The Conceptual Architecture Requirements for French Digital Building Logbook

Alan Martin Redmond
CSTB
Sophia Antipolis, France
email: alan.redmond@cstb.fr

***Abstract*— This article is based on Horizon Europe Project Demo-BLog were the business needs were pre-defined, and the challenges focused on defining requirements at an abstract opportunity/problem space domain level for an automated renovation advice tool. To accomplish this task, a System Definition process was undertaken to achieve the Engineering solution space domain. And to achieve the System Definition methodology the author decided to focus on first creating an Interface Control Document that consisted of a high-level overview architecture of the target system CLEA (Le Carnet d'Information du Logement par Qualitel - Digital Building Logbook) and the source system BDNB (Base de Données Nationale des Bâtiments/National Buildings Database). However, the alternative architectures presented challenges such as how to validate the requirements at this stage. The chosen tool/technique was Thales (Model-Based System Engineering) – Capella Tool and Arcadia Methodology. The article presents this approach, which included: operational analysis, system needs analysis, logical architecture and discussions reflecting the physical architecture relating to the requirement phases of need understanding and solution architecture design. The outcome of this article is The French Demonstration Preliminary Requirements and acknowledgement to the benefits of Model-Based System Engineering (MBSE): Improved Communications, Increased Ability to Manage System Complexity, Improved Product Quality, Reduced Recycled Time, Reduced Risk, Enhanced Knowledge Capture and Reuse of the Information.**

Keywords: Requirements, Stakeholder Needs, Interfaces, Architecture Analysis, System Engineering, "MBSE"

I. INTRODUCTION

"Requirements management is another pervasive mechanism that forces conversation between program managers and chief systems engineers. Effective requirements management practices help program managers and chief systems engineers align their work so that customers receive ideal solutions and desired program benefits, and value is realized for the business" [1]. ISO/IEC/IEEE 15288 is recognized by International Council on Systems Engineering (INCOSE) handbooks as a Technical Process compartmentalized into 4 sections: i) Concept Definition – comprising of Business Mission Analysis and Stakeholder Needs and Requirements Definition; ii) System Definition – referring to System Requirements Definition, System Architecture Definition, and Design Definition; iii) System Realization – implementation, integration, verification and validation; and iv) System Deployment and Use – transition, operation, maintenance and disposal. Each of these sections require recursion and collectively they are executed via iteration [2]. This article is based on Horizon Europe Project Demo-Blog where the business needs where pre-defined, and the challenges were associated to defining requirements at an abstract opportunity/problem space domain level for an automated renovation advice tool. To accomplish this task, a System Definition process was undertaken to achieve the Engineering solution space domain. The process is composed of: system requirements definition (transform the stakeholder, user-oriented view of desired capabilities into a technical view of a solution that meets the operational needs of the user) ; system architecture definition (to generate system architecture alternatives, select one or more alternatives that address stakeholder concerns and system requirements, and express this in consistent views and models) ; and design definition (to provide sufficient detailed data and information about the system and its elements to realize the solution in accordance with the system requirements and system architecture). Leveraging experience as project manager for CSTB on the Demo Blog project, to achieve the System Definition methodology, we decided to focus on epistemic modality (logic of the statements) of the design requirements by first creating an Interface Control Document (ICD) for the interoperable architecture of CLEA and the BDNB.

The rest of the paper is structured as follows. Section II introduces the concept of the Digital Building Logbook (DBL) and the French Demonstration whereas Section III analyses the development of requirements from abstract to domain solutions. Section IV presents a novel architecture of French Demonstration, which is an extraction from the actual ICD document produced for the Demo BLog project where each of the components are numerated and the interfaces are presented. In acknowledgement of the challenges associated to validating the requirements at this stage, section V explains the chosen tools/technique rationale of MBSE and the use of semantics to define the French Demonstration Requirements. This article's main contribution is the requirements for the demonstration that is currently under development.

II. THE DIGITAL BUILDING LOGBOOK

The Semantic Data Model [3] identifies a DBL as a common repository for all relevant data. Furthermore, it enables a variety of data, information, and documents to be recorded, accessed, enriched, and organized, under specific categories. It also represents a record of major events and changes over a building's lifecycle. However, most of this data stored (Indoor Air Quality (IAQ), operational energy use, smart buildings potential and life cycle emissions, building ratings, cert, and circularity) in the logbook have a more static nature, while others, such as smart meters and intelligent devices, are dynamic and need to be automatically and regularly updated.

According to [4], platforms are focused on the adoption of a microservice-based event-driven architecture. In our opinion, the process of mono-lithic architecture comprising of user interface, business logic, and data access layer has certainly evolved into microservice architecture (user interface, many separate micro services, and data bases) for the built environment. The adaption of Industry 4.0 (Internet of Things - IoT) including real-time smart meters and intelligent devices has changed the complexity of the platform architecture associated with buildings and smart cities.

A. The Demo BLog Project

The Horizon Europe project, 'Development and Demonstration of DBLs' (Demo-BLog), focuses on "the idea to collect data throughout the lifespan of a building and create a common digital data repository to ensure efficient design, construction, operation, and financing of buildings. In this context, the EU-funded Demo-BLog project will bring together five different DBLs with a total of 4.5 million registered units. It will demonstrate how DBLs facilitate transparency, trust, informed decision-making, and information sharing in the construction sector, among building owners and occupiers, as well as within financial institutions and public authorities" [5]. The project is compartmentalized into six work packages where the first three concern: Functionalities and user experience methodology (WP1); Data collection and interoperability, processing, governance (WP2); and Demonstration & Evaluation (WP3).

When reflecting on the System engineering process [2], the following elements are evident: concurrency – the parallel application of two or more processes at a given level in system hierarchy, iteration – the repeated application of and interaction between two or more processes at a given level in the system hierarchy, and recursion – the repeated application of the set of the life cycle processes, tailored as appropriate, at successive levels in the system hierarchy. As the work packages are progressing synchronously, iteration is in fact needed to accommodate the stakeholders (Energy Saving Trust - EST, and Qualitel - governance of CLEA software and DBL provider) decisions and evolving understanding to account for the architectural development.

B. *Define specifications and French Demonstration*

This article is based on WP1 subtask 1.1.3: Define specifications for the automated renovation advice tool were the parties involved is EST (UK), CSTB and QUALITEL (France) – The specifications produced for each demo will be presented according to general requirements/capabilities, behavior, architecture/structure, verification, and validation. This common approach will enable in-depth comparison of the planned scenarios between the demonstrations and encourages wider adoption of the learnings. Figure 1 captures and consolidates the operational needs from the stakeholders. It is a basic model; however, it creates the foundation of the process and starts to define what the users of the system have to accomplish; identifies entities, actors, roles, activities and concepts.

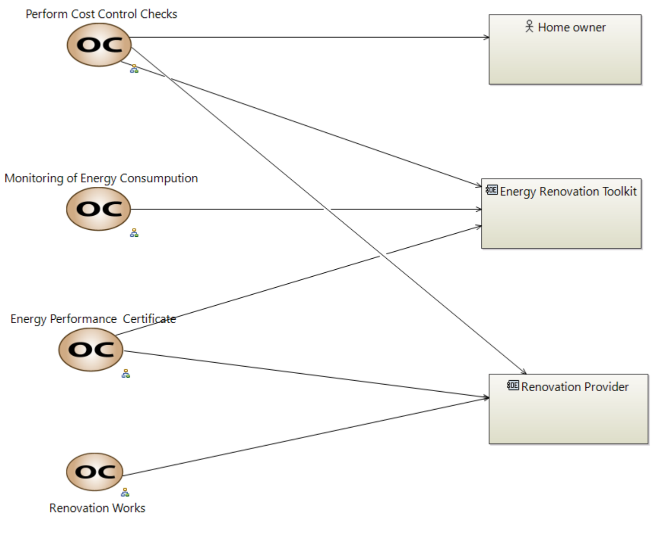

Fig. 1. Define the Stakeholder Needs and Environment for Automated Renovation Advice Tool

The French Demonstration 'Demo of user-centric automated renovation advice within CLEA DBL' concept is to exploit several new functionalities of the CLEA DBL with a stronger focus on the automatic renovation advice functionality. The main emphasis of the demonstration is to show the development and application of a renovation decision tool support within the DBL. This decision support tool will provide tailor made solutions using the building characteristics from BDNB and building owner/occupant input data. The development and application of this tool is to be demonstrated for 50 dwellings as a first step (the final target being to make it available for the 50.000 dwellings currently using CLEA). The financial and environmental benefits and the achieved energy performance certificate will be presented for these houses through CLEA. The BDNB (national repository) is governed by CSTB, and it includes:

- Open data: Project Building-ID, National benchmarks (open repositories buildings/addresses/plots) - National address base, Cadastre, BD Topo, and Official geographic code; Data from open data sources - Le diagnostic de performance énergétique/The Energy Performance Diagnosis (DPE) 2012, Agence de l'Environnement et de la Maîtrise de l'Energie/French Environment and Energy Management Agency (ADEME), Local energy data (ENEDIS), Gaz Réseau Distribution France/Gas Network Distribution France (GrDF), and Land value data (Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement/Center for Studies and Expertise on Risks, Environment, Mobility and Planning - CEREMA);
- Closed data: Restricted access " Assigns " Under commercial conditions - Land files, Registre national d'Immatriculation des Copropriétés/National Register of Condominium Registration (RNIC) and Complete Le Répertoire des logements locatifs des bailleurs sociaux/The Directory of Rental Housing from Social Landlords (RPLS); CSTB "business" services (Restricted Under commercial conditions) - Missing Data Prediction, Simulations (DPE 2021, cometh, etc.), Decision indicators (Renovation potential, Land value, etc.) and Measurements.

III. WHY SYSTEMS ENGINEERING

[6] highlighted the costs committed to the life cycle cost against time. The image described below is derived from 1993 Defense Acquisition University (DAU):

- The cumulative percentage life cycle cost against time was presented from 0 to 100% and the time duration included: concept; design; develop, production/test; and operations through disposal.
- The diagrams graph recognized that at the concept stage where 8% of time had passed the committed cost was 70% of the project budget, design representing 15% and develop 20% showed 85% committed costs.
- While production/test resulted in 95% leaving operations through disposal at both 100% for committed costs and time.

The main evaluation from the graph identifies that to extract defects at design stage it is 3-6x (costs), and at the develop stage it is 20-100x and at Production/Test stage it is 500-1000x.

Copyright (c) IARIA, 2024. ISBN: 978-1-68558-180-0

A. Requirements

For the Demo BLog project, the process of drafting the French Demonstration requirement was not just to comply with the projects required task but also to provide a collaboration mechanism between the two main partners involved in the French Demonstration: CSTB & Qualitel and the UK demonstration leader EST and their DBL provider Chimni.

The INCOSE guide to writing requirements [7] places the requirements and specification within two separate but adjoining spheres where sphere 1 includes – Design inputs: focusing on design inputs, preliminary logical & physical architectures, and sphere 2 – design outputs: focusing on design outputs, maturing the logical & physical architectures, design, design output specification, and realized system element. The step formation between the two spheres transits from 'Integrated Set of Needs transforming to Design Input Requirements (emphasizing the question design to "what") which then transforms to Architecture & Design (representing sphere 2). The continuation of the process leads to Design Output Specifications (representing "how" – build-to/code-to) before finally transforming to the System Element. The diagram also acknowledged that within the second phase (sphere) the design output specifications can include specifications, algorithms, for-mutations, drawings, & other design output artifacts. This point is key to the Demo Blog project as it enabled the author to explore further opportunities such as Thales MBSE Pillars (as explained in Workflow of CLEA and BDNB Interface).

B. Develop Requirements from Abstract to Domain Solution

[8] identified that the requirements process requires various steps: 1) understand the entity's opportunity/problem and solution spaces, 2) develop the entity's requirements domain solution, 3) develop the entity's operations domain solution, 4) develop the entity's behavioral solution, 5) develop the entity's physical domain solution, and 6) evaluate and optimize the entity's total design solution. In Wasson [9] the four domain solutions of requirements, operations, behavioral, and physical relationships are mapped to Archer's Design Process Model for integrated design solutions encompassing: data collection, analysis, synthesis, development, and communication. These four-domain solutions were aligned with the Demo BLog Task 1.1.3 specific request that the specifications produced for each demo will be presented according to general requirements/capabilities, behavior.

Furthermore, in [8] it is acknowledged that such methods require a derivation process where the mechanism involves a loop that commences with questioning 'What Outcomes' must be achieved, then 'what capabilities" are required to achieve each outcome, before referring to "under what scenarios & conditions" should each capability be achieved, and then "How Well Must" each capability be performed to accommodate scenarios/conditions. These five stages lead to identifying the performance requirement, however, to write the derived requirements statements Wasson introduces the "How" should each capability be verified to demonstrate its contribution to this requirement into the method. After one has acknowledged the "how" he suggests 'Verification Methods' and 'Valid Requirement' to achieve 'Compliance Verification' which consequently is looped back to the 'What Capability' stage before confirming a requirement. We believe this explanation of derived requirements provided the final process logic for Task 1.1.3 architecture/structure, verification, and validation.

IV. THE INTERFACE CONTROL DOCUMENT (ICD)

The concept of the ICD is to describe the relationship between the French National Building Database, called BDNB, (the source system) and the housing information booklet called CLEA (the target system). This ICD specifies the interface requirements that the participating systems must meet. It describes the concept of operations for the interface, defines the message structure and protocols that govern the interchange of data, and identifies the communication paths along which the project team expects data to flow.

For each interface, the ICD provides the following information:

- A description of the data exchange format and protocol for exchange.
- A general description of the interface.
- Assumptions where appropriate.

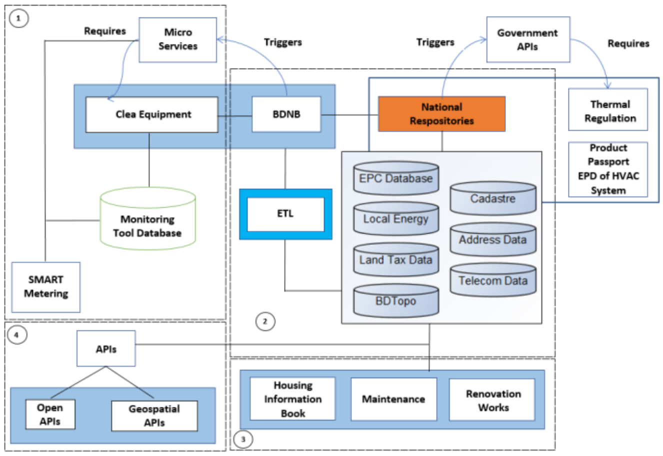

Fig. 2. Interface Control Document – French Demonstration

1) Capturing Data - The concept of microservices is embedded in the structure of Event-driven architecture. This is a type of software architecture that ingests, processes, stores, and reacts to real-time data as it's being generated, opening new capabilities in the way businesses run. The challenges associated to traditional architecture such as a time series database inefficiency with handling relational use cases or modelling, and likewise a document database structure failing to provide good analytics against those documents has increased the needs of microservices. The requirements of system design have revolved around the notion of real-time events (events drive actions and reactions, and transform between different streams, splitting, merging, and evolving). For the French Demo: Post-Occupancy Monitoring of Federated Data the event driven architecture will involve Smart Metering as an IoT device connected to CLEA equipment comprises of monitoring tools database for energy and maintenance.

2) Synchronizations of information – The French Demo pilot will provide RESTful Application Performance Interface (API) for CLEA to connect to the BDNB. As a centralized system the BDNB is openly connected to the French National Repositories including DPE (the national EPC database), Local Energy, Land value data, and INSEE - Le code officiel géographique/ The Official Geographic Code (COG). The characteristics of BDNB include 2D (+ buildings height) modeling of the territory and its infrastructures

throughout France (BD Topo) and the plan of a plot entered in a register showing the state of land ownership (Cadaster) coupled with the National Repositories will be very beneficial to The French Demo via advancing a middleware computer technology that allows massive synchronizations of information from one data source (usually a database) to another, the term associated with this middleware is called Extract-Transform-Load (ETL).

3) Energy Renovation Toolkit – The French Demo 'CLEA Equipment' will comprise of three main elements: a) Housing Information - centralization and storage of information and documents: commercial proposal, plan sketch, project, contract and descriptive notice, plan PC, A monitoring tool for regular information on progress site and alerts, photos, a booklet complete reception containing all the equipment of the house listed with its notes, etc., EPC b) Maintenance of Accommodation - information, opinions and advice maintenance, consumption monitoring energy tool, reminders for the maintenance of equipment. c) Renovation Works – details of renovation provider and certification. These external attributes will be connected to Renovation Toolkits and accessed through CLEA database.

4) APIs - REST applications are event command pattern, and they are coupled in multiple ways such as the endpoint is known (i.e., the service address); the method being called is also known (i.e., an API call) and the calls return value; they are synchronous. RESTful protocols involve the process of sending a command which will be integrated within the composition of French Demo Post-Occupancy Monitoring of Federated Data.

V. DIGITAL MODELS

[10] identified that 'System Health Management (SHM) is a reasoning process and is therefore model dependent, accuracy, completeness, and interoperability of the models are paramount. The use of automatic model abstraction, and model checking will greatly reduce the effort to certify models and the overall SHM system. And this benefit accumulates as the models are improved over the system's lifecycle.' [11] emphasized the evolution of models transition through various stages: stage 1 'document-based', stage 2 'document-centric', stage 3 'model-enhanced', stage 4 'model-centric' and, stage 5 'model-based'. The following sections identify the need for MBSE.

A. *Model-based systems engineering*

The ICD provided: 'Business Process Map' - the visual display of French Demonstration process from start to completion and the sequence of steps that must take place, 'Simplified Architecture' - consisting of data sources (CEREMA, INSEE, ADEME, and Cadastre et Territoires), data acquisitions (prediction services INSEE, typological prediction, INSEE requests for land values, and Digital Product Passport), 'data repositories' (PostgreSQL, ETL, PostgreGIS, and BD Topo), and data exchange (Linky ENEDiS – LINKYAPI, RESTAPI, gpkg (GeoPackage), and TCP/IP). It also included the 'System Elements' components breakdown of the French Demonstration, and 'Capabilities & Requirements' featuring System Product Structure (physical hierarchy) of the French Demonstration consisting of CLEA equipment, National repositories, CSTB (BDNB), and Communications (connectivity) and their interaction with multi-level behavioral capability operation and tasks comprising of Housing Information Pack, Maintenance of Accommodation and Renovation Works. However, the documentation of these models was static with no intelligent decision making defining the knowledge contribution of the models. In other words, there was no semantic attributes capturing the various elements of the models.

"MBSE is a methodology that focuses on creating and exploiting digital system and engineering domain models as the primary means of exchange of information, feedback, and requirements, as opposed to document-centric systems engineering. It involves the entire process of capturing, communicating, and making sure that all the digital models we use to represent a system are coordinated and maintained throughout the entire lifecycle of the system" [12]. The following section addresses how Thales MBSE pillars of language, method and tool was used to improve the performance of the models.

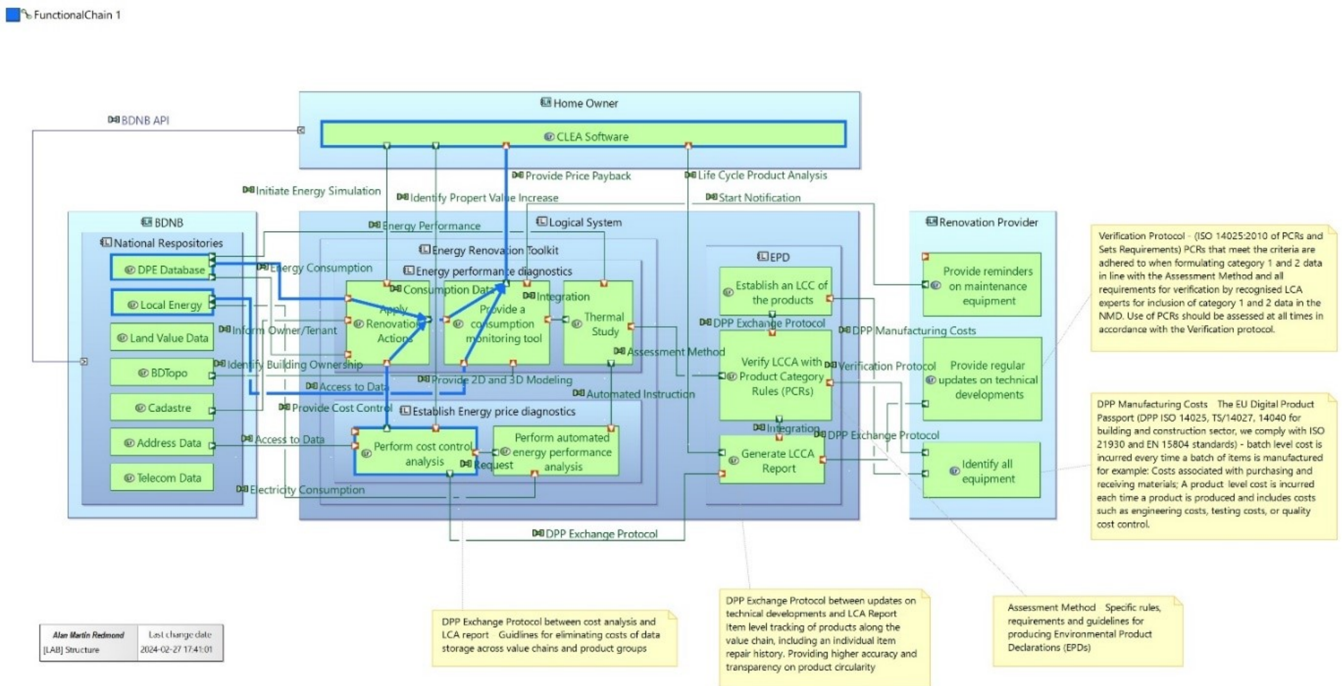

Fig. 3. The Logical Architecture Collaboration Model

 ISBN: 978-1-68558-180-0

These pillars changed the viewpoints of the original architecture and techniques such as capturing the exchange of information to be documented in an uncoordinated manner. And challenged the status quo of the rudimentary approach to deliver a heuristic model that captured the microservices in an agile process while also addressing the atomic design components.

B. *Workflow of CLEA and BDNB Interface*

Thales MBSE comprises of the tool 'Capella' an open source MBSE solution' purposely built to provide the notation and fitting the method 'Arcadia approach' high level concepts and viewpoints. The methodology for the Demo BLog requirements is divided into four phases where each phase requires different levels of modeling pertaining to different diagrams.

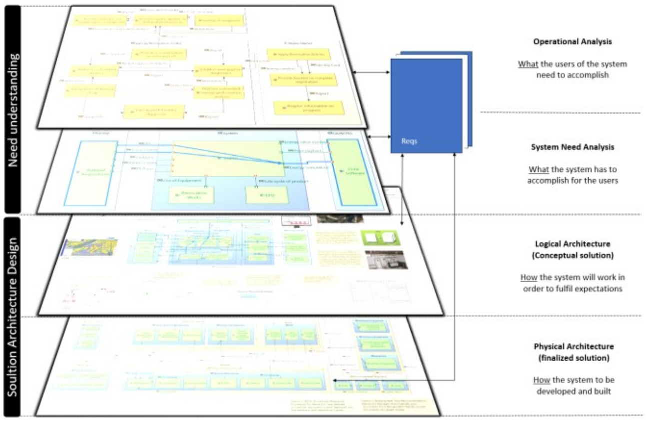

Fig. 4. MBSE – The Arcadia perspectives

Definition of the levels: the need of understanding levels comprises of: the operational analysis - what the users of the system need to accomplish, and system need analysis – what the system has to accomplish for the users, the solution architecture level include logical architecture (conceptual solution) – how the system will work in order to fulfill expectations, and physical architecture (finalized solution) – how the system is to be developed and built. Figure 3 is an illustration of the logical architecture for French Demonstration. It has been developed based on the need understanding levels and each of these levels required several diagrams such as: operational capabilities, operational analysis, architecture, entity scenarios, function data flows, functions and traceability, functional chains, states and modes, and system architecture. The next level 'solution architecture' incorporated logical functions, data flow scenarios, class diagrams, refine logical functions and assign functions to components. Figure 4 shows the various levels for the French Demonstration use of MBSE aligned to the Arcadia methodology.

C. *French Demonstrations requirements*

Data Modeling in Arcadia/Capella consists of functional exchanges from one component to the next for example in Figure 3 Logical Architectural, the Homeowner interface is connected to the National Repository component via the BDNB API. The National Repositories functions DPE (Energy Performance Certificate) database exchanges energy consumption information to function apply renovation action, and local energy function exchanges provide a consumption monitoring tool. The focus of the functional chain (highlighted in bold connecting lines) identifies the main exchanges between the data from perform cost control analysis, apply renovation actions, and provide a consumption monitoring tool. As illustrated in the diagram the provide consumption monitoring tool groups the chain of information before providing price payback data via CLEA Software. At this stage for the French Demonstration the functional chain has suggested that this path represents the main components and functional exchanges. This semantic decision is an attribute of Capella/Arcadia tool based on information accumulated from the previous layers (operational, capabilities, and system analysis).

However, as noted in 'MBSE section' the model in a holistic view captures the Housing Information Pack, Maintenance of Accommodation and Renovation Works logical functions characteristics to provide reminders on maintenance equipment, provide regular updates on technical developments, and identify all equipment.

TABLE I. FRENCH DEMO REQUIREMENTS

1.1	***Information Exchange (Files and Data)***
1.1.1	The Energy Renovation Toolkit shall provide a mechanism and interfaces for CLEA software to connect with BDNB dataset allowing a technical characterization of existing buildings. Reminder, the BDNB is the merging of national repositories (EPCs for example), data-crossing algorithms and CSTB energy simulation tool.
1.1.2	CSTB shall facilitate the exchange mechanism between the USER via CLEA Software and BDNB with secure access, reception, and registration of requests linked by BDNB RESTful APIs. The required open data databases (Building-ID, National address base, Cadastre, BD Topo, Official geographic code, DPE 2012, Local energy data) of the BDNB shall be interconnected by CSTB ETL.
1.1.3	The exchange mechanism shall also facilitate the calculation indicators of performance for energy simulations diagnostics, and access to registered EPC data.
1.1.4	The CLEA Software shall provide the Energy Renovation Toolkit with RESTful API access to LINKY ENEDIS and GAZPAR GRDF data streams. They are respectively the electricity and gas national network providers and handle real hourly energy consumption at deliver point (generally at dwelling scale).
1.1.5	The CLEA Software shall provide a mechanism and interfaces for Energy Renovation ToolKit to supply the renovation provider with access to submit the required data files for the Housing Information Book, and centralization storage of information and documents: commercial proposal, plan sketch, project, contract and descriptive notice, plan layout, and experts' advice (LCC). Typically, Automatic completion of key information exchanges shall be provided.
1.1.6	The exchange mechanism shall also facilitate exchange of data (XML files) for the integration of the thermal study and consumption monitoring tool provided by CERQUAL.
1.1.7	The CLEA Software shall provide a mechanism and interfaces for Energy Renovation ToolKit to supply the client with open access to submit the required data files for the House maintenance, and A pre-existing library of equipment to customize (regular update in depending on technical developments).
1.1.8	The exchange mechanism shall also facilitate a user-interface to retrieve data from cadaster provided by BDNB API to obtain general dwelling information. Typically, equipment modules (user guides for HVAC & devices, maintenance alerts) shall be provided.
1.2	***Information from other sources***
1.2.1	Information provided by the renovation provider on identified equipment prior to installing shall be referenced to The EU

1.1	***Information Exchange (Files and Data)***
	Digital Product Passport DPP ISO 14040 and EN 15804 standards for batch and product level costs and exchanged as part of the EPD to establish an LCA of the products.
1.2.2	Information provided by the renovation provider on regular updates on technical developments shall be verified by ISO 14025:2010 of PCRs Set requirements that adhered to formulating category 1 and 2 data in line with the assessment method of all requirements for verification by recognized LCA experts for inclusion of category 1 (in relation to EN 15804) and 2 (in relation to EN 15804/A2:2019) data in the National Environmental Database.
1.2.3	Information provided to the EPD system shall be managed by CLEA and exchange protocols for generating LCA reports and inputs to perform cost control analysis.

These functions main exchanges are between the Environmental Product Declarations (EPDs) components: Establish a Life Cycle Costing (LCA) of products, verify Life Cycle Costing Analysis (LCCA) with Product Category Rules (PCRs) and generate LCCA report. In Figure 3 the yellow boxes address the specific requirement associated with these operations for example, to provide regular updates on technical developments, this operation will require a verification LCCA with PCR. The verification protocol (ISO 14025.2010 of PCRs & sets requirements) identifies that technical developments meet the criteria of category 1 (proprietary products) and 2 (non-proprietary products) data in line with the assessment method: 'specific rules, requirements, and guidelines for producing EPDs, such information can be sourced from Product Environmental Profile (PEP) ecopassport [13] and BCG [14]. The model in Figure 3 reflects the architecture in Figure 2 where the Thales MBSE pillars of language, method and tool enriched the model to produce the French Demo Requirements as shown in Table 1. Requirement 1.1 'Information Exchange' refers to the main interactions between CLEA software and BDNB and Requirements 1.2 'Information from other sources' illustrates the assessment methods targeting EPDs for Digital Product Passports.

VI. Advancing Future Works

CSTB advancements with BDNB have already been well applied in relation to BTP-flux model where data mining, analytical techniques, and GIS tool were used to assess different datasets available at the national level to develop a common database for French buildings, BDNB [15]. The Demo BLog project will create an open API for connection to the French national repositories governed by CSTB. However, in the opinion of this article author, the future of DBL advancements will rely on graph databases/knowledge graphs and polyglot resistance (different types of data in different ways) were the Building-ID (sourced through the BDNB) is connected to a Product Catalogue (renovation products used on previous buildings) via cloud connection. This data will be sourced via Awesome Procedures (APOC) for Neo4j where the user defined procedures are written in Java, deployed into the database, and called by the Cypher. The process requires using data relationships for recommendations, such as content-based filtering to recommend items based on what previous renovation providers have used and collaborative filtering to predict products based on similarity (location, building, type) and preferences.

VII. Conclusion

This article reflects the preliminary contribution of work on French Demo Requirements undertaken by CSTB for the Horizon Europe Demo BLog project. The article acknowledges the advanced changes in platform architectures from monolithic to event-driven architecture and demonstrates the benefits of MBSE to create requirements for the adaptation of industrial 4.0 complexities associated with buildings and smart cities.

Acknowledgment

The author would like to take this opportunity to acknowledge the contribution of Mathieu THOREL (CSTB) during the Demo Blog project, and Martin Le Bourgeois (Business Developer – OBEO) and M. Lionel YAPI (Thales Group) for providing the training for the Capella Tool and Arcadia Methodology.

References

[1] Project Management Institute and INCOSE, 'Integrating Program Management and Systems Engineering, Methods, Tools, and Organizational Systems for Improving Performance', Eric S. Rebentisch, editor in Chief with foreward by L. Prusak, Published by: John Wiley & Sons, Inc., Hoboken, New Jersey, pp. 157, 2017. (Section 8.3.4 Requirements Management).

[2] INCOSE, Systems Engineering Handbook, A Guide for System Life Cycle Processes and Activities, 5th Edition, INCOSE-TP-2023-002-05, pre-pared by: International Council on Systems Engineering, 7670 opportunity Rd, Suite 220, San Diego, CA, USA 92111-2222, pp. 42-43, 2023.

[3] M. Böhms et al., 'DBL Semantic Data Model, Providing Standard Form and Meaning to Digital Building Logbook Data', DG Grow, 23. (Final), pp. 8, May 2023.

[4] R. Laigner Nunes et al., "From a Monolithic Big Data System to a Microservices Event-Driven Architecture". Conference: Euromicro Conference on Software Engineering and Advanced Applications (SEAA) At: Portorož, Slovenia, pp. 213-220, 2020. DOI:10.1109/SEAA51224.2020.00045

[5] CORDIS Résultats de la recherche de l'UE [Online]. Available from: https://cordis.europa.eu/project/id/101091749, Fact Sheet, Last update: 10 March 2023, 2024.03.15

[6] INCOSE, Systems Engineering Handbook, 'A Guide for System Life Cycle Processes and Activities', 4th Edition, INCOSE-TP-2003-002-04, 2015 pre-pared by: International Council on Systems Engineering, 7670 opportunity Rd, Suite 220, San Diego, CA, USA 92111-2222, pp. 14, 2015.

[7] M. Ryan, and L. Wheatcraft, 'Guide to Writing Requirements', INCOSE-TP-2010-006-04 | VERS/REV: 4 | 1 April 2022, prepared by: Requirements Working Group International Council on Systems Engineering 7670 Opportunity Road, Suite 220, San Diego, California 92111-2222 USA, INCOSE 2023, pp. 9, April 2022.

[8] C.S. Wasson, 'System Analysis, Design and Development, Concepts, Principles, and Practices', Published by John Wiley & Sons, Inc., Hoboken, New Jersey, Chapter 26, The SE Process Model, pp.278 and Chapter 32, Requirements Derivation, Flow Down, Allocation, And Traceability, pp. 363, 2006.

[9] C.S. Wasson, 'System Engineering, Analysis, Design, and Development', 2nd Edition, Published by John Wiley & Sons, Inc., Hoboken, New Jersey, Chapter 11, Analytical Problem-Solving and Solution Development Synthesis, pp. 251, 2016.

[10] R.M. Mackey, 'System Health Management with Aerospace Applications', edited by S.B. Johnson, T.J. Gormley, S.S. Kessler, C. D. Mott, A. Patterson-Hine, K.M. Richard and P.A. Scandura, Jr, Published by: John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK, 2011, Chapter 9, Accessing and Maturing Technology Readiness Levels, pp. 152, 2011.

[11] J. Holt, 'Systems Engineering Demystified: A practitioner's handbook for developing complex systems using a model-based approach'. Packt Publishing Ltd, 2021, Chapter 2, Model-Based Systems Engineering, pp 51, 2021.

[12] ANSYS BLOG, ‘Model-Based Systems Engineering (MBSE) Explained’. [Online]. Available from: https://www.ansys.com/blog/model-based-systems-engineering-explained#:~:text=Model%2Dbased%20systems%20engineering%20(MBSE)%20is%20a%20methodology%20that,to%20document%2Dcentric%20systems%20engineering. 2024.05.06

[13] PEP ecopassport® PROGRAM, Product Category Rules for Electrical, Electronic and HVAC-R Products, PCR-ed3-EN-2015 04 02© 2015 P.E.P. Association, http://www.pep-ecopassport.org/index.php?eID=dumpFile&t=f&f=773&token=d99658b4286d15a36ec908161ca64e93ade0cfc2

[14] WBCSD x BCG DPP, ‘The EU Digital Product Passport shapes the future of value chains: What it is and how to prepare now’ [Online]. Available from: https://www.wbcsd.org/Pathways/Products-and Materials/Resources/The-EU-Digital-Product-Passport. 2024.05.06.

[15] R. Tirado, A. Aublet, S. Laurenceau, M. Thorel, M. Louërat, and G. Habert, “Component-Based Model for Building Material Stock and Waste-Flow Characterization: A case in the île-de-France Region”, Sustainability 2021, 13, 13159. pp. 1-34 https://doi.org/10.3390/su132313159