determining the environmental impact and cost of the technologies and their integration on the buildings throughout the lifecycle of the building.

Building Monitored Data	The tool will receive monitored data from the building regarding the indoor conditions of the buildings. Such data will be used by the s-LCA module to determine the impact of the renovation on the well-being of the occupants through the calculation of suitable KPIs. In addition, up-to-date information on the energy performance will be received by the LCA/LCC assessment tool (VERIFY) from the monitoring sensors through the middleware (if available) which will lead to increased accuracy of the environmental and lifecycle cost analysis.

Table 18 - Environmental, Cost and Social Assessment tool – Outputs

Environmental, Cost and Social Assessment tool	Outputs Description
Environmental, and Lifecycle Cost performance data to the RINNO Optimizer and Planner	Results of the analysis on the environmental, and lifecycle cost assessment of the various scenarios will be fed to the RINNO Renovation Optimizer and Planner to rank them based on appropriate KPIs.
Social Impact data	Monitored data for the indoor conditions of the buildings (CO2, temperature and humidity) will be used for the calculation of suitable indicators (time outside thermal comfort conditions, etc.) as part of the assessment for the social impact of the renovation

5.2.2.2.3 Techno-economical Assessment

This submodule belongs to the RINNO Simulation and Assessment toolbox module which in turn belongs to the **RINNO Planning and Design Assistant** component. The main aim of techno-economical assessment (TEA) tool is to evaluate, for each renovation scenarios considered, the impact of the works in terms of user disturbance and waste production. With reference to waste production, the logistic implications (transport and site) will also be considered.

Specifically, the TEA tool consists of two different parts:

- Activities configuration module: to identify the worksite scenarios that minimize time, costs, and disturbance to users.
- Waste Management Module: it allows to identify quantities and logistical needs for different waste categories according to the types of waste produced.

The tool receives inputs from the building geometry, construction phases, materials, separation degree of materials of both the existing building and the related refurbishment scenarios to be assessed, through the Renovation Modelling Toolkit (BIM, Digital Twin) (T3.1, T3.2). Additional inputs for the technologies will be received from the **RINNO Renovation Repository** (WP2) about product innovations.

The output will be fed into the RINNO Renovation Optimizer and Planner (T3.4) in order to determine the optimum renovation scenario as well as the optimal sequence of works. In detail, the TEA tool will calculate the impact on different users in terms of interruption of services, indoor environmental quality (acoustic, light, air quality), accessibility to areas and promiscuity with workers.

The interconnections and the interfaces of the submodule with other submodules are depicted in figure below.

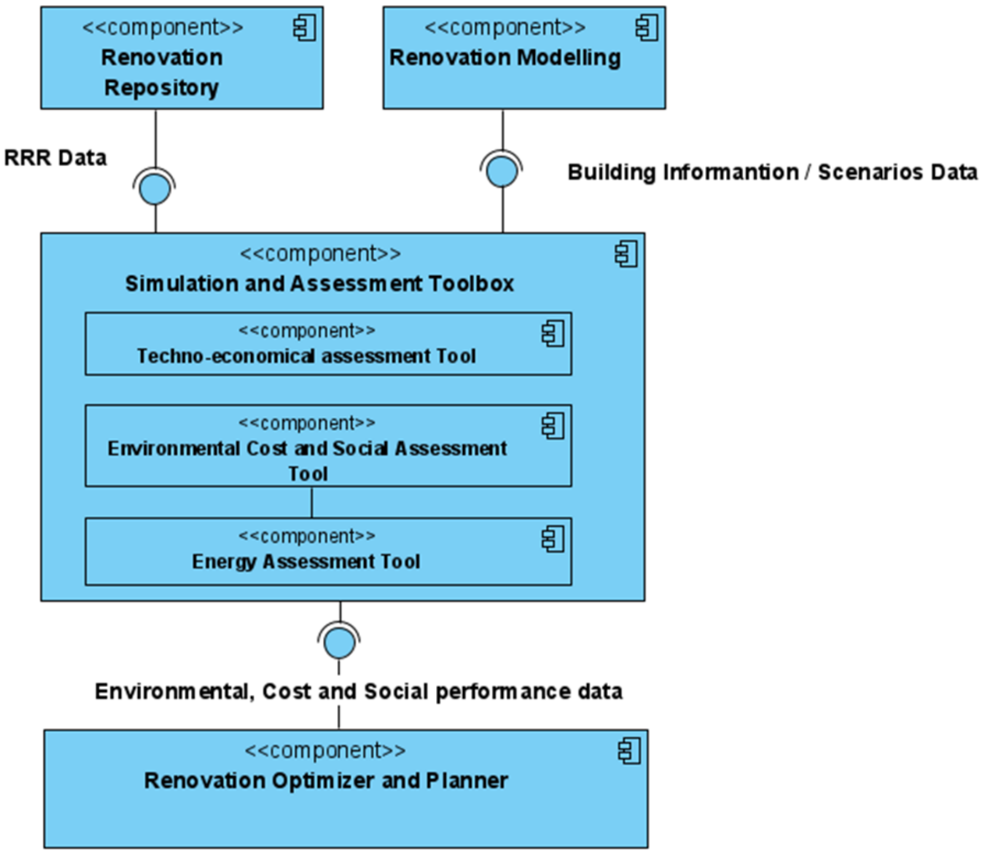

Figure 13 - Techno-economical Assessment Tool Component Diagram

Table 19 - Techno-economical Assessment Tool - Inputs

Techno-economical Assessment Tool	Inputs Description
Building information from the Renovation Modelling toolkit (BIM, Digital Twin)	The Techno-economical Assessment tool will receive input on the building geometry, construction phases, materials, separation degree of materials of both the existing building and the related refurbishment scenarios to be assessed
RINNO Renovation Repository (RRR)	Specifications of the technologies used on a renovation scenario will be taken by the RINNO Renovation Repository. Data gathered from the RRR through the Middleware will be used in BIM format. These specifications are required to assess cost and impact in terms of user disruption resulting from their integration on the buildings

Table 20 - Techno-economical Assessment Tool - Outputs

Techno-economical Assessment Tool	Outputs Description
Data on the technoeconomic performance of the renovation scenarios to the RINNO Optimiser and Planner	Renovation scenarios will be assessed in terms of user disruption, waste generation and relevant costs in terms of renovation work progress. These results will be then fed to the RINNO Renovation Optimizer and Planner to rank them based on appropriate priorities.

5.2.2.3 RINNO Renovation Optimizer and Planner

This module belongs to the **RINNO Planning and Design Assistant** component. The RINNO Renovation Optimizer and Planner will determine the optimum renovation scenario and the optimum sequence of interventions. The optimum scenario will be selected based on the results of the Energy Assessment tool (3.3.1), the Environmental, Cost and Social Assessment tool (3.3.2) and the Techno-economical assessment tool (3.3.3) and the use of appropriate KPIs defined in T1.4. The optimum sequence of interventions will be selected based on KPIs regarding retrofitting time and cost during the renovation and disturbance of occupants and will aim at minimizing them.

The module receives inputs from the simulations of the Energy Assessment tool, the Environmental, Cost and Social Assessment tool and the Techno-economical Assessment tool for all potential renovation scenarios (collectively the RINNO simulation and Assessment toolkit). The scenarios that are examined have been produced by considering the status of the building (the renovation modelling toolkit generating the scenarios receives real-time data from the **Multi-sensorial network** through the **Middleware** infrastructure). The evaluation of the scenarios will be conducted based on appropriate KPIs defined in T1.4.

The output of the Renovation Optimizer and Planner will be fed to the other components related to the construction and monitoring stage of the renovation, namely the **RINNO Retrofitting Manager** and the **Building Lifecycle Renovation Manager** through the **Renovation Workflow and Transaction Manager**.

This component success is interconnected with the interaction with multiple components as depicted in the schema below.

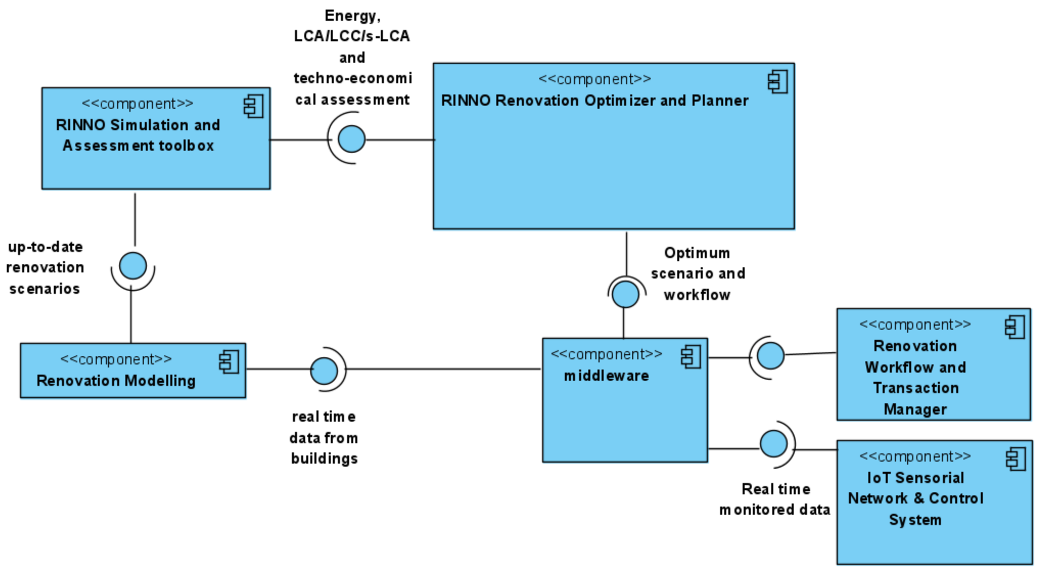

Figure 14 - RINNO Renovation Optimizer and Planner Component Diagram

The following tables explain in detail the main interfaces, and their interconnection with the RINNO Renovation Optimizer and Planner module.

Table 21 - RINNO Renovation Optimizer and Planner - Inputs

Renovation Optimizer and Planner	Inputs Description
Scenarios assessment data	The RINNO Renovation Optimizer and Planner receives inputs from the RINNO Simulation and Assessment toolkit on the assessment of the proposed renovation scenarios in terms of: • energy performance • environmental impact (LCA) and lifecycle cost (LCC) • techno-economic performance.

	Renovation's scenarios are then ranked based on their performance in these three assessment categories. The scenarios generated are based on the building's current condition. For this, the Renovation Modelling toolkit (BIM and Digital Twin) receives monitored data from the multi-sensorial network through the Middleware infrastructure

Table 22 - RINNO Renovation Optimizer and Planner - Outputs

Renovation Optimizer and Planner	Outputs Description
Selected Renovation scenario and sequence of interventions	All potential renovation scenarios will be ranked based on appropriate KPIs and for each building investigated. The planning of interventions will also consider suitable KPIs on retrofitting time, cost, and disturbance. The RINNO Renovation Optimizer and Planner will select the optimum renovation scenario for each building as well as the optimum sequence of interventions. This will then be fed through the **Renovation Workflow and Transaction Manager** and used in WP4 for the planning of the construction process, in WP5 for the validation of the renovation process and will be demonstrated in WP6.

5.2.3 RINNO Retrofitting Manager (RRM)

5.2.3.1 On-the-Job AR Environment

This module belongs to the **RINNO Retrofitting Manager**. On-the-Job AR Environment is responsible for the design of services and interfaces, as well as their integration to the workplace, to support workers within an attractive ambient environment. The target stakeholders of this module are:

- Support employees in carrying out specific operating procedures.
- Support employees by providing access to advanced information and content.

Services are provided for the support of all procedures required by the project (training and assembly) and in any procedure that this information can add value (first group of target stakeholders). An AR Assistance tool & AR Training sub-module has been developed targeting the training of employees (second group of target stakeholders) "off-line" with predefined scenarios, and/or on-site with AR techniques. An approach both "on the job" (based on Augmented Reality capabilities), and in a "simulated environment" (totally based on Virtual Reality) is implemented in order to guide users (novice workers) in their activity by presenting the step-by-step procedures interactively, by providing guidance on tools, materials, and components involved and their use. These modules are enhanced to support functionalities such as image-video sharing and VoIP. Useful information is provided to decrease:

- the construction site-work time as well as the training time of novice workers.
- the errors and faults during the renovation processes.
- any delays, since potential problems could be solved on-site at the time they arise.

Useful data are gathered from the **multi-sensorial network** to create a knowledge base. Data are retrieved from AR/VRs scanners, drones, robots, cobots, photogrammeters and allow to determine if a procedure visualized through these tools has been correctly implemented. This information is useful as training material as well for workers on real site conditions. Another source of information is from smart devices and HMIs such as smart phones, tablets and smart helmets that provide location-based data and constitute communication means available among workers.

A variety of services are available through the AR Assistance tool & Training tool. Such services include:

- exchange of information and communication
- AR-assisted architectural narratives
- geolocating BIM data on the construction site
- work-instruction delivery
- 4D phasing of construction work sites
- training platform for maintenance and repair
- AR for facility management
- object tracking
- target recognition (ML techniques).

The **Middleware infrastructure** provides interoperability among sensors and devices with different protocols, data necessary for the On-the-Job AR Environment component. It allows any kind of information to be transferred to the end users.

The presentation of the information transferred is achieved through innovative Human Machine Interfaces (HMIs) that belong to the Interactive Layer and it can be considered strictly integrated component of the On-the-Job AR Environment component. The services are designed so that through visualization tools of the available HMIs, information, and content from pre-packaged scenarios as well as generated data at runtime (based on information coming from the **multi-sensorial network**) can be distributed directly to the HMIs. These HMIs are in the form of smart devices such as smart phones and tablets as well as smart helmets and provide guidance to the whole operation (showing for example where components should be installed and further information to modules installation).

This component success is interconnected with the interaction with multiple components as depicted in the schema below.

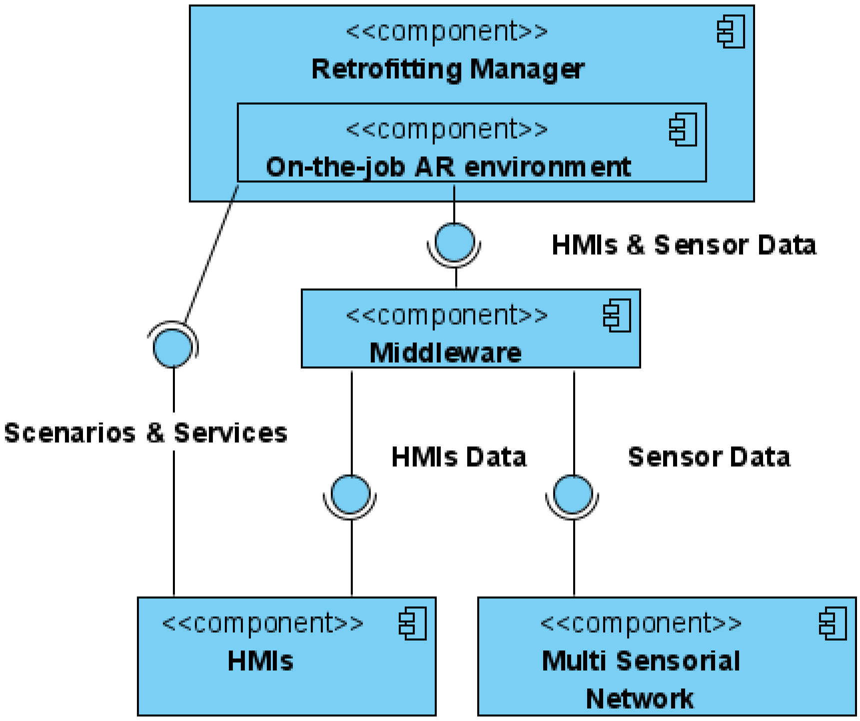

Figure 15 - On-the-Job AR Environment Component Diagram

The following tables explains in detail the main interfaces, and their interconnection with the On-the-Job AR Environment component.

Table 23 - On-the-Job AR Environment - Inputs

On-the-Job AR Environment	Inputs Description
HMIs data	Through smart devices such as tablets and smart phones as well as smart helmets, workers provide information (location-based data and communication data in the form of sound, video, text, and AR content) so that the AR Assistance tool & AR Training tool can provide guidance and practical information for training purposes along with a variety of services
Sensor Data	Through a plethora number of devices and sensors such as AR/VRs scanners, drones, robots, cobots and photogrammeters, the data gathered allow to determine if the

	renovation procedures are correctly implemented. This data from the training scenarios will also form a knowledgebase to be exploited for the training of inexperienced workers. This data must support the services provided by the AR Assistance tool and AR Training tool. Such data for example must include geolocating BIM Data of the construction site

Table 24 - On-the-Job AR Environment - outputs

On-the-Job AR Environment	Outputs Description
Scenarios & Services	The AR Assistance tool & AR Training tool makes available a variety of services and training, with predefines scenarios directly to the HMIs. The services provided are exchange of information and communication, AR-assisted architectural narratives, geolocating BIM data on the construction site, work-instruction delivery, 4D phasing of construction work sites, training platform for maintenance and repair, AR for facility management, object tracking, target recognition (ML techniques). For example, appropriate guidance during installation via AR interfaces – pointing to the exact location where a component shall be installed as well as alerts on health/safety issues in the form of sound, video, text, and AR content

5.2.3.2 RINNO Retrofitting Manager Engine (RRM Engine)

This module is part of the **RINNO Retrofitting Manager**, which integrates the following modules:

- The process Industrialization module
- The process optimization module
- The on-the-job AR Facilitating Environment module.

The RRM Engine should be able to help execute, analyse, monitor, and manage the renovation process, while it can also guide and even train the workforce on-site through the cloud.

Especially, it should:

- Make data accessible in real-time through a user-friendly interface with role-based authorization.
- Optimize the performance of works and the supply chain minimizing costs and saving space.
- Provide real-time reports on renovation progress to allow decision making.
- Notify stakeholders via email to remind submitting their data in a time.

This module will be developed based on the Smart Connected Buildings (SCB) platform made of multiple interconnected components as depicted in the following schema.

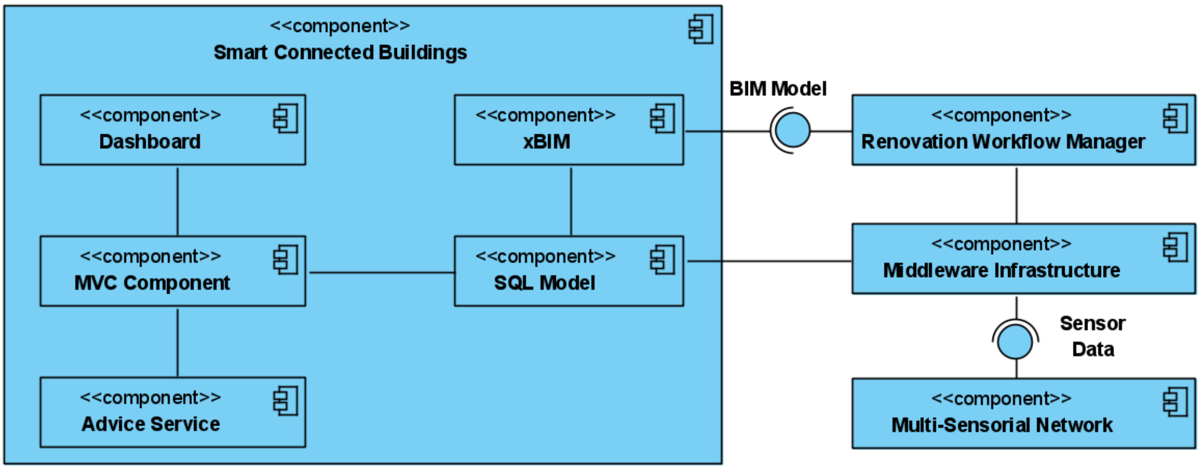

Figure 16 - RINNO Retrofitting Manager Engine Component Diagram

The following table explains the main interfaces, and their interconnection with the RRM Engine component.

Table 25 - RINNO Retrofitting Manager Engine - Inputs

RINNO Retrofitting Manager Engine	Inputs Description
Sensor Data	Through the **Middleware Infrastructure**, deployed sensors (temperature, humidity, motion, light, power, gas, etc.) provide real-time data to be stored in the SQL Model (SCB database), then used for immediate visualization or informing users via alerts/advices after processing
BIM Model	After being created by the RPDA component, the Renovation Workflow Manager provides the BIM model to be used by the SCB platform. An interface between the BIM model uploaded in IFC file format, and the SCB platform will be provided through an existing BIM Academy library xBim, providing easier access to the IFC file by creating a temporary, in memory database.

	Thus, easier extraction of the building, its floors, apartments and rooms so they can be stored in an SQL database

Table 26 - RINNO Retrofitting Manager Engine - Outputs

RINNO Retrofitting Manager Engine	Outputs Description
Sensor Data	RINNO Platform, the performance dashboard of each pilot is going to be visualised through graphs and informative fields. The performance dashboard will present the values received real-time from sensors installed to the pilot building along with the theoretical values for the optimised energy consumption of the building in order to compare and adapt the system. The administrator of the platform will be able to see the dashboards of all buildings. The building owner and the tenants will be able to see their building's dashboard.
BIM Model	RINNO Platform, BIM model will be available per building for visualizing the 3D view of the buildings. Building owners and tenants will have the opportunity to "walk" through the building, see the devices attached to each floor and flat, check the values of the sensors and receive notifications in case of exceeding max values. Moreover, through the interconnection with e-cockpit tool from WP4, the BIM model of each building will visualize the renovation process on the 3D model of the building.

5.2.3.3 Process Industrialization

The process industrialization (E-Cockpit) is sub-module that is part of **RINNO Retrofitting Manager**. It represents the global digitalization of all the site construction activities to provide relevant information on the "Production Monitoring". This module enables an objective, real time, permanent and effortless supervision of the site tasks.

The objective is to transmit synchronous information for reactivity actions and necessary adaptations to every type of events (ex: Delays on delivery, lack of manpower, bad weather, etc.).

In addition, the E-Cockpit gather productivity objective measurement information for management pertinent decision.

This permits resources savings by a close production monitoring and focus on adding value to the construction period with smooth activities organization and deployment.

The E-Cockpit is linked to the RINNO Workflow process to ensure the Execution works to keep on track. The following key aspect are part of the global monitoring:

- Progress monitoring (resources, time, costs, etc.)
- Just-in-time Logistics
- Coworking and collaboration spatial organization on site
- Quality monitoring

As the E-Cockpit collects many data, feedback will adjust the RINNO – AI module for a permanent increase of performance for current or future projects.

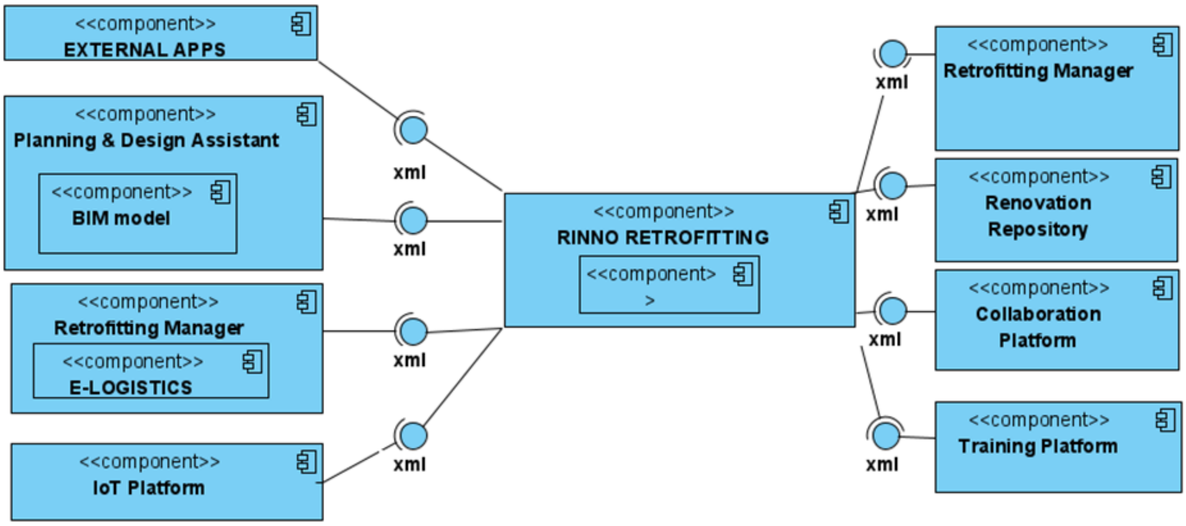

Figure 17 - E-cockpit Component Diagram

The following tables explain in detail the main interfaces, and their interconnection with the **RINNO Retrofitting Manager** component.

Table 27 - E-Cockpit - Inputs

E-cockpit	Inputs Description
Orchestration	Central element of the e-Cockpit platform: • Data acquisition for processing • Broadcasting of information(streaming) • The business logic and the processes to be implemented within the framework of the platform,

	possibly with access to the company IS and to third-party services
Warnings & Notifications	Brick allowing to send an alert or a notification to a person, at the request of the orchestrator or following an event. An alert corresponds to a signal to be sent to a person on the site (site manager, for example) so that they act immediately in the event of danger or action required, with potential stoppage on the site in the event of danger. A notification corresponds to a message sent "for information" without immediate action required
Services	Brick offering a set of production monitoring services for construction sites, which can be activated according to the desired configuration for a given site. It makes it possible to offer a modular and adjustable architecture with services such as: Control of security risks Site progress monitoring Assistance in piloting logistics the management of co-activities Others can easily be added later. This brick will manage the context and the correlation of the information received by e-Cockpit. Operation: The brick receives information tagged by the Orchestrator with the list of associated services that will have to process it. Thus, the same information can be used for assistance in the management of logistics and for monitoring the progress of the site, for example.
Administration	Administration module to perform:

	Managing objects, their attributes, and associated services Management of access rights to reporting to the administration platform (IAM: Identity and Access Management) Management of configurations and types of work sites, with the list of services activated or not on a work site, on an object, which are mandatory or optional, etc. Real-time monitoring of platform objects, active services, and overall platform status.

E-cockpit	Outputs Description
Orchestration	What services are activated for a given site To which services each data must be routed (by adding the appropriate tags so that the "Services" brick knows which pipelines to activate for processing) What additional treatments will need to be carried out for a specific use case (e.g.: once the manufactured objects have been recognized, call the BIM API to update it and ensure site monitoring).
Warnings & Notifications	An alert or notification can take the form of: • A push notification on a specifically developed mobile application. • A message • An email • A sound or light signal on the site.
Services	Each information is then transmitted via the corresponding module, to the associated processing pipelines. For example, the "progress" module will send to the RINNO Retrofitting Management pipeline, for comparison with the workflow and the planned schedule, then to the predictions with the trained model to identify the possible consequences of variations

Administration	Escalation of notifications or alerts in case of unavailability of a brick of the solution, via the "Alerts and Notifications" brick. These management services will be exposed in the form of Rest API to be integrated with external bricks in the enterprise IS if necessary, in the future. These same APIs will be used to drive and manage these services via an administrative Web HMI.

5.2.3.4 Process Optimization

5.2.3.4.1 Optimization Strategy offsite/onsite

This sub-module is the background technology of the Recommendation Engine sub-module. It consists of a multi-level decision framework. This sub-module is based on a excel document, where the user can score each criterion based on the project constraints. The first level (strategic level) conducts a feasibility study and evaluates the applicability of offsite construction. The second level (tactic level) proposes an integrated approach for the decision-making problem that combines the Analytical Hierarchy Process (AHP) and the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE). The combination of both approaches enables a careful evaluation of different construction methods and scenarios for the same project.

For the tactic level, it enables the decision maker to compare different industrialized solutions based on multi criteria decision methods. The decision maker finds the attributes of criterion in the AEC guides.

On top of this document, this sub-module will deliver:

- Offsite renovation score
- List of offsite drivers
- List of offsite constraints

Based on these results, the user will be able to decide clearly to offsite or onsite the renovation works.

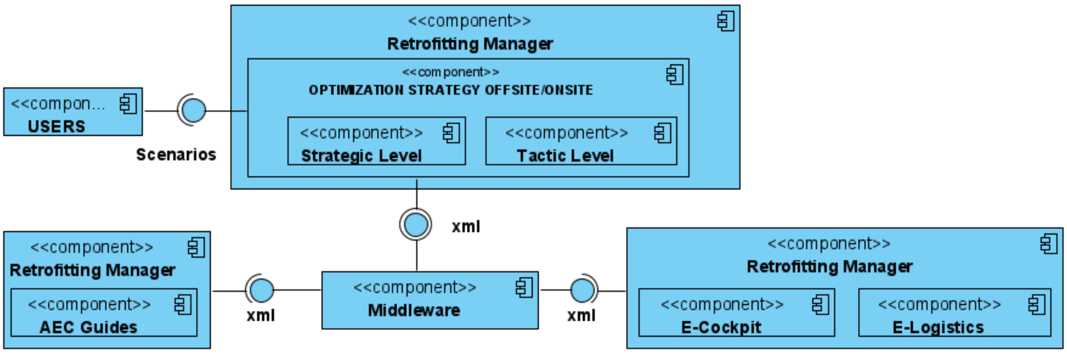

Figure 18 - Offsite/Onsite strategy Component Diagram

The following table explains in detail the main interfaces, and their interconnection with this module.

Table 28 - Offsite/Onsite strategy - Inputs

Offsite/Onsite strategy	Inputs Description
User Input (strategic level)	• Economic Factors • Site-related factors • Design and structural factors • Factors related to the project. • Factors related to the deadline, planning. • Labour-related factors
User Input (tactic level)	• Number of floors • Experience and mastery of the solution • Competence of the available workforce • Climatic conditions • Transport • Corporate culture • Availability of lifting tools • Weight • Environment • Acceptability of the solution • Architectural/aesthetic form • Cost • Complexity of the construction • Speed / Planning/ Delay • Security • Quality • Repeatability • Relationship with the supplier

Table 29 - Offsite/Onsite strategy - Outputs

Offsite/Onsite strategy	Outputs Description
User Input (strategic level)	An off-site construction score for the overall project as well as a score for each factor category. Two lists of factors: one list containing the factors that support off-site construction (the factors with the most positive weighted score) and a second list containing the factors that do not support it (the factors with the most negative weighted score).
Output (tactic level)	As a first step, it enables the importance of the different factors to be compared in order to weight them as objectively as possible, checking the consistency of the decision-maker's judgement. Secondly, this level allows to classify the compared alternatives.

5.2.3.4.2 E-Logistics

This sub-module is also part of **RINNO Retrofitting Manager** (RRM). It deals with the organization, display and tracking of all the material supply on and off site to allow risk minimization, lower costs and save space during the renovation process. The "E-logistics" platform will provide better control and overview of the whole supply chain during the renovation process addressing the related market need. To complement the renovation process optimization, the VIA-Process toolkit will be advanced to facilitate the whole lifecycle of the renovation process with an easy-to-use dashboard that will assign roles/tasks, solve any bottlenecks, and improve the engagement and monitoring of owners/users during renovation. This task forms the Process Optimization module of the RRM.

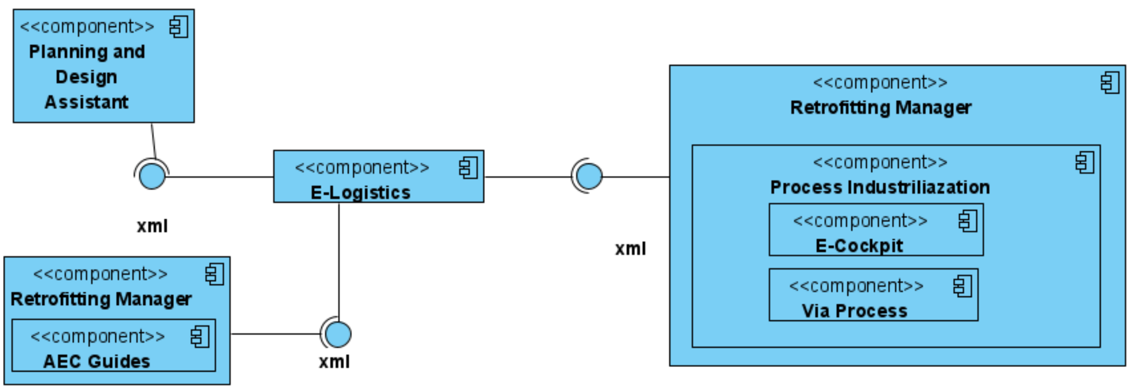

Figure 19 - E-logistics Component Diagram

The following tables explains in detail the main interfaces, and their interconnection with the E-Logistics module.

Table 30 - E-logistics - Inputs

E-cockpit	Inputs Description
BIM Model	The e-logistics will use the quantities of materials, supplies to determine the period of manufacturing and installation
Renovation Simulation and Assessment Toolbox	The e-logistics will check the solutions chosen for renovation, the suppliers selected for materials manufacturing and delivery
AEC Guides	The e-logistics will use the installation and storage guidelines integrated into this guide to optimize the integration of technology on site
Planning	The e-logistics will use the planning to coordinate all the deliveries and installations as per each task deadlines and project milestone

Table 31 - E-logistics - Outputs

E-cockpit	Outputs Description
E-cockpit	The e-logistics and e-cockpit will have an important interaction in order to optimize the deliveries on site as per the real time progress on site to optimize storage and installation flow
Via-Process	Via-process will be used to visualize the flow of operations measured and monitored by e-logistics

5.2.4 Building Lifecycle Renovation Manager (BLRM)

5.2.4.1 Intelligent Renovation Assistant

Intelligent Renovation Assistant (IRA) is the module of **Building Lifecycle Renovation Manager**. It follows the building renovation project through its whole lifetime. IRA consists of Renovation Validation and Benchmarking tool, Building Renovation Passports, Renovation Roadmap tool and Logbook Tool that allows to monitor and validate the renovation process, as well as generate information about the building. Accordingly, Validation & Benchmarking sub-module will get design data from **RINNO Planning & Design Assistant** and compare them with actual data. This module will also collect and normalize data from all available renovated buildings to create a repository for benchmarking. In that way a building information (logbook) including historic, on-site or automatically generated data enabled by IoT is formed, in accordance with the Building Renovation Passports (BRPs) approach to follow a building throughout its lifetime. This leads to the formation of the Renovation Roadmap of the building.

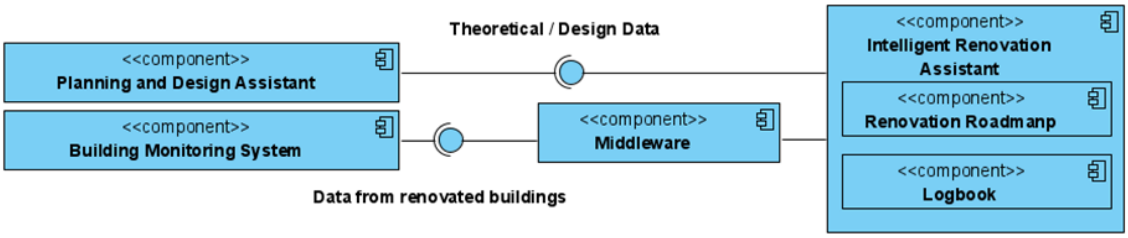

Figure 20 - Intelligent Renovation Assistant Component Diagram

Table 32 - Intelligent Renovation Assistant - Inputs

Intelligent Renovation Assistant	Inputs Description
Theoretical and design data	Assistant gets from RPDA data from the design phase of renovation
Data from all available renovated buildings	Assistant gets from Building Monitoring System data from the whole renovation history

Table 33 - Intelligent Renovation Assistant - outputs

Intelligent Renovation Assistant	Outputs Description
Renovation Roadmap	Renovation Roadmap includes systematic renovation solutions over a long period of time and in a sensible order aiming to achieve deep-staged renovation, in accordance with the BRPs approach
Logbook	It will consist of an inventory of building-related information accompanied by technologies for managing/ monitoring real time parameters along with historical data

5.2.5 RINNO Renovation Repository

RINNO Renovation Repository includes a wide range of proficient solutions that fit the requirements of the stakeholders. **Repository** provides both conventional and also innovative renovation solutions. Repository feeds the **Marketplace of the Operational Platform** with solutions and technologies. Moreover, **Marketplace** provides to the **Repository** new technologies delivered by Third-Party Stakeholders, in order to optimize each renovation solution. The **RRR** also generates automatic databases of the technologies and the renovation products. The technologies and solutions of the Repository will assist other main components of **RINNO** to generate optimal scenarios and the optimal renovation workflow.

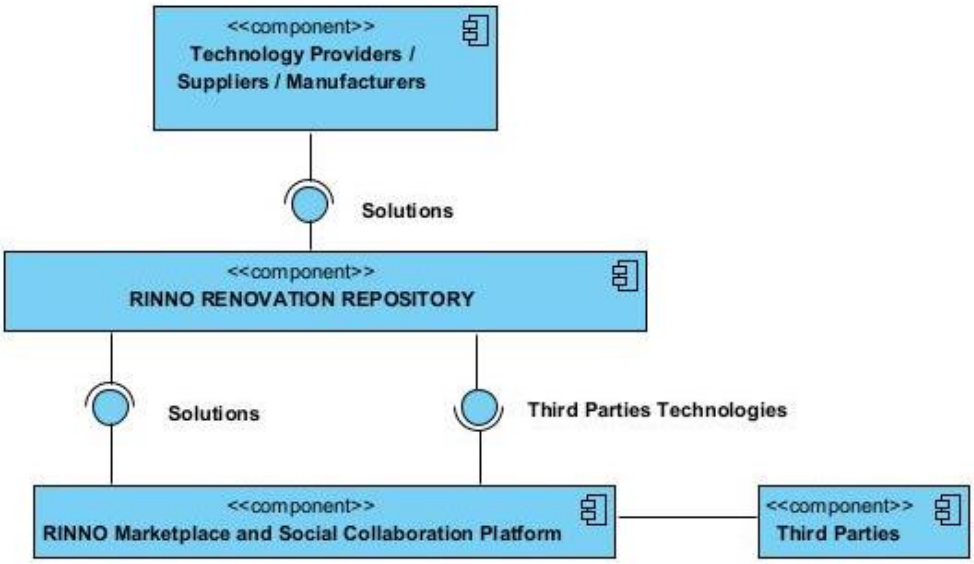

Figure 21 - RINNO Renovation Repository Component Diagram

Table 34 - Renovation Repository - Inputs

RINNO Renovation Repository	Inputs Description
Solutions provided to the RINNO Renovation Repository by the Technology Providers	The solutions of the Repository include: • Envelope retrofitting solutions. • Energy systems (RES harvesting, hybrid & Storage Solutions). • Retrofitting process improvement techniques • Business Models

RINNO Renovation Repository	Inputs Description
Third parties' technologies	RINNO Renovation Repository will be crowd-populated through the Marketplace by third parties to facilitate its natural expansion and ensure that both novel and conventional solutions are included and can be used for optimizing each renovation case.
Solutions provided to the Marketplace by the RINNO Renovation Repository	The solutions of the Repository include: • Envelope retrofitting solutions.

	• Energy systems (RES harvesting, hybrid & Storage Solutions) • Retrofitting process improvement techniques • Business Models.

5.2.6 Multi - Sensorial Network

Multi - Sensorial Network is a set of heterogeneous physical devices that are installed in the buildings. The **Multi-Sensorial Network** consists of smart devices and sensors. The buildings are monitored in energy and in environmental aspects. The Network allows the connection between the buildings and the RINNO platform. More specifically, the **Multi-Sensorial Network** feeds the **Operational Platform** of the RINNO, through the **Middleware**, in order to monitor the performance of the building both before and after the renovation.

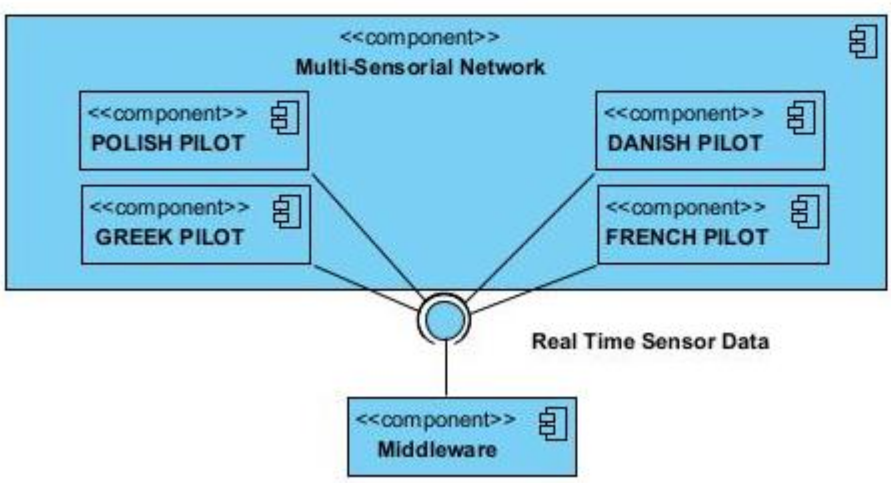

Figure 22 - Multi-Sensorial Network Component Diagram

Table 35 - Multi-Sensorial Network - Outputs

Multi-Sensorial Network	Outputs Description
Real Time Sensor Data	The Building Monitoring System gets information from any kind of device installed in the buildings through the Middleware. Middleware categorizes the data according to the building and the apartment/block of each building

5.2.7 Middleware

Middleware is as mentioned above the "glue" of the system. It ensures connectivity and interoperability between heterogeneous physical devices, and it allows data exchange among different components and modules of the RINNO platform. **Middleware** feeds the **Dashboard Monitoring System** of the **Operational Platform** with sensor data from the **Multi-Sensorial Network** in order to monitor the building performance in real time. Moreover, the modules of **Planning and Design Assistant** (RPDA), such as **Renovation Modeling** and **Optimizer**

and Planner assists **Middleware** with information about the building in form of an IFC file, with renovation scenarios as well as with the optimal renovation scenario workflow. Thus, **Middleware** will return the building, renovation and sensor information to the **Renovation Simulation and Assessment** toolbox of the same component (RPDA) in order to simulate and assess the fitting information. Additionally, **Renovation Workflow & Transactions Manager** (RTWM) assists **Middleware** with the smart contracts that have been signed between the stakeholders of the project. RTWM also enables, via **Middleware**, the information exchange between key components of RINNO. Finally, Middleware serves the On-the job AR environment module of **RINNO Retrofitting Manager** with HMI and Sensor data.

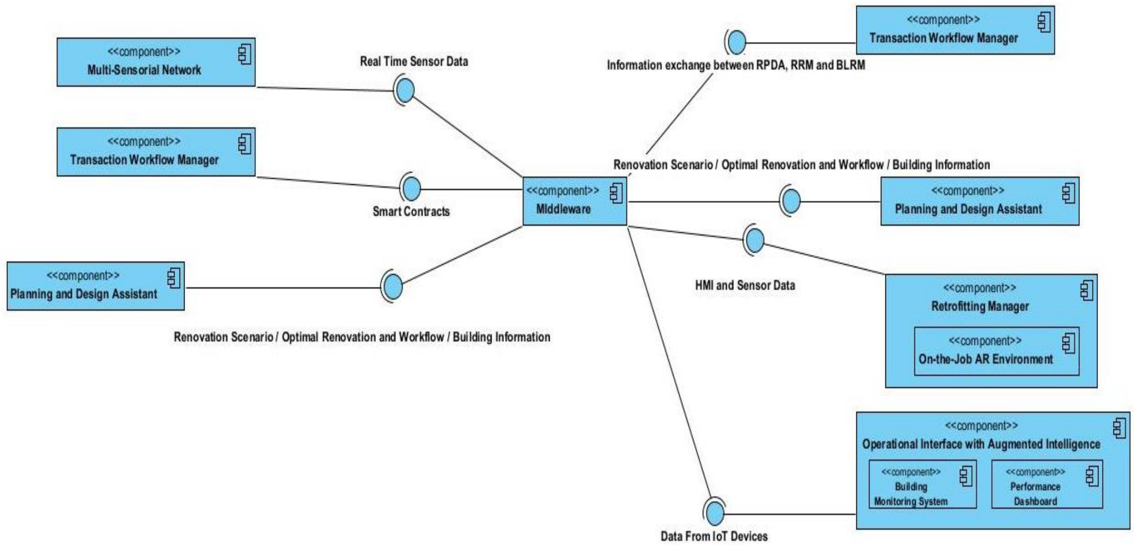

Figure 23 - Middleware Component Diagram

Table 36 - Middleware - Inputs

Middleware	Inputs Description
Renovation Scenario / Optimal Renovation and Workflow / Building Information (IFC)	Renovation's scenarios are then ranked based on their performance in these three assessment categories. BIM model in the form of Industry Foundation Classes (IFC). The Industry Foundation Classes (IFC) data model is intended to describe architectural, building and construction industry data. It is a platform neutral, open file format specification that is not controlled by a single vendor or group of vendors. It is an object-based file format with a data model developed by building SMART (formerly the International Alliance for Interoperability, IAI) to facilitate interoperability in the architecture, engineering, and construction

	(AEC) industry, and is a commonly used collaboration format in Building information modelling (BIM) based projects.
Smart Contracts	Hyperledger Fabric based smart contracts will be used to enforce the agreements between the building tenants/owners and other stakeholders (AEC). They will also be used in Solidity. RINNO will use the Ricardian Contracts approach
Real Time Sensor Data	The Building Monitoring System gets information from any kind of device installed in the buildings through the Middleware. Middleware categorizes the data according to the building and the apartment/block of each building

Table 37 - Middleware - Outputs

Middleware	Outputs Description
Renovation Scenario / Optimal Renovation and Workflow / Building Information (IFC)	Renovation's scenarios are then ranked based on their performance in these three assessment categories. BIM model in the form of Industry Foundation Classes (IFC). The Industry Foundation Classes (IFC) data model is intended to describe architectural, building and construction industry data. It is a platform neutral, open file format specification that is not controlled by a single vendor or group of vendors. It is an object-based file format with a data model developed by building SMART (formerly the International Alliance for Interoperability, IAI) to facilitate interoperability in the architecture, engineering, and construction (AEC) industry, and is a commonly used collaboration format in Building information modelling (BIM) based projects
Data From IoT Devices	The Building Monitoring System gets sensor data from every apartment of each pilot in order to monitor building performance and extract useful information such as e.g., short-

	term energy consumption predictions, data correlations, comparisons, reports
HMIs data	Through smart devices such as tablets and smart phones as well as smart helmets, workers provide information (location-based data and communication data in the form of sound, video, text, and AR content) so that the AR Assistance tool & AR Training tool can provide guidance and practical information for training purposes along with a variety of services
Sensor Data	Through a plethora number of devices and sensors such as AR/VRs scanners, drones, robots, cobots and photogrammeters, the data gathered allow to determine if the renovation procedures are correctly implemented. This data from the training scenarios will also form a knowledgebase to be exploited for the training of inexperienced workers. This data must support the services provided by the AR Assistance tool and AR Training tool. Such data for example must include geolocating BIM Data of the construction site
All information that should be exchanged between RPDA, RRM, and BLRM components.	The RWM tool will guarantee information exchange and interoperability between the main components of RINNO Suite, and during the whole lifecycle of the renovation project. BIM Model: this tool allows providing the BIM model from the IR definition stage, where it is just a set of information needs, until the operation and end of life stage.

5.2.8 Renovation Workflow & Transactions Manager (RWTM)

5.2.8.1 Renovation Workflow Manager (RWM) Tool

Renovation Workflow Manager (RWM) Tool is a module that belongs to the RINNO **Renovation Workflow and Transactions Manager** component. It enables information exchange and interoperability between **RINNO Planning & Design Assistant** (RPDA), **RINNO Retrofitting Manager** (RRM), and **RINNO Lifecycle Renovation Manager** packages.

The RWM tool allows the supervision of the whole lifecycle of the building renovation project by:

- Automating the quality assurance processes at all stages of the renovation project.

- Improving project coordination and project management reporting.
- Allowing project performance and data visualization.

Thus, technically the RWM tool should:

- Implement a documented collaboration format
- Propose and implement a suite of associated verification libraries
- Implement a cryptographic signature
- Be equipped with dashboarding capabilities
- Adopt a RESTful API infrastructure with Web service APIs

This component will be developed based on the Deep Renovation Digital Plan (DRIP) platform whose main components are the Xbim Xplorer platform and the Digital Plan of Work (DPoW) as depicted in the schema below.

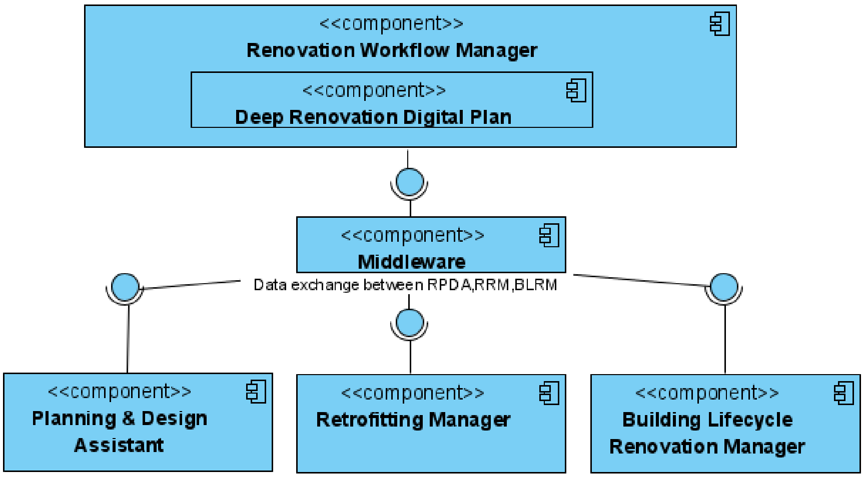

Figure 24 - Renovation Workflow Tool Component Diagram

The following table explains the main interfaces, and their interconnection with the RWM component.

Table 38 - Renovation Workflow Tool - Inputs

Renovation Workflow Tool	Inputs Description
All information that should be exchanged between RPDA, RRM, and BLRM components	The RWM tool will guarantee information exchange and interoperability between the main components of RINNO Suite, and during the whole lifecycle of the renovation project. BIM Model: this tool allows providing the BIM model from the IR definition stage, where it is just a set of information needs, until the operation and end of life stage.

Table 39 - Renovation Workflow Tool - Outputs

Renovation Workflow Tool	Outputs Description
All information that should be exchanged between RPDA, RRM, and BLRM components	The RWM tool will guarantee information exchange and interoperability between the main components of RINNO Suite, and during the whole lifecycle of the renovation project. BIM Model: this tool allows providing the BIM model from the IR definition stage, where it is just a set of information needs, until the operation and end of life stage.

5.2.8.2 Renovation Transaction manager toolkit

Transaction Manager is a module of **Renovation Workflow and Transaction Manager** (RWTM). The establishment of simpler, more effective transactions will reduce transaction costs, will provide transparency, assurance and provenance, and thus better and more trusted collaboration without the need for a central authority or a legal system. Transaction Manager uses distributed ledger (blockchain-type) technologies in order to translate conventional agreements into smart contracts for automated transactions. Smart contracts will be used to enforce the agreements between the building tenants/owners and other stakeholders. Smart contracts will be based on Ethereum and will be used in Solidity to facilitate transactions among multiple parties. The RWTM will be developed based Distributed Ledger Technologies (DLT) and more specifically in an alternative approach called Ricardian Contracts. As a result, **Transaction Manager** will advance the integration between Smart Contracts and Ricardian contracts. It will also encode, and compile rules written in the Ricardian-type, human readable language into a functional, machine-readable language that will be translatable to smart contracts in the next levels of the pipeline using appropriate compiler techniques and communication APIs.

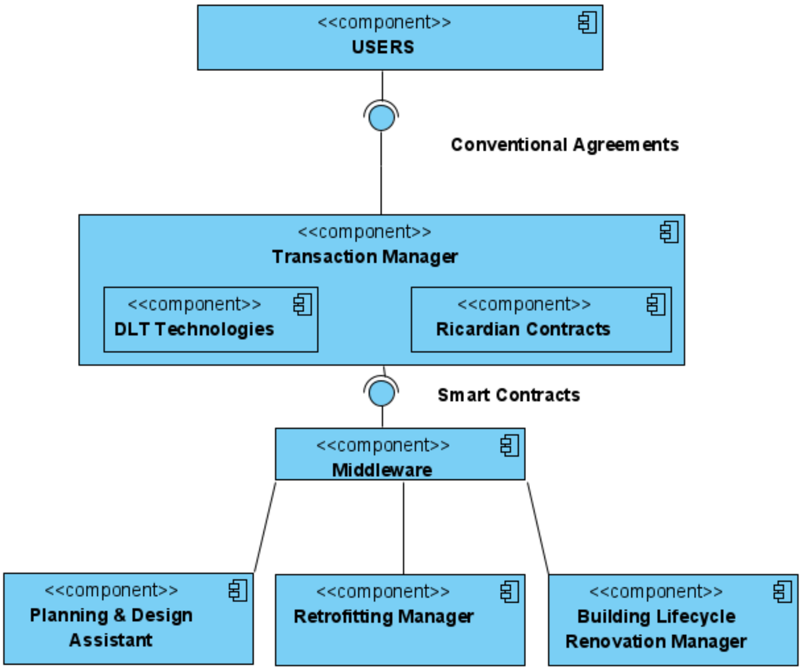

Figure 25 - Transaction Manager Component Diagram

Table 40 - Transaction Manager - Inputs

Transaction Manager	Inputs Description
Conventional Agreements	Human readable agreements between stakeholders, tenants and participants e.g. renovation subcontractors

Table 41 - Transaction Manager - Outputs

Transaction Manager	Inputs Description
Smart Contracts	Ethereum based smart contracts will be used to enforce the agreements between the building tenants/owners and other stakeholders (AEC). They will also be used in Solidity. RINNO will use the Ricardian Contracts approach

6 Deployment View

Deployment view describes how and where the system will be deployed, which physical requirements are essential for the system to go live. Another important factor is the dependencies of the various components, modules, and sub-modules, their hardware requirements, and their physical constraints. In this view the physical environment where the system will run is defined, including:

- Hardware and Technical requirements.
- Mapping of software elements to the runtime environment.
- Third-party software requirements.
- Network requirements.

In this chapter it is analysed the deployment environment of the RINNO platform.

6.1 RINNO Main Components, Modules, and Sub-modules Deployment Environment & Hardware and Technical Requirements

6.1.1 RINNO Operational Interface with Augmented Intelligence

6.1.1.1 Social Collaboration Platform

Social Collaboration and **Middleware** are deployed on the Cloud Base Infrastructure of RINNO Suite the workstations and they are interconnected with a specialized intranet, that could be wired, wireless or a combination of both technologies.

It is important to mention that some Human Machine Interfaces (HMIs), due to their huge, produced data (such as video content) they are connected directly to components that need this form of data since the **Middleware** will not be able to handle this type of information. Only metadata will be forwarded to the **Middleware** or even to the repository.

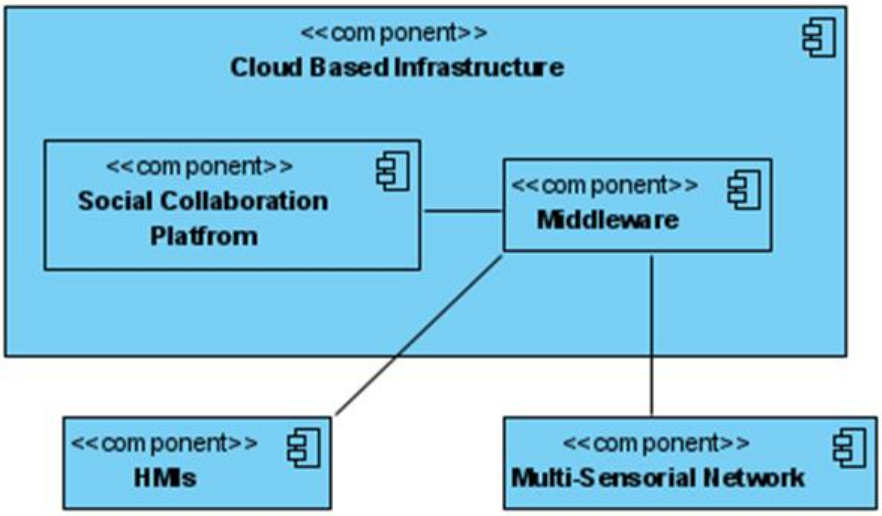

Figure 26 - Social Collaboration Platform Deployment View

Table 42 - Social Collaboration platform's Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6
Social Collaboration Platform	A PC workstation in the cloud with the following minimum requirements: • i5 CPU • 4GB RAM • 500 GB hard disk • Wi-Fi connection • Ethernet connection • USB connection • Windows 7 operating system or better

6.1.1.2 Marketplace

As shown in figure below, RINNO Marketplace is a cloud-based application interconnected with the Cloud Based Infrastructure of RINNO Suite. RINNO Marketplace connects with **RINNO Renovation Repository** directly.

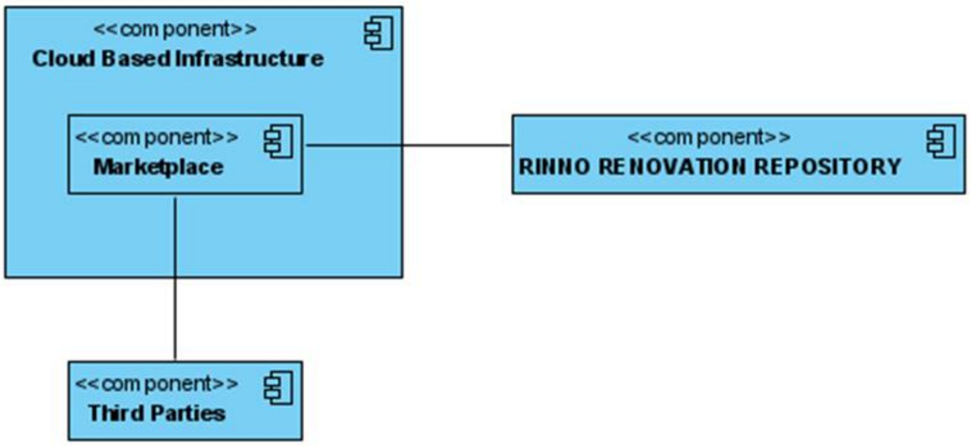

Figure 27 - Marketplace Deployment View

Table 43 - Marketplace Hardware and Technical Requirements

Name	Hardware and Technical Requirements
RINNO Marketplace	A PC workstation with the following minimum requirements: • i5 CPU • 4GB RAM • 500 GB hard disk • Wi-Fi connection • Ethernet connection • USB connection • Windows 7 operating system or better

6.1.1.3 Building Monitoring System

Building Monitoring System should be installed on the cloud based infrastructure of RINNO suite as shown in figure below. It connects directly with **RINNO Planning & Design Assistant** and feeds with data from the Building Performance Toolkit & Dashboard. Building Monitoring System gets data from the IoT devices through the **Middleware** installed in the Cloud Base Infrastructure of RINNO.

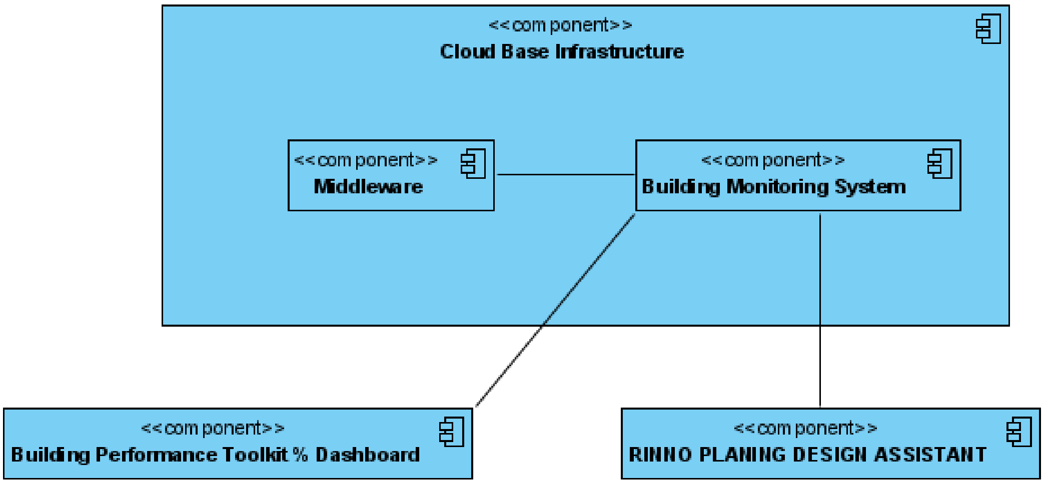

Figure 28 - Building Monitoring System Deployment View

Table 44 - Building Monitoring System Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Building Monitoring System	A PC workstation one the cloud with the following minimum requirements: • i5 CPU • at least 8GB RAM • 500GB hard disk • Wi-Fi connection

	• Ethernet/Bluetooth connection • Windows 10 operating system Use of open standard formats and libraries as • IFC • XML • COBie • XLS • bSDD • xBIMToolkit
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6

6.1.1.4 Central Dashboard

6.1.1.4.1 Building Performance Toolkit & Dashboard

Building Performance Toolkit & Dashboard should be installed on PC Workstation as shown in figure below. Building Monitoring System feeds with data the Building Performance Toolkit & Dashboard.

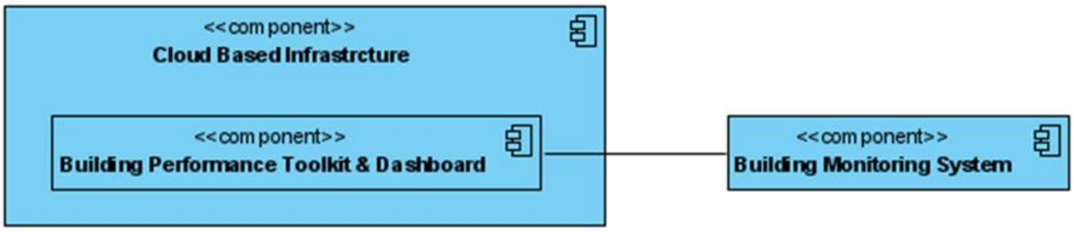

Figure 29 - Building Performance Toolkit & Dashboard Deployment View

Table 45 - Building Performance Toolkit & Dashboard Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Building Performance Toolkit & Dashboard	A PC workstation in the cloud with the following minimum requirements: • i5 CPU

	• 4GB RAM • 500GB hard disk • Wi-Fi connection • Ethernet connection • Windows 10 • MySQL 5.7 • NodeJs 14.17 (TBU) • Angular 10.1.4

6.1.1.4.2 AR/ VR User Interfaces (UIs)

This Section is referred to the User Interfaces (UIs), which will be delivered by the AR on-the-job training toolkit and it will be deployed as presented in Section 4.1.3.1.

6.1.2 RINNO Planning & Design Assistant (RPDA)

6.1.2.1 RINNO Renovation Optimizer and Planner Environment

The RINNO Optimizer and Planner component should be installed on a server machine, as it must be able to exchange data with the rest of the modules at any time. The server machine should be connected to the Internet or to a local network which interconnects the various tools and enables it to communicate with both the rest of the modules of the RPDA and the RWTM. The same machine that hosts some other tool of the RPDA can be used to host this module, too.

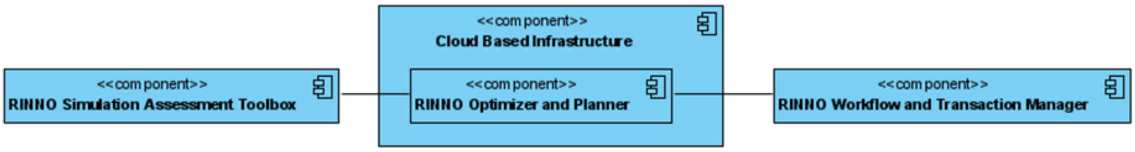

Figure 30 - RINNO Renovation Optimizer and Planner's Deployment View

Table 46 - RINNO Renovation Optimizer and Planner Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6

6.1.2.2 Renovation Simulation & Assessment tool

6.1.2.2.1 Energy Assessment tool

For the energy assessment tool, all required modules should be installed as shown in figure below, located in the Cloud Base Infrastructure of RINNO.

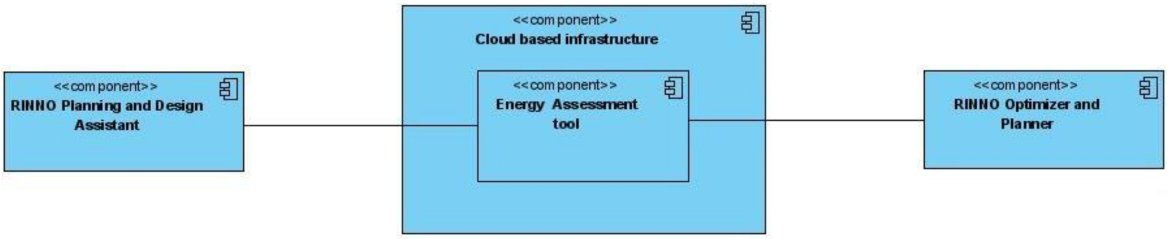

Figure 31 - Energy Assessment Platform's Deployment View

Table 47 - Energy Assessment Platform's Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Energy Assessment Tool	• Windows 10 operating system • Python Environment (e.g., anaconda or miniconda)
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6
Multi-Sensorial Network	A local installation with the following requirements: • Wi-Fi or Ethernet connection • Bluetooth connection • USB connection for direct connections to third devices (PCs, tablets, smartphones, other) • QUAD-CORE arm Cortex-A9 (set ARMv7) • 4GB RAM • 16GB ROM • Display 10” • Android 4.4 (KitKat) operating system

6.1.2.2.2 Techno-economical Assessment Tool

The Techno-Economical Assessment tool will be installed on the cloud to ensure the continuous exchange of data with the Renovation Modelling toolkit and to the RINNO optimizer and planner. The server machine should be always connected to the internet through Ethernet cable.

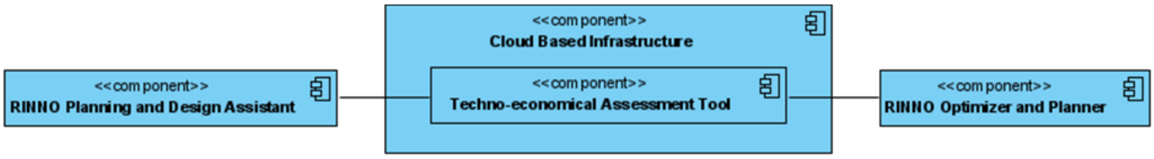

Figure 32 - Techno-economical Assessment Tool Deployment View

Table 48 - Techno-economical Assessment Tool Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6
Techno-economical Assessment Tool	• Windows 10 operating system • Python Environment (e.g., anaconda or miniconda)

6.1.2.2.3 Environmental, Cost and Social Assessment tool

Environmental, cost, and social assessment module will be developed under a web application framework scheme on the cloud. The full-stack framework will be able to execute Ruby and Python programming language, providing the ability to compute KPI's for the whole life cycle. The environmental, cost and assessment tool will be installed in a server machine, providing continuous access from and to the Renovation Modelling toolkit and to the RINNO optimizer and planner. The cloud infrastructure should be always connected to the internet through Ethernet cable.

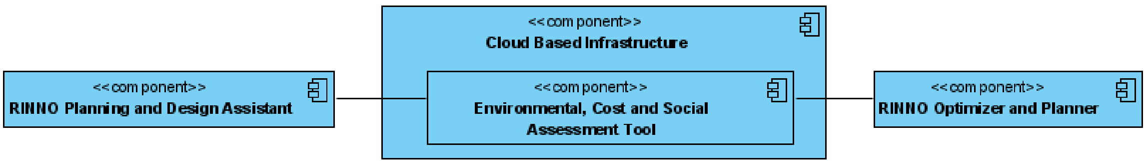

Figure 33 - Environmental, Cost and Social Assessment Tool's Deployment View

Table 49 - Environmental, Cost and Social Assessment Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6
Environmental, Cost and Social Assessment	• Windows 10 operating system • Python Environment (e.g., anaconda or miniconda)

6.1.2.3 Renovation Modelling

6.1.2.3.1 Building Capturing and Mapping Deployment View

Building, Capturing and Mapping toolbox is installed in a PC workstation locally. It provides BIM model to the system in the form of Industry Foundation Classes (IFC) via the **Middleware** located in Cloud Based Infrastructure.

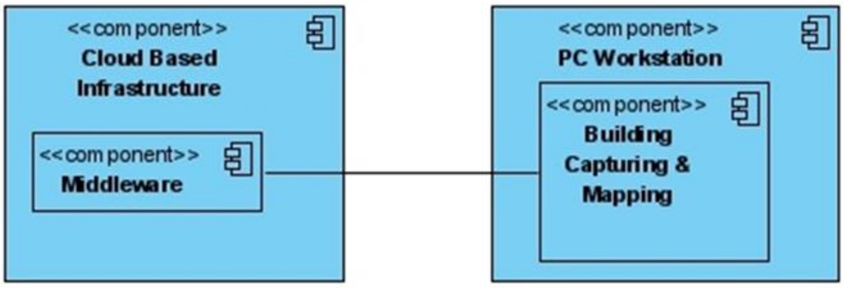

Figure 34 - Building Capturing and Mapping Deployment View

Table 50 - Building Capturing and Mapping Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Building, Capturing and Mapping toolbox	A PC workstation the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection

	Use of open standard formats and libraries as • IFC • XML • COBie • XLS • bSDD • xBIMToolkit

6.1.2.3.2 Renovation Digital-Twin component Deployment View

Renovation digital-Twin sub module will be installed to the cloud-based infrastructure of RINNO suite and can be accessed through REST API web services.

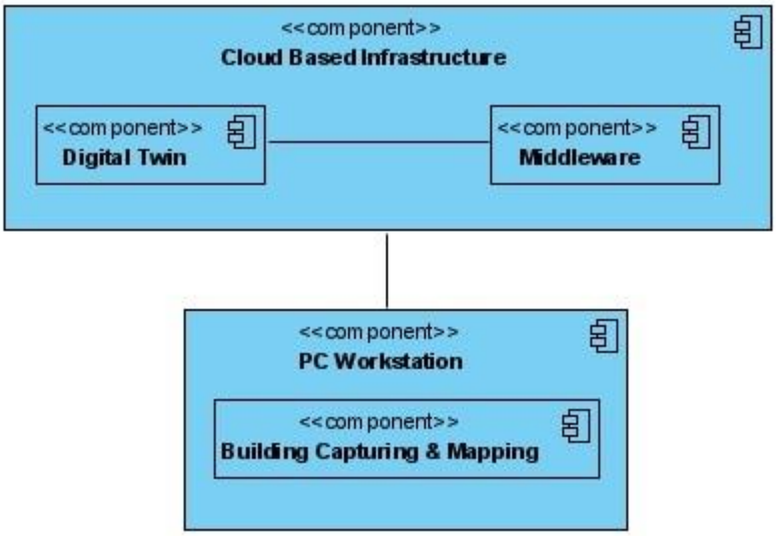

Figure 35 - Renovation Digital Twin Deployment View

Table 51 - Renovation Digital Twin Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6

6.1.3 RINNO Retrofitting Manager (RRM)

6.1.3.1 On-the-Job AR Environment

On the Job AR environment is installed locally and connects with the **Middleware** on the Cloud Base Infrastructure of RINNO Suite.

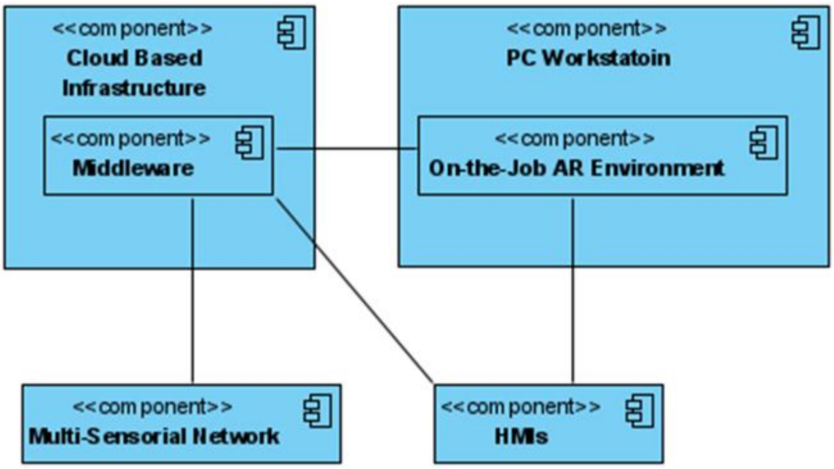

Figure 36 - On-the-Job AR Environment Deployment View

Table 52 - On-the-Job AR Environment Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6
On-the-Job AR Environment	• i5 CPU (last Generation) • 4GB RAM • 500GB hard disk • NVidia GPU GTX 650 2GB • Wi-Fi connection • Ethernet connection • Windows 7 operating system or better.

6.1.3.2 RINNO Retrofitting Manager Engine

As shown in figure below, the Smart Connected Buildings (SCB) platform is a cloud-based application and needs to be deployed on a server with all its components (Model, View, Controller and Advice Service components), interconnected with the Cloud Base Infrastructure of RINNO Suite.

The SQL Model (Database) size will be constrained by the physical hard drive space available. The number of concurrent connections including API posts, that the SCB can support is linked to the speed of which data can be queried and posted all have a relationship to the physical memory and CPU.

The **Multi-Sensorial Network** and a variety of HMIs can be in a local installation that will provide information to the cloud through the **Middleware Infrastructure**.

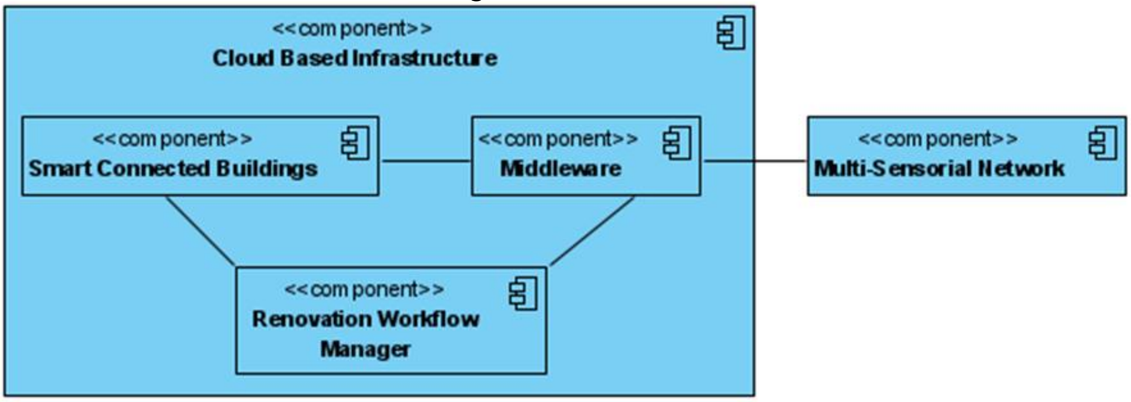

Figure 37 - RINNO Retrofitting Manager Engine Deployment View

Table 53 - RINNO Retrofitting Manager Engine Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Multi-sensorial Network	A local installation with the following requirements: • Wi-Fi or Ethernet connection • Bluetooth connection • USB connection for direct connections to third devices (PCs, tablets, smartphones, other) • QUAD-CORE arm Cortex-A9 (set ARMv7) • 4GB RAM • 16GB ROM • Display 10” • Android 4.4 (KitKat) operating system
SCB platform	A PC Workstation on the cloud will be needed with the following requirements: • i9

	• 32GB RAM • 5TB hard disk • Nvidia GeForce RTX 3080 10GB • Wi-Fi connection • Ethernet connection • Windows 7

6.1.3.3 Process Industrialization

The e-cockpit platform should be installed on the cloud as shown in figure below. It connects and exchanges data with other components and external apps in real time, through the **Middleware** installed in the Cloud Base Infrastructure of RINNO.

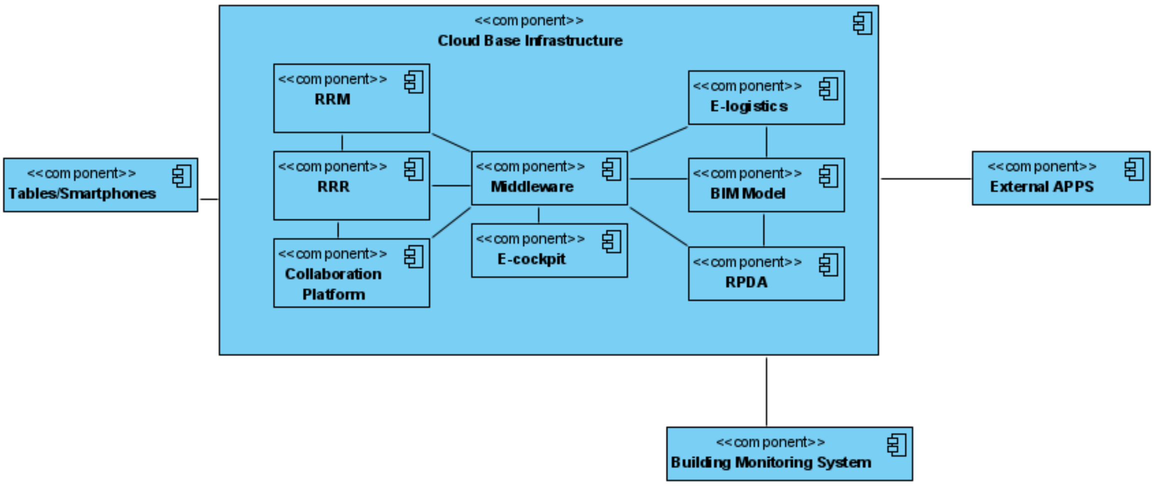

Figure 38 - E-Cockpit Deployment View

Table 54 - E-Cockpit Hardware and Technical Requirements

Name	Hardware and Technical Requirements
E-cockpit	A PC workstation on the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Use of open standard formats and libraries as: • IFC • XML • COBie • XLS

6.1.3.4 Process Optimization

6.1.3.4.1 E-Logistics

The e-logistics platform is installed on the Cloud Base Infrastructure of RINNO Suite as shown in figure below. It provides information to the **Renovation Transaction & Workflow Manager** and to e-cockpit platform through the **Middleware** installed in the Cloud Base Infrastructure of RINNO.

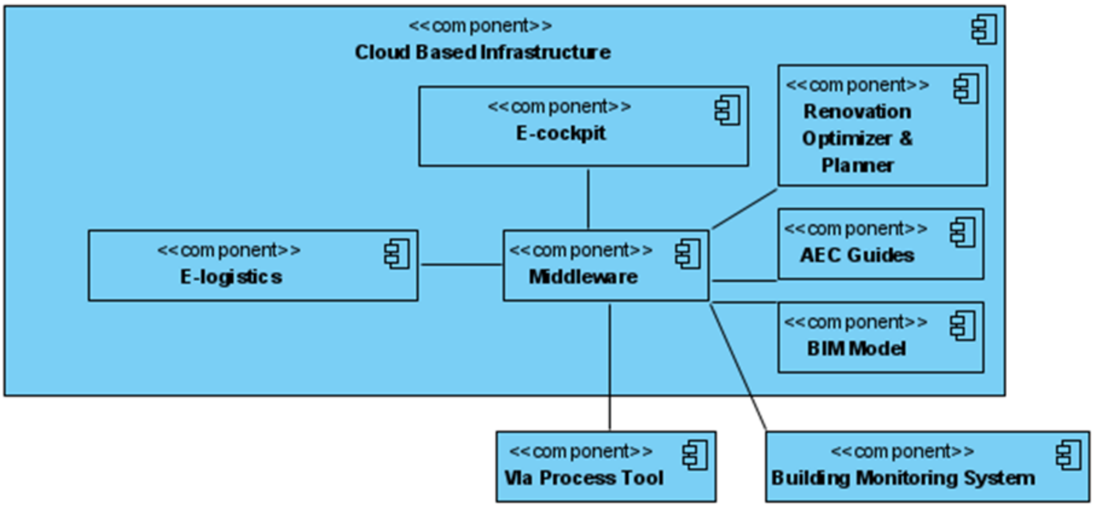

Figure 39 - E-Logistics Deployment View

Table 55 - E-Logistics Hardware and Technical Requirements

Name	Hardware and Technical Requirements
E-cockpit	A PC workstation on the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Use of open standard formats and libraries as: • IFC • XML • COBie • XLS

6.1.3.4.2 Optimization Strategy offsite/onsite

The module installed on the cloud and will retrieve data from the AEC guide via the **Middleware** the technical characteristics (installation, maintenance, performance…) of each technology and the rest of the input criteria will be identified by the user. All this to note each tactical and strategic phase to optimize the choice of the offsite/on site. The tool is in excel format with a detailed simulation via Python for the tactical phase. So, the output data will be converted itself into XML to feed the E-cockpit and E-logistics via the **Middleware**.

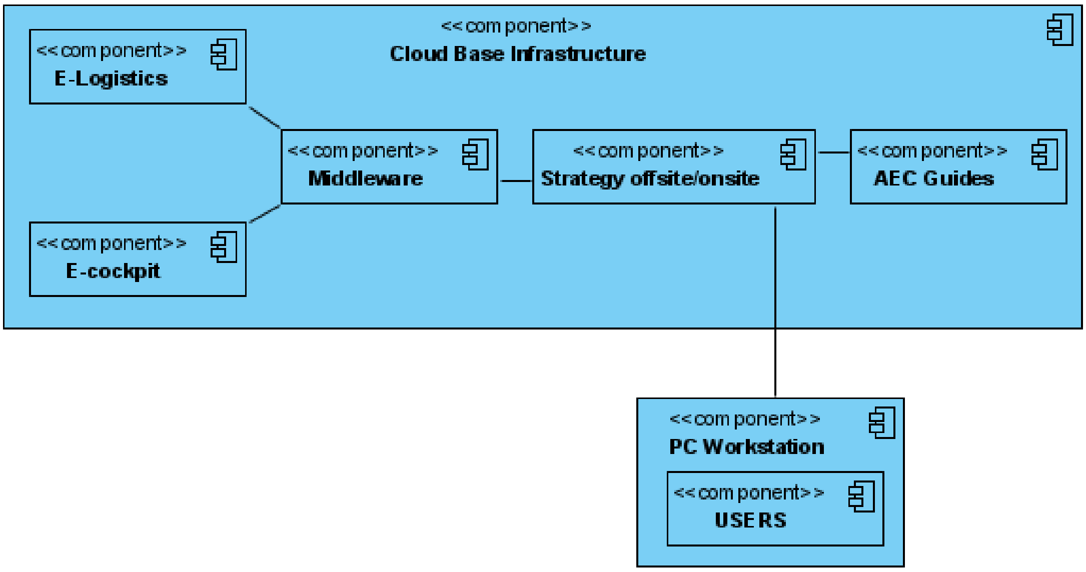

Figure 40 - Optimization Strategy offsite/onsite tool Deployment View

Table 56 - Optimization Strategy offsite/onsite tool Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Optimization Strategy offsite/onsite tool	A PC workstation on the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Use of open standard formats and libraries as: • IFC • XML • COBie • XLS
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6

6.1.4 Building Lifecycle Renovation Manager (BLRM)

6.1.4.1 Intelligent Renovation Assistant

As shown in the figure below, Intelligent Renovation Assistant on the Cloud Based Infrastructure of RINNO. It interacts directly with **Renovation Planning & Design Assistant** (RPDA) and it connects with the Building Monitoring System through the **Middleware** installed in the Cloud Base Infrastructure of RINNO.

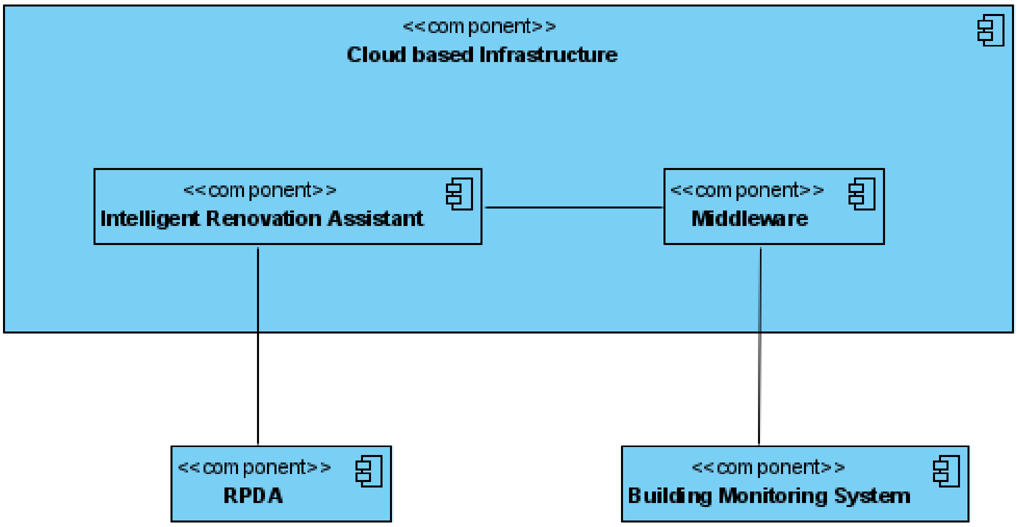

Figure 41 - Intelligent Renovation Assistant Deployment View

Table 57 - Intelligent Renovation Assistant Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Intelligent Renovation Assistant	A PC workstation on the cloud will be needed with the following minimum requirements: • i5 CPU is preferable • at least 4GB RAM • 500GB hard disk • Wi-Fi connection • Ethernet connection • Windows 7 operating system or better.
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher

	operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6

6.1.5 RINNO Renovation Repository

RINNO Renovation Repository consists of novel building and energy renovation technologies and also suitable business models. Stakeholders can have online access to the **Repository** through the **Marketplace**. It is worth to mention, that the **Repository** will be continuously updated with new technologies from third parties through the **Marketplace**.

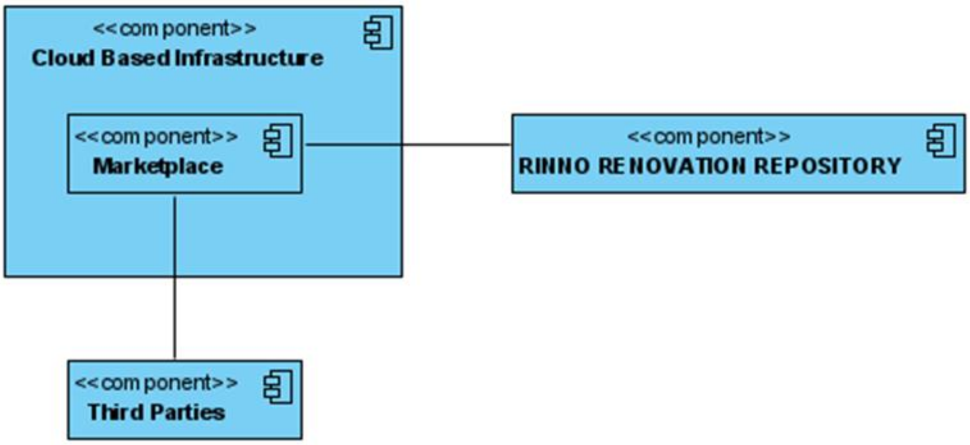

Figure 42 - RINNO Renovation Repository Deployment View

Table 58 - RINNO Renovation Repository Technical and Hardware Specifications

Name	Hardware and Technical Requirements
RINNO Renovation Repository	A PC workstation with the following minimum requirements: • i5 CPU • 4GB RAM • 500 GB hard disk • Wi-Fi connection • Ethernet connection • USB connection • Windows 7 operating system or better

6.1.6 Multi - Sensorial Network

Multi-sensorial Network is deployed locally in each pilot. It consists of a set of smart devices, smart sensors and legacy equipment that are installed on-site in each building. It directly communicates with the Middleware that is installed in the cloud.

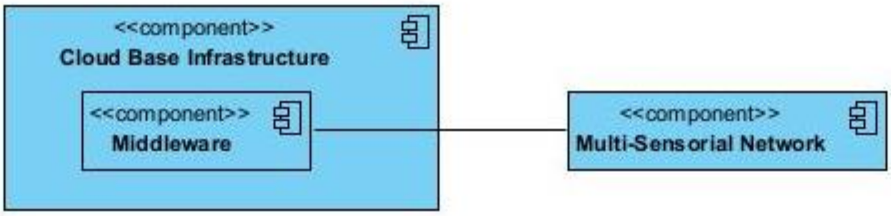

Figure 43 - Multi-Sensorial Network Deployment View

Table 59 - Multi-Sensorial Network Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Multi-Sensorial Network	A local installation with the following requirements: • Wi-Fi or Ethernet connection • Bluetooth connection • USB connection for direct connections to third devices (PCs, tablets, smartphones, other) • QUAD-CORE arm Cortex-A9 (set ARMv7) • 4GB RAM • 16GB ROM • Display 10” • Android 4.4 (KitKat) operating system

6.1.7 Middleware

Middleware as well as **Planning and Design Assistant**, **Transaction Workflow Manager** and **Operational Interface with Augmented Intelligence** are deployed on the cloud. **On the Job AR** environment module is installed locally and connects with the **Middleware** on the Cloud Base Infrastructure of RINNO Suite. The **Multi-Sensorial Network** and a variety of HMIs can be in a local installation that will provide information to the cloud through the **Middleware Infrastructure**.

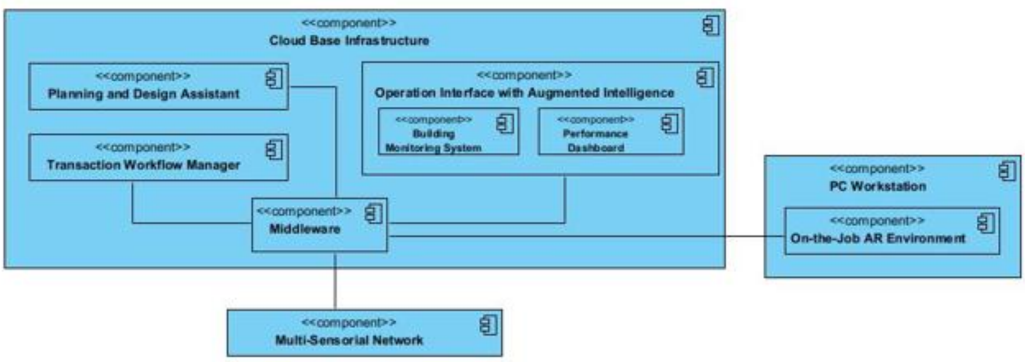

Figure 44 - Middleware Deployment View

Table 60 - Middleware Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6
Multi-Sensorial Network	A local installation with the following requirements: • Wi-Fi or Ethernet connection • Bluetooth connection • USB connection for direct connections to third devices (PCs, tablets, smartphones, other) • QUAD-CORE arm Cortex-A9 (set ARMv7) • 4GB RAM • 16GB ROM • Display 10" • Android 4.4 (KitKat) operating system
On-the-Job AR Environment	• i5 CPU (last Generation) • 4GB RAM • 500GB hard disk • NVidia GPU GTX 650 2GB • Wi-Fi connection • Ethernet connection • Windows 7 operating system or better
Operational Interface with Augmented Intelligence	A PC workstation one the cloud with the following minimum requirements: • i5 CPU • at least 8GB RAM • 500GB hard disk • Wi-Fi connection • Ethernet/Bluetooth connection • Windows 10 operating system

	Use of open standard formats and libraries as • IFC • XML • COBie • XLS • bSDD • xBIMToolkit

6.1.8 Renovation Workflow & Transactions Manager (RWTM)

6.1.8.1 Renovation Workflow Manager Tool

As shown in figure below, the RWM platform is composed of two parts, one is cloud-based application (the Digital Presentation Component) and another desktop-based application installed locally, a set of verification tools, including the Xbim Xplorer component.

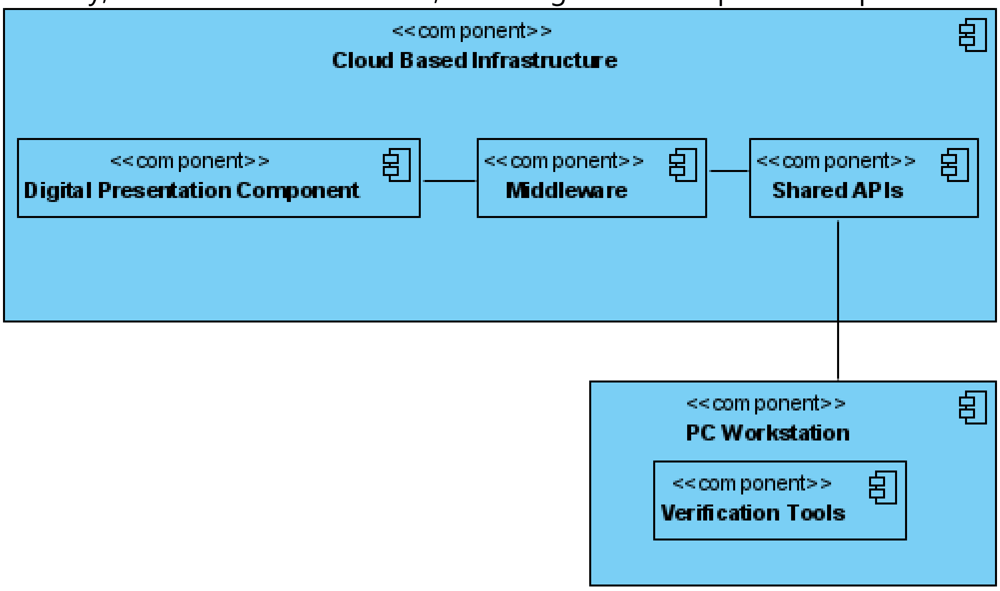

Figure 45 - Renovation Workflow Manager Tool Deployment View

Table 61 - Renovation Workflow Manager Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Verification Tools	A PC Workstation on the cloud with the following requirements: • i9 CPU • 32GB RAM • 500GB hard disk • Nvidia GeForce RTX 3080 10GB • Wi-Fi connection • Ethernet connection • Windows 7

Digital Presentation Component	A PC Workstation on the cloud will be needed with the following requirements: • i9 • 32GB RAM • 5TB hard disk • Nvidia GeForce RTX 3080 10GB • Wi-Fi connection • Ethernet connection • Windows 7

6.1.8.2 Renovation Transaction Manager

As shown in figure below, the **Transaction Manager** is a web service module and needs to be deployed on a server with all its features, interconnected with the Cloud Base Infrastructure of RINNO Suite.

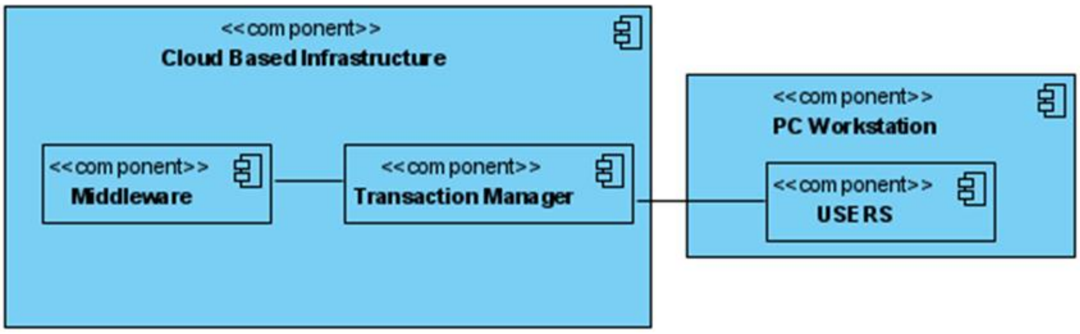

Figure 46 - Renovation Transaction Manager Tool Deployment View

Table 62 - Renovation Transaction Manager Hardware and Technical Requirements

Name	Hardware and Technical Requirements
Transaction Manager	• Windows 10 operating system • Solidity Compiler
Middleware	A PC workstation one the cloud the following minimum requirements: • I5 CPU • at least 8GB RAM • 250GB hard disk • Ethernet connection Ubuntu Server 18.04 or higher operating system with: • Ruby 2.7.0 • Rails 6.0.3 • Python 3.8.6

7 Information View

7.1 Overview of Information View

The figure below describes the data flow. The present viewpoint outlines the way that the system manages and distributes information.

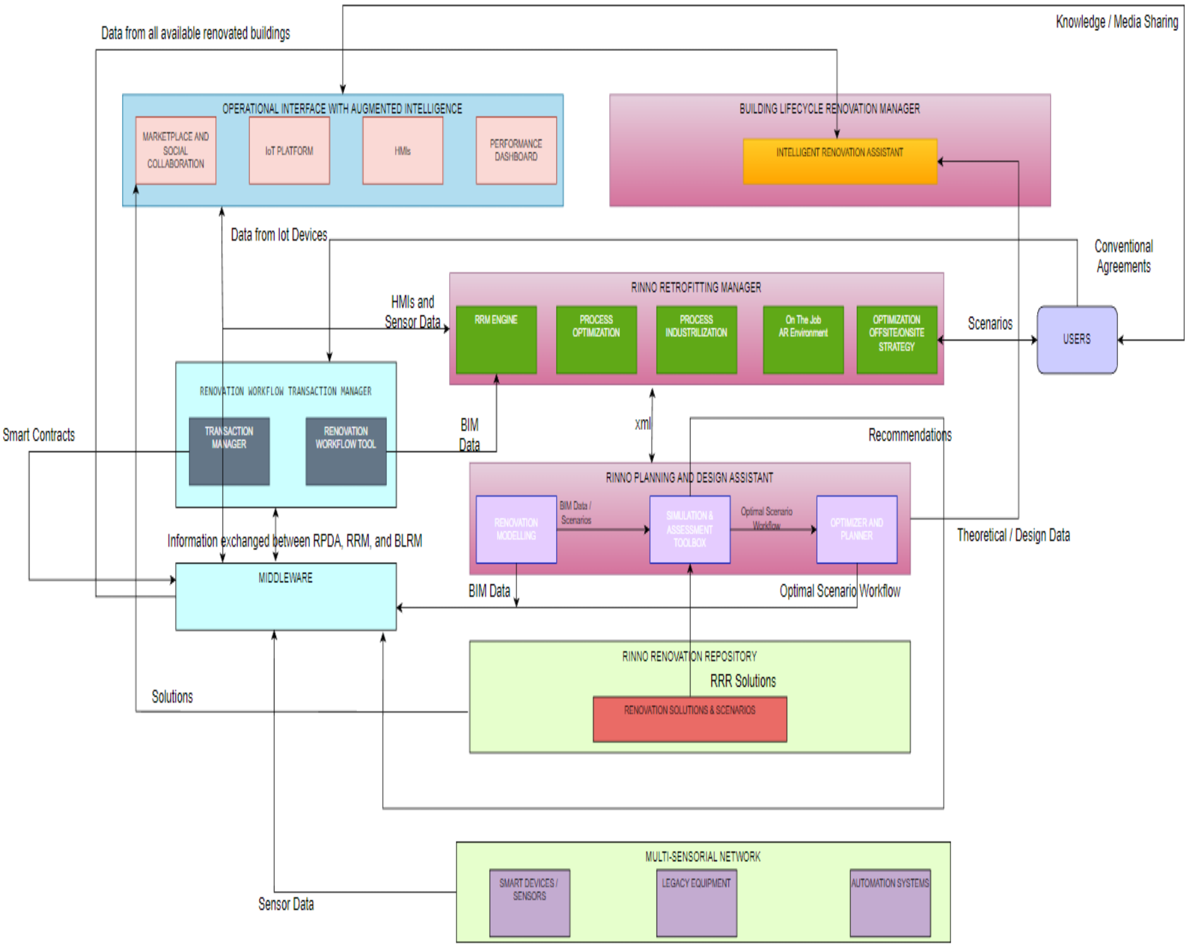

Figure 47 - Overall Information View of Architecture

8 Technical Use Cases Instantiation

This section describes some selected use cases by means of simple sequence diagrams in order to explain how the RINNO platform behaves to deliver its key services.

8.1 Use Case 1 Contractors Work Progress

Transaction Manager is responsible for the attachments of smart contracts between stakeholders (e.g. between contractors and building owners or tenants). Contractors connect with the system and receive real time "on the job" assistance from the **Operational Platform**. **Retrofitting Manager** and **Planning and Design Assistant** capture planning and design data as well as building and renovation information in order to create an AR environment. Contractor will be connected with the AR environment with smart devices and receive real time work assistance. Finally, contractors can communicate with text or video with other stakeholders through the **Operation Platform and Workflow Manager**.

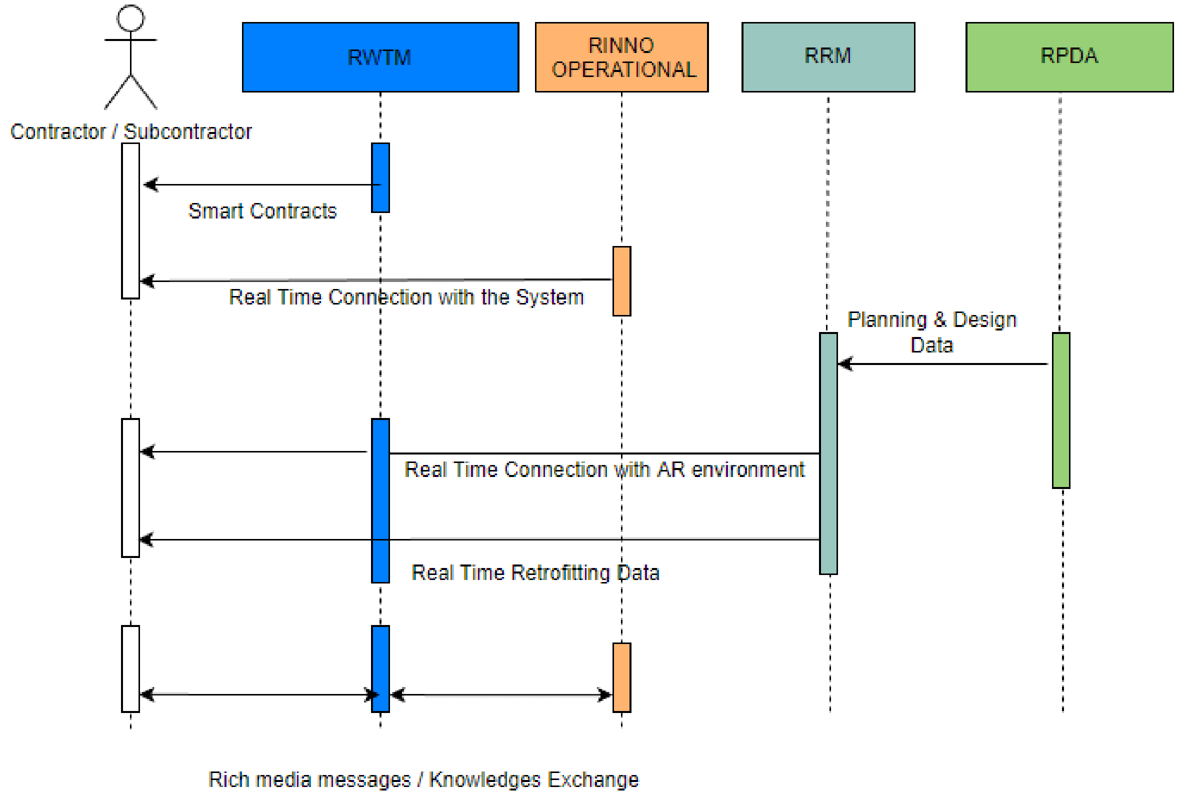

Figure 48 - Use Case 1 Diagram

8.2 Use Case 2 Building Performance Dashboard And BIM Viewer

Building Monitoring System (BMS) is a module of the **Operational Interface with Augmented Intelligence**. This module receives sensor data from buildings via **Middleware** and is capable of monitoring any IoT through the platform. Accordingly, the **Planning and Design Assistant** uses the Building Information Model in the form of an IFC file, with its Renovation Modeling module. **Monitoring System** connects renovation and sensor data with BIM context. BMS feeds the **Performance Dashboard of Operation Interface** with data produced by the devices that are installed in in pilot buildings. These data are used for comparing the before and after renovation energy consumption, monitor daily behaviour of tenants and adjusts to their preferences. The devices are connected to spaces within the pilot buildings so that the data are taken from real-life conditions Thus, building owners or tenants are able to create personalized dashboards based on the information they are interested in and also monitor the building performance through the 3d viewer (BIM with attached devices) of **Operational Interface**.

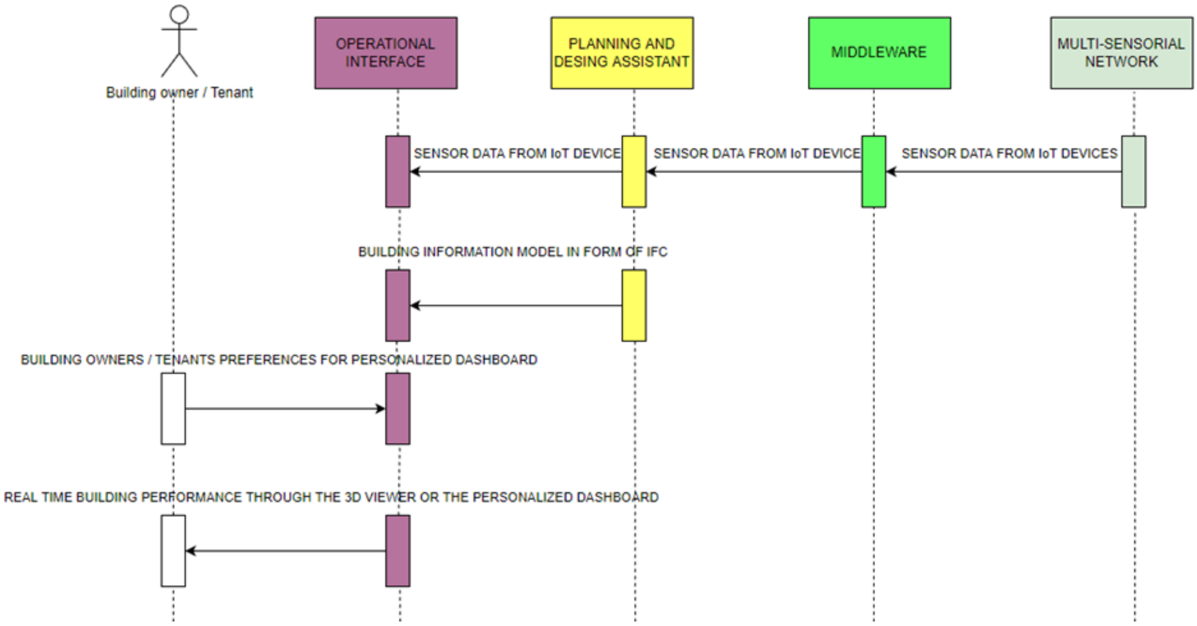

Figure 49 - Use Case 2 Diagram

8.3 Use Case 3 Assessment of Optimal Scenario

Industrial stakeholders supply RINNO material, equipment and technology solutions which are included to the **RINNO Renovation Repository** (RRR). Pilot owners define the requirements and requests of a renovation of the building via a survey. More specifically, they can examine which one of the proposed (by the project's experts) renovation scenario is more suitable to them regarding cost, energy, environmental and/or user disturbance point of view. For this purpose, **RINNO Simulation and Assessment toolbox** module of **RINNO Planning and Design Assistant** (RPDA) gathers information for cost, energy, environmental and/or user disturbance sector per proposed scenario so that it can simulate and assess the performance of each one. Afterwards, **RINNO Optimizer and Planner**, module of RPDA, along with the **Decision Support System**, module of RPDA, calculate metrics both grouped under the aforementioned categories and based on pilot owners' preferences in order to propose the optimal scenario a-priori. Finally, the optimal scenario is presented as result in the **RINNO Operational Platform** BIM viewer.

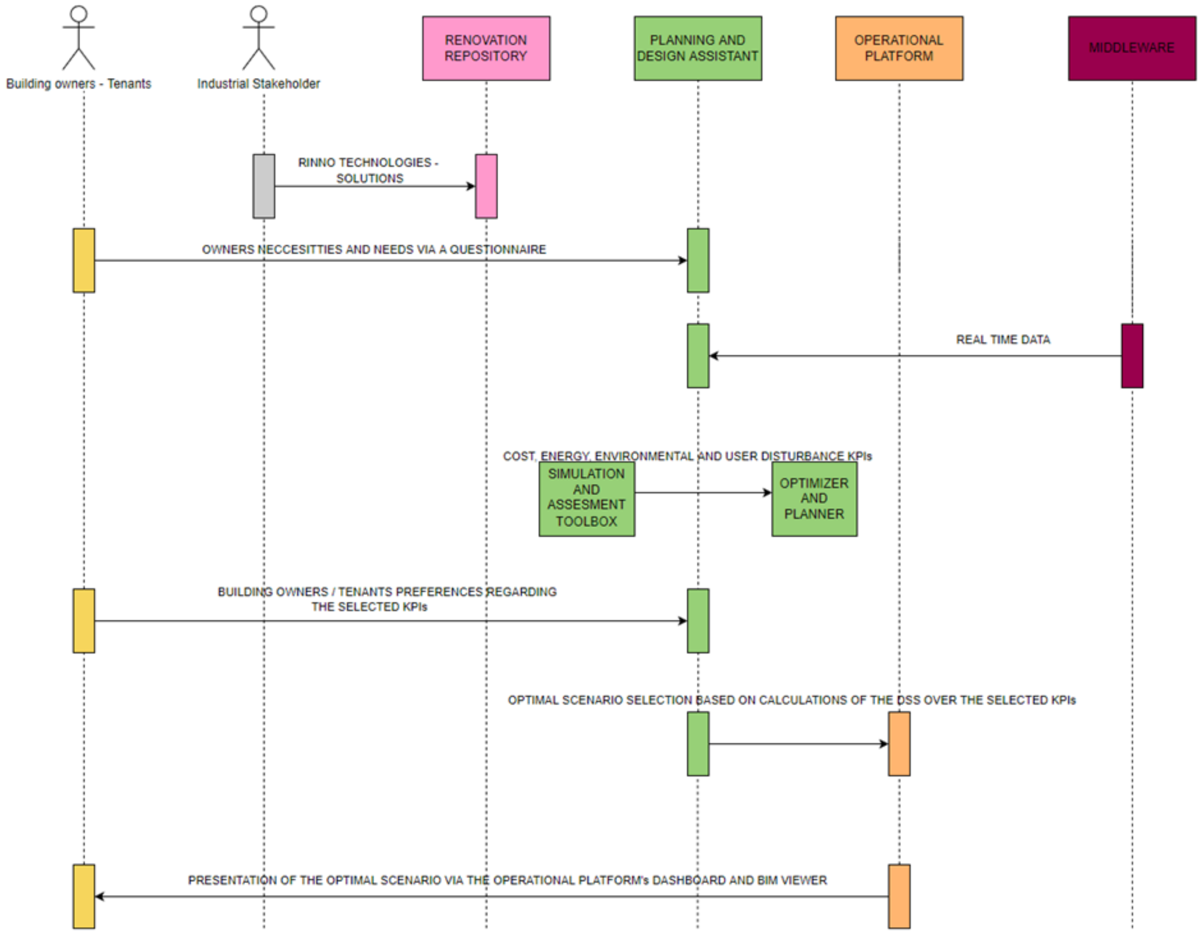

Figure 50 - Use Case 3 Diagram

8.4 Use Case 4 Interconnection of On-The-Job AR Tool With RRM

Contractors and sub-contractors, for example on-site and off-site stakeholders, receive the assigned tasks after the **Process Optimization** tool, module of the RINNO Retrofitting Manager (RRM), runs. The Process Optimization tool provides the aforementioned stakeholders with tutorials based on Augmented Reality capabilities for on-site assistance. Besides, there is available predefined educational material totally based on Virtual Reality, for off-line training purposes. This way, both "on the job" assistance and "simulated environment" training are achieved with step by step instructions. Thus, in case of off-site stakeholders, offered training material appears in **Marketplace**, module of RINNO Operational Platform with Augmented Intelligence, where the interested user can purchase it or download it for free. Regarding the on-site assistance, the contractor or subcontractor receives and opens the assigned tasks to the **AR Viewer**, module of On-the-Job AR tool. Available tutorials for these tasks are downloaded from the **AR Database** and the user can follow a tutorial dedicated to the step for which he/she needs assistance. Besides, if tutorial is not enough, the user can ask for live assistance from available users with more expertise. The available users appear in the AR Viewer and those online can annotate remotely, additional information to help the user. In Figure 51, the flow of on-the-job AR assistance is presented while in Figure 52 the offline training diagram is shown.

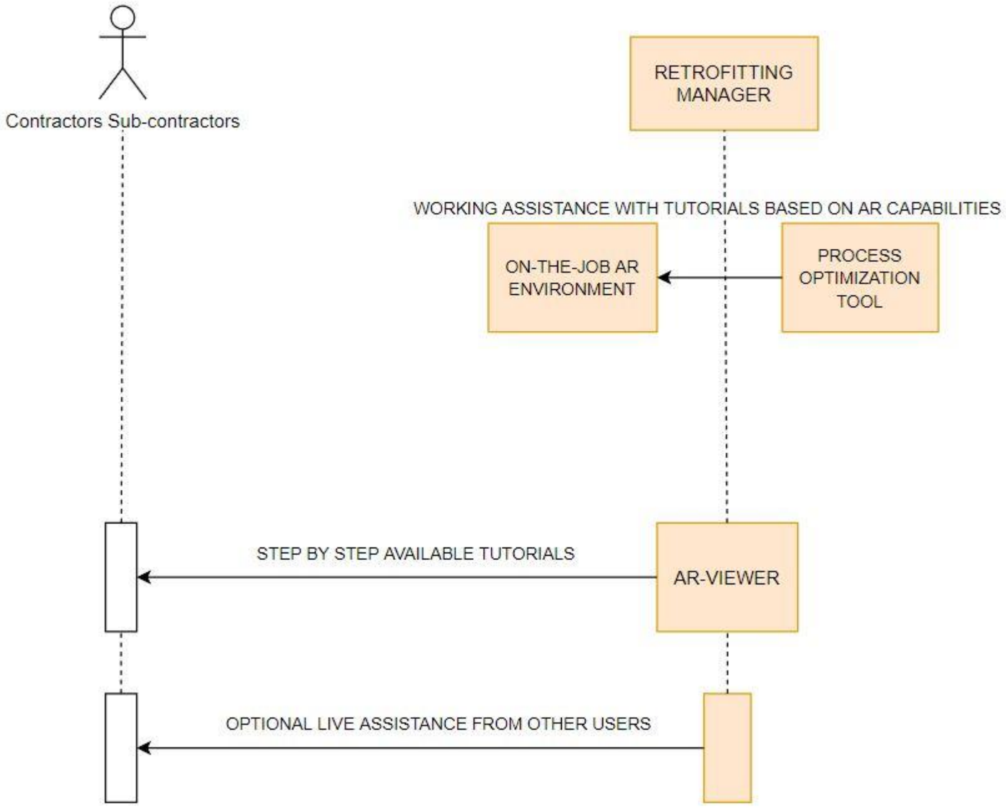

Figure 51 - Use Case 4a On-the-job Assistance Diagram

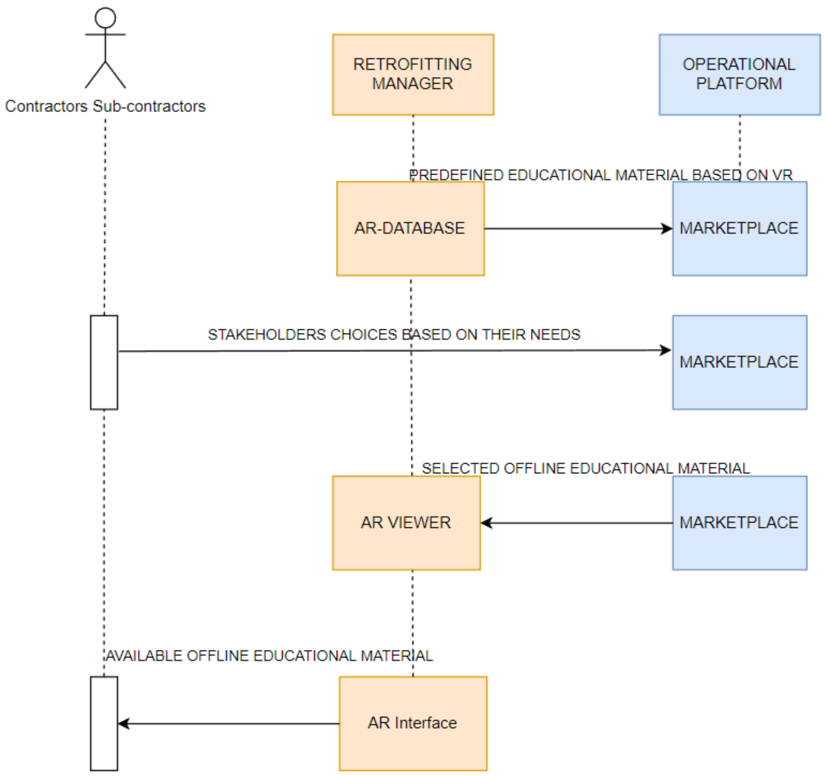

Figure 52 - Use Case 4b Offline Training Diagram

8.5 Use Case 5 Interconnection of On-The-Job AR Tool With BIM Model

Building owner can visualize the final result of the building renovation through the **AR Manager**, module of the On-the-Job AR tool. Staring by the **Process Optimization** tool, tasks for each one of the retrofitting processes of the pilots is send to the **E-Cockpit Dashboard**, module of RINNO Retrofitting Manager. Each building owner, a.k.a. site manager, is able to see these tasks via this dashboard. By using the AR Manager, the site manager can click on each task and view a 3D model of the expected result of this task performed on a pilot site. Figure 53 shows the flow diagram of this use case.

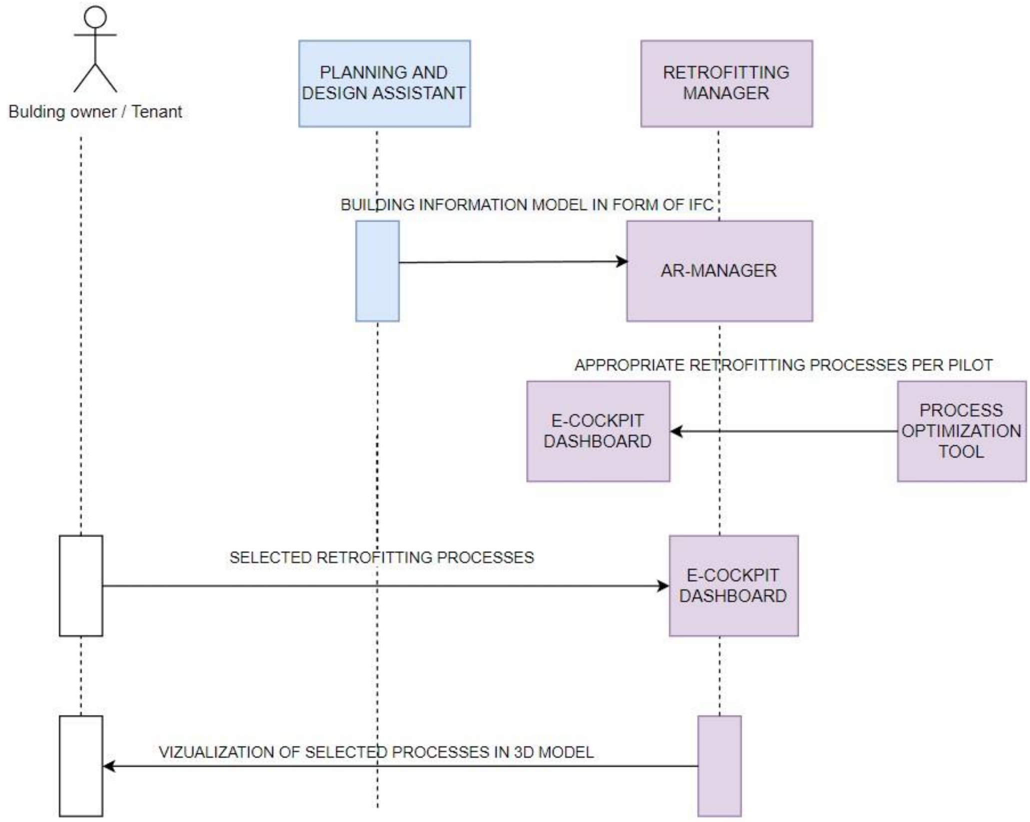

Figure 53 - Use Case 5 Diagram

9 Conclusions

This document introduced the second version of RINNO architecture framework. In total, 8 main components and 12 modules along with various sub-modules were gathered. Every responsible partner delivered the internal architecture, the features, as well as the inputs and outputs along with a brief description of the main components, modules, and sub-modules.

In the Chapter 2 the methodology that has followed to the design of the framework has been described. In the Chapter 3 there is a detailed identification of the stakeholders along with their prime concerns. Accordingly, in the Chapter 4 the conceptual architecture of RINNO is presented along with the workflow of the renovation.

Following the standard IEEE 42010 "Systems and software engineering - Architecture description" three different viewpoints of the system architecture has been presented, namely:

- The Functional View, described in Chapter 5, presents all the system's functional elements, their responsibilities, their functionalities and primary interactions with other elements.
- The Deployment View, described in Chapter 6, describes the deployment of the system, the dependencies of the components, modules and sub-modules along with their physical, software and hardware requirements.
- The Information view, described in Chapter 7, outlines the data models and the informational flow as well as their distribution.
- The Dynamic view, described in Chapter 8, presents a set of technical use cases by means of simple sequence diagrams.

Within the next version of the RINNO architectural design, Deliverable D.10 (M36), the components will be revised according to the evolution and implementation of the components. It will be a living document, which will be revised until the finalization and the integration of the RINNO framework. To this end, the interconnection of RINNO components with details, especially at the communication part, will be presented, improving the descriptions of all three views, functional, deployment and information.

ABOUT RINNO

RINNO is a four-year EU-funded research project that aspires to deliver greener, bio-based, less energy- intensive from a life cycle perspective and easily applicable building renovation elements and energy systems that will reduce the time and cost required for deep energy renovation, while improving the building energy performance. Its ultimate goal is to develop, validate and demonstrate an operational interface with augmented intelligence and an occupant-centered approach that will streamline and facilitate the whole lifecycle of building renovation.

For more information, please visit **https://rinno-h2020.eu/**

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