

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

Renovation Digital Twin for Building Retrofit Monitoring: The Case of the RINNO Project

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Forum - Repenser, adapter et rénover le parc immobilier existant
École de Technologie Supérieure (ÉTS), Montreal, Canada
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Context

- **Buildings and construction** together account for 36% of global final energy use and 39% of energy-related carbon dioxide (CO₂) emissions
- 77% of Europe residential buildings were built before 1990
- 11% of Europe's population still lives in poor quality buildings
- At **0.4 to 1.2% current renovation rates ...**
 - ...it would take over 100 years to renovate all the EU buildings!
- An accelerated renovation rate of at least 3% annually is required to accomplish the EU's Energy Efficiency and Environmental objectives
- How can the present rate be accelerated?



Retrofit

Deep Energy Retrofit (cf. Conventional)

- targets improvement in building performance
- adopts a systems thinking whole-building approach
- exploits the availability of (digital) technologies, innovative financing, materials, design, and delivery methods



Retrofit projects are inherently more difficult than new build projects. They typically have

- worse time performance (more time overruns)
- worse cost performance (more cost overruns)
- worse quality performance (results)

Challenges:

- Financing and business models - incentives to invest
- Disruption to, and by occupants – problems with adoption and adaptation
- Lack of holistic decision-making tools facilitating renovation procedures in all phases
- Lack of consistent and standardized solutions to comply with new and different building standards requirements on energy saving



Opportunities

- Technological advancements
- Familiarization of population with social media and e-commerce
- EU legislation/policies aiming to incentive and boost long term, ambitious and drastic renovation of EU's buildings

RINNO Project Overview

Welcome to the RINNO Project

Building a Low Carbon, Climate Resilient Future: Secure, Clean and Efficient Energy

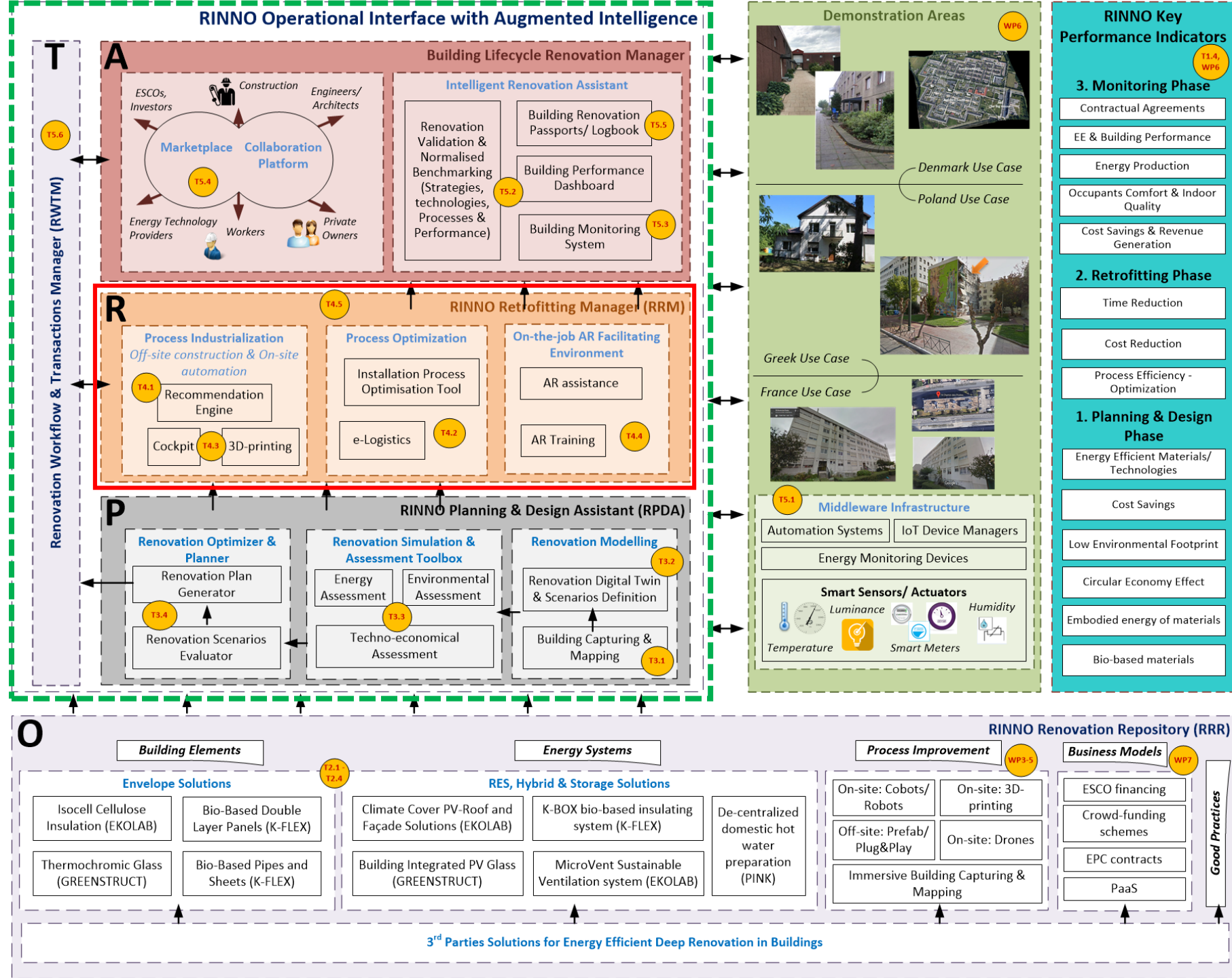
<https://rinno-h2020.eu/>

- €5M
- 48 months (2020-2024)
- 9 works packages
- 19 partners
(3 Universities)
- 10 countries
- 4 pilot (demonstrator) sites
in Poland, France, Greece, Denmark

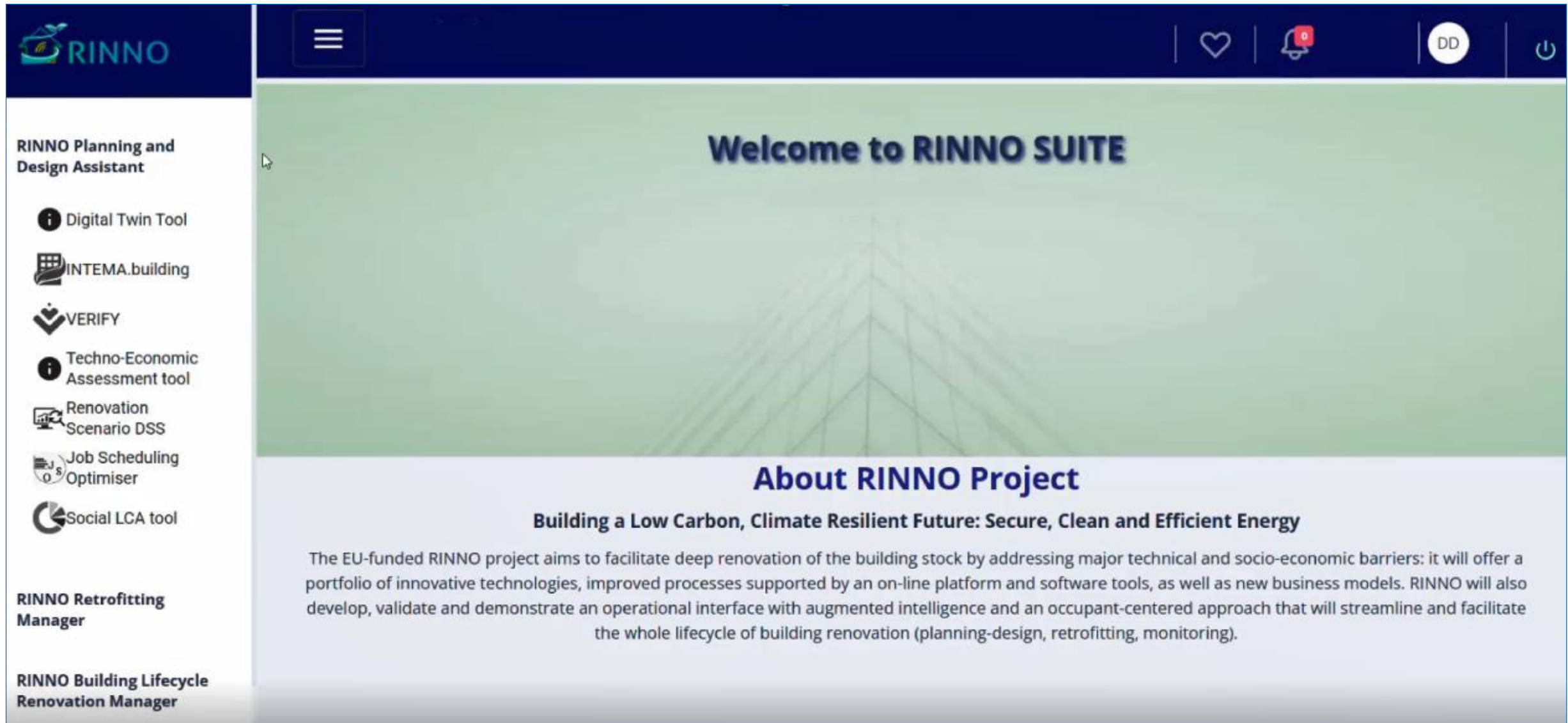


<https://rinno-h2020.eu/lille-france-2/>

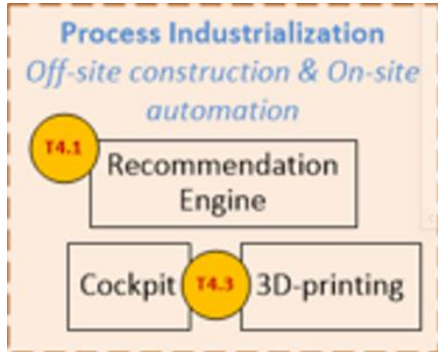
RINNO Solution for Building Retrofit



RINNO Solution for Building Retrofit (GUI)



RINNO Retrofitting Manager (RRM)

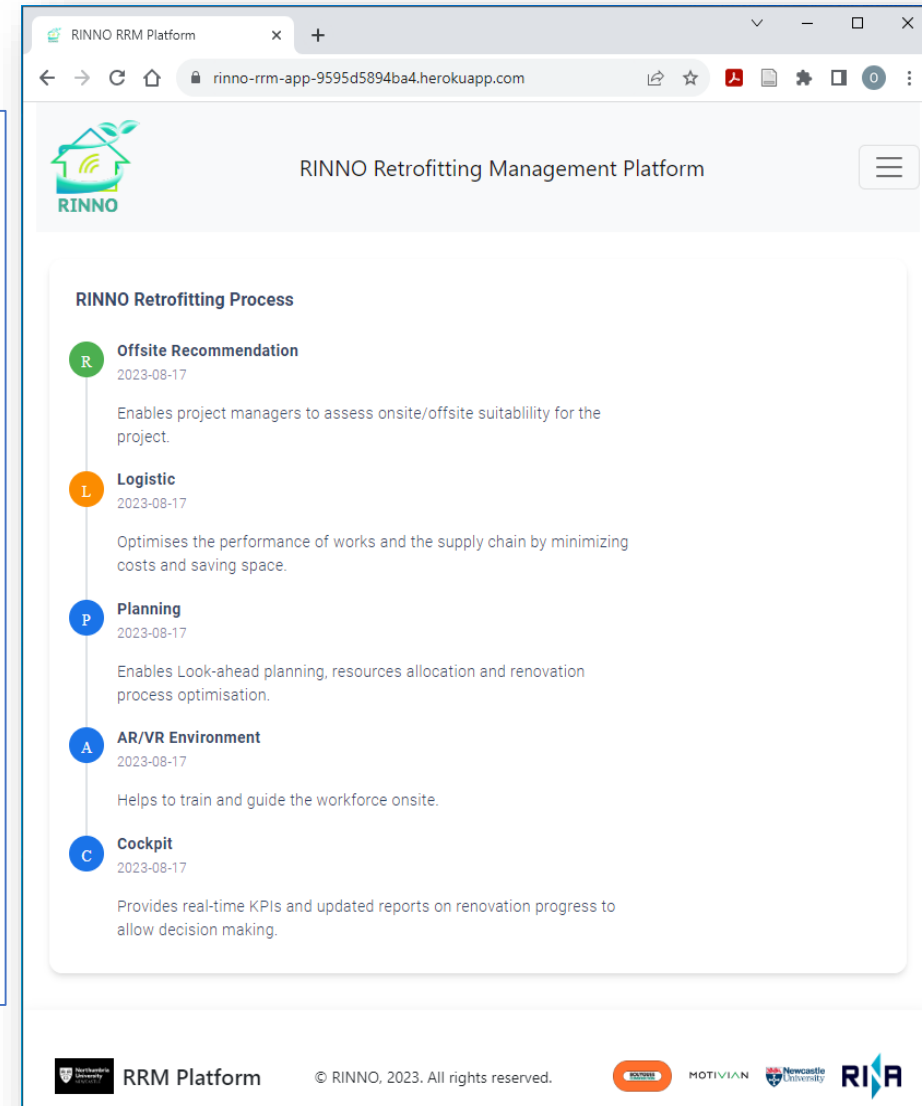
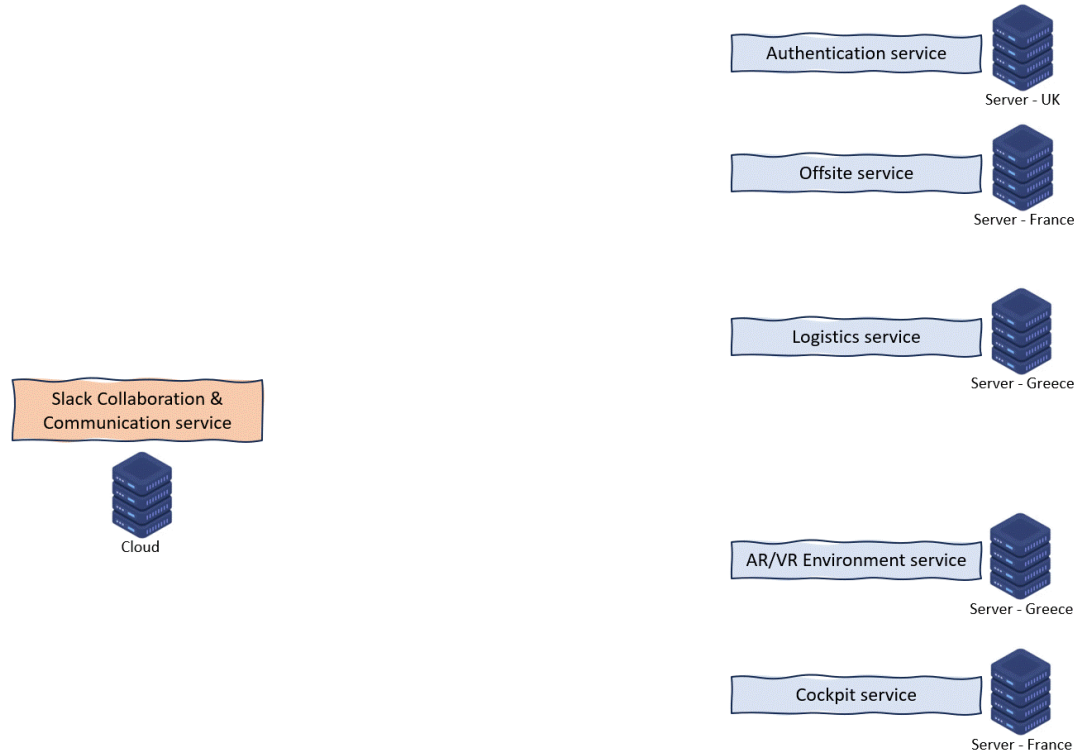


- RRM Components:

1. Authentication Service: Access and Data security
2. Offsite Service: enables Project Managers to assess suitability for offsite/onsite approaches
3. Logistic Service: optimises planning and delivery of renovation processes within time, resource and space constraints thus minimizing time, costs and waste
4. AR/VR Environment Service : helps train and guide site workforce using scenario visualisations and training videos
5. Cockpit (**Digital Twin**): provides real-time KPIs and up-to-date reports on progress to enable look ahead control and decision-making

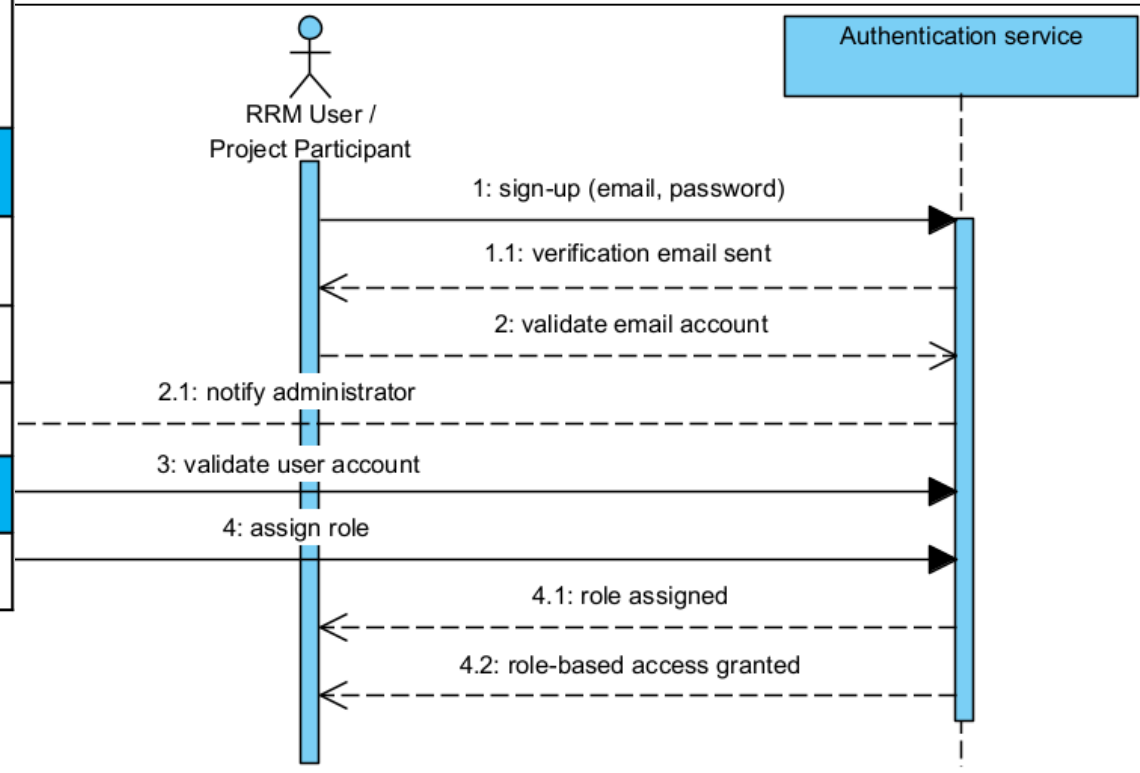
The RRM Platform: System architecture & GUI

Fragmented & isolated eco-system of tools!



RRM: Access and Data security

Service	User role										
	Architect	Construction director	Construction site manager	Construction team member	Design coordinator	Design manager	Design team member	Project owner	Site supervisor	Site worker	Sub-contractor
Authentication											
Offsite											
Logistic											
Planning											
AR/VR											
Cockpit											



RRM: Offsite recommendation

RINNO RRM Platform

rinno-rrm-app-9595d5894ba4.herokuapp.com

PRINCIPAL FACTORS **SCHEDULE AND PLANNING** LABOUR ORGANIZATION ENVIRONMENT SITE CHARACTERISTICS DESIGN COST

PRINCIPAL FACTORS

Offsite construction

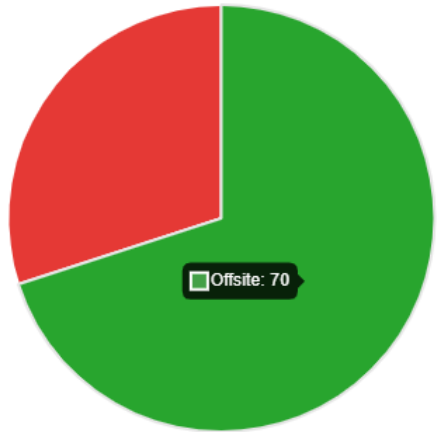
The Schedule & Planning factors aim

ID	Schedule factors
1	Short schedule
2	Early decisions
3	Planned decisions related
4	Delivery deadlines
5	Penalty

1 row selected

WEIGHTED SCORE DETAILS AND EXPLANATIONS

Weighted score
Onsite / offsite recommendations.



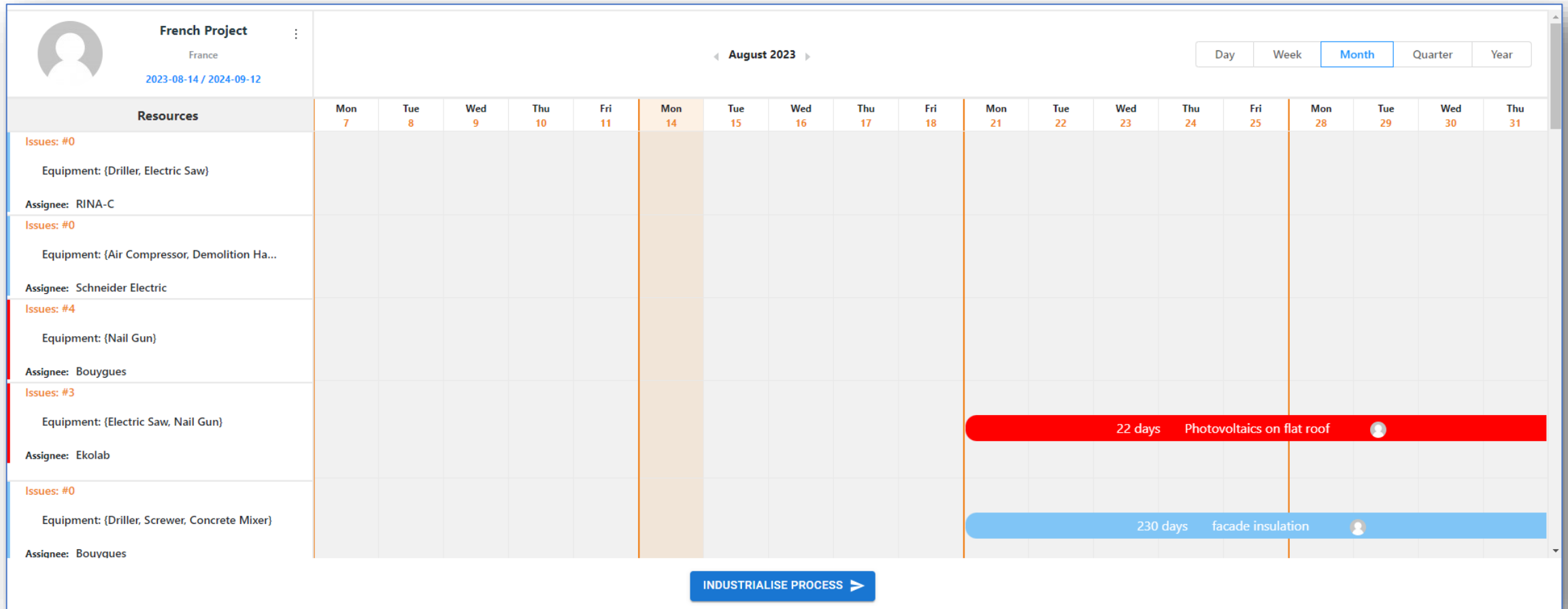
Offsite: 70

Best Renovation Scenario Alternative

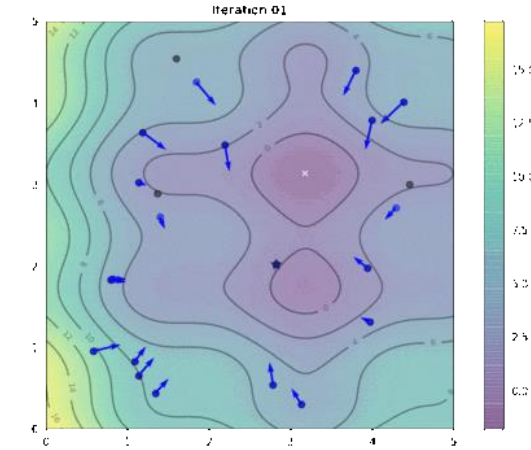
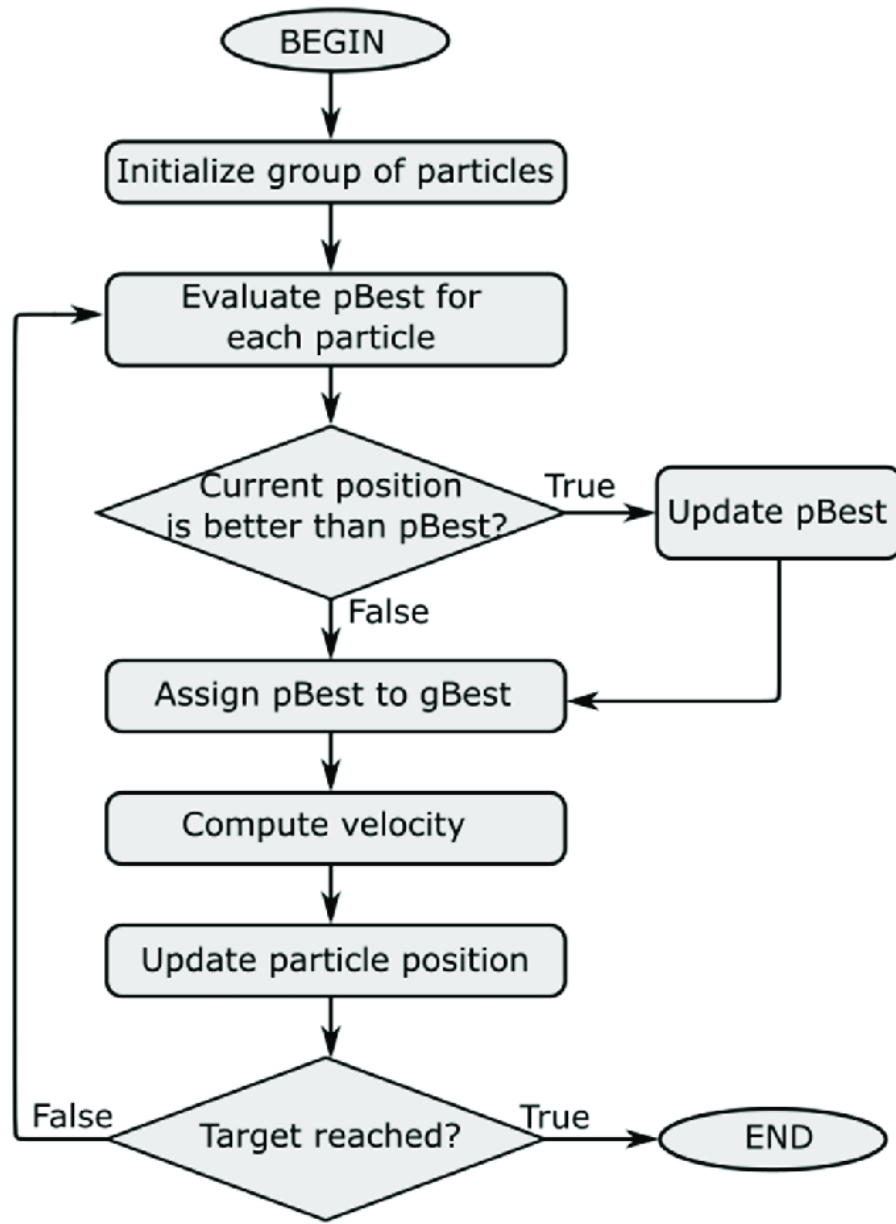
- TASK Non-centralised mechanical ventilation system**
Starting date: 0th day [DETAIL](#)
- TASK Photovoltaics on flat roof**
Starting date: 5th day [DETAIL](#)
- TASK Facade insulation**
Starting date: 5th day [DETAIL](#)
- TASK Windows and doors replacement**
Starting date: 27th day [DETAIL](#)
- TASK Wall-mounted integrated heat storage**
Starting date: 49th day [DETAIL](#)
- TASK Condensing boiler installation**
Starting date: 78th day [DETAIL](#)
- TASK Site preparation**
Starting date: 235th day [DETAIL](#)
- TASK Insulation of existing heating and domestic hot water pipes**
Starting date: 240th day [DETAIL](#)

VALIDATE ➤

RRM: Process optimisation



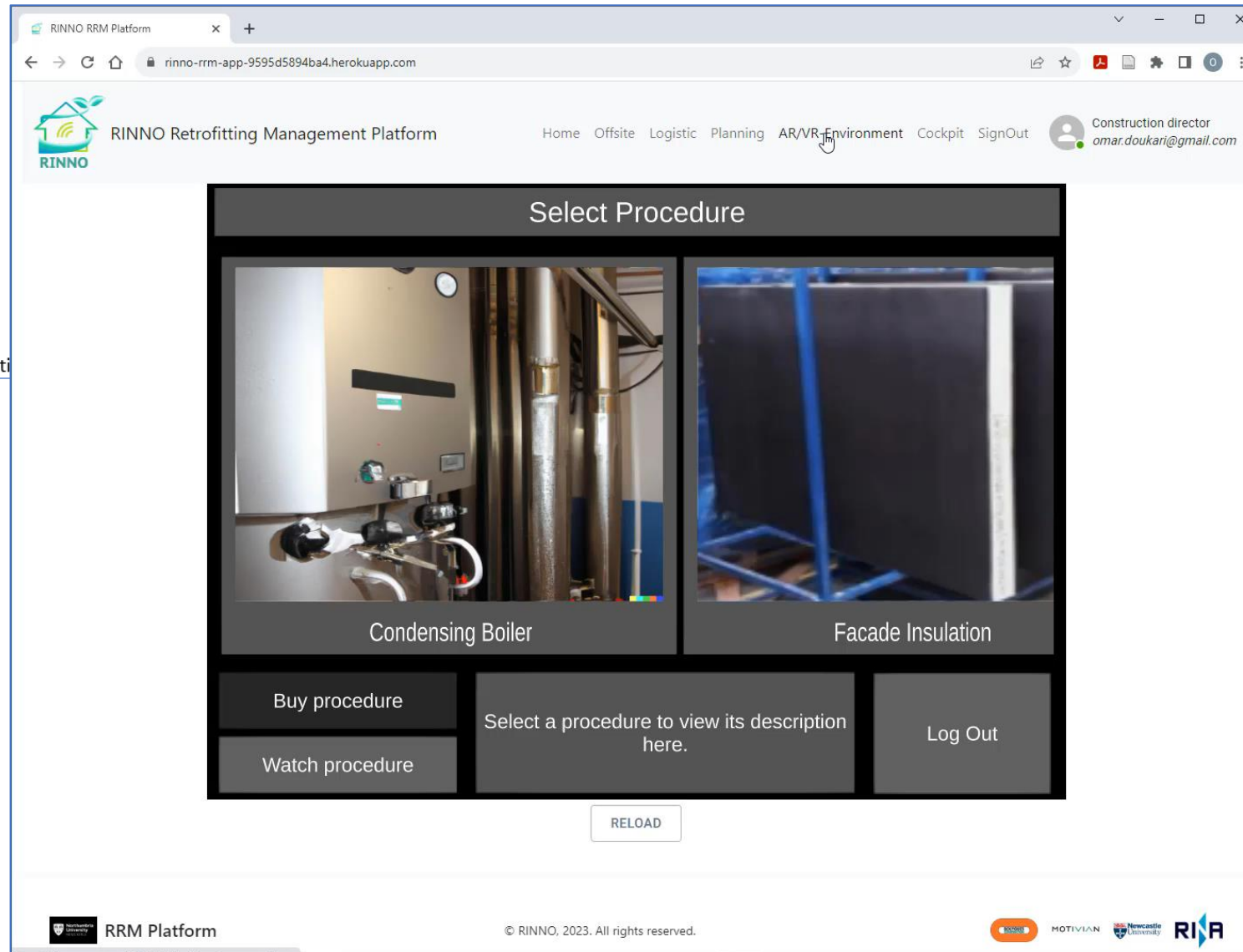
Process optimisation: AI (PSO algorithm)



$$P_i^{t+1} = P_i^t + V_i^{t+1}$$

$$V_i^{t+1} = \underbrace{wV_i^t}_{\text{Inertia}} + \underbrace{c_1r_1(P_{best(i)}^t - P_i^t)}_{\text{Cognitive (Personal)}} + \underbrace{c_2r_2(P_{bestglobal}^t - P_i^t)}_{\text{Social (Global)}}$$

RRM: Training & Support

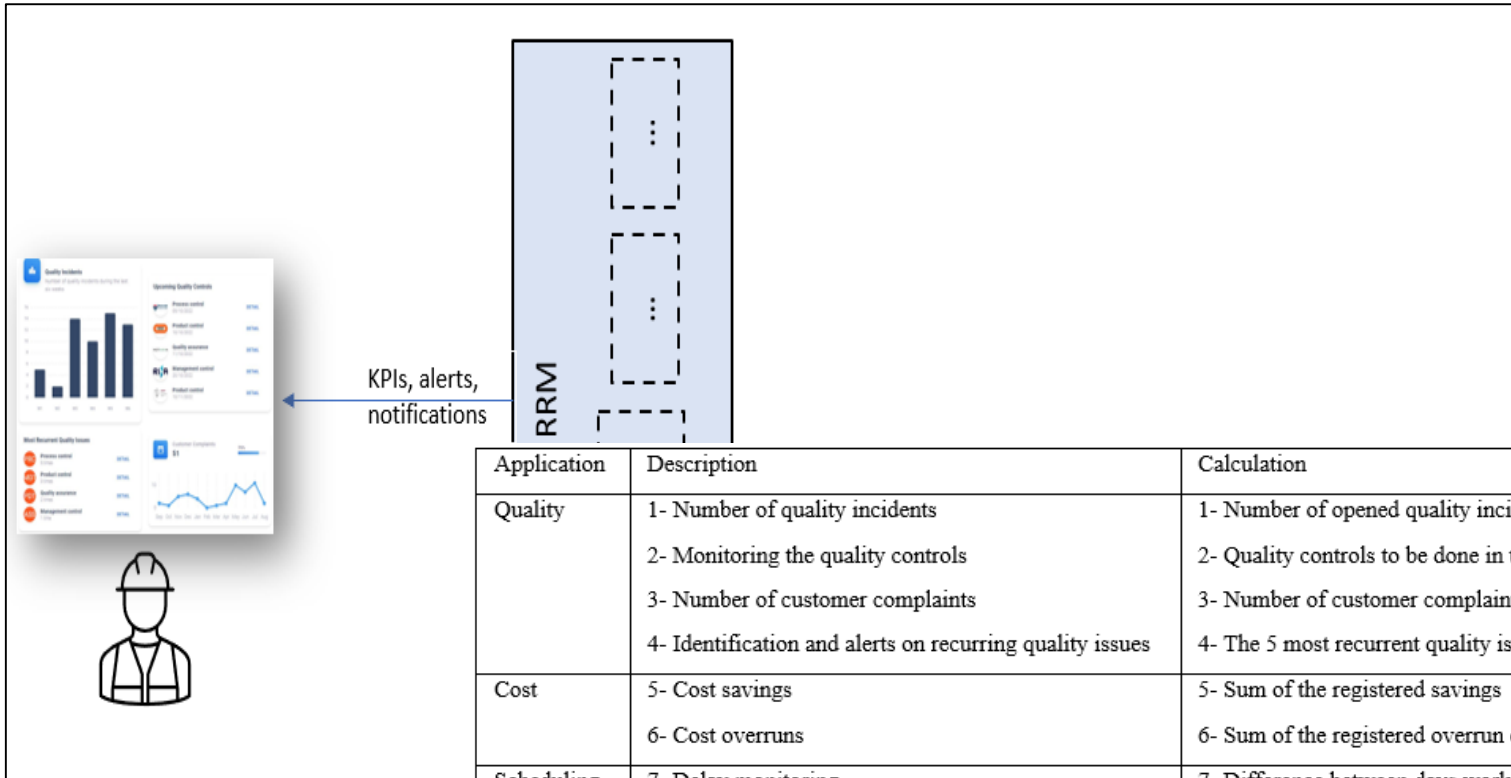


The screenshot displays the RINNO RRM Platform web application. The browser address bar shows the URL `rinno-rrm-app-9595d5894ba4.herokuapp.com`. The page header includes the RINNO logo, the title "RINNO Retrofitting Management Platform", and a navigation menu with links: Home, Offsite, Logistic, Planning, AR/VR Environment, Cockpit, and SignOut. A user profile for "Construction director" with email `omar.doukari@gmail.com` is logged in. The main content area is titled "Select Procedure" and features two large image thumbnails: "Condensing Boiler" and "Facade Insulation". Below these are three buttons: "Buy procedure", "Watch procedure", and "Log Out". A central text prompt reads "Select a procedure to view its description here." A "RELOAD" button is positioned at the bottom of the main content area. The footer contains the RRM Platform logo, copyright information "© RINNO, 2023. All rights reserved.", and logos for MOTIVIAN, Newcastle University, and RIR.



individualised training: videos, instructional procedures, AR/VR contents

RRM: Monitoring progress (Design)



DR1: Regularly provide relevant project KPIs regarding quality, cost, scheduling, safety, and environment.

DR2: Store historical project KPIs during the retrofitting phase.

DR3: Simulate project KPIs and their progress overtime.

DR4: Provide a user-friendly interface through integrating BIM and relevant charts and/or graphs.

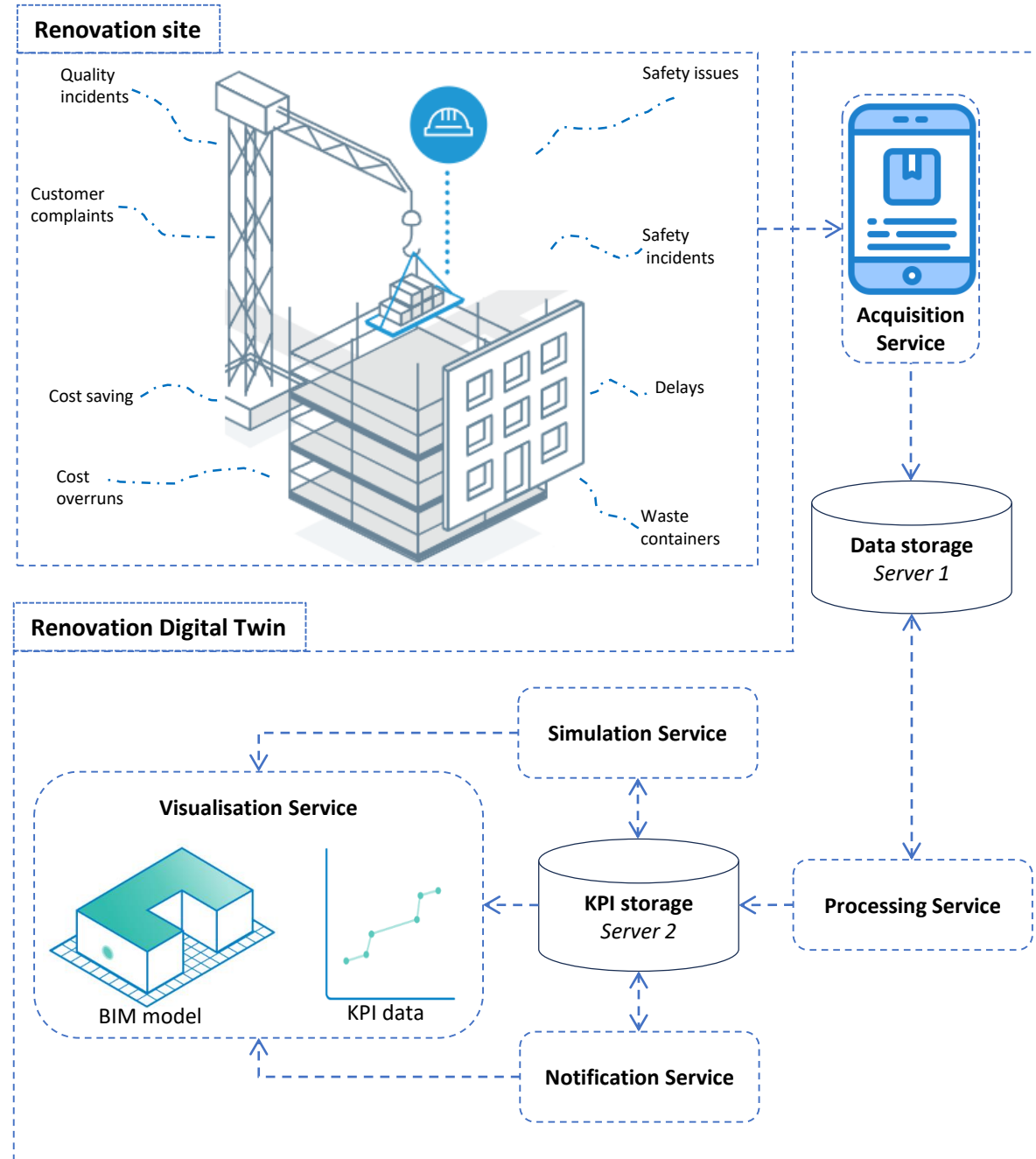
DR5: Enable stakeholders' notification when project thresholds.

Application	Description	Calculation	Representation
Quality	1- Number of quality incidents	1- Number of opened quality incident forms	1- Line chart
	2- Monitoring the quality controls	2- Quality controls to be done in the next 10 days	2- List
	3- Number of customer complaints	3- Number of customer complaints	3- Line chart
	4- Identification and alerts on recurring quality issues	4- The 5 most recurrent quality issues	4- List
Cost	5- Cost savings	5- Sum of the registered savings	5- Line chart
	6- Cost overruns	6- Sum of the registered overrun costs	6- Line chart
Scheduling	7- Delay monitoring	7- Difference between days worked and days scheduled	7- Line chart
	8- Milestones monitoring	8- % of achieved, ongoing and upcoming tasks	8- Pie chart
	9- Duration for resolving issues	9- Average duration between opening and closing issues	9- Line chart
Safety	10- Identification and alerts on recurring safety issues	10- The 5 most recurrent safety issues	10- List
	11- Number of safety incidents	11- Number of safety issues	11- Line chart
	12- Monitoring safety incidents control	12- Stakeholders involved in safety issues	12- List
Environment	13- Monitoring waste	13- Number of recorded waste containers	13- Line chart

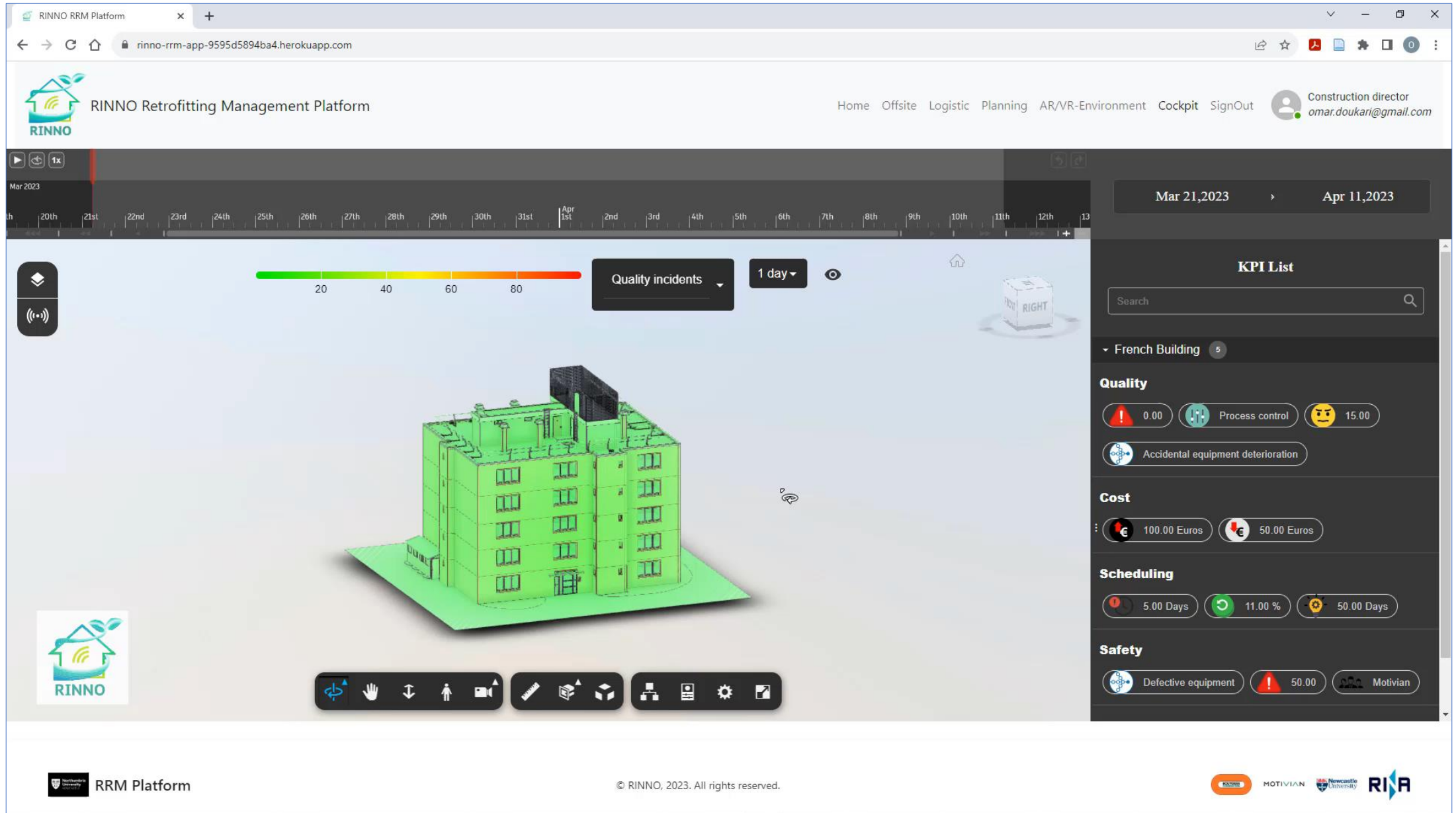
Platform should be accessible time for all project stakeholders

regulations, such as General Data (GDPR), while sensing building

RRM: Monitoring progress (Architecture)



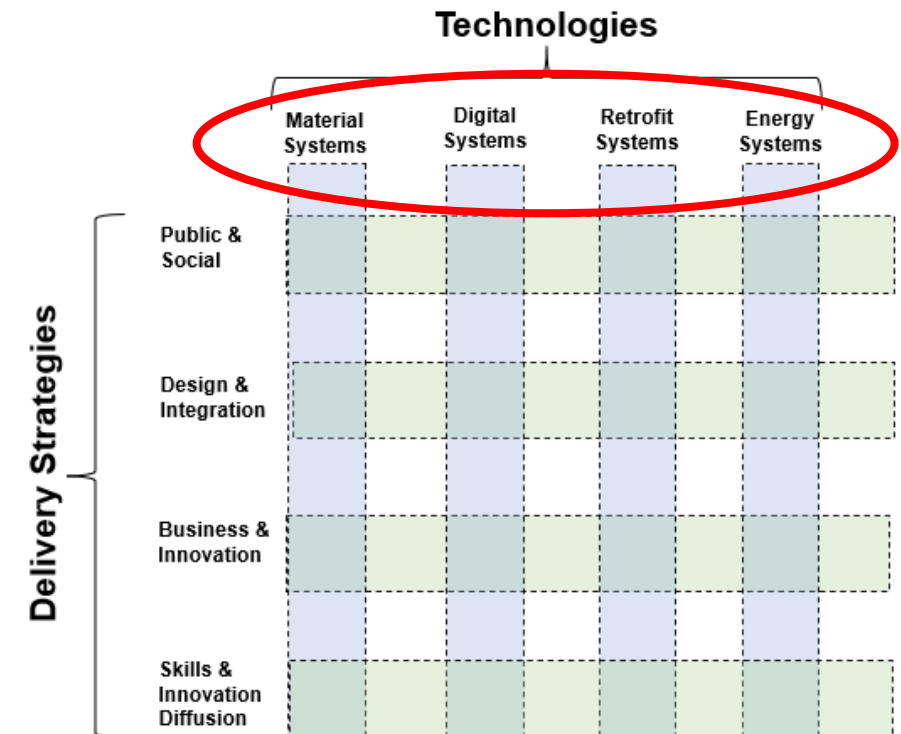
RRM: Monitoring progress (GUI)



What next?

- Project will complete (after extension) early 2025
- Partnerships & networks & future collaborations
- Taking forward the experience & knowledge

The screenshot shows the EU F&T Portal interface. The top navigation bar includes the European Commission logo, 'EU F&T Portal', a 'Sign in' button, and a language selector set to 'EN'. The breadcrumb trail reads: Home > Funding > Calls for proposals > BIM-based processes and digital twins for facilitating and optimising circular energy renovation (Built4People Partnership). The main heading is 'BIM-based processes and digital twins for facilitating and optimising circular energy renovation (Built4People Partnership)' with the call number 'HORIZON-CL5-2024-D4-02-03'. A 'Topic' button is labeled 'Call for proposal'. The 'Internal navigation' sidebar lists: General information, Topic description, Destination, Conditions and documents, Partner search announcement, Start submission, Topic Q&As, and Get support. The 'General information' section contains: Programme (Horizon Europe Framework Programme (HORIZON)), Call (Efficient, sustainable and inclusive energy use (HORIZON-CL5-2024-D4-02)), Type of action (HORIZON-IA HORIZON Innovation Actions), Type of MGA (HORIZON Lump Sum Grant [HORIZON-AG-LS]), Deadline model (single-stage), Planned opening date (17 September 2024), and Deadline date (21 January 2025 17:00:00 Brussels time). A 'Budget overview' button and a 'Forthcoming' status tag are also visible.



And don't forget - PPP

Projects produce publications: a sample

- Lynn, T., Rosati, P., Egli, A., Krinidis, S., Angelakoglou, K., Sougkakis, V., Tzovaras, D., Kassem, M., Greenwood, D., & Doukari, O. (2021). RINNO: Towards an open renovation platform for integrated design and delivery of deep renovation projects. *Sustainability*, 13(11), 6018.
- Doukari, O., Seck, B., & Greenwood, D. (2022). The creation of construction schedules in 4D BIM: a comparison of conventional and automated approaches. *Buildings*, 12(8), 1145.
- Doukari, O., Scoditti, E., Kassem, M., & Greenwood, D. (2023). A BIM-based Techno-Economic Framework and Tool for Evaluating and Comparing Building Renovation Strategies. *Journal of Information Technology in Construction (ITcon)*, 28(12), 246-265.
- Doukari, O., Greenwood, D., Aguejdad, R., & Kassem, M. (2023, July). Evaluation of building renovation strategies across three demonstration sites: a principal component analysis based multivariate sensitivity analysis. In *EC3 Conference 2023* (Vol. 4, pp. 0-0). European Council on Computing in Construction.
- Doukari, O., Kassem, M., & Greenwood, D. (2023). Building Information Modelling. In Lynn, T. et al. *Disrupting Buildings: Digitalisation and the Transformation of Deep Renovation* (pp. 39-51). Cham: Springer International Publishing.
- Doukari, O., Richard, P., & Greenwood, D. (2024). A distributed collaborative platform for multi-stakeholder multi-level management of renovation projects. *Journal of Information Technology in Construction (ITcon)*, 29(12), 219-246.
- Doukari, O., Suliman, A. (2024, July). Renovation Digital Twin for Building Retrofit Monitoring: A Software Product and an Organizational Ecosystem. In *EC3 Conference 2024* (Vol. 5, pp. 0-0). European Council on Computing in Construction.

THANKS!



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