Università degli Studi di Ferrara
DA Dipartimento Architettura Ferrara
Universiteti POLIS

BIM digital integration for existing buildings

Processes and tools to foster technological innovation of added-value building systems applied to the 20th century built asset in Emilia-Romagna

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Cycle XXXV

International Doctorate in Architecture and Urban Planning

Università degli Studi di Ferrara
IUSS

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INTERNATIONAL DOCTORATE
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Cycle XXXV

IDAUP Coordinator Prof. Roberto Di Giulio

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Curriculum Architecture / IDAUP Topic 1.5 Cultural heritages. Innovations and ICT processes for cultural heritages use and conservation.
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Fig. 001 - Google. (n.d.). [Map of the city of Bologna]. Retrieved 10/01/2023, from earth.google.com

AS-IS
TO >
BIM

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I. Acknowledgement

This PhD research was co-financed with resources from the European Social Fund Operational Programme 2014/2020 of the Emilia-Romagna Region within the framework of the "*Application of integrated digital tools for surveying, diagnostics and BIM modelling to support the innovation of components and systems, products and services with high added value for the intervention on existing buildings*".

The European Social Fund (ESF), established in the founding year of the European Economic Community, has been operating for more than 50 years as the primary financial instrument with which Europe invests in the training of its citizens. The funds used are allocated by Europe to the regions with the aim of investing in the acquisition of useful skills to cope with changes in the labour market.

Europe allocates ESF resources in seven-year periods to enable states and regions to carry out long-term programming actions, ensuring continuity of support for citizens.

For the 2014/2020 period, the Emilia-Romagna Region has established an operational programme to manage ESF funding. The programme has a strategy articulated on Objectives and Priorities identified through a governance direction carried out in agreement with the institutions and social partners of the regional territory.

The projects financed in the 2014/2020 suit respond to these objectives, guaranteeing all citizens equal rights in acquiring skills and generating the most favourable conditions for creating a synergy between the training offer and the growth needs of human capital. The selected projects are approved by the Region and are implemented by accredited training organisations. The ultimate aim of ESF activities is to create opportunities for people and businesses.

Project ID	2019-11299/RER		
CUP	F75J19000440009		
Title	Applicazione di strumenti digitali integrati per il rilievo, la diagnostica e la modellazione BIM a supporto dell'innovazione di componenti e sistemi, prodotti e servizi ad alto valore aggiunto per l'intervento sul costruito esistente		
Thematic framework	11 - ISTRUZIONE E FORMAZIONE	Thematic field	11 - ISTRUZIONE E FORMAZIONE
Sector	11.02 - EDUCAZIONE E FORMAZIONE	Planning cycle	2014-2020
Source programme typology	FSE	Source programme	2014IT05SFOP003 - POR FSE Emilia-Romagna
Macroarea	Centro-Nord	Implementation status	Ongoing
FSC Founds (CIPE N.43/2020)	86.743,44		

The research is part of the IDAUP - International Doctorate in Architecture & Urban Planning, XXXV cycle, consortium between the University of Ferrara, Department of Architecture, Polis University of Tirana and, as Associate Members, the University of Minho, Guimaraes (Portugal), Slovak University of Technology, Institute of Management, Bratislava (Slovakia) and University of Pécs / Pollack Mihaly Faculty of Engineering and Information Technology (Hungary).
The research is being developed thanks to the grant funded by the Emilia-Romagna Region. Call *“Alte Competenze per la ricerca, il trasferimento tecnologico e l’imprenditorialità (Delibera di Giunta Regionale n. 39 del 14/01/2019)”*, entitled: Application of integrated digital tools for surveying, diagnostics and BIM modelling to support innovation of components and systems, products and services with high added value for the intervention on existing buildings.
Doctoral fellowship approved by the Deliberation of the G.R. n. 462/2019 *“Approval of the research training projects presented on the basis of the Call approved by its own resolution n. 39/2019. POR FSE 2014/2020”* Ref. PA 2019-11299/RER - CUP F75J19000440009.

The PhD research has been grounded on the results of research developed both at regional level - specifically those related to the intervention on the existing building - and at international level.
The following projects were considered as reference for the development of the research thesis.

For XX century regional asset and for the development of an inclusive approach to the application of Building Information Modeling in the processes of intervention and management of the existing built environment:

The **InSPiRE project** - *Integrated technologies for Smart buildings and PREdictive maintenance* - is financed within the framework of the Emilia-Romagna Region's S3 Intelligent Specialization Strategy under the POR-FESR 2014-2020 programme, call for 'Strategic industrial research projects addressing S3 priority areas', Axis 1, Research and Innovation of the Emilia-Romagna Region (2019-2022).
The project is coordinated by TekneHub Laboratory, Ferrara Technopole, University of Ferrara. Partners: CIRI EC - Centro Interdipartimentale di Ricerca Industriale Edilizia e Costruzioni dell'Università di Bologna; CRICT - Centro Interdipartimentale di Ricerca e per i Servizi delle Costruzioni e del Territorio dell'Università di Modena e Reggio-Emilia; Istec CNR - Istituto di Scienza e Tecnologia dei Materiali Ceramici di Faenza; Cifla - Centro per l'innovazione tecnologica e sociale - Fondazione Flaminia di Ravenna. Companies: ACER Azienda Casa Emilia-Romagna della Provincia di Bologna; ACER PRO.M.O.S. Programma di Manutenzione Ordinaria e Straordinaria; Fassa S.r.l. Spresiano, Treviso; Sestosensor S.r.l. Zola Predosa, Bologna; Finsoft S.r.l. Milano; Giancarlo Maselli S.r.l. Nonantola, Modena; ACSoftware Lamezia Terme, Catanzaro. Stakeholder: Clust-ER Build Associazione Clust-ER Edilizia e Costruzioni della regione Emilia-Romagna.

The **eBIM project** - *existing Building Information Modeling for intervention on existing buildings* - is financed within the framework of the Emilia-Romagna Region's S3 Intelligent Specialization Strategy under the POR-FESR 2014-2020 programme, call for 'Strategic industrial research projects addressing S3 priority areas', Axis 1, Research and Innovation of the Emilia-Romagna Region (2019-2022).
The project is coordinated by CIDEA Centro Interdipartimentale per l'Energia e l'Ambiente dell'Università degli studi di Parma. Partners: TeckneHub Laboratory, Ferrara Technopole, University of Ferrara; CIRI EC, Centro Interdipartimentale per la Ricerca Industriale Edilizia e Costruzioni dell'Università degli studi di Bologna; Centro Ceramico; Certimac. Companies: CMB Società Cooperativa, Carpi, Modena; POLITECNICA Ingegneria e Architettura Società Cooperativa, Modena; Buia Nereo S.r.l., Parma; Telematica Informatica S.r.l., Torino; Nemoris S.r.l., Bologna; Smart Domotics S.r.l., Faenza, Ravenna; Cooprogetto Società Cooperativa, Faenza, Ravenna; Ceramiche Refin S.p.A., Salvaterra, Reggio Emilia; Tonalite S.r.l., Modena; Monitor the Planet S.r.l., Faenza, Ravenna.

For advancement in Heritage digitization, the development of integrated survey protocols, the assessment of semantic technologies, web-based platforms, BIM platforms and data aggregations:

The **INCEPTION project** – *Inclusive Cultural Heritage in Europe through 3D semantic modelling* – applied under the Work Programme Europe in a changing world – inclusive, innovative and reflective Societies (Call - Reflective Societies: Cultural Heritage and European Identities, Reflective-7-2014, Advanced 3D modeling for accessing and understanding European cultural assets) has received funding from the European Union's H2020 Framework Programme for research and innovation under Grant agreement no 665220 (2015-2019).

The project has been developed by a consortium of fourteen partners led by the Department of Architecture of the University of Ferrara. Academic partners of the Consortium, in addition to the Department of Architecture of the University of Ferrara, include the University of Ljubljana (Slovenia), the National Technical University of Athens (Greece), the Cyprus University of Technology (Cyprus), the University of Zagreb (Croatia), the research centers Consorzio Futuro in Ricerca (Italy) and Cartif (Spain).

The clustering of small medium enterprises includes: DEMO Consultants BV (The Netherlands), 3L Architects (Germany), Nemoris (Italy), RDF (Bulgaria), 13BIS Consulting (France), Z + F (Germany), Vision and Business Consultants (Greece).

III. Abstract ITA

Il progetto di ricerca rientra nella categoria riservata ai progetti finanziati dalla Regione Emilia-Romagna, Progetto di Ricerca per il Trasferimento Tecnologico e l'Impresa, con la tematica: *"Applicazione di strumenti digitali integrati per il rilievo, la diagnostica e la modellazione BIM a supporto dell'innovazione di componenti e sistemi, prodotti e servizi ad alto valore aggiunto per l'intervento sul costruito esistente"*.
La ricerca ha avuto come obiettivo la definizione di un processo metodologico di acquisizione e integrazione delle informazioni e lo sviluppo di strumenti digitali in ambiente BIM (*Building information Modeling*) finalizzati a promuovere la permeabilità tecnologica nell'intervento sugli edifici esistenti. L'obiettivo principale della ricerca riguardava la definizione di processi ottimizzati per la digitalizzazione del costruito e la definizione di strumenti digitali a supporto dell'applicazione di tecnologie innovative sul patrimonio edilizio esistente.
Tali strumenti digitali sono finalizzati a favorire l'uso di tecnologie innovative (Ad es. strumenti che possono agire come driver di innovazione per componenti, sistemi e prodotti avanzati) nell'ambito della ristrutturazione, rigenerazione, manutenzione e per la gestione del patrimonio edilizio. In aggiunta a una gestione più razionale dell'intervento sul costruito, gli strumenti digitali sviluppati nell'ambito della ricerca mirano ad un uso più efficiente dei dati digitali raccolti nel tempo e all'interoperabilità tra i sistemi (*Open access data*), nonché ad un'applicazione più efficiente della modellazione parametrica per affrontare la tematica della frammentazione nel processo edilizio. Questa procedura può portare all'integrazione di diverse tipologie di dati informativi (ottenuti nelle fasi di rilievo, analisi e documentazione) in "pacchetti BIM" (Componenti o *funzionalità* BIM), da utilizzare come "*toolkit*" fruibili come catalogo di componenti e strumenti al servizio della progettazione.
I pacchetti con funzionalità BIM prodotti sono strutturati in modo da trasmettere il *know-how* e l'innovazione tecnologica nell'intervento sul costruito. L'approccio legato all'uso dei dati digitali e all'applicazione degli strumenti BIM è mirato a favorire una forma di collaborazione inclusiva tra gli attori coinvolti nella filiera delle costruzioni e a veicolare le soluzioni tecnologiche proposte dai produttori del settore edile, al fine di facilitarne l'utilizzo.
Durante la realizzazione della ricerca, le attività sono state supportate da una rete di partenariato che comprende la Regione Emilia-Romagna, la Rete Alta Tecnologia dell'Emilia-Romagna, il Centro DIAPReM del Dipartimento di Architettura dell'Università di Ferrara, il laboratorio di ricerca industriale TekneHub, il Tecnopolo dell'Università di Ferrara, il Clust-ER BUILD – Edilizia e Costruzioni (Associazione di organizzazioni pubbliche e private), Istituzioni pubbliche, Enti locali e imprese private. Il progetto di ricerca si basa sui risultati di ricerche precedentemente sviluppate sia a livello regionale - nello specifico quelle relative all'intervento sull'edificio esistente - sia a livello internazionale, pur limitando l'ambito di applicazione ad un approfondimento relativo al sistema delle pareti verticali esterne.
Il risultato principale della ricerca è la definizione di un processo per la realizzazione di modelli BIM focalizzati su edifici realizzati con tecnologie costruttive non standard, e lo sviluppo di "pacchetti" che potranno essere utilizzati dagli operatori per intervenire su questi edifici a fini di ristrutturazione e rigenerazione.
I risultati ottenuti sono stati testati su casi di studio selezionati nell'ambito del patrimonio regionale del XX Secolo, un asset complesso già indagato nell'ambito di progetti in corso e conclusi, al fine di garantire la continuità della ricerca in corso, contribuendo all'ulteriore sviluppo di procedure e all'applicazione di strumenti digitali integrati.
Il settore scientifico-disciplinare di ricerca è ICAR/17, nell'ambito della tematica "Innovazione e processi ICT", pertanto il focus principale è legato al rilievo, alla modellazione e alla gestione dei dati all'interno di un processo più ampio che in futuro coinvolgerà sempre più aziende nell'utilizzo delle tecnologie BIM.

III. Abstract ENG

The research proposal is applied under the position reserved to projects funded by Emilia-Romagna Region, Research Project for Technology Transfer and Business, for the following subject: *Application of integrated digital tools for surveying, diagnostics, and BIM modeling supporting the innovation of high added value components, systems, products and services for the intervention on existing buildings*.

The research aimed at defining a methodological process of information acquisition and integration and at developing digital tools in BIM environment (Building information Modeling) to promote technological permeability in the intervention on existing buildings. The main objective was the definition of optimized digitalisation processes and digital tools to support the application of innovative technologies on existing building stock.

These digital tools aim at fostering the use of innovative technologies (i.e. tools that can act as drivers of innovation of advanced components, systems and products) for the refurbishment, regeneration, maintenance and management of built asset.

In addition to a more efficient management of the intervention on the built environment, the digital tools developed within the research aim to deal with a more efficient use of digital data collected over time and interoperability between systems (*Open access data*), and with a more efficient application of parametric modelling to address the fragmentation of the building process. This procedure can lead at integrating different information data (obtained in the survey, analysis and documentation phase) in “BIM packages” (BIM objects or *features*) i.e. BIM “toolkits” to be used as objects catalogue and design tools.

The packages are structured in such a way as to convey know-how and technological innovation in the intervention on the built environment. This approach to the use of digital data and the application of BIM tools is targeted at encouraging an inclusive collaboration between the actors involved in the construction supply chain and conveying the technological solutions proposed by manufacturers in the construction sector, in order to facilitate their use.

During the project implementation, the study was supported by a partnership network including the Emilia-Romagna Region, the Emilia-Romagna High Technology Network the DIAPReM Centre of the Department of Architecture, University of Ferrara, the industrial research lab TekneHub, University of Ferrara Technopole, the BUILD Clust-ER - Building and Construction (association of public and private organisations), public institutions, local authorities, and private enterprises. The project started from the results of research developed both at regional level - specifically those related to the intervention on the existing building - and international level, while limiting the scope of in-depth application to the system of external vertical walls.

The main research outcome is the definition of a process for the implementation of BIM models focused on buildings made with non-standard construction technologies, and the development of “packages” that will be used by companies to work on these buildings for refurbishment and regeneration purposes.

The results achieved were tested on selected case studies within the regional heritage of the twentieth century, a complex asset already investigated within ongoing and completed projects, in order to ensure the continuity of current research, contributing to further development of procedures and application of integrated digital tools.

The scientific-disciplinary field of research is ICAR/17, under the topic “innovation and ICT processes”, therefore the main focus is related to survey, modeling and data management within a broader process that in the future will involve more and more companies in the use of BIM technologies.

IV. Thesis dissemination

The research activities that led to the development of the thesis were disseminated through publication in journals and conference proceedings both nationally and internationally. The list of publications and conferences is listed below.

Selected pubblications:

Maietti F., Tasselli N., *Digital connections. Data integration in BIM environment for the intervention on existing buildings*, Connettere, Un disegno er annodare e tessere / Connecting, drawing for weaving relationship. Conference proceedings. Reggio Calabria/ Messina Sept. 17-18-19, 2020

Tasselli N,. Maietti F., *Digital data integration for the intervention on the existing built asset.* Conference proceedings. XV International Conference on Graphic Expression Applied to Building, APEGA 2021 Redrawing the Future.

Tasselli N., Maietti F., *Data management implementation. New strategies addressing built assets*, ArchiDOCT www.archidoct.net Vol. 8 (2) / Feb 2021, ISSN 2309-0103 (SCOPUS, Double blind peer reviewed)

Tasselli N., Maietti F., *Bim for existing heritage: from 3D integrated survey to parametric modeling for refurbishment and management.* Conference proceedings. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVI-2/W1-2022 9th Intl. Workshop 3D-ARCH “3D Virtual Reconstruction and Visualization of Complex Architectures”, 2–4 March 2022, Mantua, Italy

Raco F., Balzani M., Planu F, Tasselli N., *Modellazione semantica HBIM per la rappresentazione digitale dell’intervento sul patrimonio esistente*, 43° Convegno Internazionale dei Docenti delle Discipline della Rappresentazione. Congresso della Unione Italiana per il Disegno. DIALOGHI. VISIONI E VISUALITÀ. Genova | 15-16-17 settembre 2022

Lecturer:

XV International Conference on Graphic Expression Applied to Building, APEGA 2021 Redrawing the Future. May 28, 2021

3D-ARCH “3D Virtual Reconstruction and Visualization of Complex Architectures”, 2–4 March 2022, Mantua, Italy
Bim for existing heritage: from 3D integrated survey to parametric modeling for refurbishment and management

Salone del Restauro 2022, Between Project and Research, 9/06/2022, Sala Oceania, Ferrara Exhibition Centre. “*Materiali e componenti a sistema nel progetto digitale, La ricerca Fassa BIM*”.

V. List of Abbreviations

List of Abbreviations			
ENG	*Full text*	*ITA*	*Testo completo*
Num.			
2D	Two dimensional (x,y)		
3D	Three-dimensional modeling (x,y,z)		
4D	Four-dimensional modelling (i.e. time schedule data)		
5D	Five-dimensional modelling (i.e. time and cost data)		
6D	Six-dimensional modelling (Life-Cycle management information)		
7D			
A			
AEC	Architecture, Engineering and Construction Industry		
AIA	American Institute of Architects		
AMF	Asset Management Framework		
API	Application Programming Interface		
AIM	Architectural Information Modelling		
AIM	Asset Information Model		
ADP	Automatic Digital Photogrammetry		
AT	Activity Theory		
		ART	Articolo
		ACDat	Ambiente Condiviso dei Dati
		A1	Prima approvazione
		A2	Seconda approvazione
		A3	Terza approvazione
AIR	Asset information requirements		
		AFO	Ambiti funzionali omogenei
		ASO	Ambiti spaziali omogenei
B			
BAF	BIM Academic Forum		
BCF	Building Collaboration Format		
bcXML	Building and Construction eXtensible mark-up Language		
BDS	Building Description System		
BEP	BIM Execution Plan		
BEP	Building Energy Performance		
BIM	Building Information Modelling		
BIMs	Building Information Model		
BIMM	Building Information Modelling and Management		
BLIS	Building Lifecycle Interoperability Consortium		

BMS	Building Management System		
BPEP	BIM Project Execution Plan		
BRep	Boundary Representation		
bSDD	buildingSMART Data Dictionary		
BSRIA	The Building Services Research and Information Association		
BoQ	Bill of Quantity		
BPO	Business Process Operation		
BIm3	BIM Maturity Model		
BEIIC	Built Environment Industry Innovation Council		
BM	Business Model		
BMI	Business Model Innovation		
BIMCO	BIM Corporate		
BIMMS	BIM Method Statement Process		
		BIMSM	BIM Specifica Metodologica di servizio
C			
CAD	Computer-Aided Design		
CA(A)D	Computer-Aided (Architectural) Design		
CityGML	City Geography Markup Language		
CE	Civil Engineering		
		CE	Comunità Europea
CMAR	Construction Management At Risk		
COBie	Construction Operations Building information exchange		
CSG	Constructive Solid Geometry		
CAMS	Computer-Aided manual Surveying		
CEN	European Committee for Standardization		
CWM	Closed World Machine		
CFA	Confirmatory Factor Analysis		
CLD	Causal Loop Diagram		
CDE	Common Data Environment		
CMM	Capability Maturity Model		
CIFE	Integrated Facilities Engineering		
C#	C Sharp Programming Language designed for the Common Language Infrastructure		
CAFM	Computer Aided Facility Management		
D			
D2RQ	Database to RDF Query		
DB	Design-Build		
DB	Database		
DBB	Design-Bid-Build		
DCC	Dynamic Content Creation		
DWG	file format used for storing 2D and 3D design data and metadata		
DL	Description Logic		

DTV	Design Transfer View		
DXF	Drawing eXchange Format		
DOIT	Diffusion of Innovation Theory		
		D.Lgs	Descreto legislativo
DTM	Digital Terrain Model		
DIKW	Data, Information, Knowledge, Wisdom		
DfMA	Design for Manufacturing and Assembly		
E			
EIF	European Interoperability Framework		
ETL	Extract, Transform and Load		
ETSI	European Telecommunication Standards Institute		
EUPPD	European Union Public Procurement Directive		
EU	European Union		
		EP	Elenco prezzi
ERP	Enterprise resource planning		
F			
FM	Facility management		
FBM	Feature-Based Modelling		
FEM	Finite Element Analysis		
G			
GIS	Geographic Information System		
GUID	Globally Unique Identifier		
GUI	Graphic User Interface		
GPS	Global Positioning System		
GDL	Geometric Description Language		
GPU	Graphics Processing Unit		
gbXML	Green building XML		
GC	General Contractor		
GP	General Planner		
H			
HVAC	Heating, Ventilation and Air Conditioning		
HTML	HyperText Markup Language		
HTTP	HyperText Transfer Protocol		
HBIM	Heritage building information modeling		
I			
IAI	International Alliance for Interoperability		
ICT	Information and Communication Technologies		
ICE	The Institution of Civil Engineers		
		ICE	Indice di costo energetico
IDM	Information Delivery Manual		
IFC	Industry Foundation Classes		
IFD	International Framework for Dictionaries		
IPD	Integrated Project Delivery		
ISO	International Standards Organisation		
ISP	The Information Systems Panel		

IMechE	Institution of Mechanical Engineers		
IDT	Innovation Diffusion Theory		
INT	Institutional Theory		
IPD	Integrated Project Delivery		
IBC	International Building Code		
IpD	Integrated Project Delivery		
IDM	Information Delivery Manual		
I-BIM	Infra BIM		
IFS	Infrastructure Facility Services		
IC	Industrialized Construction		
IHB	Industrialized House Building		
		IRS	Indice di rischio sismico
J			
JSON	JavaScript Object Notation		
JBM	Joint Board Of Moderators		
K			
KRS	Knowledge Representation Systems		
KM	Knowledge Management		
KSF	Key Success Factors		
L			
LD	Linked Data		
LoD	Level Of Detail		
LODt	Level Of Development (LoG+LoI)		
LOD	Linked Open Data		
LOI	Level of Information		
LID	Level of Information Detail		
LOC	Level of Certainty		
LCC	Life Cycle Cost		
LOG	Level of Geometry		
LCA	Life Cycle Analysis		
		L0	Livello di Condivisione 0
		L1	Livello di Condivisione 1
		L2	Livello di Condivisione 2
		L3	Livello di Condivisione 3
		LC1	Livello di Coordinamento 1
		LC2	Livello di Coordinamento 2
		LC3	Livello di Coordinamento 3
M			
MEP	Mechanical, Electrical and Plumbing		
MVD	Model View Definition		
MACE	Metadata for Architectural Contents in Europe		
MR	Mixed Reality		
MMI	Model maturity index		
MIDP	Master Information Delivery Plan		
MPS	Model Progression Specification		
ML	Machine learning		
N			
N3	Notation 3		
N3Logic	Notation 3 Logic		
NLP	Natural Language Processing		
NBS	National Building Specification		
NBN	National Bureau for Normalization		

NDA	Non-disclosure agreement		
		NTC	Norme Tecniche per le Costruzioni
NBIMS	National Building Information Model Standard		
NBIMS-US	National BIM Standard - United States		
NDS	Network Data Server		
		NOD	Nucleo opere digitali
O			
OBDA	Ontology-Based Data Access		
OWL	Web Ontology Language		
OLE	Object Linking and Embedding		
OLR	Ordinal Logistic Regression		
O&M	Operation and Maintenance		
OPEX	Operating Expenditure		
ODBC	Open Database Connectivity		
		OE	Operatore economico
OIR	Organizational Information requirements		
		oGI	Offerta di Gestione Informativa
P			
PAS	Publicly Available Specifications		
PDT	Product Data Templates		
PLC	Product Life Cycle		
PSRL	Semantic Web Rule Language		
PLM	Product Lifecycle Management		
PCM	Point Cloud Model		
PIM	Project information model		
Post-2016 Period	Post-mandate (UK Government BIM Strategy time- horizon)		
Pre-2011 Period	Pre-announcement of BIM mandate (UK Government BIM Strategy time-horizon)		
PPP	Public Private Partnership		
PWD	Public Work of Department		
PM	Performance Measurement		
		pGI	Piano per la Gestione Informativa
PIP	Project Implementation Plan		
PIR	Project Information Requirements		
Q			
QCA	Qualitative Comparative Analysis		
QA	Quality Assurance		
QA	Quality Assessment		
QC	Quality Control		
QS	Quantity Surveyor		
QTO	Quantity take-of		
R			
R2RML	RDB to RDF Mapping Language		
RDF	Resource Description Framework		
RDFa	Resource Description Framework in Attributes		
RDFS	RDF Schema		
RIF	Rule Interchange Format		
RV	Reference View		
RIBA	Royal Institute of British Architects		

RICS	The Royal Institution of Chartered Surveyors		
RTS	Robotic Total Station		
RQs	Research Questions		
RFI	Request for Information		
ROI	Return on Investment		
RM	Responsibility Matrix		
RFID	radio frequency identification		
R&D	Research and Development		
S			
SKOS	Simple Knowledge Organization System		
SDK	Software Development Kit		
SFM	Structure From Motion		
SQL	Standard Query Language		
SOAP	Simple Object Access Protocol		
SPARQL	Simple Protocol and RDF Query Language		
STEP	Standard for the Exchange of Product Model Data		
SPF	STEP Physical File		
SWRL	Semantic Web Rule Language		
SEM	Structural Equation Modelling		
SLR	Systematic Literature Review		
SMEs	Small and Medium Sized Enterprises		
SWOT	Strength, Weaknesses, Opportunities and Threats		
SMC	Solibri Model Checker		
STEP	Standard for the Exchange of Product Model Data		
		SAL	Stato avanzamento lavori
SCCS	Supply Chain Capability Summary		
SCIP	Supply Chain Integration Practice		
		S.A.	Stazione appaltante
T			
TLS	Terrestrial Laser Scanning		
TAM	Technology Acceptance Model		
TIDP	Task Team Information Delivery Plan		
TFS	Technical Facility Services		
TVD	Target Value Design		
U			
URI	Unique Resource Identifier		
UBAT	Unified BIM Adoption Taxonomy		
USA	United States of America		
UK	United Kingdom		
		UE	Unione Europea
		UNI	Ente nazionale italiano di unificazione
UI	User interface		
UAV	Unmanned Aerial Vehicle		
V			
VRVS	Virtual Reality - Visual Simulation		
VSC	Virtual Simulation and Calculation		

W			
W3C	World Wide Web Consortium		
WWW	World Wide Web		
WLC	Whole-life cost		
WBS	Work breakdown structure		
WIP	Work in progress		
X			
XML	eXtensible Markup Language		
XAML	Extensible Application Markup Language		
XSD	XML Schema Definition		
X3D	eXtensible 3D		

VI. List of Acronym

Acronym	Extended term	Definition
Tenderer		Contracting economic operator
AS-IS	As it is (in the condition that something is in)	The existing state of the building, the result of surveying, investigation and evaluation activities.
Archive		Section of the ACDat (CDE) in which the models and deliverables are stored.
Asset		Built or unbuilt unit, public or private. Each property is identified by a code ("ASSET CODE") and may consist of several entities.
BIM Manager		Role in the planning, management and verification of BIM workflows. (UNI 11337-7)
Functional block (Blocco Funzionale)		Parts into which the building is subdivided. The subdivision follows the technological criterion. Several disciplines can be defined for each functional block. The number is defined according to the complexity of the building.
Building (Fabbricato)		The physical built entity which consists of one or more structurally or functionally connected units. Each Building is identified by a “BUILDING CODE”.
Federation (Federazione)		Grouping activities of several disciplinary models.
Open format (Formato aperto)		File format organised on specific public syntaxes whose use is open to all operators.
Proprietary format (Formato proprietario)		File format based on a proprietary encoding from a specific manufacturer. Its use is restricted to specific terms of use.
Federated model (Modello Federato)		Model created through the union (federation) of several disciplinary models. Different kinds of federated models exist: Functional Block Federated Model; the Overall (Asset) Federated Model; Discipline Federated Model and Summary Federated Model.

Functional Block Federated Model		A federated model representing a Functional Block, composed of the models of its component disciplines.
Discipline Federated Model		A federated model which represents a building defined by a single discipline. It joins the functional blocks that compose it.
Overall (Asset) Federated Model		Federated model representing a building composed of its component disciplines. It combines federated models composed of disciplinary functional blocks.
Summary Federated Model		A federated model representing an Asset in all its disciplines.
Digital asset		The set of graphic and informative data describing the digital asset. It corresponds to the AIM (Asset information model, PAS 1192-3)
PUBLISHED		Section of the ACDat (CDE) where models and deliverables are published after the verification phase.
Base point (Building)		The relative origin of BIM models. Located at the intersection of two grid axes in the federated summary model. It must be related to the survey point.
Survey origin (Asset)		The absolute origin of the asset.
Repository		Digital data archive, structured as a directory of folders (ACDat/CDE) in which project data are managed.
BIM project manager		Contractor's BIM Manager, responsible for BIM activities.
Discipline Manager		BIM coordinator in charge of a specific discipline.
SHARED		Section of the ACDat (CDE) where models are shared between the working groups.
Service		Procurement activities
Project structure		Multi-part asset breakdown and the related BIM model.
Use / Scope (of BIM model)		Specific objectives to be achieved in the implementation of the BIM model. The use of the model is often related to the nature of the client's activity.
Operator user		ACDat User (CDE) identified by the contractor (Discipline Manager)
BIM Manager User		An ACDat user (CDE) similar to the BIM service and process manager.

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Chapter 1 – Introduction

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Introduction

1.1 Research background

The research focuses on possible innovative approaches in the application of BIM – Building Information Modeling to the existing built heritage, in particular for refurbishment, regeneration and management purposes. The scope of the research is bounded by 20th century heritage in the Emilia-Romagna region; this is to respond to a need for widespread redevelopment of existing assets, which has emerged from specific studies concerning the construction sector (S3, 2021), and to deepen some studies related to innovation processes in the practice of renovation.

Including global challenges from programmes as Horizon Europe (Horizon Europe, 2021) or the Green Deal (European Commission, 2021), priority issues such as digitisation, territorial heritage and regional identity and open innovation are considered to be at the centre of future actions within the construction sector.

Digitisation is both a social trend and a technological priority at international, national and regional level, involving processes, products and services and requiring specific skills (European Commission, 2019).

Within the Regional Research and Innovation Strategy for Smart Specialisation 2021-2027 (S3), digitisation focuses on data throughout its lifecycle: survey, processing, integration, transfer, archiving, making it necessary to use platforms, models and applications for data and processes interoperability, and the implementation of new innovative services. The use of Digital Twin from support in industrial plant design applications to facility management (Jouan and Hallot, 2020), management of cultural heritage (La Russa and Santagati, 2020) or entire cities (Bianchini et al., 2021), is an example of the transfer and customisation of digitisation models across sectors.

The introduction and extensive use of integrated digital tools for building and space design, site management and maintenance (“smart” construction site, BIM, predictive monitoring and maintenance, IOT) are part of this development direction. The priorities are AI - Artificial Intelligence applications (Grilli and Remondino, 2019), High Performance Computing, Cybersecurity together with the development of widespread Advanced Digital Skills.

Within the regional S3, the main innovation directions include acquisition, archiving, monitoring, restoration, integrated conservation, management and enhancement of the tangible and intangible heritage and its digitisation (Grilli and Remondino, 2020), including new technologies, advanced methodologies, new materials and AI applications (Teruggi et al., 2021) and the use of big data for risk prevention and optimisation (Harirchian et al., 2020). The need to provide more advanced tools for the conservation process is a crucial issue given the huge availability of assets, the need to increase knowledge and ensure their protection and the positive effects (economic, social, cultural significance) that these assets

represent for the regional and national context. These advanced tools include the integration of data to facilitate the careful monitoring of assets and their integrated management.
Regarding existing buildings, not only historical but also modern and contemporary, the topics of greatest interest include digital technologies applied to eBIM (existing BIM), advanced 3D models, predictive maintenance of the built heritage (Achille et al., 2018) and innovation in technological approaches to diagnostics.
The advancement of these procedures can contribute to a faster data acquisition, even in emergency condition, and to a more efficient building site management, to the development of new materials, to the regeneration and assessment of the built heritage and to a data management able to foster digitisation processes and a more efficient data sharing among authorities and operators/professionals.
The research aims to face the topic of 3D virtual reconstruction and visualization of complex architectures according to two main meanings: complex architectures (existing assets, changed over time, characterised by mixed and layered structures), and complexity of information management (Carnevali et al., 2019).
Smart 3D reconstructions, modelling, accessing and understanding of digital environments from multiple data sources are among the main drivers to innovate the use of BIM applied to existing heritage.
Nowadays, the research scenario in the field of BIM digitization of existing assets is wide and challenging (Barbero et al., 2021), when digitization processes or digital renovation workflows are a priority (Olawumi et al., 2019).
At European level, several funded projects (P2Endure, Net-UBIEP, BIM-SPEED, BIMEET, BIM4EEB, BIMplement, BIM4REN) or Task Groups (BIM4SMEs, theBIMHub) and current research avenues under the Horizon Europe programme are pursuing the same goal.
The Emilia-Romagna Region promotes and supports the building regeneration process through public and private initiatives, fostering civil awareness and promoting the active participation of enterprises in funded projects that match aspects related to technological permeability in production field, through the involvement of the regional research system.
During the research implementation, studies and analyses were based to the support of a partnership network including the Emilia-Romagna Region, Public Institutions and Local Authorities. Moreover, the Emilia-Romagna High Technology Network and the DIAPReM Centre of the Department of Architecture, University of Ferrara were involved as well as the BUILD Clust-ER - Building and Construction (association of public and private organisations supporting the innovation system), the industrial research laboratory TekneHub, University of Ferrara Technopole, and private enterprises.
The research integrated the results of several research developed both at regional level - specifically those related to the intervention on the existing building - and at international level, while limiting the scope of in-depth application to the system of external vertical walls.
The results achieved were tested on selected case studies within the regional heritage of the twentieth century, a complex asset already investigated within ongoing and completed projects, in order to ensure the continuity of current research, contributing to further development of procedures and application of integrated digital tools.
The following projects were considered as reference for the development of the research proposal just to mention the most relevant ones:

- The Horizon 2020 project "INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling" (2015 – 2019), Work Programme Europe in a changing world – inclusive, innovative and reflective Societies (Call - Reflective Societies: Cultural Heritage and European Identities, Reflective-7-2014. Project Coordinator: Prof. Roberto Di Giulio; Technical Coordinator: Prof. Federica Maietti.
- BIMtob Academy: integrated competences for the use of Building Information Modeling tools in the management of building intervention" developed under the "Piano Triennale Integrato Fondo Sociale Europeo, Fondo Europeo di Sviluppo Regionale e Fondo Europeo Agricolo per lo Sviluppo Rurale. Alte competenze per la ricerca, il trasferimento tecnologico e l'imprenditorialità" Delibera dell'Assemblea legislativa n. 38 del 20/10/2015.
- "Optimisation of survey procedures and application of integrated digital tools for seismic risk mitigation of cultural heritage: The Emilia-Romagna damaged theatres" (Supervisor: Prof. Marcello Balzani), completed research developed under the Bando Alto Competenze 2018 "Invito a presentare progetti di formazione alla ricerca in attuazione del piano triennale alte competenze per la ricerca, il trasferimento tecnologico e l'imprenditorialità approvato con deliberazione dell'assemblea legislativa N.38 del 20/10/2015 POR FSE 2014/2020 Obiettivo tematico 10. Delibera di Giunta regionale n.388 del 19/03/2018.
- The project "eBIM: existing Building Information Modeling for intervention management on existing buildings", funded under POR-FESR EMILIA ROMAGNA 2014-2020, Asse 1 - Ricerca e innovazione, Azione 1.2.2 - Supporto alla realizzazione di progetti complessi di attività di ricerca e sviluppo su poche aree tematiche di rilievo e all'applicazione di soluzioni tecnologiche funzionali alla realizzazione della strategia di S3, Bando 2018 "Progetti di ricerca industriale strategica rivolti agli ambiti prioritari della Strategia di Specializzazione Intelligente".
- The project "InSPiRE - Integrated technologies for Smart buildings and PREdictive maintenance", funded under POR-FESR EMILIA ROMAGNA 2014-2020, Asse 1 - Ricerca e innovazione, Azione 1.2.2 - Supporto alla realizzazione di progetti complessi di attività di ricerca e sviluppo su poche aree tematiche di rilievo e all'applicazione di soluzioni tecnologiche funzionali alla realizzazione della strategia di S3, Bando 2018 "Progetti di ricerca industriale strategica rivolti agli ambiti prioritari della Strategia di Specializzazione Intelligente".

Among the above mentioned research in the region, we can highlight as starting points for the research the eBIM project and the InSPiRE project (POR-FESR 2014-2020), aiming at defining protocols for the knowledge of the built heritage through the integration of diagnostic data into platforms, and at integrating enabling technologies within building components to track their deterioration, pursuing the objective of predictive maintenance. The network includes the Emilia-Romagna High Technology Network and the Clust-ER BUILD - Building and Construction, particularly the issues addressed within the Value Chain Innova-CHM - Innovation in Construction and Cultural Heritage Management, including BIM for the knowledge management of materials and technologies.

1.2 Research problem(s) identification

The construction industry is one of the driving economic and employment sectors for the Emilia-Romagna region, and it is a very articulated environment[1]. The productive system is made up of a network of highly qualified and competitive Small and Medium-sized Enterprises (SMEs), which also play a leading role at national level. However, the construction chain is not a linear system, but rather an articulated environment characterised by a segmented approach involving a variety of skills and expertise with different roles and responsibilities.
For several years now, the sector has been suffering from an economic crisis affecting both larger companies and Small and Medium-sized Enterprises. Since 2007, the crisis in the real estate industry (and in the construction sector) happened together with the end of an economic and financial cycle[2] based on the expectation of unlimited growth.
In addition to this, the need to invest in environmental protection is a priority, according to the European directives[3]. Therefore, the refurbishment of the existing heritage, urban regeneration, architectural quality, reduction of land consumption, economic, technological, design and process sustainability are among the central topics of the technological priorities for the regional construction sector.
The 2012 earthquake[4] also highlighted the need to work towards improving the safety of the built asset.
Moreover, the construction industry in Emilia-Romagna is characterized by a lack of responsiveness to innovation (Document "S3 - Smart Specialization Strategy - Emilia-Romagna. Innovative guidelines for the regional innovation strategy for Smart Specialisation", Forum S3 - June 2018) due to the so-called "non-technological barriers" (i.e. regulatory aspects, information management, costs of tests and experimentations, etc.) that prevent innovations from radically improving the construction sector and finding application on the market.
The research project is defined within this framework, where technological development and the implementation of innovative processes can be a key factor to support the competitiveness of the construction supply chain.

1 See the Document "S3 – Smart Specialization Strategy – Emilia-Romagna. Innovative guidelines for the regional innovation strategy for Smart Specialisation", Forum S3 - June 2018 (retrieved from https://www.aster.it/pubblicazioni/orientamenti-innovativi-per-la-strategia-regionale-di-innovazione-per-la-smart?page=1, Accessed July 11 2019; retrieved from https://fesr.regione.emilia-romagna.it/s3, Accessed July 19, 2019), and monitoring reports on the state of implementation of regional research and innovation strategies.

2 See reports from the 87th Conference EUROCONSTRUCT, "The construction industry 2018-2023" (retrieved from http://www.cresme.it/it/congiunturale-cresme.aspx, Accessed July 3, 2019); Regional statistics - The residential real estate market. Emilia-Romagna (published on June 4, 2019, reporting period: year 2018), Agenzia delle Entrate, Direzione Centrale Servizi Estimativi e Osservatorio Mercato Immobiliare (retrieved from https://www.agenziaentrate.gov.it/wps/content/Nsilib/Nsi/Schede/FabbricatiTerreni/omi/Pubblicazioni/Statistiche+regionali/, Accessed June 27, 2019).

3 "Energy, Climate change, Environment" (retrieved from https://ec.europa.eu/info/energy-climate-change-environment_en, Accessed July 20, 2019), and the report "2030 targets. EU policy, strategy and legislation for 2030 environmental, energy and climate targets".

4 See "2012-2018. L'Emilia dopo il sisma Report su sei anni di ricostruzione" (retrieved from https://www.regione.emilia-romagna.it/terremoto, Accessed May 14, 2019); Open ricostruzione, (retrieved from https://openricostruzione.regione.emilia-romagna.it, Accessed July 18, 2019).

Particularly, the establishment of the regional Clust-ERs [5] (associations of public and private organisations that aim to support the innovation system according to the S3 priorities) mapped out technological scenarios through Value Chains as thematic working groups focused on S3 priorities and representative of the value chains most relevant to the regional economy.

Within the Clust-ER Build, three main Value Chains have been identified, highlighting the pressing needs of the intervention on the built-up environment in the current scenario: Innova-CHM, aimed at the conservation and enhancement of the built, historical and artistic heritage; Green2Build, focused on energy efficiency and sustainability in construction; and SICUCI, oriented towards buildings and infrastructure safety.

The main objectives of the project proposal are closely related to the activities of the Value Chain Innova-CHM - Innovation in Construction and Cultural Heritage Management, according to the following strategic aims:

- Development of new diagnostic technologies and optimisation of available technologies for in situ investigations and advanced data acquisition;
- Development of accessible databases collecting documentation of the whole building life-cycle (BIM for the knowledge management of materials and technologies)[6];
- Optimisation, standardisation and process interoperability towards the development of integrated design.

Value Chain's primary activities include the development of ICT tools and technologies for the interoperable management of project data (BIM tools, ICT tools for data integration from integrated survey to modeling, tools for the assessment of project scenarios), included the research proposal.

Therefore, the choice to apply the research proposal to the existing widespread built heritage takes into account the technological priorities defined by the S3 Strategy and the strategic priorities identified by the Clust-ER Build.

The research is specifically focused on:

- Application of integrated digital survey for documentation, data acquisition, archiving, analysis, management and representation by drawing up a protocol able to integrate metric and morphological data to different information levels, enhancing the management of the intervention on existing buildings;
- Application of the BIM methodology as a substantial improvement of refurbishment and regeneration processes of the regional built heritage, through the creation of digital archives accessible to all actors of the construction supply chain, towards the definition of new

5 See https://www.art-er.it/Clust-ER/ (Accessed February 4, 2023), listing the regional Clust-ER for different sectors (Agrifood, Build, Greentech, Create, Health, Innovate, MECH); for the Construction sector see Clust-ER Build (https://build.clust-er.it/en/).

6 EU-BIM is a pan-European Task Group aimed at develop best practices in BIM (building information modelling), bringing together national efforts into a common and aligned European approach to develop a world-class digital construction sector. The focus of the group is to develop a handbook containing the common principles for public procurers and policy makers to consider when introducing BIM to their public works or strategies.

integrated technological solutions;
- New methods of accessibility to available - but barely applied - technologies and cutting-edge research outcomes, proposing new integrations and applications of digital technologies and tools already at a high readiness level.

The twentieth century buildings redevelopment is not only an essential regional target, but it also covers the main needs to meet the goals of emission reduction, energy consumption and use of renewable energy sources (RES) throughout the building life cycle.
Consequently, the issue of digitisation processes or digital renovation workflows arises as a technological priority[7]: processes that act as a gatherer between the information and data collection (technical specifications, sensors, etc.), data management (Procurement, Project, Process) and their conservation and sharing (Life Cycle Assessment - LCA) are needed.
The research also explores the growing trend of manufacturing companies to make their products available in IFC models. IFC is “Industry Foundation Classes”, a file format developed by buildingSMART - International Alliance for Interoperability, to facilitate data sharing between the disciplines of architecture, engineering and construction industry, used for models based on the methodology of Building Information Modeling. Currently, this trend is spreading mostly in the United Kingdom (BIM4SME[8]).
At European level, several projects and initiatives are developing the use of BIM for regeneration, such as the ongoing BIM4REN project[9] and INSITER project[10], funded under Horizon 2020.
The management of the building process through the use of BIM applications allows a more effective data interoperability and improvement in supporting interventions. Information will be available to all the actors involved, and it will be possible to query digital archives allowing data sharing in real time.

7 By 2025, BIM will be mandatory for all public contracts. See Decreto Ministero delle Infrastrutture e dei Trasporti n.560/2017 (Decree of the Ministry of Infrastructure and Transport n.560/2017). Modalità e i tempi di progressiva introduzione dei metodi e degli strumenti elettronici di modellazione per l’edilizia e le infrastrutture (Modalities and timing of the progressive introduction of digital modeling methods and tools for construction and infrastructure).

8 BIM4SMEs is a non-profit making organisation made up of individuals from different sectors within the construction industry. They are part of the national BIM Task Group and enable small and medium sized businesses in the BIM journey (www.bim4sme.org). See also theBIMHub (https://thebimhub.com/). See also BIM4M2 – the home of BIM for Manufacturing, a working group concerned with BIM for manufacturer developed to support the work of the BIM Taskgroup, BIM4M2 was formed by the Construction Products Association (CPA) (http://bim4m2.co.uk/).

9 BIM4REN is a H2020 funded project involving 23 partners spread across 10 countries for a 4 year long series of developments on the topic of the exploitation of BIM potential for the energy renovation of existing buildings for the whole construction value chain (https://bim4ren.eu/) .

10 INSITER - Intuitive Self-Inspection Techniques using Augmented Reality for construction, refurbishment and maintenance of energy-efficient buildings made of prefabricated components, is a H2020 focused also on scaling-up the use of BIM for standardised inspection and commissioning protocols, involving all actors in the value-chain (https://www.insiter-project.eu/en). See also P2ENDURE - Plug-and-Play product and process innovation for Energy-efficient building deep renovation, Horizon 2020 funded project. P2ENDURE promotes innovative solutions for deep renovation based on prefabricated Plug-and-Play systems in combination with on-site robotic 3D-printing and Building Information Modeling (BIM) (https://www.p2endure-project.eu/en).

1.3 Research questions

Pursuing the main objective of fostering the development of information acquisition and management protocols (morphological and diagnostic) leading to the development of BIM tools to support the intervention project, the operational part of the research is divided into four main phases.

The analysis of integrated survey methodologies, morphometric and diagnostic, and the development of data acquisition and management criteria are included the first phase, aimed at optimizing the acquisition procedures according to the specific needs of analysis and intervention on the built environment. In addition to metric-morphological survey procedures with high information density, the study of documentation and diagnostic survey tools that can be integrated in the data acquisition process is essential in order to obtain a model in which technological/conservative information are integrated with metric information. An archiving system of survey data and aggregated information (material, state of conservation, documentation on previous interventions etc.) considering the different types of users involved in the intervention and aimed at structuring an integrated interoperable database (Logothetis et al. 2018) is included. This data structuring methodology allows the integrated management of different information, keeping track of the source data in order to verify their accuracy.

The representation of the integrated three-dimensional survey aimed at BIM modeling requires optimization procedures able to manage and structure morphological and diagnostic information, managing different parameters (accuracy, precision, costs, time, data reliability, usability, etc.). This step is addressed in the second phase, which involves the analysis of data acquisition protocols aimed at producing an upgradable parametric information model. The protocol is set as a procedural guideline in which all the necessary information levels are integrated into the metric and morphological acquisition of the existing heritage. The protocol must ensure the integration and accessibility of the aggregated information in digital models, encouraging communication and collaboration between different professional figures, identifying an optimal workflow for a coherent development of procedures for investigation and intervention on existing assets. The procedures defined through the protocol must interact and integrate with current software solutions, encouraging the effective use of the acquired data and integrated information and the protocol that discretizes them.

The data acquisition procedure through the protocol is aimed at BIM modeling, defining a workflow able to optimize the acquisition based on the characteristics / information levels needed (Olawumi et al. 2019) according to the set objectives. Starting from the survey, the third phase is therefore focused on the definition of methodologies and procedures for parametric modeling, developing a procedure in which all information related to geometry are integrated with additional information. These information can be related to materials, implementation phases, costs, technical characteristics, etc. The building is therefore related to environmental factors, defining the L.O.D. (Level of Detail) - L.o.G. (Level of Geometry) and L.o.I. (Level of Information) - according to the objectives of the model, the representation outputs, and the specific design stage (preliminary, definitive, executive).

Within the fourth phase, the BIM model resulting from the application on case studies of the methodologies described above, includes and integrates the information related to

documentation on past interventions, materials, structural components and technological systems, and aggregates them making this information accessible, usable and interoperable. In this way, the model is set as a virtual copy of the existing building and archive of information (documentary, diagnostic, archival, technical, etc.) that is often difficult to access in a direct inspection or that are generally disaggregated. The model becomes the working and comparison tool for all the actors involved in the process, fostering the identification of the technologies to be used in the requalification process and for the management of the site phases, or data for monitoring activities.
After outlining the optimized data acquisition and BIM modeling procedures, the applicability of these digital tools is set in particular toward the:
- Creation of specific structured digital archives, usable by all the actors involved, for the definition of new integrated technological solutions;
- Definition of intervention, diagnostic and monitoring protocols;
- Integration of ICT tools and technologies for the interoperable management of project data (BIM tools, ICT tools for the integration of survey data integrated with project descriptive models, tools for the evaluation of project scenarios) (Osello et al. 2015);
- Advancement of the Industry Foundation Class (IFC) standard format able to describe different data and information related to existing heritage buildings within the BIM process;
- Creation of BIM solutions that standardize technological answers to recursive problems or define custom solutions for particular intervention conditions;
- Application on case studies. Digital archives based on BIM models are the support to propose operational protocols for the management of the intervention on existing heritage.

Following the procedure described above, the main **research questions** addressed are:
RQ1 - Is it possible to foster the adoption of digital technologies for the integrated survey, parametric modelling and standardisation of components for the intervention on existing buildings in Emilia-Romagna (focusing on social housing)?
RQ2 - Is it possible to develop an operational toolset suitable and efficient both for the operator carrying out the renovation process and for the customer who has to commission a specialist to carry out the process itself?
RQ3 - Can the development of envelope-oriented packages in BIM environment be the first step to integrate ICT and digital tools in the existing buildings refurbishment processes?

1.4 Research objectives

The research aims to analyse and apply the benefits of BIM tools' application to the existing building asset.
The creation of digital BIM models in open standard format and integrated with specialised information leads to the creation of an operational tool organised into:

Survey
- Methodological procedure (survey purpose, tools, outputs)

Representation
- Modelling parameters for parametric application (LoR);
- Aggregate information modes;

Intervention (Fabrication/4.0)
- Development of application packages with BIM functionality;

Test
- Test phase on case studies.

The main research objectives are:
- The definition of methodologies and tools strictly focused on the requirements for refurbishment and management of the existing building stock and able to bring innovation in the series of actions and interventions on the built environment;
- The application of protocols to optimise integrated survey based on metric accuracy and high information density;
- The identification of parameters for accessible databases aimed at managing the intervention in the different project phases (documentation, project, management, programming, etc.), in which to assemble several levels of information (energy, structural, environmental, etc.);
- The integration of BIM models into existing multidisciplinary platform , allowing many professionals to work in an integrated and coordinated way;
- The progress in the management competencies for BIM tools according to the evolution of the current legislation, which introduces the information modelling and management as a development factor in the public works' sector while aiming at the competitiveness of Small and Medium-sized Enterprises as well as professionals to operate in an international framework with a digital-driven perspective, towards a progressively mandatory use of BIM tools;
- The contribution in defining operational tools for the refurbishment of the widespread existing building stock in Emilia-Romagna, which embodies a high potential for innovation, technology transfer, economic and social impact on the processes of territorial transformation (therefore, employment potential);
- The activation of new forms of accessibility to data aggregated to 3D models (interoperable and open access) for an intersectoral and interdisciplinary use of digital tools;
- The contribution to the improvement, development and validation of structured processes in the ongoing research domains capitalising on the outcomes.

1.5 Research Methodology

Following the regional strategy, the research aims to suggest a working methodology specifically designed to deal with the digitalisation of the built heritage of the 20th century in Emilia-Romagna by providing guidelines and tools developed ad-hoc in a parametric BIM environment.

The proposed methodology focuses on the drafting of indications concerning the conversion of the digital survey data to a parametric model. These indications are enhanced by a set of parametric tools (Libraries, templates and families) useful for digitising building elements typical of the period and area.

The connection between the digitisation of the building (BIM As-Built) and the enterprise supply chain (Industry 4.0) comes through the development of BIM Smart Packages developed to integrate the various actors' needs in the decision-making process, conveying information at an integrated system level: Problem-Solution Approach, Integrated Solution (A+B+C), System Certification (A+B+C Compatibility and Installation), Lifecycle Warranty.

The definition of the key criteria on which to articulate the intervention methodology starts from the analysis of the existing built heritage in the region, beginning with the quantitative analysis, through the data gathered in the ISTAT reports and the re-elaborations carried out by CRESME. From this analysis, it was possible to define the number of buildings and their purpose. The assessment showed that the regional heritage comprises just under one million units (943,307) and represents 6.5% of the national stock. Of this sample, 87% is made up of buildings intended for residential use (higher than 84.3% of the national data) and 13% non-residential (15.7% national data). The data analysis also shows a quantitative inhomogeneity in the territorial distribution. Bologna, Modena and Reggio Emilia provinces are more urbanized than the other provinces, although they keep a constant ratio between residential and productive buildings.

This analysis was followed up with an in-depth analysis of the construction period. The data relating to the construction period is essential to evaluate the longevity of construction elements and their state of maintenance.

A major part of the buildings in the region were built before the First World War and in the period between the end of the Second World War and the 1980s. From the early 1980s to the present day, we can record a significant decrease in new buildings (Cresme, 2021).

From this analysis, it is possible to gather indicators concerning the longevity of buildings, the life cycle of components (ISO 15686), and the maintenance cycles carried out and to be planned. These indicators, implemented in the BIM modelling including constriction elements, are essential in the renovation planning phase.

The technological-structural features of buildings were analysed to understand how the building process evolved during the 20th century. From a structural point of view, it is evident that there has been a gradual shift from the almost exclusive use of construction technologies considered "traditional" (e.g. load-bearing masonry structures) at the beginning of the century to the increasingly widespread use of reinforced concrete, which, in the 1970s corresponded the load-bearing masonry system in terms of the number of constructions. This period also marks an increase in the use of construction technologies such as steel and wood, previously not widely used for structural purposes.

This technological transition took place throughout the twentieth century, driven by the transition from the handcrafted process to the industrial process (Trivellin, 1998). The industrialisation of the building component manufacture process also led to the standardisation of components (Daglio and Ginelli, 2021).

The industrialisation of processes and applied research led to increased technological performance of materials and construction elements. As a result, the morphology of technological units also changed, and the concept of prefabrication was adopted extensively in construction.

In the process of intervention on the built environment, we work on stratified fabrics, composed of elements that can result from both craft and industrial processes, assembled on-site or prefabricated with performance differences that can be very different. Following the concept of the life cycle (Ingrao et al., 2018) of a building component, the construction period significantly impacts the maintenance of the operating features.

A further feature to be taken into account is the ownership of the property. The Italian real estate market is historically known to be particularly fragmented, with the percentage of individual owners among the highest in Europe (Muzzicato et al, 2008). This peculiarity brings both positive and negative aspects in terms of refurbishment. While the owner/resident is particularly careful about the maintenance of the residential building, it also makes it particularly challenging to deal with multi-family buildings. In order to keep the research development within a manageable timeframe, it was decided to focus the selection process on buildings that were as less fragmented as possible.

This aspect has led to considerable benefits in terms of authorisations since it was possible to approach a single stakeholder.

The analysis made it possible to identify the main criteria to focus on the following phases of the research development. In order to achieve a representative sample of buildings, exhaustive enough in terms of construction technology and size, it was decided to identify a set of buildings to be used as case studies by selecting them among those available.

The buildings to be used as case studies were chosen from those managed by the Azienda casa Emilia-Romagna (ACER) of the Province of Bologna. ACER is a public economic body that deals mainly with real estate management. Buildings can be owned by ACER itself, the municipality, or other bodies. ACER operates according to economic, energy and social sustainability criteria by intervening on buildings mainly for residential purposes (Fanzini et al., 2020).

The particular attention that ACER pays to the energy efficiency improvement of the buildings (Fava and Maranghi, 2021) and the availability of an internal core of maintenance services focused on the technological innovation of the processes has made ACER an ideal partner for identifying case studies.

A representative sample in the urban context has been selected, using as selection criteria the size of the building, its location and the construction period.

The case studies have been identified among those present in the ACER Bologna heritage, which present such constructive and dimensional characteristics to cover a relevant part of the issues to be exhaustively addressed. Of these case studies, the issues related to the external envelopes will be deepened, as these are more involved in decay issues (Lo Turco et al., 2017) and energy efficiency measures.

The research has been developed according to the following steps:

WP1 - State of the Art and analysis of the research framework;

WP2 - Analysis of methodologies and techniques for the integrated, morphometric and diagnostic digital survey on the built assets: requirements and issues; selection of criteria useful to key studies selection.

WP3 – Application of data acquisition protocol aimed at achieving an upgradeable parametric information model;

WP4 - Definition of methodologies and procedures for parametric modelling: from survey to BIM;

WP5 - Digital tools to support the innovation of components, systems and materials: integrated and accessible BIM models of high informative value;

WP6 - Application of the methodology on selected case studies.

The above mentioned research structure is presented in the following chapters.

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Chapter 2 - Regional built heritage and 3D integrated survey: State of the art

2.1 Exhisting built assets, National level
2.2 The energy transition in Emilia-Romagna. (Residential)
2.3 The post-unification city - The historical suburbs
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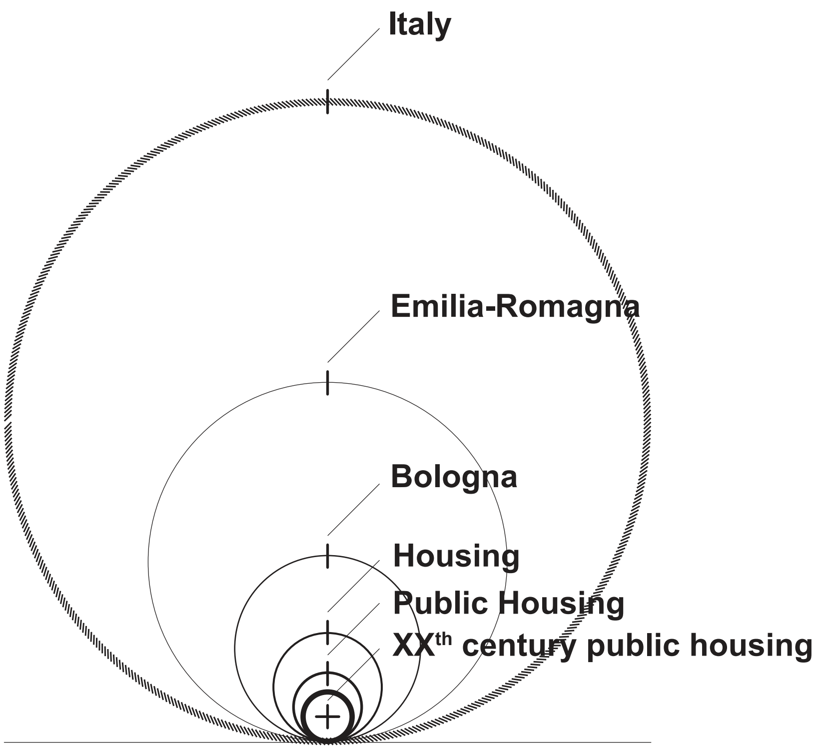


Fig. 002 - Schematic outline of the selection process of the intervention theme. Starting from the analysis of the composition of the Italian heritage, the specific scope of intervention is gradually defined.

Chapter 2
Regional built heritage and 3D integrated survey: State of the art

2.1 Exhisting built assets, National level

The composition of the Italian-built heritage is complex and articulated, presenting a high level of inhomogeneity at a territorial level. The complex nature of the available information makes analysing the statistical data particularly tough, forcing analysts to develop compensatory strategies. The values reported in the main reports produced at the national level show how the complexity of the collected data results in assessments of aggregate data that are difficult to read, often subject to the interpretation provided by the statistical models used in the analysis.

To quantitatively assess the housing stock, we can rely on the data produced by the most reliable ‘data sources’ at the national level. Public and private bodies regularly draw up assessments on the state of the real estate stock. Among these are those produced by ISTAT[1], the Osservatorio del Mercato Immobiliare[2], the Ministry of Economy and Finance[3], and the report developed by CRESME.

The source of the data used for the reports examined consists of the following databases:

- the database of the Urban Building Cadastre
- the Real Estate Market Observatory quotation database;
- the tax returns (UNICO and 730) and the Single Certificates of Employee Income (CUD);
- the database of Property Tax payments (IMU, TASI);
- the register database;
- the Public Administration database.

The database information are highly heterogeneous and refers to the same element by providing biased information. For example, there is information on a property’s location and cadastral consistency, but finding building features and architectural characteristics is rare. Further issues arise from the cadastral classification of real estate in the late 1980s, which does not allow the recording of the urban evolution that real estate has undergone over time.

Analysts know that the available tools do not accurately describe the existing heritage, but

1 ISTAT. (2015). Censimento 2011 - 18 Costruzioni. In https://www.istat.it/. Retrieved January 15, 2021, from https://www.istat.it/it/files/2015/12/C18.pdf

2 Osservatorio del Mercato immobiliare. (2022). RAPPORTO IMMOBILIARE 2022, Il settore residenziale. In https://www.agenziaentrate.gov.it/. Agenzia delle Entrate. Retrieved January 1, 2023, from https://www.agenziaentrate.gov.it/portale/documents/20143/263076/RI2022_Residenziale_20220519.pdf/3934f1ef-9aac-7e84-172a-7cbf82745322

3 Ministero delle Finanze & Agenzia delle Entrate. (2019). Gli Immobili in Italia - 2019. In https://www1.finanze.gov.it/. Ministero delle Finanze. Retrieved September 15, 2022, from https://www1.finanze.gov.it/finanze/immobili/public/contenuti/immobili_2019.pdf

even if approximate to date, it is the most effective tool available.
On a national level, it emerges that 50% of the building surveyed were built before 1975, that is before Law 373/1976, which introduced energy performance requirements for buildings. Of this sample, about 80% of the buildings are listed as being in average maintenance condition, while the data for residential units is more encouraging. This finding points to a greater tendency to carry out maintenance work on private units rather than on the common parts of the building. The report drawn up by the Gabetti Studies Centre highlights how the forms of tax incentives introduced in recent years are actually facilitating interventions on private units rather than on overall buildings. The rigid rules for accessing funding and the fragmentation of ownership contribute to the slowdown in the activation of redevelopment interventions on shared ownership properties.

2.2 The energy transition in Emilia-Romagna. (Residential)

The EU directive for energy efficiency provides actions that, if approved in their current form, should bring all residential buildings to energy class E by 2030 and by 2033, class D should be reached.
According to data collected by Gabetti's Studies Office on a representative sample of regional real estate, the Emilia-Romagna context is still far from the required threshold. According to the Studies Office, a significant portion of the heritage is in energy class G (55.7%), while 13.2% would even be in class F.
The Government incentives for redevelopment included in the Relaunch Decree (Decreto Rilancio) of 2020 have given a solid impulse for energy and structural regeneration of the existing heritage. The funded interventions mainly impacted apartment blocks (54.1%), single-family residential buildings (30.4%) and detached houses (15.5%).
In 2017, the Emilia-Romagna Region adopted an 'Energy Efficiency Plan' to implement European directives and provide implementation tools for interventions. In 2022 the 'Three-year Implementation Plan 2022-2024' (PTA 2022-24) was approved, which provides for the allocation of funds to reach the objectives of decarbonisation, energy efficiency, increase in renewable sources and carbon neutrality.

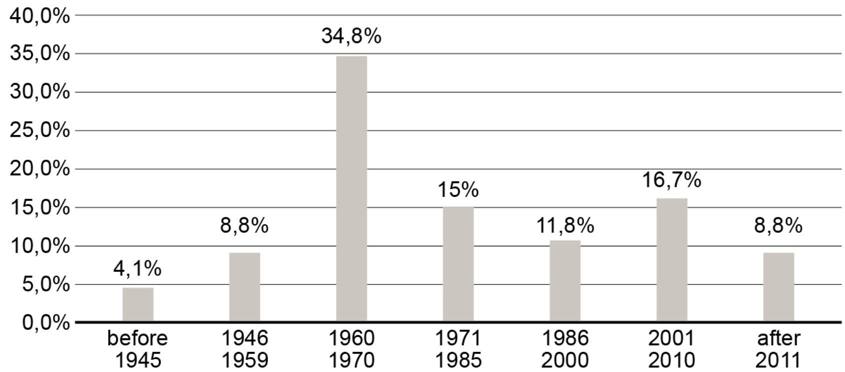


Fig. 003 - Real estate indexed by construction period. Data analysis by Gabetti, Data source by ABACO Team.

The analysis of the building stock provides an overview of the technical performance characteristics of the buildings in the region. Looking at the age of construction, we can see that 62.7 per cent of the buildings date back to a construction period before 1985. This

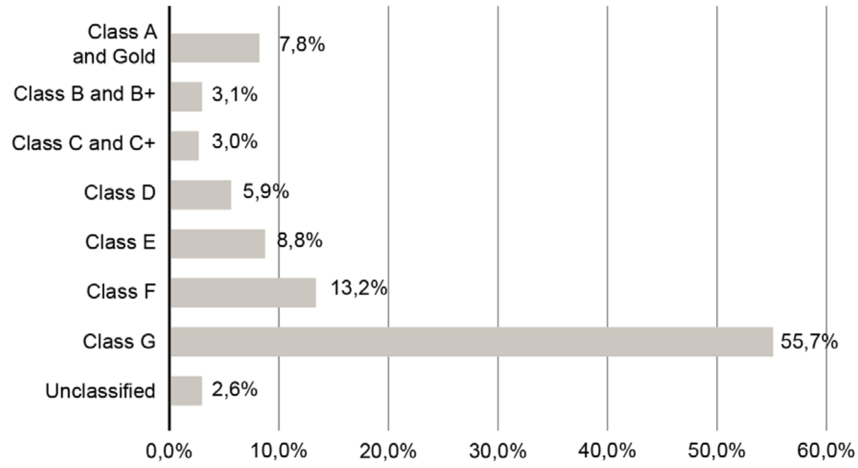


Fig. 004 - Real estate indexed by Energy efficiency class. Data analysis by Gabetti, Data source by ABACO Team.

data is helpful because it outlines a building stock that does not conform to the energy and earthquake-proof standards required by today's market.
The age of construction is also a factor in the energy performance of buildings. The analysis shows that 55.7% of housing units are rated in energy class G. Adding up the values for energy classes F and G, those that should be redeveloped by 2030, we find that 71.5% of the residential stock will need redevelopment by the first deadline, while by 2033 the figure will rise to 80.3%.

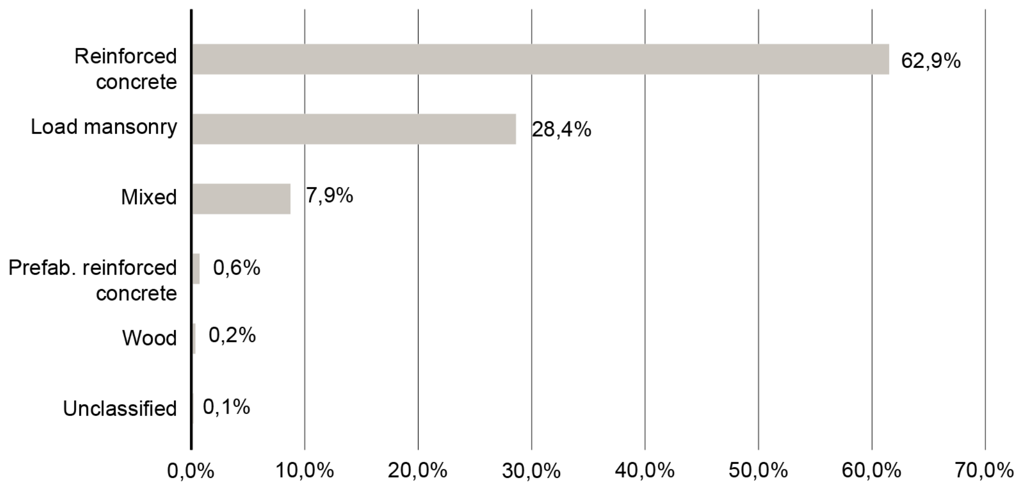


Fig 005 - Real estate indexed by Structural typology. Data analysis by Gabetti, Data source by ABACO Team.

Analysing the structural system, we can see that the most common type of structure is reinforced concrete (62.9%), followed by load-bearing masonry (28.4%), which is widely used, especially in historic buildings. Other structural systems, such as wood and steel, are still used in a negligible percentage.
Among the factors that may be useful in understanding the conformation of the existing building stock is the typology of the heating system. The analysis shows that 91.8% of the heating systems sampled are powered by natural gas and only a negligible percentage by alternative sources such as electricity (3.3%) or cogeneration.

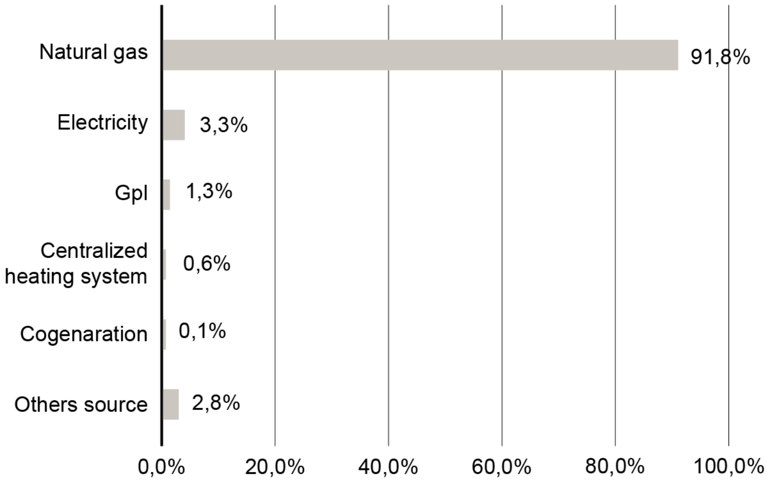


Fig. 006 - Real estate indexed by Heating system fuel. Data analysis by Gabetti, Data source by ABACO Team.

The most common heating system typology is autonomous (84.5%), while only 13.8% of the systems are centralised. The stand-alone nature of systems and the small percentage of systems powered by renewable sources mean that the advantages of collective production and self-consumption should be more exploited.
The data on installations in relation to the housing stock shows that replacing the original diesel installations in favour of natural gas has already been almost completed. However, more than this improvement will be required to achieve energy category G, requiring a more incisive energy retrofitting intervention.
The intervention required will therefore have to be more extensive and include interventions on both active and passive elements. It will, therefore, not be sufficient to replace the heating and cooling system by focusing on systems powered by renewable energies. However, it will be necessary to provide for the performance adjustment of windows and doors and the thermal insulation of walls, roofs and floors.
In addition to reducing energy costs and improving living comfort, these interventions actively contribute to revaluating property value.

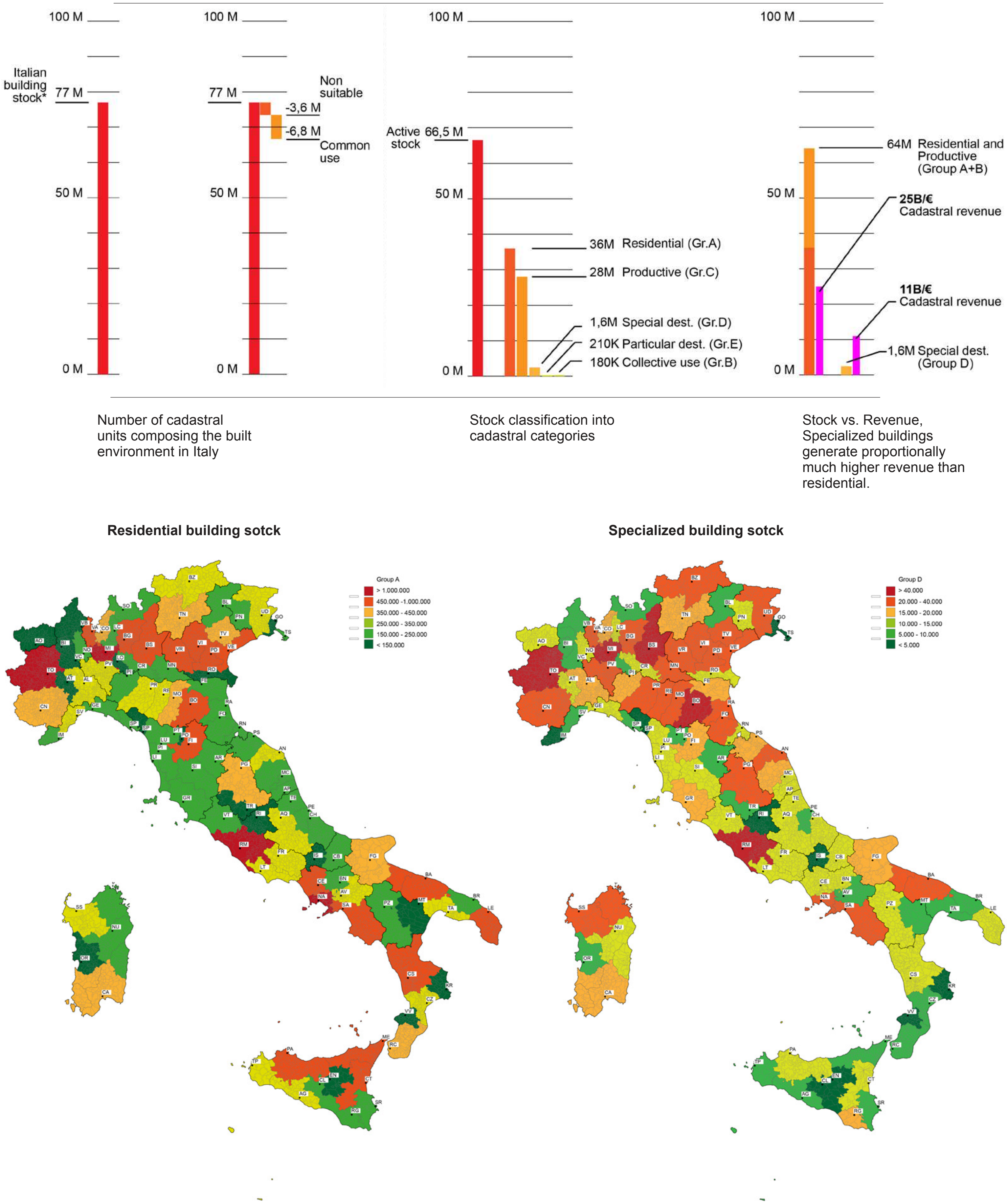
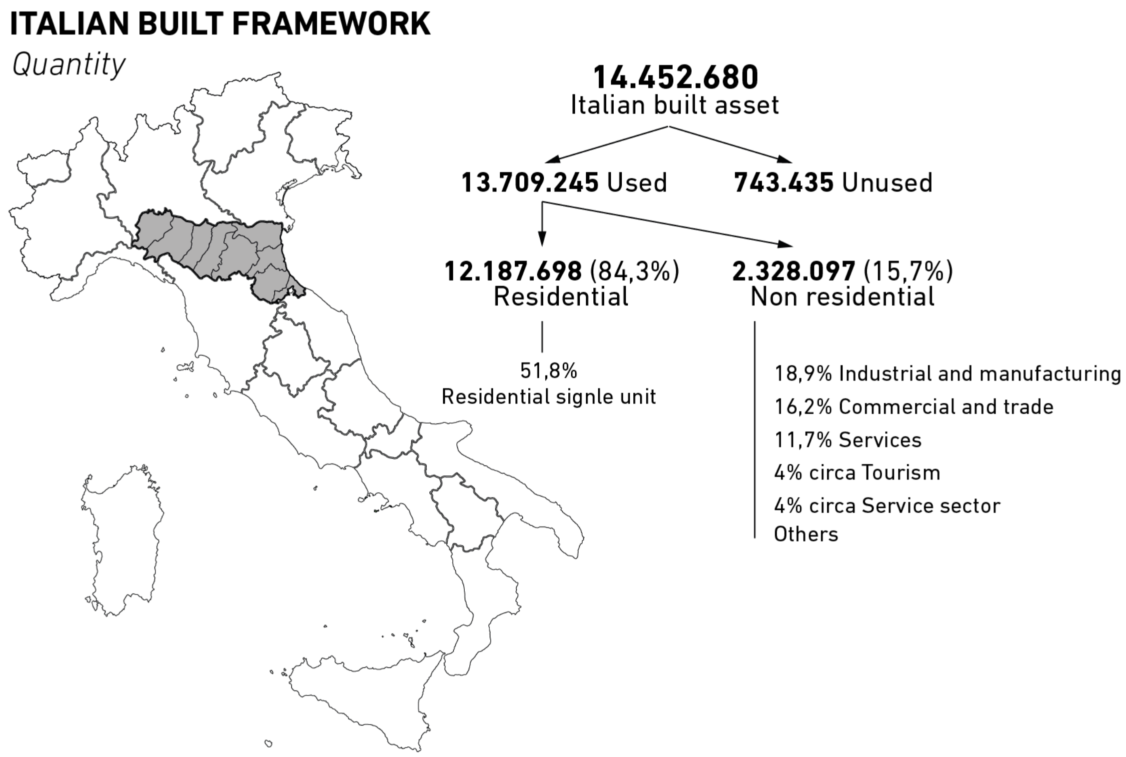


Fig. 007 - An infographic showing the size and territorial distribution of the Italian real estate market. The values for the residential and specialised sectors are detailed. These sectors have the most significant impact in terms of numerosity and revenue. Data source: MEF, Miniestero dell'Economia e delle Finanze



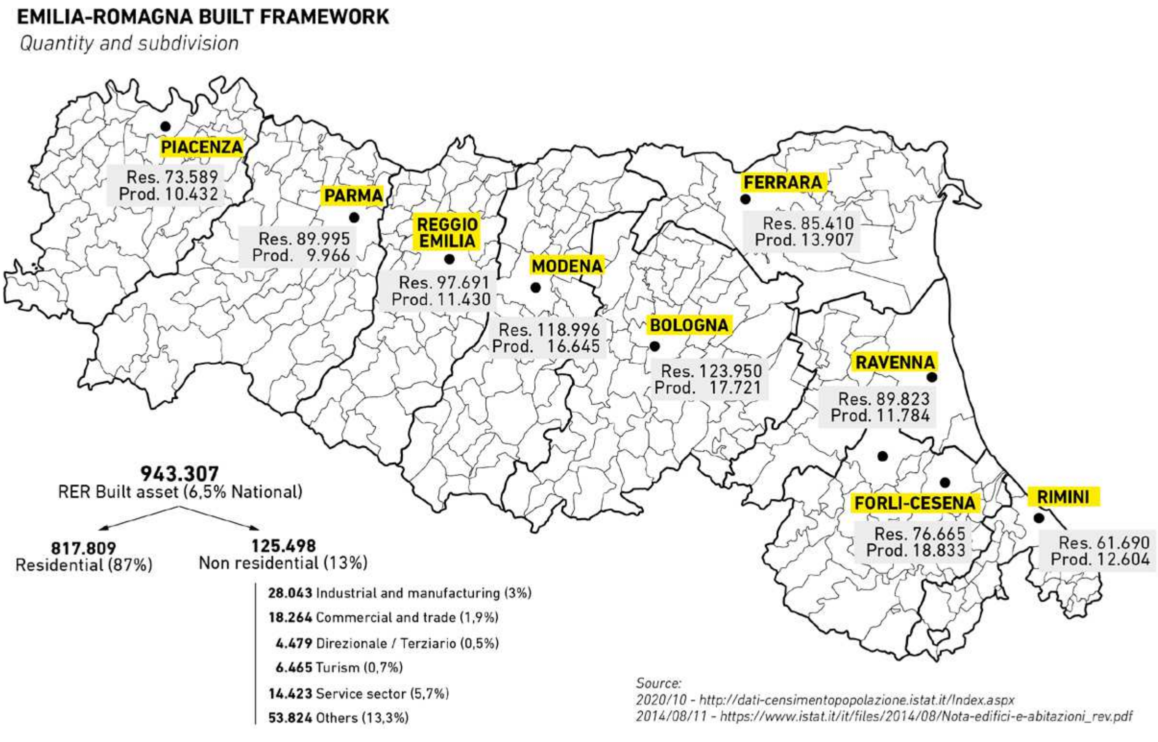


Fig. 008 - Infographic showing the composition of real estate assets on a regional scale, the percentages for cadastral items are illustrated. The regional figure aligns with the national figure, although slight variations exist.
Data source: Cresme Report.

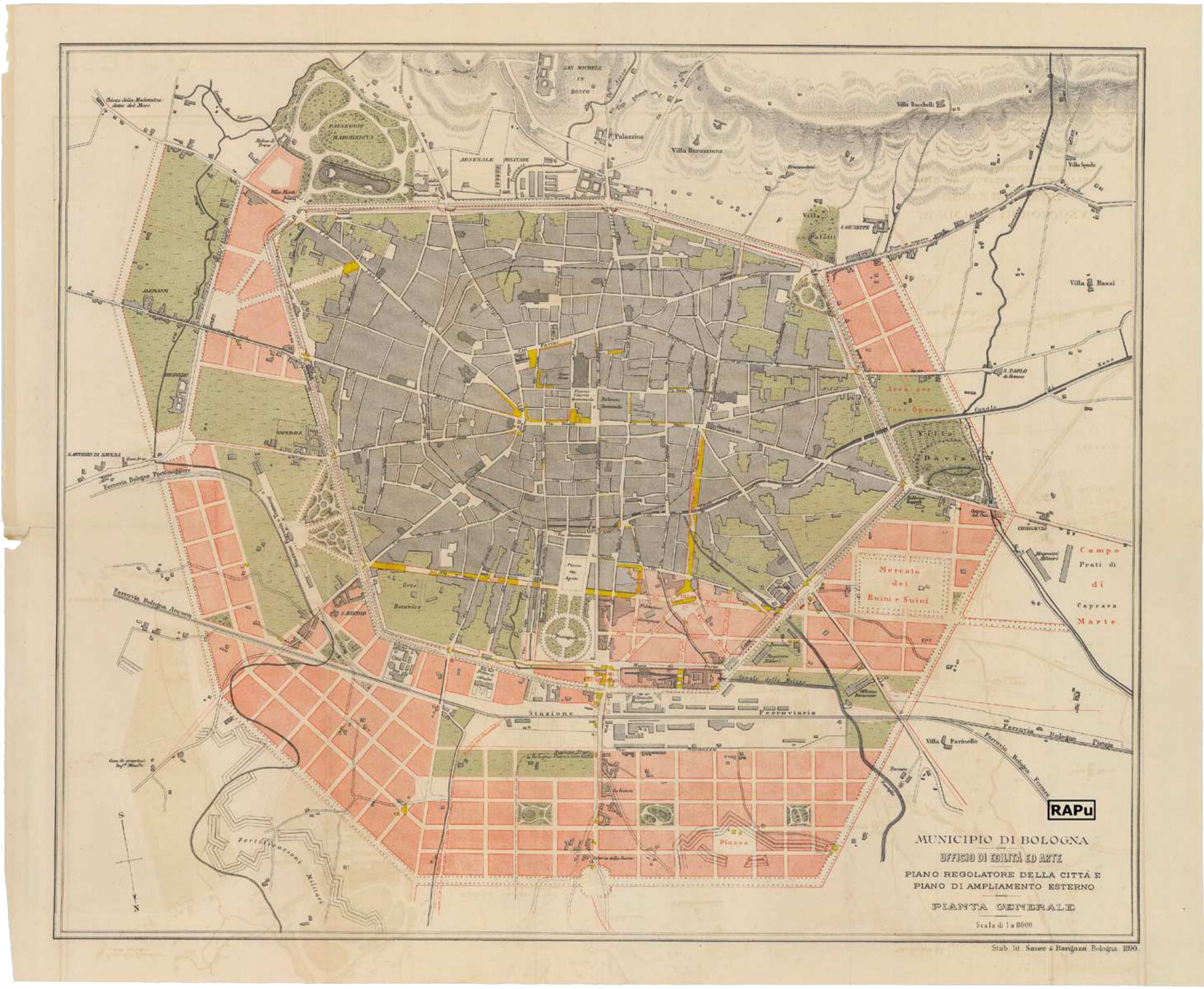


Fig. 009 - Municipality of Bologna. Office of Construction and Art, “City plan and external extension plan. General plan” - Chromolithography, Bologna, Sauer & Barigazzi, 1899, detail (Biblioteca comunale dell’Archiginnasio di Bologna, Gabinetto disegni e stampe, Raccolta piante e vedute della città di Bologna, Cartella 8, n. 81)

2.3 The post-unification city - The historical suburbs

At the end of the 19th century, Bologna, like many other European cities driven by growing economic and industrial dynamism, considered the presence of the 15th-century fortified walls as a limit to urban expansion.
In order to meet this need, it was decided to initiate the demolition of the city walls except for only a few sections and the main gates, which should have been preserved as symbols in memory of the historical morphology.
Once Bologna was annexed into the Kingdom of Italy (1861), the municipality had to deal with the housing supply problem. It was necessary to meet the growing demand for housing units for the populations moving from the countryside and the Apennine territories in search of fortune in the city's flourishing industrial activity.
The modernisation of the urban fabric focused both on developing expansion neighbourhoods outside the old city walls and renovating and requalifying the existing city. The primary needs to be addressed were connected to the growing and changing mobility in the city centre, building aesthetics and sanitation.
In this phase[1], the actions for redevelopment were directed by the Chief Municipal Engineer Coriolano Monti (1815-1880). Architect and railway engineer, he took advantage of means made available by the unified state, notably the building regulation plan for works on the existing city and the development plan for new urban expansion areas. From the outset, Monti was at odds with his design colleagues in Bologna, reporting paucity and unpreparedness when criticising their use of architectural orders in project proposals for new constructions (Bernabei et al. 1984).
The existence to the north of the physical boundary represented by the Milan-Ancona railway line and the newly built railway station led the plan to develop mainly around this feature, arranging the connections between the historic city centre and the new expansions made beyond the railway line. Therefore, the 'continuity of communications' was the fundamental reason for the planned works.
The city's development follows urban planning rules already codified abroad (France, Germany, England) mediated by the needs of the middle class, which will play a critical role in the city's planning until the outbreak of the Second World War.
The urban development outside the walls - *extra moenia* - developed since 1889 (urban expansion plan) has a marked compositional homogeneity made of large-scale regular lots contrasting with the irregular fabric of the historical part.
This urban fabric of large, often unfinished plots, based on an orthogonal urban grid, is today referred to as the 'historical suburbs' or 'post-unification city'.

2.4 The 1889 Regulatory and Development Plan for Bologna

Building replacement in the historic centre and urban development in the suburbs.

The drafting of a new building plan started with the Chief Municipal Engineer Eduardo Tubertini in 1884. It was presented to the municipal council at the end of 1885 and later

1 Modernisation activities began in Bologna in 1860

debated until approved and converted into law in 1889.

The plan, designed by a group of municipal technicians, envisaged demolishing the city walls and the old city gates, widening the ring road, using the land unlocked by the walls' levelling and filling the building lots already available in the Galliera, Mascarella and Lame districts.

The main aim was to build a certain amount of public housing, but this was possible only after 1900 (Calabi, 1995) and the establishment of the *Istituti Autonomi per le Case Popolari* (IACP) and housing cooperatives[2].

In this context, the almost exclusive presence of private investment from the middle class and the intense building speculation taking place meant that only a few housing units were earmarked for social and affordable housing in this first development phase.

The disposition to go along with consolidated models (Florence, Madrid) led to failure to meet the territory's real morphological needs, which also emerged in the actual 'design' of the plan. The orthogonal street grid on which the plan is developed is oriented following the pre-existing axes, leading to the construction of large, more or less uniform rectangular blocks, approximately 100 x 140 m in size. Building speculation also caused the absence of large green areas within the urban fabric, relegating the creation of the few green spaces and gardens to the unbuilt portions of the block.

The railway

The geographical location of Bologna makes it a natural transit point between northern and southern Italy. This condition ensured that the city lays on the route of the main communication infrastructure even historically. The first experimental station was built in Bologna in 1859 (Bernabei et al. 1984) on the Piacenza-Bologna route. This first track would be followed by connections to Ancona (1861), Ferrara (1862), Pistoia (1864), Padua (1887), Massa Lombarda, Verona (1911), up to Florence with the "direttissima", completed between 1913 and 1934. The city's railway network, with all the required infrastructure to connect many lines, soon came to occupy an area slightly smaller than the entire historic core of the city.

Watercourses

The various waterways that had been the engine of the city's economy for centuries were wholly neglected in drafting the 1889 plan. Having represented a central element for the movement of goods and people, they were relegated to suburbs and later buried to create new surface streets.

The ring road

The demolition of the city walls and the consequent widening of the perimeter avenues initiated the construction of what would later be called the city's 'ring road'. This thoroughfare, conceived according to the most advanced urban planning principles of the time, was only partially realised. As with much of the planned fabric, it was only completed later.

2 Luzzati Law, LAW 31 may 1903, n. 254, Published on Gazzetta Ufficiale n.159 08/07/1903

Fig. 010 - View of one of the social housing blocks (base module) built by the IACP in the 1920s.

The only district built almost entirely following the urban design of the plan was the Bolognina to the north, followed by the Cirenaica to the east. These neighbourhoods were built by some worker's housing cooperative societies that operated almost exclusively for speculative purposes. These new dwellings served to house citizens evicted from their homes to carry out urbanisation works in the city centre.

In 1903, the *Istituti Autonomi per le Case Popolari* (Giardini, 1996) was established with the enactment of the Luzzatti Law. This circumstance gave a strong impetus to the city's building activity, which experienced the beginning of solid cooperation between the municipality, the IACP and the Cassa di Risparmio (later the Istituto di Credito Fondiario). The IACP's relationship with the credit institutions, which operate with the finances provided by the wealthier sections of the citizenry, resulted in future works being increasingly aimed at the middle class rather than the less affluent working class. Thus, the IACP and private financiers' partnership led the speculative spirit of the city's middle class to prevail despite the initial spirit of the project, actually thwarting the 1889 plan, which was not completed. However, it laid the foundations for the new city layout.

In 1910, no actual development of the new suburbs took place, but work continued to renovate the historic centre. Contrary to Tubertini's plans, the hillsides to the city's south were urbanised in the early 20th century. These new spontaneous settlements that developed almost uncontrolled were built by the rising small and middle class, which experienced growth at a fast rate in these years.

Fig. 011 - View of one of the social housing blocks (base module) built by the IACP in the 1920s. In the picture, is it possible to see the shared services block. Thoose were later removed, making way for later expansion work.

2.5 The IACP

Since its foundation in 1906, the IACP has been the main figure in developing new urban areas. It was responsible in 1906-16 for the urbanisation of the lots provided for in the '89 plan.
The work was based on the development of three basic building typologies, all courtyard settlements with some variations:
- The first type is the series-aggregated model, developed along the street frontage and over four storeys and six stairwells around the lot's perimeter (*i casamenti*);
- The second type has side wings, marked by one or three staircase bodies, depending on size, and four storeys. The main bodies were arranged on the main sides of the lot. This typology left an open courtyard within the lot (*Cyrenaica* terraced houses);
- The third typology is a variation of the second one with further smaller bodies placed perpendicularly between the main bodies to 'close' the lot. (Workers' and Bourgeois houses in the *Bolognina* neighbourhood);
In its first period of activity, the IACP focused on making two districts, first *Bolognina* to the north and then *Cirenaica* to the northeast. These areas are those envisaged by the '89 PRG and provide for the construction of residential buildings to accommodate workers and the less affluent population. In the *Cirenaica* (*Via Libia*), buildings were realised with highly low-cost standards and, for this reason, called '*Popolarissime*'.
The *Cirenaica* district is isolated from the historic city since railway branches surround it. On the contrary, the *Bolognina* appears as an expansion area more naturally connected with

the centre, although built close to the railway line. However, both districts owe their good fortune to the special attention reserved for the road system (subways and overpasses) connecting the historical core to the new development areas planned in the PRG despite the limitation imposed by the presence of the infrastructure.

2.6 The Fascist period

In the first two decades of the 20th century, urbanisation works also began in other districts created outside the walls. They grew to the city's south in areas not included in the '89 development plan. Two- to three-storey villas and cottages were built on regular lots for the city middle class in these neighbourhoods. These allotments were distinguished by large green spaces, granting them the appellation 'garden city'.
In 1923 the Fascist movement came to power in Bologna, and the IACP became the sole agent on which almost all investments in new building projects fell since then. For this reason, adopting the European rationalist style in Italy was interpreted as the architecture of Fascism.
During these years, the redevelopment of the historic centre, already planned in the '89 PRG, also began, and buildings were constructed to house people displaced from the city centre. The IACP delivered housing in the rent-to-own scheme in the parcels on the northern outskirts, while the more valuable southern strip was left to private initiative. '*Popolarissime*' public housing was also built in the *Libia* district and *San Donato* during this period.
A special department called *Azienda Case Popolarissime* was set up within the IACP to help the speed of execution. With its decision-making autonomy, it was responsible for building very cheap housing located strictly outside the historic city.
Under the fascist regime, an extremely dynamic phase began driven by propaganda: these activities were intended to promote the concept of social modernisation by linking it to Fascism. In this context, impressive works are done, such as the airport, the stadium, the first indoor swimming pool and the electricity supply in large city areas. Following these interventions, functional and social zoning 'phenomenon' emerged in Bologna. Residential areas outside the walls were identified, and working-class neighbourhoods were built beyond the railway line to the north and in other peripheral areas to the east and west.
At the end of the 1930s, the IACP completed and delivered around seven hundred council housing units. Later in 1937, thanks to a law issued by the fascist government (Law no. 1129/1935), it became a provincial authority, incorporating all the council housing developers.
The interventions carried out in these years represent more of a spontaneous development, often linked to reasons that can be traced back to building speculation rather than realising what had been planned in 1889.

2.7 The first post-war period

The city's town planning facts in the post-war period are rooted in the plans developed during the second half of the 1930s. Adapting and reconstructing the historic fabric from the damage caused by the conflict gave rise to intense building activity. The hypotheses for a new urban development plan started in 1938 were only concluded in 1947, passing through

Fig. 012 - Photograph illustrating the damage done to real estate by the Second World War. The images provide a valuable source of information, allowing us to investigate the composition of the building elements.

Fig. 013 - Many buildings have been lost, making way for post-World War I and later interventions.

various vicissitudes with the approval of the reconstruction plan. This tool would regulate interventions in the city until 1958. Between 1939 and 1958, the successive administrations, although ideologically very different (Bernabei et al. 1984 p. 161), maintained a shared vision of the city's problems. The historic centre was identified as the only valuable centre from which to begin structuring the development model for future planning. Substantially, the organisation pattern of the historic city based on the square-street-residence-services relationship remains also adopted for the new planning.
The city's rapid expansion immediately revealed the problematic aspects of the plan drawn up in 1889. While the conflict was still ongoing, it was deemed necessary to call for a competition to draw up a new plan. The proposals submitted focused on the railway junction as a critical point and how to reconnect the old city with the urban expansions to the north. Regarding methodology, the plans are based on rationalist concepts: they include large road axes and functional zoning, which introduces a strong separation between industrial and residential settlements.
The Reconstruction Plan, approved in 1948, is the tool that will actually be used to carry out the works necessary for post-war reconstruction. However, the adopted plan is a technical tool that leaves out an urban vision and proposes concrete interventions that can be realised in the short term, introducing problems that are still visible today. The plan envisages building reconstruction as an incentive for economic recovery, leaving planners wide latitude. This incentive, combined with intense building speculation and planners' lack of urban planning/architectural sensitivity, will produce irremediable damage to the urban fabric.
The drafting of a new town plan to incorporate the activities envisaged in the reconstruction plan began in 1952, was adopted in 1955 and only saw approval by the municipal council in 1958. The drafted plan was developed in line with the other plans of the time and provided for the use of large peripheral areas for development. With this plan, indiscriminate land use, driven solely by real estate speculation, began.

2.8 Affordable housing

Several affordable housing developments found their place in this climate of wild building speculation. The settlements developed in this period are equipped with essential services and large garden areas and are developed on three or four stories. The reference for these buildings is rooted in the rationalist model derived from the northern European experience. The buildings from this period can almost exclusively be attributed to the renovated IACP: it worked using the state funds available for this kind of low-cost intervention, collaborating with specially created institutions, such as Ina-casa, Incis and Unrra-casa.
With the '58 PRG, the neighbourhood unit concept was assumed: the new districts were conceived as autonomous communities with dedicated services. The projects developed in this period are distinguished by abandoning the courtyard typology in favour of the more modern tower and linear ones marked by large bodies.
In 1963, the municipal administration approved the adoption of the first PEEP plan (*Piano per l'Edilizia economica popolare*, Plan for affordable housing), lasting ten years, which provided for new public housing and the completion of previously started neighbourhoods. The targeted districts, often distorted by the PEEP interventions, became large 'ghetto'

neighbourhoods for immigrants from southern Italy. It is immediately realised that the building indices applied are not sustainable, and corrective measures are introduced in the immediately following years. The municipality began to abound in services and public spaces to solve the issues, with a much higher index than before. The international rationalist derivation style inspired the new buildings, though without an innovative style. What had been constructed during the 1970s differed significantly in shape and size from what had previously been achieved in subsidised housing.
In the 1970s, the IACP was again reformed: it became provincial in scope and had to incorporate all the affordable housing actors.
The changed sensitivity in urban planning turns factual with the enactment of the '*Legge Ponte*' (Law n.1150/1967). New guidelines for a more modern PRG began to be developed in those years. The new plan draws ideas from the Intermunicipal Regulatory Plan (PIC), which was prepared but never adopted, and a renewed urban planning policy (*piani di minima* - minimum plans). This activity gave rise to the new PRG (*Grande Variante*) developed in 1970 and approved in 1973. The plan introduced a substantial reduction in building indices in favour of services, infrastructure and public green spaces. At the end of the 1970s, the steps foreseen in the PEEP were completed.
During the 1980s, the activities envisaged by the PEEP variant proceeded, and the production of affordable housing abandoned the 1960s-1970s model and moved towards the concept of a more disaggregated suburb, paying particular attention to the quality of space. The interventions are small and medium-sized and pay particular attention to the relationship respectively with the pre-existing buildings and their environment. (*Piano Decennale dell'Edilizia*, Nicolazzi Law n.94, 1982)
In 1985 a new General Regulatory Plan was adopted (on a *CTC - Carta Tecnica Comunale* basis, CTC - Municipal tecnical map), which was not finally approved until 1989. The social and economic events that had begun in the previous decades led to a decreasing demand for building areas. Moreover, the resident population stabilised. These circumstances forced the municipal administration to revise the regulatory plan criteria. For the first time, consideration was given not only to the municipal territory of Bologna but also to the municipalities that lay close to the periphery, defining the whole as a metropolitan territory (Area vasta, 1984).
At the end of the 1980s (1988), the IACP began recovering the units built in the early 20th century with the '*nuove corti*' project. On the one hand, the new-generation constructions occupied empty areas left by the PEEP, effectively sacrificing the green areas. Third-generation courtyard buildings were built in these lots, with shops on the ground floor and open gardens in the inner courtyards. On the other hand, the planned interventions on the existing buildings are not oriented towards modifying the urban structure but rather towards technological adaptation and restyling. All the interventions carried out in this period have the pursuit of urban quality as a common denominator.

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Bologna: Town planning milestones	
1889	Approval of the town planning and expansion plan (Engineer Eduardo Tubertini)
1906	Establishment of the *Istituto Autonomo per le Case Popolari* (IACP)
1929	Validity extension of the 1889 Regulatory Building Plan
1937	Provincial IACP, incorporating all the other public housing bodies
1938/40	Competition for the new Regulatory Plan (won by Arch. Plinio Marconi)
1944/45	Unofficial town-planning scheme (Pizzighini, Scagliarini and Vignali)
1947/48	Approval of the Reconstruction Plan
1952	New PRG, never approved, coordinated by Arch. Plinio Marconi
1955/58	General Regulatory Plan (PRG) developed by the Municipal Administration
1963/64	First Popular Economic Housing Plan (PEEP) (Law 167/1962)
1967	First draft of the Bolognese Inter-municipal Plan (PIC) and 'minimum planning' criteria
1968	North-East variant (the market area, mercantile centre and car port)
1969	Hill Plan (arch. Paolo Nannelli) and PEEP Historic Centre (arch. Pier Luigi Cervellati, arch.Leonardo Benevolo)
1969/73	Great PRG variant (Adoption)
1973	Services Plan (PRG)
1974	Plan for Productive Settlements (PIP)
1985	General Regulatory Plan (PRG) based on CTC (Municipal Technical Map) approved 1989
2007	Municipal Structural Plan (PSC) includes expansion outside the city walls to the historic centre

Tab. 01 - The main milestones of urban planning in the city of Bologna

2.9 Heritage protection policies

The protection and redevelopment of the urban landscape

The issue of heritage protection in Italy was first addressed in the period around the unification of Italy (1861). In this period, when the country was in search of symbols of national unity, the issue of heritage protection began to be tackled by establishing the basis for structuring rules useful for its management. After unity, it was still a long time before a proper commission was established at the national level to preserve architecture and land (1874). Despite the proliferation of various initiatives aimed at heritage protection, it was still a long time before a political debate took place to arrive at a series of measures that introduced the founding principles of protection[1] into our country's legal system. The principles of notification, the state's right of pre-emption over the property and the creation of public agencies to deal with property protection on a national level represented a crucial step in protecting property. Subsequently, the principle of a time limit for the protection action was introduced[2], which set a minimum limit of at least 50 years from the date of construction to subject a property to protection, in addition to the limit that the author was not yet alive.

The policy of property protection, which from its inception had to contend with the needs of speculators, was radically reformed during the Fascist regime. Under the regime, a series of regulations were promulgated to protect the 'things' and 'natural beauty'[3] that are distinctive of the Italian territory and people. The regulations developed during the Fascist period, although innovative for the time, only considered the protection of individual buildings (passive protection), not considering the urban context in which they were located, leaving the field open for large-scale interventions. With the institution of the first National Urban Planning Law[4] (LUN) in 1942, objectives and instruments to be adopted throughout the country were defined, effectively standardizing possible actions through the institution of the General Regulatory Plan and Detailed Plans that described possible interventions on the historic fabric. However, the legislator's efforts did not find application in the post-war period, where it was preferred not to apply restrictive regulations to favor reconstruction.

In the post-war period, Italy was challenged with the problem of reconstructing the damage caused by the bombing and the liberation campaign of 1942. The damages caused during the years of conflict extended not only to the built fabric, historical and non-historical but also to the infrastructure and landscape heritage. The precariousness of the situation, especially in the areas hardest hit during the conflict, and the need to provide tools for rapid large-scale reconstruction favored the proliferation of new planning tools whose main objective was the speed of execution and simplicity of procedures.

In the first post-war period, the legislator had to adapt the instruments developed in 1942 to the new context, having to concentrate its forces no longer on the development activities

1 Ministerial Decree No. 683bis/1882 'On the Restoration of Monumental Buildings'.

2 Nasi Law no. 185/1902

3 Law n. 778/1922, "Protection of natural landscapes and buildings of particular historical interest"; Law n. 1089/1939 for the "Protection of assets with artistic or historical interest"; Law n. 1497/1939 for the "Protection of natural landscapes".

4 Law no. 1150/1942

of the urban fabric, but on the definition of actions and instruments useful for restoring severely compromised urban and social fabrics. Reconstruction Plans (PdR)[5] were therefore instituted in 1945 to provide indications on the work to be carried out in emergencies and the needs for the future development of the urban fabric. The drafting of the PdR was the responsibility of the municipalities, which communicated the needs to the Ministry of Public Works, which if approved were financed. The Ministry of Public Works was in charge of drafting the PdR for those municipalities that were not able to develop the plan themselves. To simplify the reconstruction process, the required drawings were reduced to the bare minimum, identifying only those areas affected by war damage and defining the works necessary to accommodate evacuees. The PdR in fact operates as a Detailed Plan and is part of the PRG and should take up its indications. Therefore, the new structures would not be exact reconstructions, but buildings developed following the indications promoted by the plan. However, the plan's directives were not always respected, preferring speed of execution and economic interests to the plan's development directives.

2.10 The articulation of the Bolognese territory

With the adoption of the Municipal Structural Plan (PSC)[6] in 2008, we witnessed the first significant investigation into articulating the fabric that makes up the historic centre. Starting from the articulation proposed in the regional urban planning law of 2000, which identified three main areas[7]: the rural territory, the urban territory to be structured and the structured territory, a more articulated subdivision is proposed in the drafting of the PSC to define the development phases of the city. Four historical contexts are therefore identified: the Nucleus of Ancient Formation; Garden District; Compact Fabric; Specialized. For each area, the objectives and indications for transformations are identified.

In the Drafting of the RUE, much attention is paid to the historic city, considering in the planning of possible interventions both buildings and open spaces and streets, and how public spaces relate to private ones.

The area of the Nucleus of ancient formation identifies the part of the city developed in the medieval age within the 14th-century walls and represents what is today identified as the "historic centre". In this area, the Rue regulates interventions of an exclusively conservative nature. In this zone, interventions to transform the fabric are only possible in the case of works of public interest, while possible interventions are those aimed at consolidating the existing relationship between solids and voids, between buildings and open spaces.

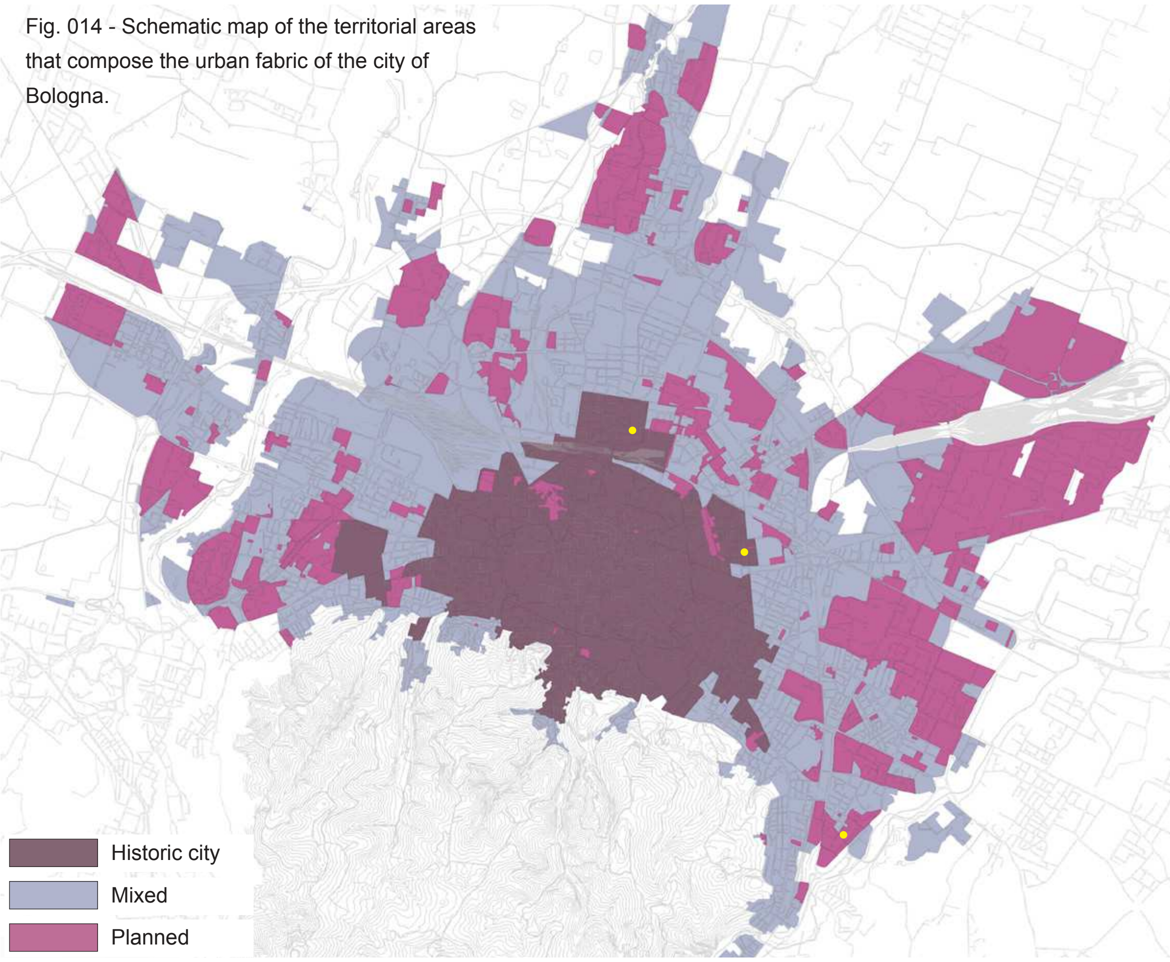
The Garden District is the southern area of the city, located at the foot of the hill. This expansion is due to the expansion that began following the introduction of the 1889 Regulatory Plan, which foresaw for these areas lots of single- or multi-family buildings with gardens, thus defining the creation of prestigious residential neighborhoods. In this area, the Rue provides for interventions to protect and enhance the heritage, both architectural and environmental.

5 DL n. 590/1945 General instructions for the design of reconstruction plans for areas damaged by the war.

6 D.c.c. no. 133/2008 based on regulations L.r. no. 20/2000 "General regulations on the protection and use of the territory".

7 L.r 20/2000 art. A-7 Objectives, Endowments, Services, Intervention modalities.

Fig. 014 - Schematic map of the territorial areas that compose the urban fabric of the city of Bologna.



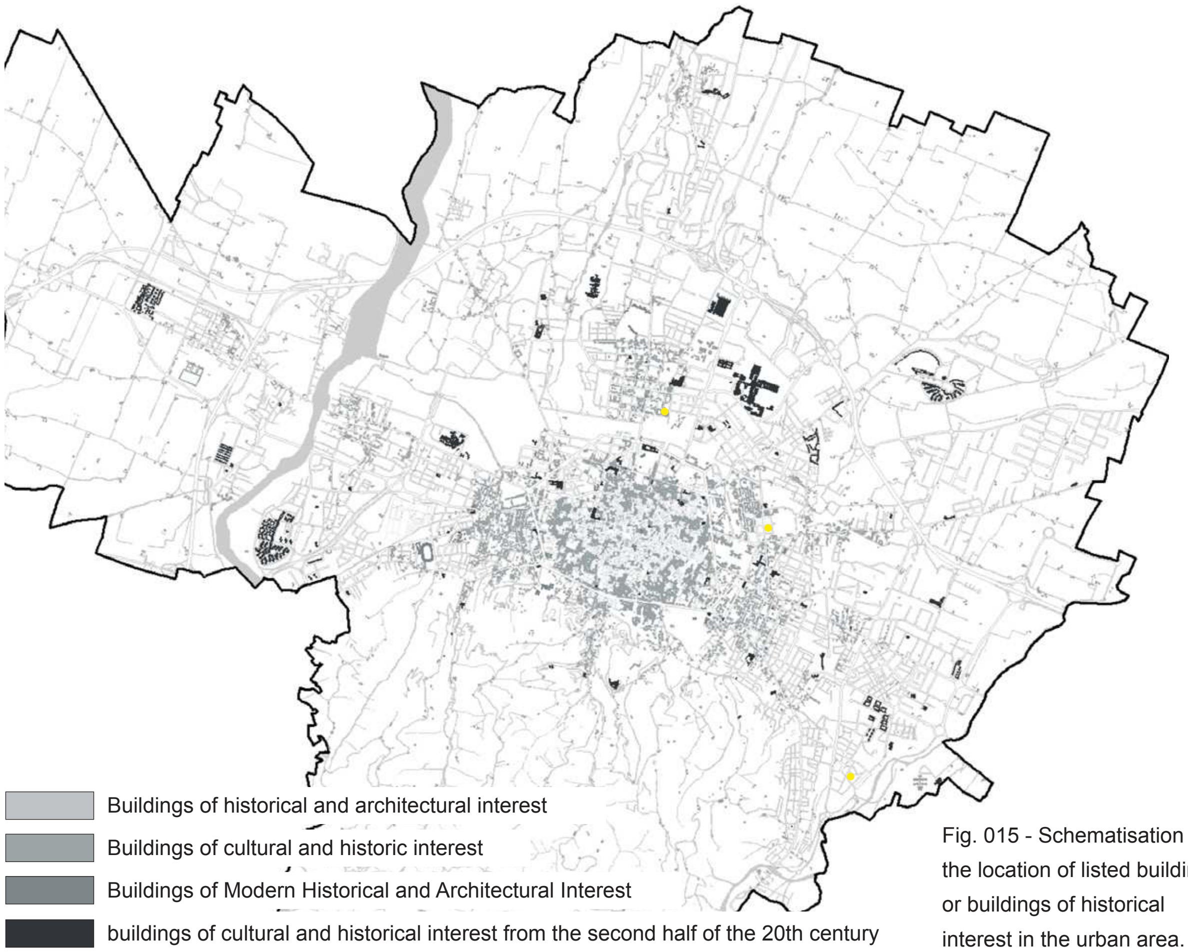


Fig. 015 - Schematisation of the location of listed buildings or buildings of historical interest in the urban area.

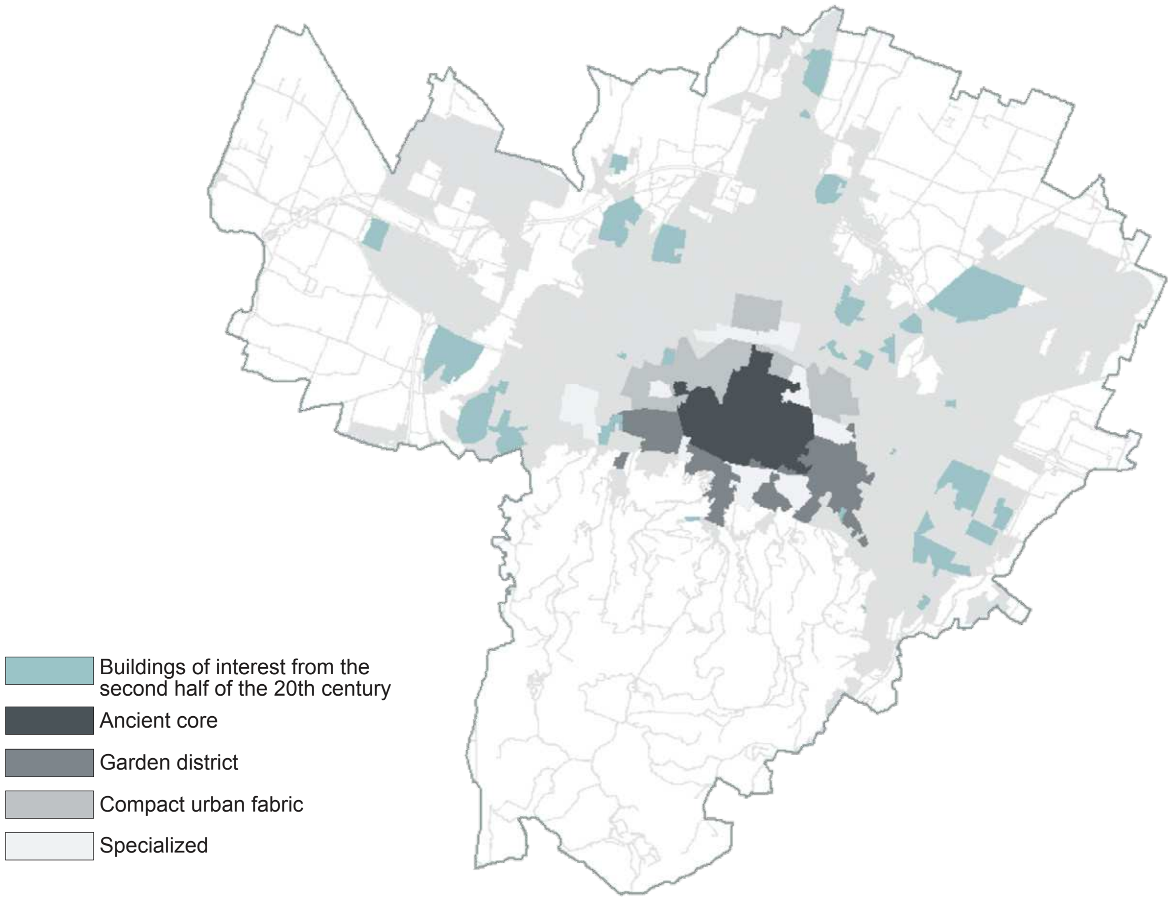


Fig. 016 - Schematisation of urban fabric development areas. The Ancient core, and the successive phases of planned expansion.

Demolition and reconstruction activities are also foreseen while indicating the operative methods to guarantee high-quality levels and the adequacy of the new interventions to the context.

The Compact Fabrics area defines the city's historical outskirts, mainly developed in the north with the Bolognina district and in the east with the Cirenaica district. Developed according to the design of the 1889 urban development plan, these expansions are characterized by aligned blocks of flats facing the street with a large central courtyard, defining semi-public areas within them. These areas represent the working-class suburbs, residential buildings built between the end of the 19th century and the first half of the 20th century to provide housing for the growing population drawn to the city by the industrialization boom. The housing built (Council housing) is characterized by a medium-high density with reasonably good quality characteristics to the buildings existing at the time.

On the other hand, the specialized historical area identifies those expansion areas identified in the 1889 Regulatory Plan with non-residential but civil, industrial, or military destinations. The university district, the Sant'Orsola complex (Hospital), the Ex-Staveco (Military compound) and many others are part of this ambit. In this area, activities are planned to preserve the pre-existing forms, both buildings and open spaces.

The Psc identifies as a 'historic city', the territory made up of the entire urban fabric dating from the medieval layout to the new late 19th-century expansion, inside and outside the 14th-century walls, even beyond the northern limit of the railway axis. In this vision composed of different areas, we see the overcoming of the traditional historic centre (enclosed by the historic walls) by extending the concept of protection of the historic fabric to the expansion areas[8]. The new approach frees itself from the chronological criterion and suggests intervention policies also for settlements that belong to the modern and contemporary that are recognized as having value, including the landscape[9].

The Psc and the Rue have deepened the issues related to protecting modern and contemporary buildings through analyses of the built works on the territory, highlighting those of ‘particular historical’ interest[10]. In addition to buildings of public interest, buildings considered to be of modern documental interest were also selected, with the aim of implementing them in the Rue documentation to maintain the distinctive elements and characteristics of modern and contemporary buildings[11].

8 The 1969 Regulatory Plan already protected the urban fabric outside the former city walls without historical value to the 19th-century expansion.

9 Psc of the Municipality of Bologna, C.c. 133/2008.

10 ‘Carta unica del territorio’, Psc of the Municipality of Bologna.

11 Art.57 Comma 3c, Rue, Bologna.

2.11 Digitization of Built Heritage

The research aimed to propose a possible methodology for data management able to foster digitisation processes in the intervention on the existing building stock in Emilia-Romagna.
The digitisation of processes has been a widespread trend in the construction field for a long time (Negroponte, 1970), extending from the planning phase to cover the whole construction life cycle. This is even more the case when working on new buildings, where regulations (European, national, or regional; see UNI EN ISO 19650, UNI 11337:2017) recommend or impose intervention guidelines to achieve EU objectives regarding land consumption, sustainability, and energy saving.
Limited to the Emilia-Romagna region, the research context is rich in a very extensive 20th-century building heritage. Nevertheless, it requires adaptation works such as restoration of materials and components, plant upgrading, roofing systems renovation, or structural reinforcements due to age or need (for instance, subsidence or seismic risk).
Working in terms of digitisation of processes applied to existing buildings requires the definition of procedures that consider the needs of all the operators involved, either being owners, officials, contractors, component manufacturers or technicians.
To support the implementation of innovative processes in a sector such as construction (OICE, 2018) in the Emilia-Romagna territory – mainly made up of small and medium-sized enterprises historically unwilling to adopt a particular type of technological shift –, it is necessary to provide tools and methodologies simplified in use, immediately adoptable and able to help operators understand what added value they can gain from them.
The digital component in architecture is supported by the expanding availability of hardware and software tools offered at increasingly favourable costs. These tools' output represents a data source widely used during all phases of a building's life.
For instance, a network of temperature sensors (RICS, 2014) housed in interconnected thermostatic valves (Wired/Wireless) semi-autonomously regulate the temperature inside a building. Such sensors collect data processed by a control unit that operates according to sets of instructions created using unique calculation models to maintain constant indoor comfort when external conditions vary while containing costs. Like much more complex ones, similar automation processes are becoming increasingly popular as being supported by the value they generate compared to the investment for their implementation (energy efficiency in this case).
The data management and use become value. Processes that previously would have required the efforts of several professionals are now carried out semi-automatically, in real-time.
Devices (e.g., Sensors) interconnected via infrastructures (Wired/Wireless - E.g. A wi-fi network connected to a data collection system) are necessary to generate data. Such infrastructures require to adopt architectural arrangements which should be planned in the design phase (in case of new constructions), otherwise obtained during the redevelopment process as in the case of intervention on existing buildings.

2.12 Digital integrated survey for Architecture

The State of the Art in the field of digitization of existing heritage (Bianchini 2014; Brusaporci 2019) and parametric modeling in BIM environment (Bianchini, Inglese, & Ippolito 2016) is a rich and articulated panorama, in which research and different applications range in providing increasingly targeted contributions to the resolution of different critical issues (López et. al. 2016; Bolognesi & Fiorillo 2019).
Among the essential areas of research for the conservation and enhancement of the built, historical and “widespread” heritage there are:
- the development of new survey and diagnostic technologies and the optimization of technologies for the rapid data acquisition (Gallozzi et. al., 2019);
- the development of accessible databases for the documentation of the life-cycle of the built environment (Apollonio et. al. 2019; Tommasi et. al. 2019);
- and, in general, the optimization, standardization and interoperability of processes in the direction of the integrated project.
In addition to a more efficient management of the built environment through integrated digital tools, the research aimed to address the obsolescence of digital data (due to the lack of standardization) by promoting a more efficient use over time of the collected digital data and interoperability (Djuedja et. al. 2019) between different systems (Open access data). On the one hand, the research aimed to optimize the digitization of the existing building, on the other hand to respond to the fragmentation of the process and the inefficient use of data through parametric modeling, by integrating different information data (information obtained in the survey, analysis and documentation phase) in BIM models (both volumetric/morphological and technological).
The research was structured in four main areas. Starting from the definition of the State of the Art, the optimization of an integrated survey protocol was assessed starting from available standards and guidelines. The application of a survey protocol allows the acquisition and management of information according to the scale and complexity of the intervention (Fassi et. al. 2015). This step is connected to a critical analysis of the features to be implemented in the management of survey information in a parametric BIM environment (Osello et. al. 2016) for the development of integrated data information tools/packages to support the intervention on the existing building. The last phase provided for the application on case studies identified in the regional context, belonging to the existing heritage of the twentieth century characterized by levels of complexity useful to test the proposed digital tools.
Pursuing the main objective of fostering the development of information acquisition and management protocols (morphological and diagnostic) leading to the development of BIM tools to support the intervention project, the research was divided into four main phases.
The analysis of integrated survey methodologies, morphometric and diagnostic, and the development of data acquisition and management criteria were included the first phase, aimed at optimizing the acquisition procedures according to the specific needs of analysis and intervention on the built environment. In addition to metric-morphological survey procedures with high information density, the study of documentation and diagnostic survey tools that can be integrated in the data acquisition process was essential in order to obtain a model in which technological/conservative information are integrated with metric information, toward

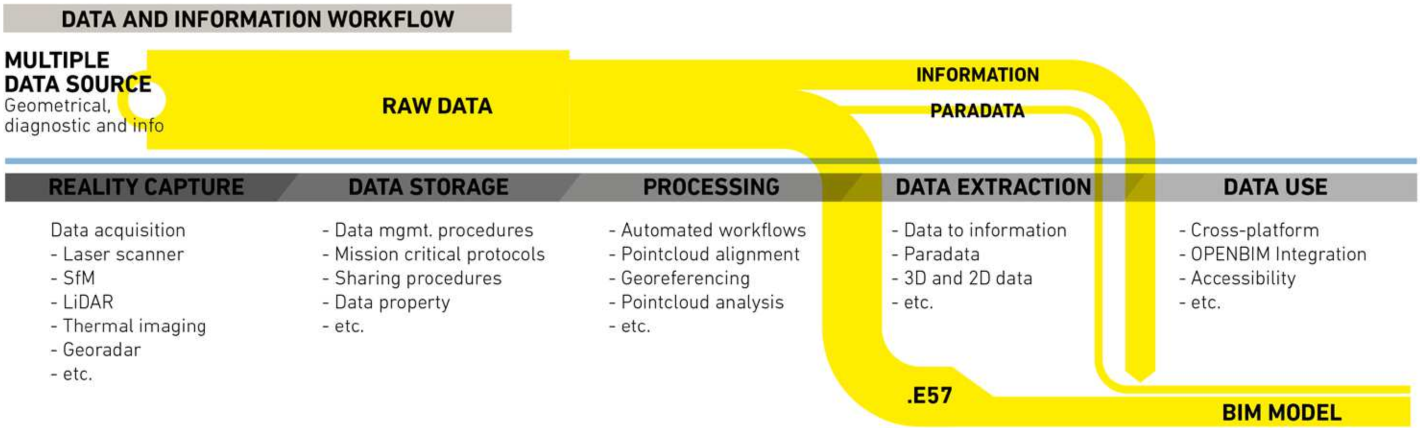


Fig. 017 - Schematisation of data management

the structuring of an archiving system of survey data and aggregated information (material, state of conservation, documentation on previous interventions, etc.) considering the different types of users involved in the intervention and aimed at structuring an integrated interoperable database (Logothetis et. al. 2018). This data structuring methodology is a valuable support for the integrated management of different information, keeping track of the source data in order to verify their accuracy.

The representation of the integrated three-dimensional survey aimed at BIM modeling requires optimization procedures able to manage and structure morphological and diagnostic information, managing different parameters (accuracy, precision, costs, time, data reliability, usability, etc.). This step was addressed in the second phase, which involves the assessment of data acquisition protocols aimed at producing an upgradable parametric information model. Several references were analysed. A useful guideline should be set as a procedural workflow in which all the necessary information levels are integrated into the metric and morphological acquisition of the existing heritage. The protocol should ensure the integration and accessibility of the aggregated information in digital models, encouraging communication and collaboration between different professional figures, identifying an optimal workflow for a consistent development of procedures for investigation and intervention on existing assets. The procedures defined through the protocol should also interact and integrate with current software solutions, encouraging the effective use of the acquired data and integrated information and the protocol that discretizes them.

The data acquisition was aimed at BIM modeling, defining a workflow able to optimize the acquisition on the basis of the characteristics / information levels needed (Olawumi et. al. 2019) according to the set objectives. Starting from the survey, the third phase was therefore focused on the definition of methodologies and procedures for parametric modeling, developing a procedure in which all information related to geometry are integrated with additional information. These information can be related to materials, implementation phases, costs, technical characteristics, etc. The building is related to environmental factors, defining the L.O.D. (Level of Detail) - L.o.G. (Level of Geometry) and L.o.I. (Level of Information) - according to the objectives of the model, the representation outputs, and the specific design stage (preliminary, definitive, executive).

Within the fourth phase, the BIM model resulting from the application on case studies of the methodologies described above, included and integrated the information related to documentation on past interventions, materials, structural components and technological

systems, and aggregates them making this information accessible, usable and interoperable. In this way, the model can be conceived as a virtual copy of the existing building and archive of information (documentary, diagnostic, archival, technical, etc.) that is often difficult to access in a direct inspection or that are generally disaggregated. The model can be the working and comparison tool for all the actors involved in the process, fostering the identification of the technologies to be used in the refurbishment process and for the management of the site phases, or data for monitoring activities.
After outlining the optimized data acquisition and BIM modeling procedures, results applicability assessment concerned the:
- creation of specific structured digital archives, usable by all the actors involved, for the definition of new integrated technological solutions;
- definition of intervention, diagnostic and monitoring protocols;
- integration of ICT tools and technologies for the interoperable management of project data (BIM tools, ICT tools for the integration of survey data integrated with project descriptive models, tools for the evaluation of project scenarios) (Osello et. al. 2015);
- advancement of the Industry Foundation Class (IFC) standard format able to describe different data and information related to existing heritage buildings within the BIM process;
- creation of BIM solutions that standardize technological answers to recursive problems, or define custom solutions for particular intervention conditions.
The procedures identified were applied and tested on selected case studies (Chapter 5), from data acquisition up to modeling with integration of all the information surveyed. Digital archives based on BIM models are the support to propose operational protocols for the management of the intervention on existing heritage (Maietti & Tasselli 2020).

2.13 Data acquisition protocols and guidelines

In this section the most recent and relevant guidelines and protocols addressing the data capturing workflow are summarized.
The **Basic principles and tips for 3D digitisation of cultural heritage** (European Commission 2020) developed by the Expert Group on Digital Cultural Heritage and Europeana include some principles relevant for the data capture workflow, even if developed specifically for Cultural Heritage. In particular, the second point ("Select what to digitise and for what use cases or user groups") focuses on the purpose of the 3D digitisation project (what the client/cultural heritage institution wants to achieve) and its relationship to the selection of assets and the digitisation workflow. The target users and how they will use the content are also highlighted. The principle states that the purpose of the digitisation project guides planning decisions for the project from the assets selected to the digitisation workflow and the way in which access is provided, determining minimum quality requirements, appropriate equipment, relevant standards, digitisation strategy.
"Determine the minimum quality needed, but aim for the highest affordable" is the fifth principle, highlighting that quality in 3D digitisation is not only about capture accuracy and resolution, but also about fitness for purpose and the range of data and metadata generated. Quality is an essential aspect of 3D digitisation and also a significant challenge, there are many factors and parameters involved. The principle recommends: investigating how high

the capture accuracy and resolution could be, and what the costs are (in time and money) as well as the equipment, software and skills needed; determining the minimum quality needed for the target users and the ways that they will use the content; assessing whether the project budget and timescale will permit capturing at a higher level of accuracy. In this way projects can aim for the highest 3D capture quality for the largest number of assets the budget and time available allows for.

The sixth principle is “Identify the different versions and formats needed for the different use cases targeted”.

The 3D raw data resulting from the capture stage of projects requires processing to generate 3D models. At the capture stage it is important to follow standards and best practices and where possible to choose open and/or commonly used formats.

“Plan for long-term preservation of all data acquired” is a principle highlighting that it is important to take long-term preservation into account from the beginning of the project. A strategy and commitment are needed to set aside the resources needed for digital preservation. Clear plans are needed covering: where to store; how to process; how to manage; how to find, use and reuse 3D datasets.

A project data management plan is needed covering the objectives, the target user group(s), all decisions made concerning digitisation and preservation.

For long term preservation it is not sufficient to upload 3D datasets on a general purpose distribution platform. Data should be deposited in an archive that can offer a preservation service. It is important to keep as much data as possible including:

- Raw data, photographs for photogrammetry or point clouds
- Measurement data
- Major post processing steps
- A description of the workflow
- As well as the 3D models

Equipment, methods and workflows are faced within the eight principle. There is no one-size-fits-all method for 3D digitisation. Factors such as size and characteristics of the target, intended uses, logistics, budget, timing and environmental conditions all influence the choice of equipment.

Projects working with large buildings may use multiple techniques and data from different sources, which needs to be brought together in a reliable way.

The **Study on quality in 3D digitisation of tangible cultural heritage - VIGIE 2020/654** (European Commission 2022) covers the process of digitising movable and immovable tangible cultural heritage. The Study includes aspects which are particularly relevant to data capturing in its planning and execution, such as accuracy and precision, level of detail, object size, documentation methods and parameters for measuring data quality. A large part of the Study is focused on the concept of complexity. The study states that complexity derives from the stakeholder’s requirements, the location and condition (of the cultural heritage asset). The complexity of the object alone is not sufficient for 3D digitisation planning, the intended use of the 3D model is important when choosing the best technology and setting technical specifications for digitisation.

An existing protocol developed to manage 3D data capturing workflows is the **DAP - Data Acquisition Protocol** (Maietti et al. 2020), set up under the EU INCEPTION project. The

DAP was developed in order to face the main challenges related to 3D survey of complex architectures and to start solving the issue of the large amount of captured data and time-consuming processes in the production of 3D digital models. The protocol was followed by the digitization and documentation of nine selected Demonstration Cases, dealing with some issues such as complexity of heritage sites and accuracy of 3D models, integration of metadata and semantics into the 3D model, integration with additional information such as images, structural analysis data, materials, preservation records, etc., archiving of 3D digital records using widely accepted standards. This procedure allowed testing the Protocol applicability on different heritage assets and according to different digitization and modelling needs.

The DAP was strongly connected to the data modelling into a BIM environment. In addition to the optimization of a workflow able to guide the data capturing procedure according to the specific purpose of the 3D survey, the need within the project was also to manage captured data into a parametric environment for data enrichment within the semantic web. However, the DAP can be considered as a guideline for data capturing regardless of the modelling output.

Other relevant reports on the topic are those produced by the **Historic England** (Historic England 2021), that have released technical advice on how to survey historic places to the best standard possible. Technical advice is available on the following topics:

Metric Survey Specifications for Cultural Heritage - This publication provides Historic England's standard specifications for metric survey to ensure metric survey data is both appropriate and 'fit for purpose'. It includes all metric survey techniques for a range of heritage applications: laser scanning, multi-image photogrammetry/Structure-from-Motion (SfM), the capture of low level aerial imagery using Small Unmanned Aircraft (SUA) and Building Information Modelling (BIM).

3D Laser Scanning for Heritage - This provides updated advice and guidance on laser scanning in archaeology and architecture. It covers a variety of surveying and imaging technologies including pedestrian and vehicle based mobile mapping systems. The guidance is supported by a number of case studies.

Photogrammetric Applications for Cultural Heritage - This guidance covers the practical application of photogrammetry in recording cultural heritage, with particular reference to structure from motion (SfM) techniques.

Multi-light Imaging - This publication offers user-friendly guidelines and advice on recording cultural heritage by capturing the surface of an object through multiple photographs which, when processed, enable the enhancement of surface-level details. This technique is flexible, versatile and can be undertaken at low cost with a minimum of equipment.

Using Airborne Lidar in Archaeological Survey - This guidance is designed to help those intending to use airborne laser scanning (ALS), also known as lidar, for archaeological survey. The aim is to help archaeologists, researchers and those who manage the historic environment to decide first, whether using lidar data will actually be beneficial in terms of their research aims, and second, how the data can be used effectively.

Traversing the past - The total station theodolite in archaeological landscape survey - This publication covers the electronic total station theodolite (TST) and its use in landscape archaeology.

Where on Earth are we? - The Role of Global Navigation Satellite Systems (GNSS) in Archaeological Field Survey.

2.14 Digital documentation

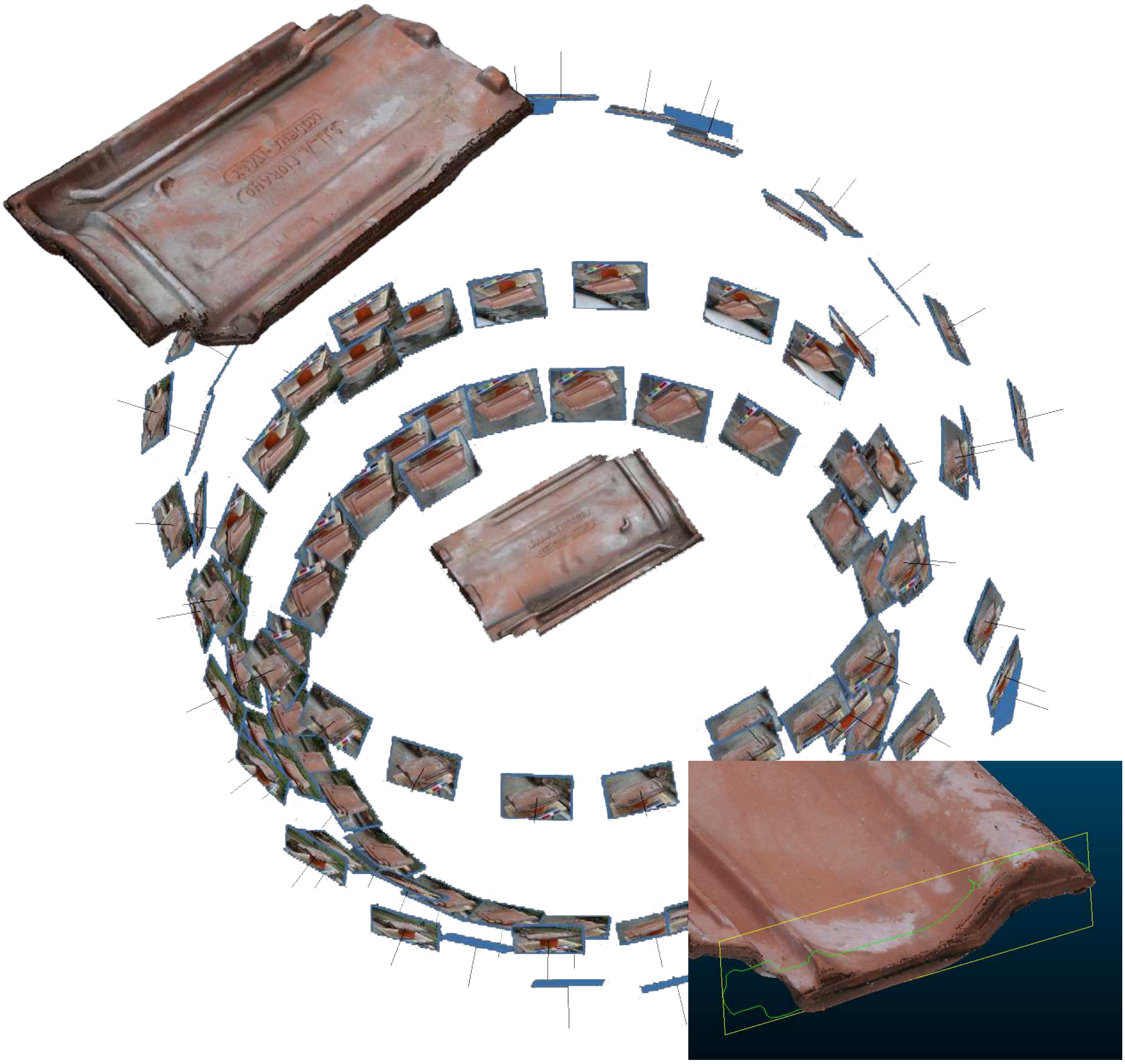


Fig. 018 - The digitisation phase of building components is achieved through the structure from motion methodology (SFM). From the resulting model, it is possible to extract valuable geometric information for 3D modelling. In this specific case, the collected geometries were used for documentation purposes.

In the field of intervention on the built environment, the data defining state of the art are “created” through a multidisciplinary investigation process. This analytical method aims to create multiple datasets (even of a very diverse kinds) handled through specific processes aimed at transforming data into information.

Besides dealing with the conversion of a large amount of data into information, this process generates information itself. This information, called paradata (Denard 2012), represents the trace of the discrete method used for the transformation and lays the foundations for the ontological organisation of the collected information, guiding the process towards the correct understanding of the object (De Luca et al. 2007). Thus, the obtained information is used to define a synthesis model representing the characteristic elements of the building

and all the components that define it (structural, HAVC, to name a few) as accurately as possible (Fuller et al. 2020).
The data collection tools are now advanced technologies, constantly being developed by manufacturers, focusing on performance values and ease of use. Ease of use is a crucial factor, which is essential for broadening the user base and making their application possible in new fields.
For instance it is possible to mention the evolution of the terrestrial laser scanner, which has gone from being a complex object (Tucker 2002) to a portable object that could be sold in an Apple store and controlled through an App in the space of twenty years.
The SfM (Structure from Motion) (Luhmann et al. 2020) procedure is also widely used.

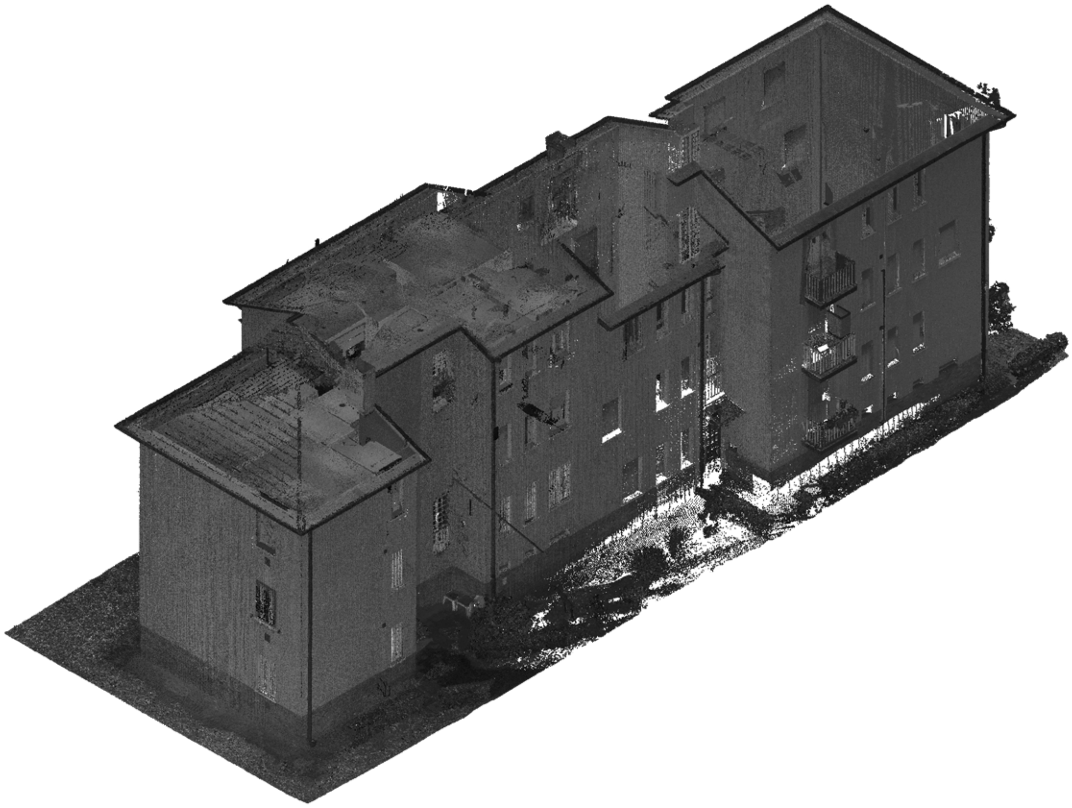


Fig. 019 - View of the point cloud of Case Study I, exported in E57 format, processed in Autodesk Recap.
Data source: Inspire project.

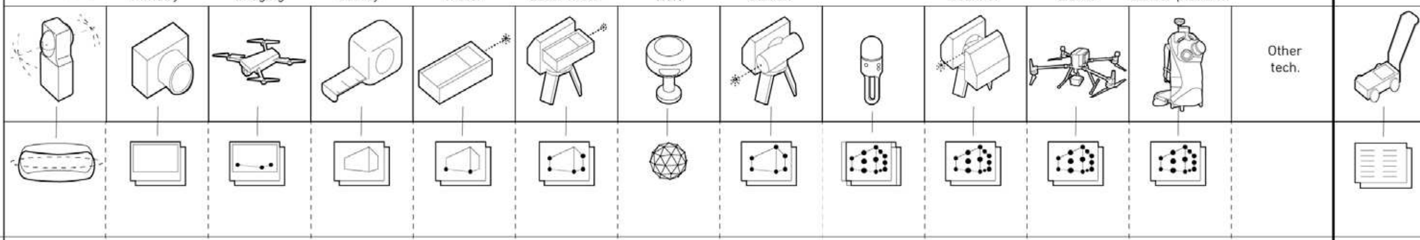
Considered to be one of the most promising technologies, it uses algorithms capable of sampling a series of two-dimensional images to generate a three-dimensional point cloud. This system makes it possible to use hardware developed for other purposes (e.g., DSLR cameras, Smartphones, or Action Cams, among others) and properly developed commercial software. This technology has such promising development horizons that even producers of traditional laser survey tools invest in the acquisition of the companies that develop these algorithms.
The two technologies described above provide a 'point cloud' as output. These points, described in a three-dimensional environment, include spatial information (X, Y, Z) and additional information such as the intensity value or the RGB value of each point. The limitation that does not currently allow the superimposition of the two technologies lies in the accuracy of the generated data. Today, the workflow of a survey carried out using laser scanner technology is still more reliable than a SfM (but also usually slower and more expensive).

A strength that can be attributed to SfM technology is using images acquired by consumer SAPRs (drones), which allow investigations in areas that are difficult to inspect with other technologies (roofs, crumbling buildings, large portions of land) with relatively low costs.
The laser/SfM survey makes it possible to obtain the data necessary to create an aggregate "point cloud" with a degree of accuracy defined according to the purpose, which is indispensable to creating a synthesis model of the object. The data accuracy and reliability become essential information for the subsequent phases.
In addition to the morphological aspects, other effective data for in-depth knowledge of the case study are also collected. Stratigraphic data, thermographic data, temperature, or humidity trends (to name a few) contribute to defining not secondary informative levels,

Fig. 020 - Overlaying the model on the point cloud for the deviance verification phase.

depending on the specific object needs. Heterogeneous in terms of output, these data require specific methodological steps to be converted into information (often through databases) to be used within a three-dimensional digital model.
The technologies used and the methodological process of required elaboration contribute to the definition of more or less substantial "intervention budgets". Therefore, it is necessary to carefully examine which, when, and how to employ one of these technologies or more during the planning phase of the survey campaign.
Thus, the digital model becomes a synthetic container, created using a discrete method, set up to be as close as possible to the needs for which it was created. A massive data collection is not always a good practice. Excessive data (thence excessive information) can undermine computational systems that operate on technological apparatus based on limited resources. A too dense and heavy cloud is unusable by most workstations, just as a set of data from sensors can provide misleading indications.

	Survey tools and methodologies													
	Dimensional and morphological data													
	360 Imaging	Photogrammetry	SAPR Imaging	Direct survey	Laser distance meter	3D Laser meter	GPS RTK	Total Station	Slam	TLS Laser scanner	Airborne LiDAR	Mobile Sensor platform	Other tech.	Georadar
Cost	€	€€	€€	€	€	€	€	€€	€€	€€€	€€€	€€€€	/	€€
Operational complexity	Easy	Mod	Mod	Easy	Easy	Mod	Mod	Adv	Adv	Adv	Adv	Adv	/	Mod
Outputs	Spherical imaging	3D + 2D Information	3D + 2D Information	2D Information	2D Information	3D + 2D Information	3D + 2D Information	3D + 2D Information	3D Information	3D + 2D Information	3D + 2D Information	3D + 2D Information	/	3D + 2D Information
Accuracy	*	**	**	**	***	***	****	****	***	****	****	***	/	***
Best for	Spatial mapping	Quick 3D survey	Air 3D survey	Quick survey	Quick survey	3D measure	3D measure	Accurate survey	Accurate survey	Accurate survey	Accurate survey	Accurate survey	/	Depth materia[l] survey



2.15 Data collection purposes and survey tools

The analysis of currently available methods for the data creation, management, and the definition of valuable procedures for their transformation (information/knowledge) represents the basis on which to articulate a methodological process that analyses and discretises the possible approaches helpful in solving the problem of technological permeability.
The main areas of investigation are closely linked to the technological maturity of the tools, infrastructures, and operational practices currently in use. Such technologies – even those coming from different fields (e.g., AR/VR, Digital Fabrication, or Blockchain) – should be sufficiently mature to guarantee short and medium-term effects without running the risk of proposing attractive solutions linked to the “fashions” of the moment, which in practice would require indefinite time for widespread adoption.
Of no less importance are the aspects arising from applying regulations (European, national, regional) and their effects on operational practices. Developing a theoretically

Fig 22- Using 360° images was crucial to reducing the number of case study inspections (conducted during the first wave of Covid 19). The photos are used for documentation purposes to check the positioning of elements in the model visually.

						Modelling and data aggregation				Production and digital fabrication				
Diagnostic data						Hardware		Software		Hardware			Software	
Sensors	Endoscopy	Thermal imaging	Spectrophoto meter	IR imaging		Workstation	DB & Storage	Data processing	Data aggregation	Workstation	Automated prod. plant	Automated machinery	Automated process	Automated supply chain
					Other tech.									
€€	€€	€€	€€	€€	/	€€	€€	€€	€€	€€	€€€€€	€€€€	€€€	€€€
Adv	Easy	Mod	Easy	Easy	/	Mod	Adv	Adv	Adv	Mod	Adv	Adv	Adv	Adv
Trend Information	2D Information	2D Information	Value	2D Information	/	/	Aggregated information	High-End Data	3D + Info Environment	/	/	Prefab. elements	Production process	Real-time supply needs
****	***	***	****	***	/	****	****	****	***	****	***	****	****	****
Long-term data survey	non-invasive survey	Thermal data	Chromatic value	Not-visible information	/	/	Data sharing management	Process and enhanche data	Aggregate data	/	Standardized process	Repetitive operation	Process control	On-demand supply

Fig. 021 - The synoptic table is used for indexing the technologies that can be implemented in the workflow stages.

high-performance methodology, which contrasts with the current practices, partly defeats the “ready-made” concept that lies at the heart of the research.

Defining the purpose of data collection is an essential step in planning the field intervention. Knowing the purpose makes it possible to structure the a priori process and define which technologies and methodologies to use, thus setting its budget. The purpose may be purely documentary, or it may be an analytical investigation phase in the broader process involving subsequent intervention actions. Depending on the reasons governing the intervention, it is possible to decide on planning punctual activities (a single survey, more or less integrated) or envisaging medium-long term scheduled activities that return data describing a trend over time (Brusaporci 2015). Indeed, different types of intervention require specific tools and related acquisition methods.

The tools needed to pursue the research objectives are those effectively collecting information during an integrated digital survey campaign. They are tested and analysed to define which aspects help plan the survey campaign.

The final purpose of the survey defines the whole process from data collection, through processing, to the modelling phase. Therefore, it is possible to say that the purpose of the survey defines the budget (economic and time) allocated to the various work phases at the outset. The use of more accurate instruments, which produce higher quality data and require adequate economies, will only be envisaged for those interventions where they are truly sustainable. On the other hand, other interventions will foresee using less accurate yet exhaustive tools following the purpose envisioned in the planning phase. In this direction, previous experiences of protocols or workflows aimed at guiding the processes of digitization, respecting needs, requirements and specificities of heritage assets to be surveyed have been analysed (Di Giulio et. al., 2017).

The instruments foreseen can be divided into dimensional and morphological survey instruments and diagnostic instruments.

Among these technologies, it is possible to list Camera 360, DSLR, SAPR, Traditional direct survey instruments, Digital survey instruments (disto, disto 3D), Total station, and Laser

scanner.
On the diagnostic side, Georadar, Active sensors (sensor and data taker), Endoscopy analysis, Thermography, Spectrophotometry, IR images.
The data obtained by these instruments are collected, processed, and stored using hardware and software equipment duly dimensioned in terms of calculation and storage capacity. The final objective of the research is to share the information acquired and conveyed by the synthesis model.

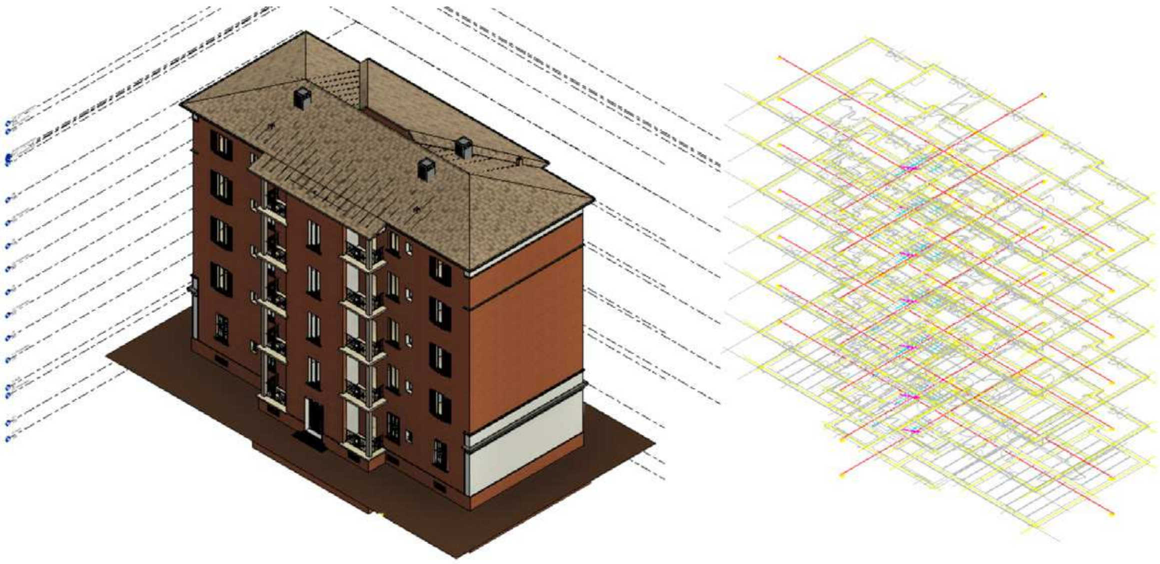


Fig. 023 - For those buildings of which there was already a traditional cad-drawn survey, information was organized and exploited to model the building. Modeling methodology from CAD can be used for those case studies where it would not be possible to plan the budget for a laser scanner survey.

The technologies used are all available and have advanced levels of technological maturity. The CAD to BIM process has been applied as well, starting from available 2D drawings of the case studies analysed.

2.16 Data process and analysis

Once the data collection process has been completed on-site, a preliminary check is carried out to assess the compliance and quality of the material collected. Many unforeseen hardware and software issues can save much time if handled on-site. Today’s digital tools make it possible to check the quality of collected data in real-time and make redundant copies to guarantee its integrity.
At the end of the on-site activities, it is possible to proceed to the data processing and analysis phase. In this phase, paradata are created in addition to the information (Apollonio & Giovannini, 2015). The raw data is processed using specific procedures optimised for each type of data (geometric, two-dimensional, and informative, among others) to obtain ontologically structured information. This process requires a meticulous data storage management structure. At least one unaltered copy of the original data is kept as the data processed in each subsequent stage of the process.
In addition to data in its phase-specific form, the activities carried out by the operator who processed it (paradata) are also recorded. Each information set requires specific software applications, which alter its conformation at each step, to be processed. It may happen

during the processing phase to realise that some procedure has been done wrong, and it is not always possible to undo the operations carried out (considering data sets of tens of GB). Therefore, having a copy of the starting data and the record of the carried-out operations is not an excessive scruple but a fundamental requirement. The material collected, processed, and all the information created throughout the process is organised in special storage facilities with a standardised organisational structure. It is accessible and usable by the involved operators and has a certain level of redundancy to guarantee security (local copies for daily operations and cloud for long-term storage).

2.17 Data aggregation (Modelling) and sharing

After the processing phase, the information collected is aggregated and contributes to creating the model. The model is produced according to the purpose and gathers and integrates information into a kind of knowledge tool. The parametric model, which is created by employing specific commercial applications, makes it possible to aggregate and superimpose sets of information belonging to different disciplines, cataloguing them ontologically (Olawumi & Chan 2019).

The parametric elements aggregation makes it possible to create a questionable knowledge model, useful both as an information container and a tool for analysing the whole. The model is created to share information among the actors involved in the process (Daniotti et. al. 2021). Therefore, it is converted from a proprietary format (specific for each software) into an open format that allows it to be used by all stakeholders.

Provided by law as a “common data environment”(CDE/AcDAT), the management system (storage/repository) described above is used to share all available data. The person in charge of data protection will provide the targeted sharing of information since not all data can be freely shared or easily used by anyone. Targeted data sharing is essential when working with a considerable amount of data where there is a risk of unnecessarily overloading the system. It is the responsibility of the administrator of the sharing system to ensure that the dedicated material for each activity is available to the operators. The local sharing system can be hosted by a dedicated workstation or server, adequately set up to perform redundant backups both locally and in the cloud. Data security issues are a topical concern.

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Chapter 3 - Legislative framework of BIM application on construction industry

Chapter 3
Legislative framework of BIM application on construction industry

3.1 Introduction

The introduction of BIM methodology in Italy at the legislative level is recent. With the introduction of DM 560/2017, we witnessed a first step towards the mandatory adoption of BIM in public procurement procedures. The decree set 1 January 2019 as the first step towards compulsory adoption for public contracts above €100/B.
Until then, the legislation had limited to stating the adoption of this methodology for complex works, which are those contracts where the organisation and long-term preservation of the information component were fundamental criteria for the execution of the construction phases and for the future management of the asset.
In 2018, with the introduction of ISO 19650, an EU (and international) regulatory plan was introduced to standardise BIM processes and foster a gradual implementation in those nations where the BIM methodology was still marginally exploited.
To facilitate implementation at a national level, national standards have been developed (and updated) in Italy UNI 11337, which align with ISO directives and provide guidelines and operating methods for managing the BIM process. There are no deadlines for the compulsory use of BIM in the private sector. The regulations currently only foresee a threshold for the full adoption of BIM in public procurement set on 1 January 2025.

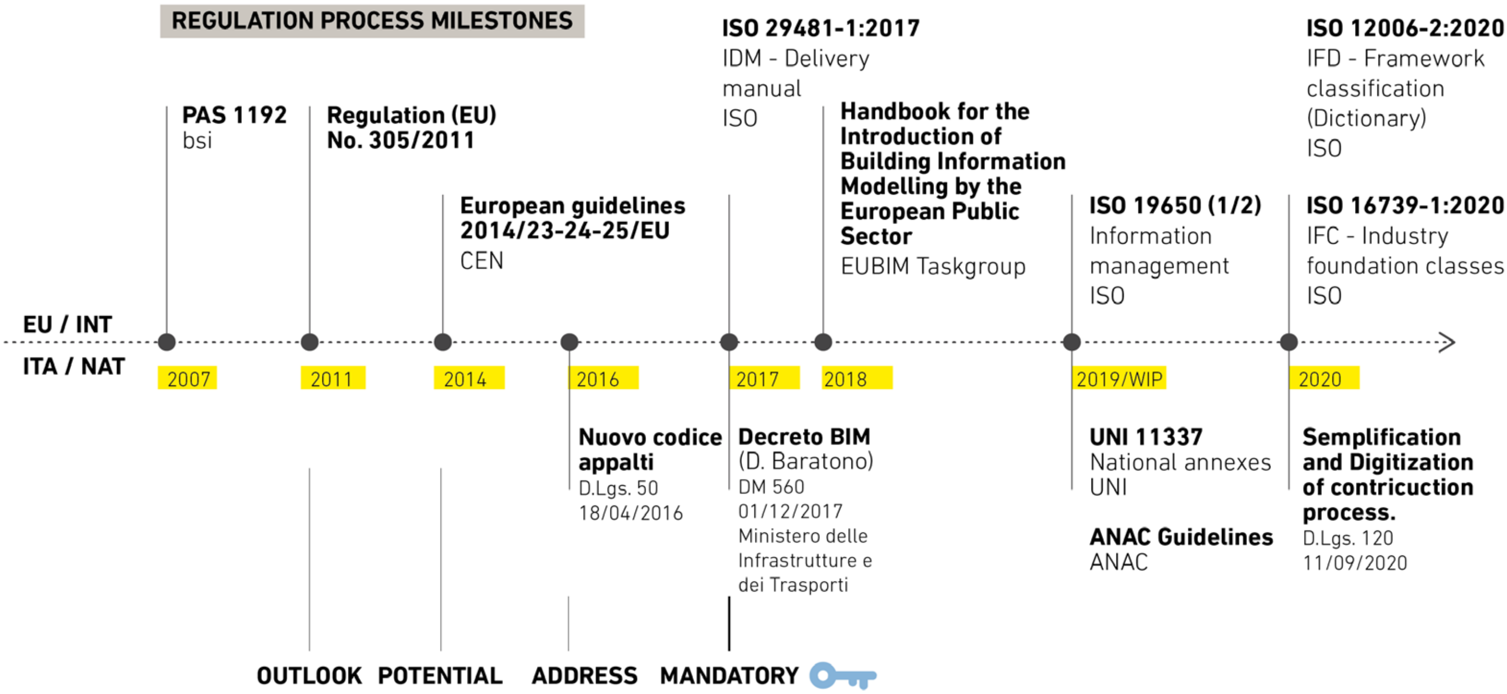


Fig. 024 - Timeline of the main regulations that have ruled the implementation of BIM in Italy.

3.2 Directive 2014/24/EU
EU Public Procurement Directive - Potential

The rule suggests that Member States may require using specific electronic tools for public procurement procedures related to public works contracts or design contests. These tools may be electronic simulations for building information management or similar tools (Art. 22, Paragraph 4).

3.3 Legislative Decree 50/2016: Procurement Code
Guidelines

The Code regulates the design levels for procurement contracts and work and services concessions (Art. 23). The design of public works is articulated according to three successive levels of technical detail: the technical and economic feasibility project, the final project and the executive project. To this end, the rule promotes making design and verification activities more efficient by encouraging employing specific electronic building and infrastructure modelling methods and tools[1].

Paragraph 13 indicates that contracting authorities or entities may require using specific electronic methods and tools for new works and recovery or requalification works or variations (works defined as complex). These tools must utilise interoperable platforms based on non-proprietary open formats (IFC). Interoperability is intended to be the lever for developing competition between technology producers and suppliers, increasing involvement among the professionals involved in the process. The use of these electronic methods and tools can only be requested by those contracting authorities that have provided proper training for their staff. A special commission (Baratono Commission[2]), set up at the Ministry of Infrastructure and Transport, establishes the methods and timeframes for adoption, according to type and complexity, until they become mandatory.

The employment of these electronic methodologies and tools represents an evaluation parameter of the awarding requirements in the tender process[3].

1 D.Lgs. 50/2016, Art. 23 Paragraph 1, Section H
2 D.Lgs. 50/2016, Art. 23 Paragraph 13
3 D.Lgs 50/2016, Art. 38

3.4 Ministerial Decree 560/2017, BIM Decree / Decreto Baratono Requirement

For the first time in the legislative framework, Decree 560, known as the BIM Decree, introduces rules, especially deadlines for adopting BIM processes in public contracts. It incorporates the provisions of the Procurement Code, published the previous year, and introduces some new features into the text.
The decree is organised into nine points:
1 - Purpose. The first article defines the scope of the rule, stating that the use of BIM is related to the design, construction and operation phases of the work;
2 - Definitions. The concept of the information management plan, which encompasses both the information management offer (tender) and the information management plan (contract), as well as the definition of the data sharing environment (ACDat / CDE) are defined;
3 - Preliminary Tasks of Contracting Authorities. The third article introduces the concept of the training plan, which provides a series of introductory activities for managing the process;
4 - Interoperability. The rule specifies the need to use open formats for creating and exchanging information models, going beyond the concept of a three-dimensional model;
5 - Electronic methods and tools. Contracting authorities that have already fulfilled the requirements are allowed to use electronic methods and tools since the decree comes into force;
6 - Timing of compulsory introduction. Timeframes for methodology adoption are specified in addition to economic thresholds;
7 - Information specifications and technical itemised lists. The rule specifies information requirements that will make up the information specifications, including how the information is to be stored;
8 - Monitoring commission. The role and activities of the monitoring commission are specified, changing from a passive to an active body;
9 - Entry into force. The rule also extends the proposed regulations to tenders already underway and for which the design phase has not yet started.

As drafted in 2017, the text is amended by Ministerial Decree 312/2021 by updating the definitions for greater integration with EU regulations.
Among the most important indications is the timing of BIM mandatory adoption in public procurement, which is planned to be phased in from January 2019[1]. The criterion selected to establish the time schedules is linked to the tender amount, starting from works equal to or greater than 100 M/€ for January 2019 to works with an amount equal to or greater than 50 M/€ for January 2020. Subsequent steps concern 2021, with amounts of 15 M/€; 2022, with amounts linked to the thresholds of Art. 35 of the Public Contracts Code; 2023, with amounts of 1 M/€; finally, 2025, in which tenders of less than 1 M/€ are included. The decree sets January 2025 as the deadline by which every tender for public work must be carried out in BIM mode.

1 D.M. 560/2017, Art. 6

The decree also identifies the preconditions that contracting authorities must fulfil to use the methods and tools provided[2]. Contracting authorities will have to provide a plan for training internal employees, determined according to their role in the process and structured in such a way as to provide adequate knowledge of the methods and electronic tools to create data models. In addition to staff training, the contracting authority must develop a plan for acquiring and maintaining the hardware and software instruments necessary for decision-making and information management processes. This equipment will have to be dimensioned according to the work and the process phase to which it will be dedicated.
Finally, the contracting authority will have to draw up an organisational act specifying the supervision and data management process in addition to handling conflicts between the parties involved.
The legislator defines the contracting authorities to employ interoperable platforms using open and non-proprietary data formats to manage the BIM process[3]. This specification aims at defining an information-sharing method that provides for the exchange of data between the participants in the work's various design, construction and operation phases. The rule defines the data-sharing environment as an organised digital environment in which data is stored and made accessible by the contracting authority to the actors involved. This digital environment is configured to preserve information over time, recording the phase transitions that the information models undergo and retaining processing responsibilities as well as intellectual property aspects. The information must therefore be available for use avoiding specific commercial applications.

The text also defines the concept of the BIM Information Specification, which is one of the main aspects of the rule. It assigns the contracting authority the role of determining entity in the process management, regulating the manner to be used in the information exchange. The contractor is provided with the information management plan (pGI) tool to guide how the contract is to be carried out.

D.M. 560/2017 BIM Decree

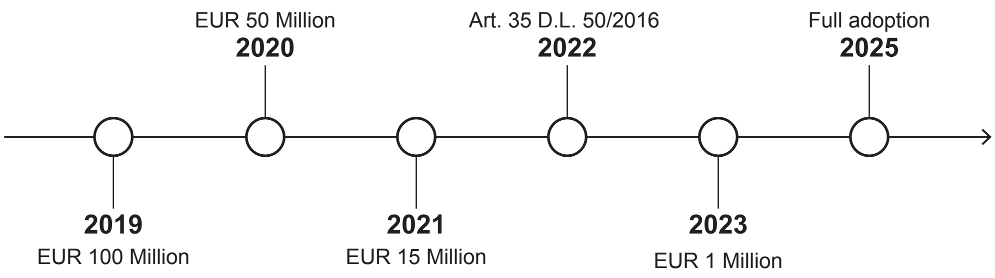


Fig. 025 - Adoption steps provided in the BIM decree, later updated with less optimistic deadlines.

2 D.Lgs 50/2016, Art. 23 Paragraph 13
3 M.D 560/2017, Art. 4

3.5 UNI/PdR 74:2019 BIM Management System (SGBIM) Requirements

Definition of the requirements for a BIM Management System (SGBIM[1])that can be used by an organisation to improve the process of planning, production, operation and decommissioning of a work. The proposed guidelines are developed under UNI EN ISO 9001:2015 to provide tools aligned with the standards for Quality Management Systems (QMS).
Drafted by IMCQ and UNI Ente Italiano di Normazione. Reference Practice elaborated by the Table “BIM Management Systems” coordinated by UNI.
The ‘Reference Practice’ provides for non-compulsoriness. These practices are foreseen by EU Regulation No. 1025/2012 and introduce technical prescriptions. The UNI-coordinated authors draft the procedures, which last for five years, at the end of which they can be converted into a rule or withdrawn.

The UNI/PdR 74:2019 BIM Management System (SGBIM) reference practice defines the management system requirements that an organisation can use to improve the efficiency of the planning, design, realisation, operation and eventual demolition process of work.
The practice structures the BIM Management System process following the HLS (High-Level Structure[2]) approach. It analyses the organisation’s context and identifies the needs and expectations of the actors involved, analysing all planning actions to address possible risks, opportunities and objectives.
The practice also identifies the support elements needed to implement the management system, such as providing the resources needed to carry out the implementation phases (establishment, implementation, maintenance and improvement of the BIM management system). Furthermore, the reference practice defines the elements useful for performance evaluation, using specific internal audits alongside the BIM management system review tool to ensure its quality. The competence requirements for each function are carried out under UNI CEI EN ISO/IEC 17021-1:2015.

Understanding the operational context of the organisation is the basic element for defining the requirements of the BIM system (What I can achieve depending on my market and investment). Different internal structures will be required depending on the type of organisation, whether it is a client, managing designer or evaluator. These structures will require the fulfilment of specific needs, expectations and fields of application.
Among the aspects that contribute to the efficiency of a BIM management system are the availability and characteristics of BIM authoring applications, their integrability with processes and procedures, the hardware and all the digital technological infrastructures that are indispensable for network connection, hosting and cloud-based archiving. In-house and available outsourced expertise must be added to the hardware and software components.

1 SGBIM certification can be a supporting tool for the organisational act required by Art. 3 paragraph 1 letter c, DM 560/2017

2 Aggiungere spiegazione

Needs and expectations

The organisation must identify the parties involved (client, planner, manager, coordinators of specific activities, the companies involved, public administrations, etc.) and then analyse each stakeholder's common and specific expectations and requirements.

Implementation field

The organisation will be responsible for determining the limits and manner for applying the BIM management system. This activity is essential to establish the implementation field, considering internal and external factors and the requirements highlighted by the stakeholder analysis. The BIM management system's implementation field refers both to the role (client, designer, manager, etc.) and the expertise (Infrastructural, Architectural, Structural, Plant Engineering.) as its use differs according to the profile.

Leadership

The appointed party must show leadership in adopting the BIM management system by introducing a standard implementation policy based on goals consistent with the context and strategic directions.

Furthermore, integrating the BIM management process and the availability of resources must be ensured by integrating the BIM process into the organisation's development plan.

Other activities that contribute to the correct process management concern the communication of effective BIM management and compliance with requirements, favouring the achievement of expected results, also employing actions to promote the participation of the personnel involved. The involvement action is also fundamental to the process's continuous improvement perspective.

Policy

The BIM policy must be established a priori by the appointed party and follow specific guidelines to ensure its proper functioning. It must be appropriate to the purpose and context, be the basis to set goals, support the processes that contribute to their achievement, and meet the criteria required by the continuous improvement of the BIM management system when pursuing them. The BIM policy must be continuous and coordinated during all phases (feasibility, design, production and operation). It shall be promoted along the supply chain to create an integrated and shared process between all actors wherever possible.

Roles and responsibilities

The appointed party must ensure that roles and responsibilities are evident within the organisation. To this aim, it is essential that the BIM management system complies with the requirements and is constantly monitored and reported to the appointed party.

The roles will be as required by the regulations, namely:

- the data sharing environment manager (CDE Manager);
- an information modelling and management operator (BIM Specialist);
- an information flow coordinator (BIM Coordinator);

- a digital process manager (BIM Manager).

Depending on the organisation, one or more of these roles may be held by the same entity, or they may be absent. In this case, a documented justification for the choice must be kept.

Planning (6)

Actions to address risks and opportunities (6.1)

In planning BIM management, the organisation must consider factors related to operational context, needs, and expectations. The risks and opportunities related to achieving expected results, mitigating undesirable effects and adopting strategies to achieve process improvement will be assessed from this analysis by planning specific actions specifically structured to address the risks. Then, the actions required to integrate corrective measures into the processes will be evaluated, and their effectiveness evaluated.

Objectives and planning for their achievement (6.2)

The organisation must establish objectives according to the functions, levels and processes required for the BIM management system to operate. They must be consistent with the BIM Guidelines, drawn up following the BIM policy. They must be measurable and enforceable, and their impact shall be monitored. Updating steps must be foreseen at intervals or following the monitoring phase, taking into account the risks resulting from the change of procedures. The objectives must be documented, keeping track of their evolution and planning changes in the strategy to pursue them if necessary. The documentation must indicate the actions to be carried out, the resources required, the responsible persons, the necessary timeframes and the mechanism for evaluating the results.

Changes to the management system (6.3)

When required, the need for changes to the BIM management system must be planned to evaluate the users' needs and the possible impact. In doing so, the purpose and consequences of the required changes should be considered, along with maintaining the management system's integrity, quality, and quantity of required resources. A note must be drafted informing the entities involved if the changes affect their responsibilities. Adaptations may also affect hardware equipment and software applications, in which case their modification or replacement must be handled with the same level of care.

Support (7) / Resources (7.1)

Generality (7.1.1)

The organisation must provide the necessary resources for all processing phases, from instruction to implementation to maintenance and continuous improvement of the BIM management system.

Therefore, the status of existing resources with their deployment restrictions shall be considered, and any external resources must be planned.

Personnel (7.1.2)

Regarding personnel for the BIM management system, the necessary functions are to be identified for information management and coordination, planning, management and maintenance, as well as for information modelling and management of data-sharing environments.

The defined practice is part of a broader framework relating to the digitisation of organisations, making it necessary to adapt the hardware and software equipment. At the same time, the need for duly trained personnel must be determined and structured to guarantee an effective implementation of the BIM management system.

Infrastructure (7.1.3)

The organisation must define and make available the infrastructure required for processes to work, which includes the hardware and software equipment necessary for the digitised processes to function. In detail, it refers to all those technologies involved in digitisation, including network equipment (also cloud), that deal with data storage and management. Software components (applications), which deal with the production, management, and control of the content produced, are also part of the infrastructure equipment (Authoring, Checking, Collaboration and Integration, ACDat, etc.). Specifically, reference is made to the UNI 11337-4 standard and the UNI EN ISO 19650:2019 standard Parts I and II for the data-sharing environment (ACDat).

Organisational knowledge (7.1.6)

The organisation must determine the knowledge for operating the processes in place. This aspect refers to acquired knowledge, which must be maintained and shared within the organisation. Knowledge management must consider, besides current knowledge, the knowledge that must be acquired as a function of newly emerging needs or as a result of changes over time. It may be gained through experience derived from internal or external resources. Internal resources include those endowments of experience derived from the practice and its failures.

Competencies (7.2)

The definition of the expertise required to perform the activities must be determined to select the personnel in charge, which must be competent and trained, including specific actions to promote the acquisition of such expertise.

These actions must be recorded to keep track of the skills acquired by providing constant professional updating over time.

Actions that may be envisaged are related to personnel training and redeploying or recruiting qualified persons in a specific field.

Precisely, the organisation must ensure adequate competence to the figures involved in the operation of the BIM management system. (CDE manager, BIM Specialist, BIM Coordinator, BIM Manager).

A professional certification issued by an accredited body may be considered sufficient to guarantee the required standard of competence. If absent, the level of competence should be demonstrated through documentation of past experience. In the case of a working group operating as a project team, the required competencies may be fulfilled by the sum of the expertise of the individual members as set out in UNI 11337-7.

Awareness (7.3)

The organisation must ensure that the persons involved in the BIM management process are informed and aware of the BIM policy (guidelines), the objectives, the contribution the individual is expected to make, the importance of compliance with the requirements, and their own level of digital maturity.

Communication (7.4)

Communication aspects are among the most important in using a BIM management system, which makes information sharing its raison d'être. The organisation will therefore have to define and share among the actors involved the guidelines concerning the data to be shared (what), when the information will be shared, who the interlocutors will be and how the exchange will take place. The presence of multiple entities involved in the data interchange phase means that careful planning is also required at this stage.

Documented information (7.5)

Generality (7.5.1)

The BIM management system must include valuable information sets for completeness, understanding and use. Thus, it must include the information required by the regulations, the necessary information for the system's effectiveness, and the knowledge derived from past experience. These sets should be managed in the form of internal and external flows. Internal flows relate to data and documentation produced and processed internally by organisation members, while external flows are related to communications with external suppliers, contractors, clients, etc.

Internal flows can be further subdivided into flows directly related to BIM activity and flows of another nature, including information developed in BIM management's context, such as contractual documentation, minutes, audits and descriptive procedures.

These information flows require structured and defined management methods based on assessing risks and opportunities, considering the possibility of conveying and tracking them through an ACDat.

Concerning flows external to the organisation, the client defines the usage procedures. However, they must be able to be integrated into an ACDat management system, which should be structured according to the requirements derived from its role in the BIM process.

The structured ACDat management system must fulfil specific requirements. It must be accessible according to pre-established rules by all actors involved and support the traceability of interventions on the material with a chronological criterion. The system must support a wide range of file and data formats, which may also be large. It must guarantee that the data can be interrogated and easily accessed by users and that it can be stored and updated over time (preferring open formats such as IFC (UNI EN ISO 16739). The system must also guarantee high levels of confidentiality in operations and ensure the security of the archived data.

Creation and Updates (7.5.2)

In the material creation and updating phases, information must be collected to identify the data created or processed (nomenclature, date, author, reference) by creating appropriate information description elements. The type of format used must also be defined, accompanied by specifications (language, version, styles) linked to the target medium (digital, paper). Then, the documents created will be evaluated and approved if deemed suitable.

The creation (and updating) of graphic templates, graphic or documentary designs and all accompanying material shall be managed through specific software applications. Their sharing will occur through an ACDat system in compliance with the indications provided by the reference regulations and practices. The specifications for the individual file formats (formats, nomenclature, development levels, etc.) will be defined according to what is established in the development guidelines by the organisation.

Information control (7.5.3)

The information collected by the BIM management system must be stored and secured, ensuring both its availability to users and its functional suitability. Therefore, an adequate level of protection must be ensured both for their use and for the integrity of the data through planned actions such as backup and disaster recovery to an extent appropriate to what was highlighted in the risk and opportunity assessment phase.

These actions can also be implemented using ACDat by guaranteeing accessibility, maintaining readability, and recording information on the changes made (versioning). Information from external sources must be appropriately identified and catalogued to ensure proper integration into the BIM management system.

Access to the data will be regulated by a system of permissions from the view-only level to the levels that allow modification.

Conserving and maintaining information are two distinct concepts. Conservation refers to consolidated information that will no longer be modified, while maintenance refers to information related to processes and activities that evolve and change over time. The transient nature of this information makes it necessary to have a codified management system to ensure that it is updated over time (operating procedure or instruction).

Operational Activities (8)

The organisation must provide for defining, implementing and supervising the processes necessary for the BIM management method to operate. The type and structure of the processes are defined according to the specific activities performed, the organisation's characteristics or the services offered.

The Italian standardisation body (UNI) has made available a control tool, codified in the form of a Checklist[3], to verify a series of requirements necessary to check the effectiveness of the BIM management system, which defines whether the BIM management system reaches a sufficient degree of maturity to ensure its effectiveness. The requirements assessed range from infrastructural aspects (hardware and software) to information security management systems. Aspects relating to the organisation of processes and procedures are also assessed.

3 Appendix A – additional Checklist , page 26 – Aggiungere riferimento corretto al documento

Performance assessment (9)

Monitoring, measurement, analysis and evaluation (9.1)

Generality (9.1.1)

Regarding the evaluation phase of the data management process, the organisation must determine which features of interest will be evaluated and how and when the assessment will be performed. The BIM management system shall be evaluated in terms of performance and effectiveness, keeping track of the data obtained.

Feedback information (9.1.2)

The organisation must collect and analyse information gathered from the parties involved in the process, with particular attention to the fulfilment of expectations about adopting the BIM system and its effectiveness in terms of communication (internal and external).

Internal audit (9.2)

The organisation must conduct internal audits regularly to verify the BIM management system's requirements and the effectiveness of its use. For this purpose, audit activities should be planned, and their frequency, method and responsibilities should be defined. Reports must be compiled from this activity and communicated to the parties involved. These activities must be carried out considering the specifications required by the standard UNI EN ISO 19011 "Guidelines for management systems" to draw comprehensive reports that comply with quality management standards.

Review and management (9.3)

Management must plan and carry out review activities of the BIM management system to ensure its continued suitability, adequacy and effectiveness. The review should consider aspects of the past situation, external and internal changes that may have occurred, information on the management system's performance, monitoring and the result of previous audits. The organisation also needs to assess the necessary resources available to support improvement activities.

Improvement (10) / Generality (10.1)

Non-conformity and Corrective Measures (10.2)

In the event of non-conformity, the organisation must react by taking corrective actions and addressing the consequences promptly. Subsequently, corrective measures should be developed to prevent the non-conformity from recurring. Information on these corrective actions must be stored, and the actions taken must be documented.

Continuous improvement (10.3)

The organisation shall undertake actions to continuously improve the suitability, adequacy and effectiveness of the BIM management system.

Requirements for personnel involved in the certification process (11)

Certification to the reference practice (UNI 74/2019) may be requested by any public and private organisation of any size and working sector that has adopted a BIM management

system. The certification body must define the competence, knowledge and skill requirements for each function performed following the indications provided by the UNI CEI EN ISO/IEC 17021-1:2015 standard.
For management system functions, reference is made to UNI CEI EN ISO/IEC 17021-3 (5, 6). The certified criteria are the same as those for UNI EN ISO 9001.

Audit Duration (11.1)
Reference is made to Table QMS 1 of IAF MD5 for the audit duration, starting from the number of workers involved in BIM activities.

Risk level (11.2)
The certification body must establish the level of risk associated with the activities performed and their level of complexity. The risk should be calculated according to the impact a wrong adoption of BIM procedures may bring to the building management process. To calculate the risk, consider table QMS 2 (Examples of Risk categories) of IAF document MD 5.

ACDat
ACDat should be considered a technology platform that works on a shared cloud-based storage system. This platform must make it possible to create an aggregate model, facilitating the management of decision-making processes[4] through automated workflows, which must guarantee content state transitions cyclically for each process step. The ACDat must be able to manage graphical models, information processing and documents operating through metadata. The technological solution may also be composed of different software that must contribute to defining an ‘agreed information source[5]’ for each project.
ACDat may be integrated with other software solutions according to the needs that emerge, especially in the case of integration with business systems such as ERP or CRM.
ACDat may also be a solution developed for a single project in less complex cases, provided it can guarantee an effective way of sharing information.

4 UNI 11337-4
5 UNI EN ISO 19650

3.6 Law Decree 77/2021 - Simplifications Decree 2021

The rule named “Governance of the National Recovery and Resilience Plan and first measures to strengthen administrative structures and accelerate and simplify procedures”, abbreviated to Simplifications Decree, deals with the discipline of the BIM methodology in Art. 48 paragraph 6.
The article addresses the topic by defining three concepts:
The first point defines the introduction of the bonus score in design tenders. The scoring is introduced as the possibility for contracting authorities to include a clause in the tender phase providing a bonus score for using specific electronic tools in the design phase. The rule clearly references Art 23 of DL 50/2016 to establish the type and manner of use.
The second point defines the concepts of interoperable platforms and the use of non-proprietary open formats. In using electronic design tools, the need to adopt platforms that favour the interchange of data through open formats is made explicit. The legislator wants to foster competition between software application producers and avoid the creation of closed ecosystems.
The third point specifies that DL77/2021 will be followed by an implementation measure issued by the Ministry of Infrastructures. The rules and technical specifications for implementing the electronic methods and tools envisaged by the rule will be made explicit.

3.7 Ministerial Decree 312/2021 - MIMS2 Digital Transition / New BIM Decree (PNRR)

The Ministry of Infrastructure and Transport has deemed it appropriate to issue a directive updating the manners for employing BIM in public procurement, amending and supplementing the previous decree[1]. It aims to adopt the EU directives for digitising the construction sector[2], with particular attention to public administration processes, and interpret them for the Italian context. Among the changes applied, rules and technical specifications are introduced for using electronic methods and tools involved in the BIM process, as well as timelines for making them mandatory in public works contracts. The decree accelerates the timeframe, though without distorting the approach of the previous rule, providing clarifications, and actually confirming the centrality of the BIM approach in the management of the construction process. Some definitions are also corrected (for example, the concept of ‘electronic model’ is updated to ‘information model[3]’, making it more akin to the BIM concept and less to a simple three-dimensional model), and the concepts of ‘specific workflows’ and of digital deliverables traceable to an information model are specified.
Another important step towards simplifying the procedures for BIM adoption is introduced by allowing contracting authorities to issue the first BIM notices after just planning the introduction of the method[4]. Equally important are the directions removing the compulsory requirement

1 D.M. 560/2017 Baratono

2 Directive 2004/18/CE, Regulation of Public Procurement in the Member States of the European Union. https://www.mit.gov.it/normativa/direttiva-201424ue

3 As defined by ISO EN UNI 19650

4 D.M. 312/2021, Art. 5

for simple maintenance works and the exemption for the contracting authority to produce the state-of-the-art model. Thus, the As-is model can be a service commissioned to the contractor. The decree establishes new deadlines for introducing mandatory BIM in public procurement. On the one hand, these changes are intended to respond to the difficulties experienced by contracting authorities in adapting and restructuring their organisations and, on the other

D.M. 312/2021 MIMS2

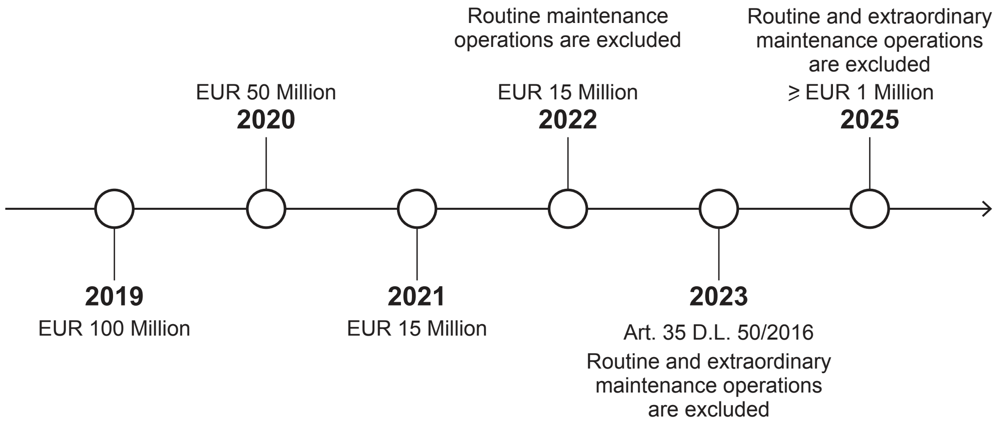


Fig. 026 - Adoption steps provided in the DM312/2021 decree, with updated deadlines.

hand, to increase acceptance of digital methods and systems by introducing the bonus score system. Therefore, the new deadlines are set for January 1st 2022, 2023 and 2025. In the deadline set for 2022, BIM is mandatory for new construction works and interventions on existing buildings for amounts exceeding 15 million euros; from 2023, for new construction works and interventions on existing buildings for the amounts prescribed in the Public Contracts Code[5] (5.382.000€ for public contracts); from January 1st 2025, the threshold is set instead at 1 million euros for new constructions and works on existing constructions. Thus, the rule does away with the principle introduced with the Baratono Law that stipulated a single deadline for introducing the mandatory use of BIM for all works regardless of the amount.

The regulation also introduces the concept of bonus scores[6] to encourage BIM implementation even in those areas where it would not be mandatory. The score is calculated on a comprehensive set of criteria, ranging from employing strategies for planned maintenance over the entire construction life cycle starting from the BIM model to using augmented reality in the construction phase, construction site safety up to life-cycle cost management. A further bonus criterion is adopting digital methods and tools that allow the contracting authority to monitor the activities' progress (work plan and cost).

All things considered, Ministerial Decree 312/2021 contributes to spreading digitalisation in construction, simplifying implementation procedures and adding the rewards principle to support those entities that want to invest in this direction.

5 D.Lgs. 50/2016, Art. 35, Soglie di rilevanza comunitaria. Valori aggiornati al 2022.

6 D.Lgs. 312/2021, Art. 7

3.8 The Standardisation System and the Vienna Agreement

An overview of the international regulatory system and how it relates to the national one is necessary to introduce UNI 19650.
International standards are developed and promoted by ISO (International Organisation for Standardisation) and can be taken over voluntarily by the states that adopt the system. The prefix UNI ISO identifies ISO standards in Italy. At the Community level, the standard-setting body is CEN (European Committee for Standardisation), which produces the reference regulation apparatus for the member states, which are obliged to adopt and adapt (or withdraw) national standards if they are in conflict. CEN standards in Italy can be identified by the prefix UNI EN. At the national level, the regulations are drawn up by UNI (Ente Nazionale Italiano di Unificazione) and CEI (Comitato Elettrotecnico Italiano): the standards produced have national value and are compiled in Italian.

Legislative framework

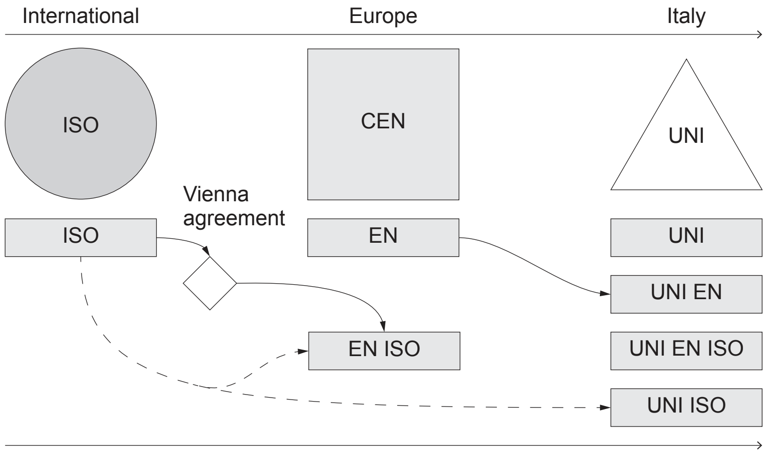


Fig. 027 - The regulatory hierarchy, at the international (ISO), European (CEN), and Italian (UNI) levels.

The Vienna Agreement was designed to allow standards to be drawn up jointly at international and EU levels, thereby promoting indispensable regulatory uniformity when drafting contracts involving international players. The availability of this type of technical regulation has as its objective free competition and the possibility for economic operators to operate in a global context. In the Italian case, the common standards take the suffix UNI EN ISO. UNI is responsible for the translation of the EN ISO standards into Italian.
The regulatory apparatus promoted by the bodies mentioned above can be composed of technical standards (UNI; BS; DIN), technical specifications (CEN/TS or ISO/TS) and technical reports (ISO/TR or UNI/TR). General technical requirements (Publicly Available Specifications), standards such as the English PAS, also exist.
In Europe:
EN ISO 19650:2019 and Ancillary regulations CEN TC442 (prEN 17412, prEN 17473, etc)
In Italy:
UNI EN ISO 19650:2019 (1 and 2) and National Annexes UNI 11337 (Published several times in 2015, 2017, 2018, 2021 in the first seven parts).

3.9 ISO 19650:2018 Organisation of information on construction works and Information management using BIM

The standard promoted by ISO represents an international standard that regulates information management applied to a built asset's life cycle through the Building Information Modeling methodology. The standard defines the concepts and collaborative processes to implement for information management during the delivery and operational phase of built assets. ISO 19650 is developed from the standard[1] BS PAS (UK)[2] and is applied to national contexts through specific interpretations named after the local standard-setting body and specific National Annexes that allow for more detail on the issues addressed. The National Annexes[3] also have the task of translating the concepts expressed in the previous national standards and producing conversion tables to help those involved in adapting concepts and nomenclatures. If BS EN ISO 19650:2019 fully replaces BS 1192:2007 and incorporates BP PAS 1192-2:2013 in the English context, the same does not happen in the Italian context, where the previous standards remain in force.

From Maturity Levels to Phases

Among the main changes introduced by ISO 19650, the concept of BIM Maturity Level 2 (in PAS identified as Level 2 - BIM) is abandoned[4]. In the new standard, there is no longer the four levels division (0-3), but instead, a change to the designation in Phases (Stages) from 1 to 3. In the schematisation provided in ISO 19650, the initial stage (Stage 1) no longer includes CAD as a starting point. Also, the name BIM is removed from the descriptions and replaced by the term Federated Models. The removal of national normative references also reflects the international character of the standard. The requirements parameters are also changed in the schematisation, which now become functional states (Standard Level, Technology Level and Information Level).

From LOD to Level of Information Need

Another important innovation introduced by the standard involves the concept of LOD[5], which UNI 19650 defines as 'Level of Information Need'. The new concept is no longer defined by a predetermined numerical scale. Instead, it depends on the combination of specific needs linked to the state of the process and the type of object. The new concept is very interesting as it is pragmatic: by linking the information need to the specific functional necessities of each contract, time wastage and associated cost increase are avoided. If not indispensable for the contract purpose, excessive detail entails a share of extra costs for the contractor and a share also for the client, who will have to deal with the monitoring for which it is responsible.

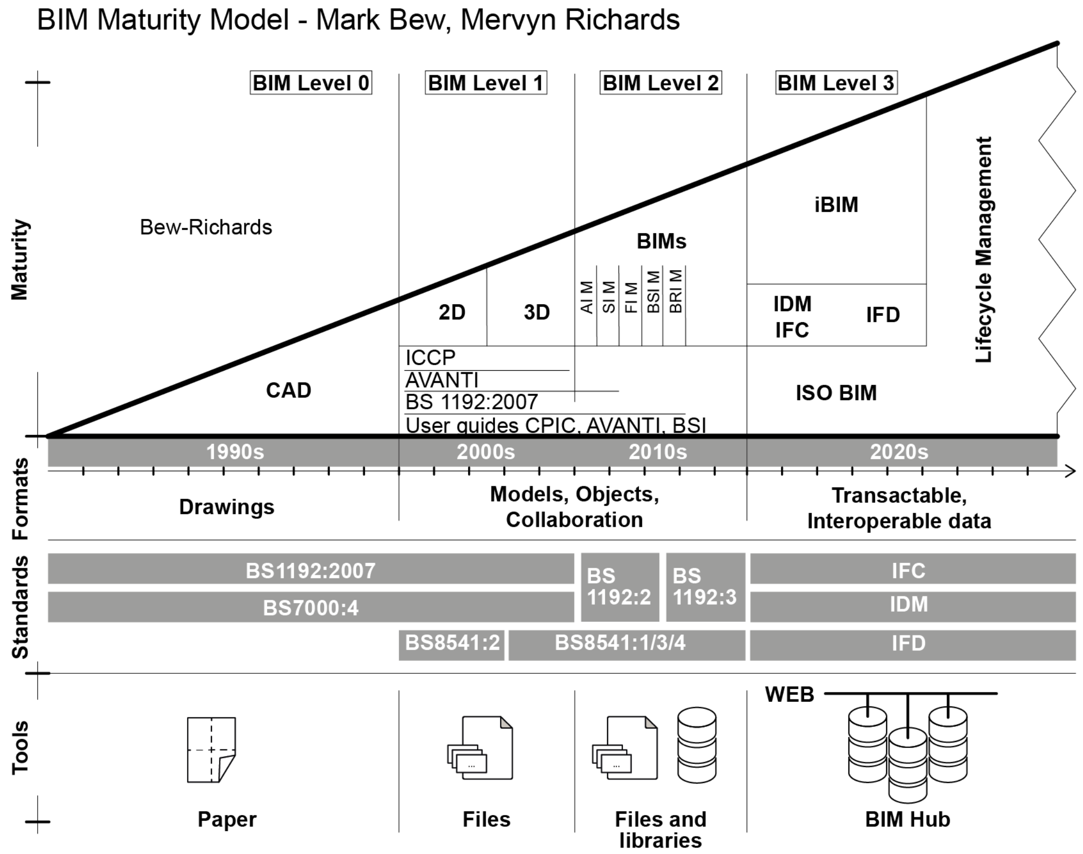
1 Publicly Available Specification, (Reference Practice) similar to a technical standard, which aims at defining and standardising principles useful to encourage fair participation in tenders and competitions.

2 BS PAS 1192-2:2013; BS PAS 1192-3:2014 - The introduction of BS EN ISO 1650:2019 (1 and 2) replaces PAS, which should no longer be referred to in favour of the new standard.

3 UNI 11337 for the Italian context.

4 Bew, M., & Richards, M. (2008). BIM Maturity Model. Paper presented at the Construct IT Autumn 2008 Members' Meeting. Brighton, UK.

5 "Level of Development" for the US or "Definition" for the UK.



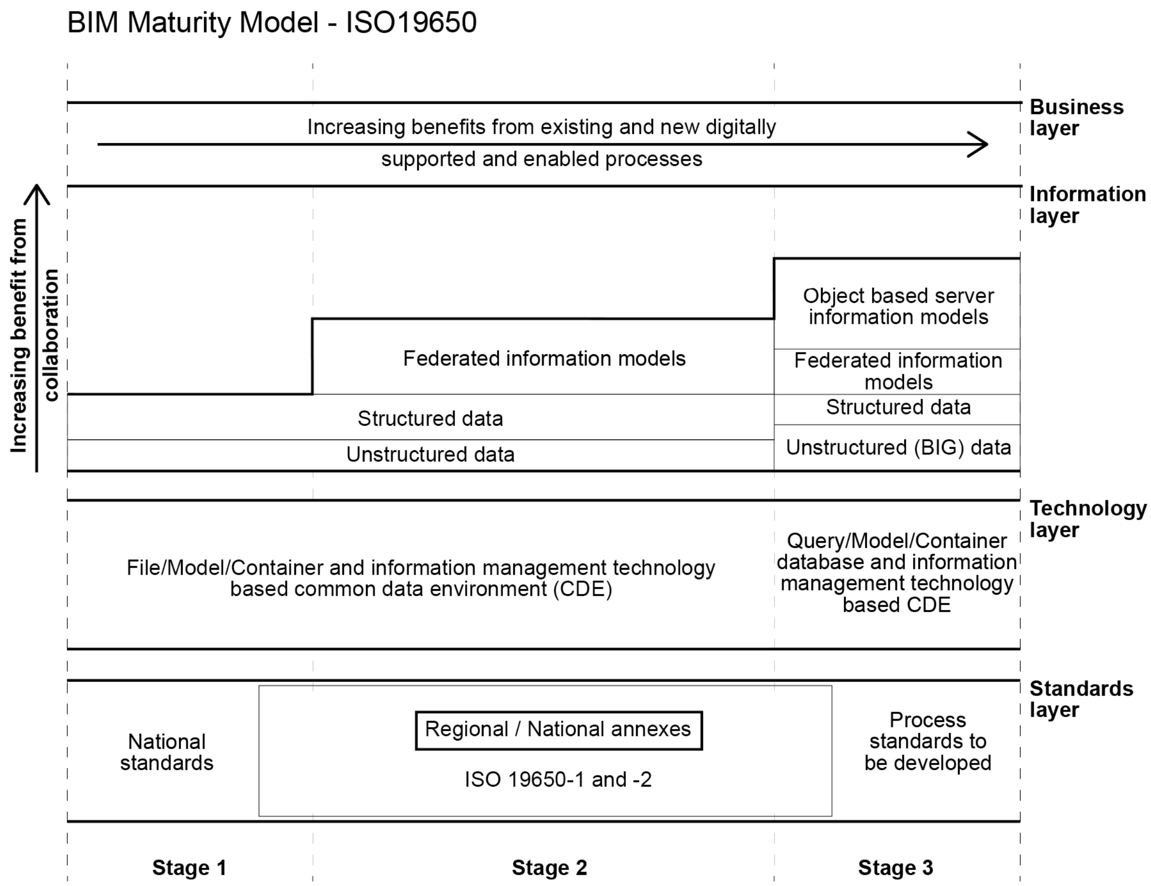


Fig. 028 - The conceptual transition from the Bew-Richards matrix of BIM process management to the updated matrix provided by ISO 19650.

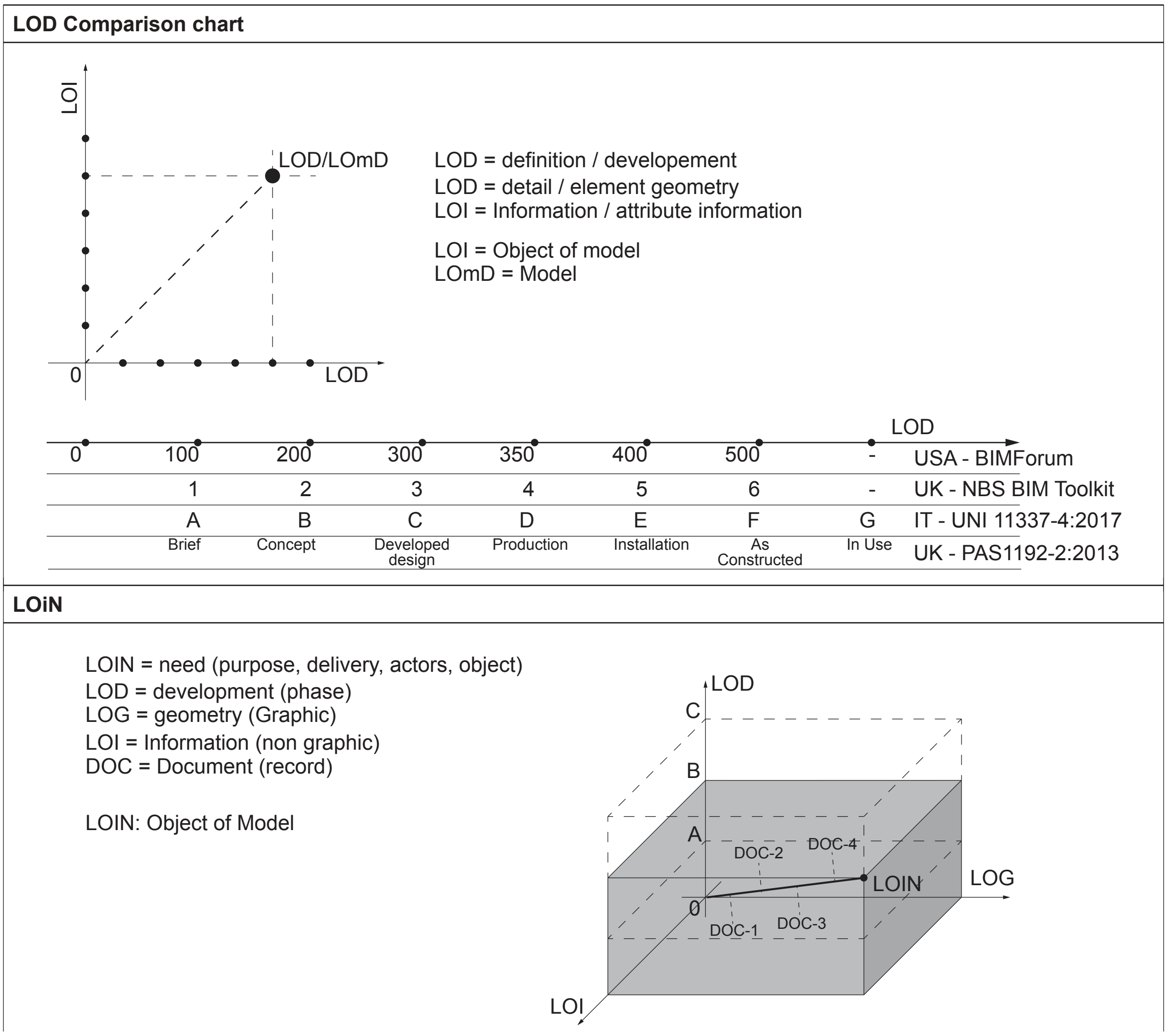


Fig. 029 - The conceptual schematization of the transition from LODs to the Level of Information Need concept set out in ISO 19650.

The UNI EN 17412-1:2021 standard provides detailed indications on the 'Level of Information Need', dividing them into geometric information (previously defined as LOG), alphanumeric information (previously defined as LOI) and Documentation. Notably, acronyms are dropped, and concepts are always expressed in full. In the Italian standard, the 'Level of Information Need' is called 'Information Requirement Levels', as indicated by UNI EN 17412-1:2021. The new definition has an impact on the application methodologies of UNI 11337-4:2017, still envisaging using LODs, which will require a revision to update the methods and procedural schematisation, adding the parts concerning Documentation not previously covered.

The first five parts of the standard adapted by UNI have been issued to date:
UNI EN ISO 19650-1:2019 Concepts and principles[6]; UNI EN ISO 19650-2:2019 Handover phase of real estate assets[7]; UNI EN ISO 19650-3:2021 Management phase of real estate assets[8]; UNI EN ISO 19650-4:2022 Exchange of information[9]; UNI EN ISO 19650-5:2020 Security-oriented approach to information management[10]

6 https://store.uni.com/uni-en-iso-19650-1-2019
7 https://store.uni.com/uni-en-iso-19650-2-2019
8 https://store.uni.com/uni-en-iso-19650-3-2021
9 https://store.uni.com/uni-en-iso-19650-4-2022
10 https://store.uni.com/uni-en-iso-19650-5-2020

3.10 UNI EN ISO 19650-1:2019 - Part 1, General concepts and principles

In the **first part**, the standard defines the basic principles related to information production, the methods to be used for delivery and the organisation of production activities. It is structured to provide for activities involving the building in the phases of its life cycle regardless of size, type and complexity.
The standard consists of twelve chapters: *1 Purpose and application field; 2 Regulatory references; 3 Terms and Definitions; 4 Information on the building asset and order; 5 Definition of Information Requirements and Resulting Information Models; 6 The Information Delivery Cycle; 7 Functions of Real Estate and Job Order Information Management; 8 Capacity and Resources of the Delivery Team; 9 Collaborative Work Based on Information Content; 10 Information Delivery Planning; 11 Collaborative Information Management and Production; 12 ACDat Solution and Workflow.*

Looking at the most interesting parts, we can mention the **third part**, which lists the main definitions and acronyms providing a definition, and the fourth one, which provides the updated definition of the BIM maturity concept, articulated in phases instead of levels as in the previous schematisation. The phases represent the evolutionary steps of the process, in which data are increasingly integrated. In the second phase, data is shared through templates and attached files. In contrast, the data will be disaggregated and queryable directly on the model provided by the logic used for big data in the third phase.
Part five addresses the issue of the hierarchy of information requirements. The proposing party is called upon to draw up the necessary documentation to clarify the requirements for all the parties involved in the various phases. This phase, which in fact represents the Employer Information Requirement envisaged in the PAS (or the information specifications of UNI 11337-5/6), is renewed by developing the request for information starting from the Client's objectives[1] according to the job order, thus defining the technical specifications and the verification steps to be performed. The fundamental principles derive from PAS, in which the technical aspects were merged with the management ones. The information requirements are then revised and linked to the parties to whom they are addressed.

OIR, PIR, AIR, EIR, PIM, AIM

OIR Organisation Information Requirements - It contains information about the Client's strategic objectives, such as strategic business activities, property management, regulatory obligations, interest policies, and asset management planning.

PIR Project Information Requirements - It outlines the information needed to achieve the PIR objectives, but not in a general form defined according to a specific job order. Each item in the RIP will refer to an item in the OIR.

AIR Asset information requirements - It defines the technical-management procedures regarding real estate assets. An AIR will be drawn up for each planned assignment, the sum of which will define the set of information requirements.

1 ISO 19650-1:2018, Table 1, Pag. 8

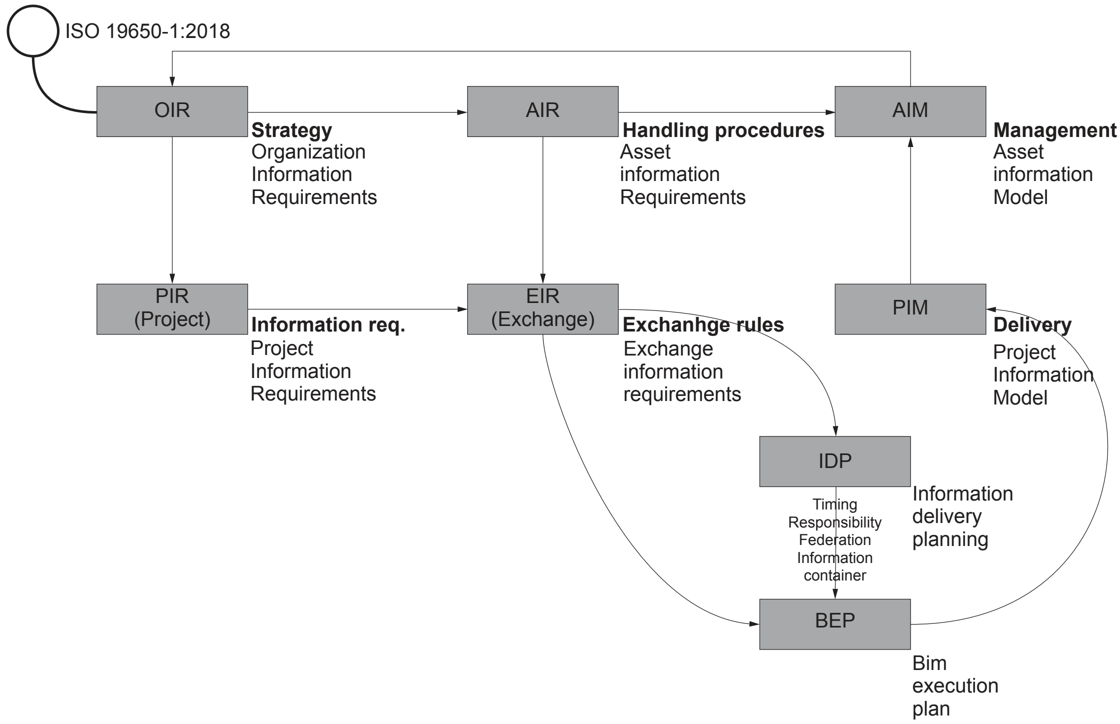


Fig. 030 - The conceptual schematization of the information management structure in the BIM process set out in ISO 19650.

EIR Exchange Information Requirements - It defines technical aspects (project coordinates, interchange formats, plan setting) and management. This document is drawn up with the information obtained in the order development.

PIM Project Information Model – Delivery - It is the model from which the information will be derived: the dimensional data, quantities and technical specifications useful for the design will be extracted.

AIM Asset Information Model – Management - It is the model to be used for the operation, management and maintenance phase. The information included is about the equipment in place, with installation and maintenance dates.

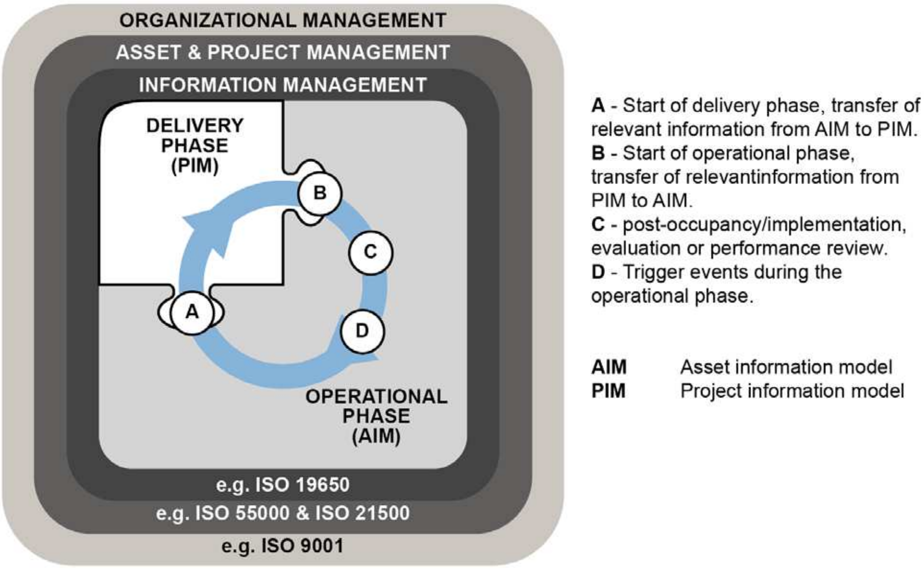
Part six structures the information delivery cycles planned in the pre-contractual phase. The structure follows a four-principle logic:
- Information management is necessary and must be developed for the duration of the order;
- Information is developed progressively;
- Information requirements must be transferable;
- Information exchanges must take place through the use of a data-sharing environment (ACDat/CDE) using open formats.

The Data-Sharing Environment is, therefore, a fundamental tool for managing and sharing information throughout the process. The standard schematises the data exchange workflow by showing how it can move from the management phase (AIM[2]) to the delivery phase (PIM) and back to the management phase. This recursive transition occurs because the PIM model is expected to be developed in different phases until it is delivered to the AIM for

2 In the sense of ‘reference model’, it may not contain geometries.

the management phase of the real estate asset.
The triggering of the transition between the two phases occurs at each “trigger event[3]” in the sense of a ‘planned or unplanned event’ that changes its state during the life cycle. Planned trigger events are covered in the PIR (Project Information Requirements), which is included in the OIR (Organisation Information Requirements) that is drawn up for work management. Each triggering event requires the identification of an appointed entity[4].
Given the complexity of the process, the standard produces functional diagrams that illustrate the methods of execution, identifying the entity or groups in charge, the decision-making points, the information exchange phases, the verification and validation of information, and the flow they follow in the process. In effect, the flow identifies the steps carried out in the ACDat (CDE) sections.

The **following chapters** describe the ways and principles useful for defining each point covered in the illustrated process. The timescales for deliveries, the roles assigned to the actors involved, their responsibilities, and the strategies to be used for the aggregation (or breakdown) of the “information content” as “a coherent set of information retrievable within a file, system or hierarchical structure[5]” are defined.



Source: ISO 19650-3

Fig. 031 - The diagram of the organizational structure and flow governing the deliveries between the various actors involved.

Part ten deals with the issue of deliverables as envisaged in the order’s RIP. The standard stipulates that the person in charge must verify the requirements in the AIR (Asset Information Requirements) and the EIR (Exchange Information Requirements) at the time of the assignment. It will also be necessary to establish the timing and method of delivery, identifying the responsible person and the recipient for each delivery. Then, to organise this procedure, it will be necessary to structure a delivery plan, a responsibility matrix and an aggregation strategy to simplify the reading of the parts.
The delivery plan (or plans) represents the chronology of the information status transitions;

3 Better defined by UNI 19650-3:2021, A.3, Pag. 26
4 It can be an individual or a team.
5 UNI EN ISO 19650:2019 Part 1, Art.3.3.12

in the case of particularly complex structures, several plans may be drawn up depending on the asset division. The responsibility matrix identifies and associates roles and consequent responsibilities with each information management function. The aggregation strategy is defined based on simplifying the geometric model to which functions and appurtenances are assigned, organising them in relation to the totality. The schematic volumes derived simplify the reading of the asset, identifying the competence, the disciplinary field or the whole. A specific univocal coding will accompany the schematisation and allow its identification in the models and deliverables. The coding system (unique code) is not specified in the ISO standard and is referred to in the National Annexes.

Part eleven of the standard addresses the issues of collaborative information management and production. The standard defines the concept of (spatial) interference and (functional) inconsistency in collaborative production[6]. Information interference (clash detection) is subsequently divided into several levels: the interference is defined as ‘hard’ where two elements overlap; it is defined as ‘soft’ where there is interference in the operating space of one element; and it is defined as ‘time’ where two elements appear simultaneously in the same time.

The standard then defines the level of information requirements according to the purpose of the model. The data quality, quantity and granularity features[7] define the level of need (formerly LOD).

Part twelve explores the role of the data-sharing environment (ACDat/CDE). The ACDat is the tool that regulates information management (AIM-PIM[8]) during the four stages of information management. Incoming data must have a coding that identifies the revision step and one that identifies the permissible purposes (Processing, Sharing, Publication, Archiving).

In the ‘Processing’ state, editing permissions and intervention responsibilities are maintained in the ACDat. In the ‘Sharing’ state, data approved by the verification phase are accessed and subsequently made available to assigned parties. The ‘publish’ status is for data that have reached a sufficient level of reliability to be used. In the final status, the ‘Archiving’, the data are kept to record the steps taken. Each state passage requires a conformity check of the data: if this is not passed, the data returns to the previous stage.

Part thirteen states the distinction between information management and data production while maintaining constraints and relationships between them. The standard concludes with a summary diagram illustrating the process.

6 UNI EN ISO 19650-1:2019, Art. 11.1 Pag. 23

7 The standard defines ‘granularity’ of information as the principle used to articulate an aggregate of information in a form that allows the individual pieces of information that make up the whole to be read, allowing the possibility of querying only those that are necessary for a given use.

8 UNI EN ISO 19650-1:2019, Part six

3.11 UNI EN ISO 19650-2:2019 - Part 2 Delivery phase of real estate assets

The second part of the regulation deals with the preliminary planning, work plan and strategy phases to be adopted for the execution of an order, defining the necessary steps through specific steps. UNI EN ISO 19650-2:2019 illustrates the steps to be carried out and how they are to be developed abstractly to provide an overview of the methodology without giving a specific example.
In the first part, the concepts relating to the roles involved in the assignment procedure are taken up. Thus, we have a “Proposing Party”, which represents the commissioning of the activities, a “Principal Appointee” who, together with any “Appointees”, form the “Appointed party” for which the Principal Appointee is responsible. The Appointed Party is the “Delivery Group” accountable for producing the information models.
In the fourth part, the standard deals with managing the order by dividing the process into eight management phases[1].
The management phases identified are:

1. Feasibility assessment and formulation of requirements
2. Invitation to tender
3. Tenders
4. Assignment
5. Mobilisation
6. Collaborative production of information
7. Delivery of information model
8. Closing of the order

Each identified phase is connected to the next, phase 7 has a further cross-reference to phase 2 according to the logic that each assignment contributes to the next.

The **first phase** (Feasibility Assessment and Needs Formulation) begins with the assignment of the Information Manager[2], who is responsible for collecting the information on behalf of the proposing party (PIR). In this phase[3], deadlines are set in relation to the defined decision points, and the information production flow is structured. The decision points match the moments of verification and checking by the appointing party. In this phase[4], the data-sharing environment is also defined, providing indications of the unique identification system to be adopted and associating each domain with a status (in addition to the revision step). The ACDat must guarantee the traceability of the activities, identifying the authors and the status steps of the information. The regulation provides for the ACDat to be operational before the beginning of the assignment, thus creating a double ACDat. We will therefore have an ACDat in which the documents useful for the tender will be hosted (diffuse ACDat) and a second environment that will contain the material specific to the contract (contract ACDat).

1 Management phases are not project phases, they are normally replaced by project-specific triggering events.

2 Bim Manager appointed by the client

3 UNI EN ISO 19650-2:2019, Feasibility assessment and requirements formulation, 1.2-1.6

4 UNI EN ISO 19650-2:2019, 1.7 Information management process, Fig. 4 Page 7

Common data environment types and content summary

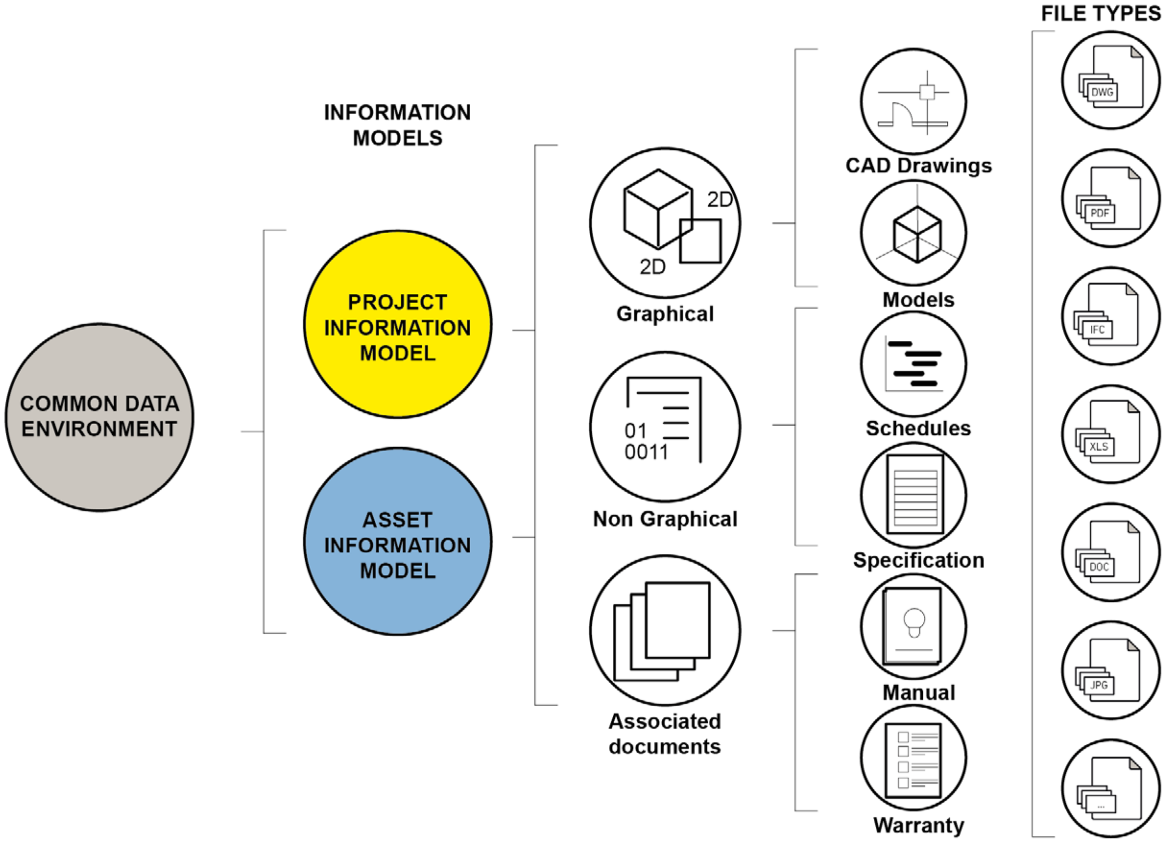


Fig. 032 - The common data environment (ACDat/CDE), and the structure of the information it contains.

The **second phase** (Invitation to Tender) defines how the appointing party identifies the “exchange requirements” (2.1) of the information (EIR/Capitular Information). The requirements at this stage are those relating to the Organisation (OIR), to the Real Estate asset (AIR) and the Contract (PIR). Once this phase has been completed, information from previous activities is collected (2.2), and the criteria for evaluating offers are defined (2.3). The second part concludes with the drafting of the document containing helpful information for submitting bids (2.4).

The **third phase** (Tenders) outlines how each “Supply Group” identifies a “Supply Manager” and submits an “Information Management Offer (oGI). The offer must include the resume of the participants; the information delivery strategy; the information production strategy; the composition of the “Supply Group”; the strategy for model aggregation; the responsibility matrix; and any proposals for additions or changes to the information production methods. The “Supply Group” is called upon to evaluate the offers received from the “Appointed Parties” based on CVs, previous experience and technical equipment. The third phase ends with the communication to the “Principal Appointee” belonging to the “Supply Group” that has successfully assigned the order.

The **fourth phase** (Assignment) starts with the confirmation of the information management offer (oGI), which is drafted in the form of an Information Management Plan (IMP). In this phase, the references of the figures involved are updated, the procedures are revised and the ‘detailed responsibility matrix’ (RACI[5]) is set up, which makes the process control roles definitive. In addition, documents such as the ‘Information Container Delivery Plan’ (TIDP) or the ‘Master Information Delivery Plan’ (MIDP) are added to the documents which are inherited from the information management offer[6], listing the deliverables, identifying the responsible person for the procedure and the expected timeframe.

The **fifth phase** (Mobilisation) defines the preliminary preparatory phase used to verify the availability of planned resources, the verification of interchange procedures and the proper functioning of IT platforms. Also, for this phase, there is a procedure for checking the correspondence of the documentation provided by the supply group.

The **sixth phase** (Collaborative Information Production) identifies the steps to be performed in the information production stage. The steps in this phase are visualised in the scheme proposed by the regulations as parallel steps due to the nature of the activities that can be carried out in parallel by several commissioned groups. According to the TIDP (Task Information Delivery Plan), the data produced by the designated groups must follow the directive to stay within the required information needs and not to operate outside the assigned area. The information flow continues with the verification phase (PIR), following the MIDP (Master information delivery plan). If the verification phase is unsuccessful, the material returns to the team in charge, which will make corrections.

The **seventh phase** (Delivery of the Information Model) takes charge of the documentation created in the previous part, which is validated through a review phase performed by the person in charge, verifying the indications foreseen in the MDIP (Master information delivery plan), those of the PIR (Project Information requirements), those of the person in charge and the level of the information requirements (LOIN).

The **eighth phase** (Closing Phase) concludes the activities foreseen for managing the order. In this phase, the model is archived in ACDat. The archived model must remain accessible to authorised parties over time. The workflow ends with the acquisition stage of lessons learnt during the execution of the order; this stage is a preparatory activity for drafting subsequent procedures.

5 The RACI (Responsible, Accountable, Consulted, Informed) matrix describes the relationship between the resource (specific assigned group) and the activity to be performed. The four identified roles perform activities of ‘production’, ‘responsibility’, and ‘collaboration’ in its realisation and of ‘knowledge’ concerning the fact that the task has actually been performed.

6 The set of models, drawings and documents that will be produced in the development of the order.

3.12 UNI 11337 - Digital management of construction information processes

Working Group UNI CT033 Construction process.

The UNI 11337 standard represents the national implementation methodology of the UNI EN ISO 19650:2019, the primary standard at the EU level and includes the declinations developed by each country as a 'national annexe'. The standard is set by the UNI/CT 033/SC 05[1] working group that deals within UNI with the standardisation process of the digitisation of the building process. Both public and private stakeholders representing the entire supply chain are part of the working group. Representatives of design, construction companies, contracting authorities, research institutes, universities and companies involved in the development of software applications take part in the commission's activities and specific technical tables. The commission must rearrange the standards already drawn up at the national level to align with the EU directives promoted by standard 19650 to complete the alignment with the international standardisation levels CEN and ISO. The Committees will therefore be asked to elaborate specific activities to revise and convert concepts already introduced, such as the introduction of the 'Level of information Need (LoIN)' that will replace the LODs present in Part 4 of the standard or the definition of the information attributes of digital objects and products, described in Part 3. The aspects concerning the ACDat/CDE[2] will be better defined by defining a more optimal conformation (Part 5) in support of the information flow (CI information specification), which is supplemented by defining the concepts of OIR (Organisation information requirements), AIR (Asset information requirements), PIR (Project information requirements), AIM (Asset information model) and PIM (Project information model). These standards are essential for operators to provide a basic set of rules to be applied at the national level to enable them to act autonomously without having to refer to regulatory references mainly from English-speaking countries. The regulatory set developed by the commission following its publication is then monitored, where stakeholder requests and objections are considered and evaluated. If accepted, changes contribute to the drafting of updates to the legislation. This process is carried out every three years.

Today, the standard gathers and organizes the parts published and updated since 2009[3] and is structured as follows:

UNI 11337-12017 Part 1: Models, elaborations and information objects for products and processes.

UNI/RT 11337-2:2021 Part 2: Information flows and decision-making processes in the management of information by the client.

1 Previously called UNI/CT 033/GL 05, it is changed to sub-commission UNI/CT 033/SC 05 in which eight working groups are further identified to draft specific parts of the standard. GL 01 Information classes, codification and identification; GL 02 Information attributes, structure and schemes; GL 03 LOIN, structure for the national market; GL 04 Collaboration and sharing environments and management tools; GL 05 Information specifications; GL 06 Qualification of personnel working in BIM and information flows; GL 07 Building file; GL 08 BIM administrative management; GL 09 BIM infrastructures.

2 The separation of data sharing environments is introduced, moving beyond the concept of a single ACDat/CDE, introducing the one for the contracting party (appointing party) to be prepared at the tender stage and the one specifically for the contracting parties (appointed party).

3 UNI113377:2009 Coding criteria for construction works and products, activities and resources.

UNI/TS 11337-3:2015 Part 3: Models for collecting, organizing and storing technical information for construction products.
UNI 11337-4:2017 Part 4: Evolution and information development of models, processes and objects.
UNI 11337-5:2017 Part 5: Information flows in digitised processes.
UNI/TR 11337-6:2017 Part 6: Guideline for drafting information specifications.
UNI 11337-7:2018 Part 7: Requirements for knowledge, skills and competence of figures involved in information management and modelling.

PdR - Reference practice / TS - Technical specification / TR - Technical report

UNI 113377:2017 Digital management of construction information processes (BIM).

Part 1 (2017)[4] - Models, drawings and information objects for products and processes. The regulation introduces the general aspects of digital information process management in the construction sector. Among these, it defines the structure of information constraints, the structure of processes and product information management. It also describes the scope of applicability of the standard, between construction and infrastructure, at any stage of the process (conception, production or operation). The regulation applies to both new construction and the existing built environment.

Part 2 (2021)[5] - Client information management's information flows and decision-making processes. (Designation and classification) The standard, structured as a technical report, provides guidelines for applying BIM standards nationally[6]. The regulation refers to the relationship between information management and project management, taking up the concepts of UNI EN ISO 19650, UNI ISO 21500 and UNI 11337. The standard emphasises the centrality of the project's life cycle and the asset's useful life, highlighting the importance of proper management by both the client and the service provider.

Part 3 (2015)[7] - Models for collecting, organising and storing technical information for construction products. The regulation, articulated as a technical specification, identifies standard criteria functional to qualitatively and quantitatively describe and identify CE-marked and non-CE-marked construction products. For each product, there is a qualitative description (not measurable) and a quantitative description (measurable). The regulation also outlines the procedures for structuring, organising, and archiving this information under the CE standard. The regulation applies to all those involved at the various stages of process development.

Part 4 (2017)[8] - Evolution and information development of models, processes and objects.

4 https://store.uni.com/ uni-11337-1-2017
5 https://store.uni.com/uni-tr-11337-2-2021
6 As required by EN ISO 19650
7 https://store.uni.com/uni-ts-11337-3-2015
8 https://store.uni.com/uni-11337-4-2017

The standard defines the qualitative and quantitative aspects to be achieved in the digital management of the information process. Therefore, the objectives to be pursued for each of the stages of a process are identified, and the ways in which the model, objects and deliverables contribute to their achievement. A shared scale of information development level is also defined for the objects to be included in the models, and a shared scale for describing the states of processing and approval of the contents produced.

Part 5 (2017)[9] - Information Flows in Digitized Processes. The regulation defines roles, requirements and required workflows in information production, management and delivery by defining the information specifications. The regulation includes flow diagrams of the levels of coordination in various stages of development, clash detection phases between models of the same discipline and across disciplines, and the requirements according to

Informative process - UNI 11337-5

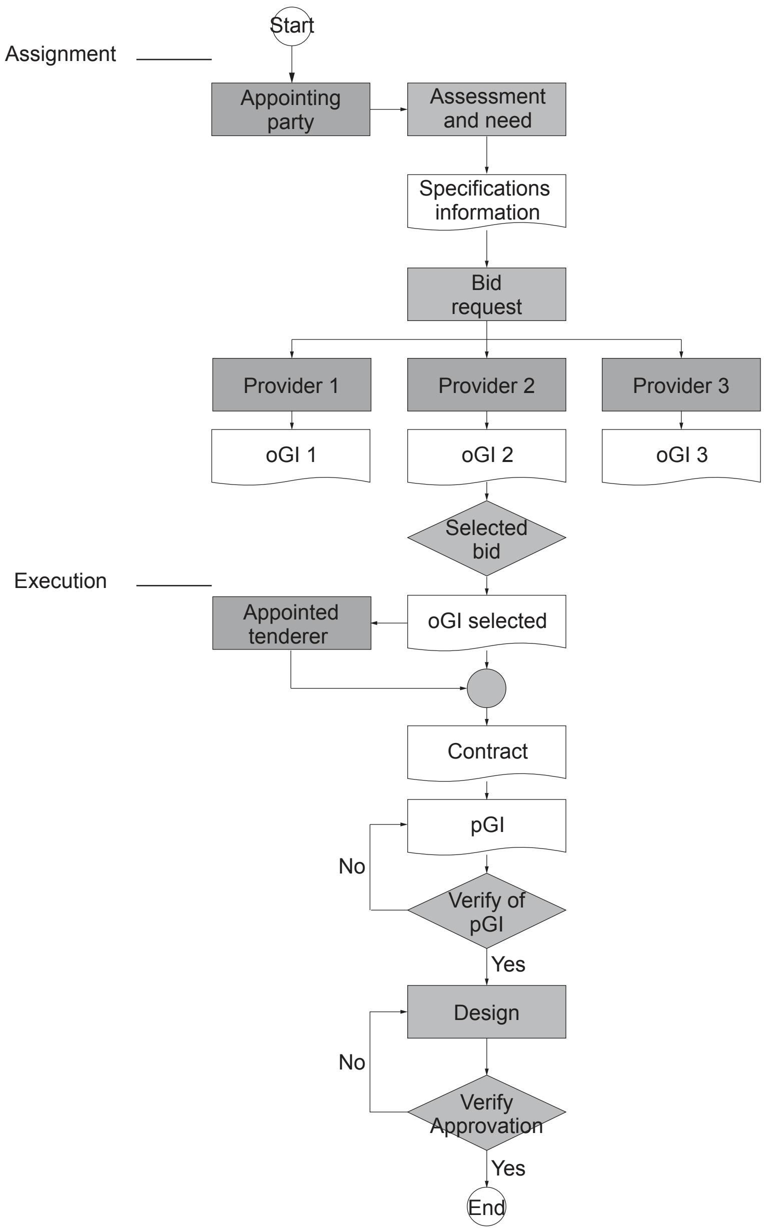


Fig. 033 - Information management flowchart according to UNI 11337-5.

9 https://store.uni.com/uni-11337-5-2017

which the information management and storage system (CDE / ACDat) is to be structured.

Part 6 (2017)[10] - Guidelines for the drafting of information specifications. The regulation, structured as a technical report, provides guidelines for drafting information specifications (UNI 11337-5). It provides procedural indications and an outline of the contents required for drafting the information specifications. The proposed scheme is suitable for drafting an information specification for any kind of product, whether construction or infrastructure.

Part 7 (2018)[11] - Knowledge, skill and competence requirements for figures in information management and modelling. Four certifiable professional figures are identified in the standard: the CDE Manager, who oversees managing the data sharing environment; the BIM Manager, who oversees managing digitized processes; the BIM Coordinator, who is in charge of coordinating information flows; and the BIM Specialist, who is identified as an advanced information management and modelling practitioner. The standard sets out the various professional figures' requirements in information management and modelling. The specific requirements for each figure are identified by breaking down the tasks and activities performed. The necessary knowledge, skills and competencies are established following the European Qualification Framework (EQF). (UNI/PdR 78:2020)

Further parts of the regulation are currently under development, the contents of which are known, and which will cover aspects related to implementation practice, arising from the audit activity with stakeholders and the integration of the BIM methodology with emerging technologies, such as Artificial Intelligence and Blockchain.

Part 8 - Guidelines for applying BIM to industry processes.
Part 9 - Operation Phase and BIM Dossier
Part 10 - Automated Digital Verification of Paperwork
Part 11 - Blockchain and data security
Part 12 - BIM Management System (UNI/PdR 74:2020)

10 https://store.uni.com/uni-tr-11337-6-2017
11 https://store.uni.com/uni-11337-7-2018

BIM Maturity level

Maturity level (UNI 11337-1)	Level 0	Level 1	Level 2	Level 3	Level 4
Requirements needs by the regulation	Processes and documents on non-digital media	Processes and documents on non-digital media resulting from digital processing	Models, drafts and documents in both digital and non-digital media produced from digital processing	Digital models, drafts and documents	Digital model, including virtualised designs and documents

Application field

Building/structure survey	Survey with traditional celerimetric techniques and production of paper documents with classic orthogonal projection drawings obtained using 2D CAD	Digitisation of survey materials, use of instrumental measuring equipment for accurate topographical surveys (total stations, GPS instruments, etc.), digitised material and site condition photographic imaging	Digitisation of the built environment by automated survey systems (TLS and digital photogrammetry) for the production of shared information archives for the As-Built, production of models and subsequent data processing from digital surveys	Data processing of acquired survey data in a wholly digital chain, production of semantic models adapted to the target knowledge, semi-automated generation of building components by comparison (HBIM) or for exclusive production (Scan2BIM)	Use of high-resolution surveying techniques, digital aerial proximity photogrammetry, lidar and terrestrial laser scanning as a preparatory step to semi-automated Scan2BIM processes Information integration with existing documentation systems (in particular with standardised archives for historical/monumental heritage)
Digital fabrication	Production of paper drawings for product analysis	Prototyping through digitised systems with mixed (paper/digital) manufacturing data transmission	Component prototyping based on production mathematics derived from design models	Component prototyping based on production mathematics derived from design models. Quality control with LCA systems in production control (materials and manufacturing processes) and code checking for regulatory compliance	Mathematics transmission through coordinated design systems from the designed component to the finished product, always in a digital chain. Advanced connection with AI systems

Tab. 002 - Table on the identification of BIM maturity characteristics for AS-IS and Digital Fabrication activities

3.13 UNI 8290 "Housing stock. Technological system"

Three levels of system breakdown, named according to UNI 7867-4: Classes of technological units (1 Level), technological units (2 Level), and classes of technical elements (3 Level).
The UNI 7867-4 standard defines the technological system as "The structured set of technological units or technical elements according to the meta-project or design operational phase of the building process to which it refers".
The UNI 8290/1 "Provides the classification and structure of the technological units and technical elements into which the technological system is broken down" and breaks it down into three levels.
The UNI 8290 aims to "define the reference framework of the REQUIREMENTS with respect to the agents that motivate them, to the NEEDS to which they are transposed and to the objects of the technological system to which they refer".

Requirements:	
Reliability	Ability to maintain its quality significantly unchanged over time under given conditions of use.
Intrinsic energy content control	Containment of the quantity of energy stored in an object with reference to both its nature and its production cycle.
Efficiency	Constant capacity for performance in operation.
Ease of intervention	Possibility of easy inspection, maintenance and restoration. (Maintainability, Recoverability, Replaceability)
Acoustic insulation	Ability to provide adequate resistance to the passage of noise.
Thermal insulation	Ability to provide adequate resistance to the passage of heat depending on climatic conditions.
Mechanical resistance	Suitability to effectively counteract the occurrence of serious cracks or deformations under the action of specific stresses.
Water tightness	Ability to prevent the ingress of water.
Ventilation	Ability to obtain air exchange by natural or mechanical means.

Esigenze dell'utenza finale / End-user needs:				
4	Classi di esigenze e relative definizioni		Classes of needs and related definitions	
4.1	Sicurezza	Insieme delle condizioni relative alla incolumità degli utenti, nonché alla difesa e prevenzione di danni in dipendenza da fattori accidentali, nell'esercizio del sistema edilizio.	Safety	Set of conditions relating to the safety of users, as well as the defense and prevention of damage due to accidental factors, in the construction system.
4.2	Benessere	Insieme delle condizioni relative a stati del sistema edilizio adeguati alla vita, alla salute ed allo svolgimento delle attività degli utenti.	Welfare	Set of conditions related to building system conditions adapted to the life, health and performance of user activities.

4.3	Fruibilità	Insieme delle condizioni relative all'attitudine del sistema edilizio ad essere adeguatamente usato dagli utenti nello svolgimento delle attività.	Usability	Set of conditions related to the attitude of the building system to be properly used by users in carrying out their activities.
4.4	Aspetto	Insieme delle condizioni relative alla fruizione percettiva del sistema edilizio da parte degli utenti.	Apperarence	Set of conditions relating to the perceptive use of building systems by users.
4.5	Gestione	Insieme delle condizioni relative all'economia di esercizio del sistema edilizio.	Management	Set of conditions related to the operating economy of the building system.
4.6	Integrabilità	Insieme delle condizioni relative all'attitudine delle unità e degli elementi del sistema edilizio a connettersi funzionalmente tra di loro.	Integration	Set of conditions relating to the attitude of the units and elements of the building system to functionally connect to each other.
4.7	Salvaguardia dell'ambiente	Salvaguardia dell'ambiente - Insieme delle condizioni relative al mantenimento e miglioramento degli stati dei sovra sistemi di cui il sistema edilizio fa parte.	Environment protection	Set of conditions relating to the maintenance and improvement of the status of the super-systems of which the building system is part.

Tab. 003 - Table of the identification of end-user requirements and needs as provided by UNI 8290.

UNI 8290-1:1981 - Technology system classification					
Classes of technological units		Technological units		Technical element classes	
Code	*Description*	*Code*	*Description*	*Code*	*Description*
1	**Load-bearing structure**	1.1	Foundation structure	1.1.1	Direct foundation
				1.1.2	Indirect foundation
		1.2	Elevation structure	1.2.1	Vertical elevation structures
				1.2.2	Horizontal and inclined elevation structures
		1.3	Retaining structure	1.3.1	Vertical retaining structures
				1.3.2	Horizontal retaining structures
2	**Closure**	2.1	Vertical closure	2.1.1	Vertical boundary walls
				2.1.2	Exterior vertical fixtures
		2.2	Horizontal bottom closure	2.2.1	Ground slabs
				2.1.2	Horizontal fixtures
		2.3	Horizontal closure on external spaces	2.3.1	Floors on open spaces
		2.4	Top closure	2.4.1	Roofing
				2.4.2	Exterior horizontal fixtures
3	**Internal partition**	3.1	Vertical internal partitioning	3.1.1	Interior vertical walls
				3.1.2	Interior vertical fixtures
				3.1.3	Protection elements
		3.2	Horizontal internal partitioning	3.2.1	Floor slabs
				3.2.2	Mezzanines
				3.2.3	Interior horizontal fixtures
		3.3	Inclined inner partition	3.3.1	Indoor stairs
				3.3.2	Indoor ramps
4	**External partition**	4.1	Vertical external partitioning	4.1.1	Protection elements
				4.1.2	Separation elements
		4.2	Horizontal external partitioning	4.2.1	Balconies and lodges
				4.2.2	Walkways
		4.3	Inclined external partition	4.3.1	External stairs
				4.3.2	External ramps

The standard associates a numerical value to each field as Technical Element Class.
This standard is referenced by two Classification values entered as parameters for export to IFC. They are stored in a PSet called Coding Element.
- IfcElement.ElementCoding.ClassTechnicalElement
- IfcElement.ElementCoding.DescriptionTechnicalElement

Tab. 004 - Classification table of technological units as per UNI 8290. The proposed breakdown system is still used for the classification of the constituent elements of the asset.

5	**Service delivery system**	5.1	Air-conditioning system	5.1.1	Connection
				5.1.2	Thermal units
				5.1.3	Fluid treatment plants
				5.1.4	Distribution and terminal networks
				5.1.5	Moisture drainage systems
				5.1.6	Exhaust ducts
		5.2	Plumbing system	5.2.1	Connection
				5.2.2	Hydraulic systems
				5.2.3	Storage
				5.2.4	Heaters
				5.2.5	Cold water distribution networks and terminals
				5.2.6	Hot water distribution networks and terminals
				5.2.7	Hot water recirculation networks
				5.2.8	Sanitary fixtures
		5.3	Liquid disposal system	5.3.1	Faecal drainage networks
				5.3.2	Domestic water drainage networks
				5.3.3	Stormwater drainage networks
				5.3.4	Secondary ventilation networks
		5.4	Aerosol disposal plant	5.4.1	Power supply
				5.4.2	Equipment
				5.4.3	Ducting networks
		5.5	Solid disposal plant	5.5.1	Chute duct
				5.5.2	Exhalation duct
		5.6	Gas distribution system	5.6.1	Connection
				5.6.2	Distribution networks and terminals
		5.7	Electrical system	5.7.1	Power supply
				5.7.2	Connection
				5.7.3	Electrical equipment
				5.7.4	Distribution networks and terminals
		5.8	Telecommunications system	5.8.1	Power supply
				5.8.2	Connection
				5.8.3	Distribution networks and terminals
		5.9	Permanent transport system	5.9.1	Power supply
				5.9.2	Equipment
				5.9.3	Moving parts
6	**Safety equipment**	6.1	Fire protection system	6.1.1	Connection
				6.1.2	Detector and transducers
				6.1.3	Distribution networks and terminals
				6.1.4	Alarms
		6.2	Earthing system	6.2.1	Pillage network
				6.2.2	Ground plates
		6.3	Lightning protection system	6.3.1	Capturing elements
				6.3.2	Network
				6.3.3	Ground plates
		6.4	Burglar and intrusion alarm system	6.4.1	Power supply
				6.4.2	Detector and transducers
				6.4.3	Network
				6.4.4	Alarms
7	**Indoor equipment**	7.1	Home furnishings	7.1.1	Storage walls
		7.2	Service block		
8	**Outdoor equipment**	8.1	Collective outdoor furniture		
		8.2	Exterior fittings	8.2.1	Fences
				8.2.2	External flooring

Chapter 4 - Methodologies and procedures for parametric modelling

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Chapter 4
Methodologies and procedures for parametric modelling

4.1 Introduction

To proceed with the realisation of the BIM model of an asset, we must establish a set of rules that allow collaboration between different teams and guarantee the correct cataloguing of deliverables. Regardless of the size and complexity of the asset to be digitised, it is necessary to plan the operations following the regulations to guarantee the client an execution compliant with current quality standards.

When working on the existing asset, additional steps will be necessary to integrate the information source of survey data with the parametric model. Standardised procedures, now widespread nationally and internationally, allow us to benefit from guidelines which can be tailored to operate in the national context, selecting which ones to implement and which ones cannot be implemented due to methodological or investment-related inconsistencies. Methodological aspects include defining the model's purpose (BIM use), structuring the operational mode and helping to plan subsequent operations. The development of IT tools that support the modelling and information management phase contributes to simplifying the process and breaking down barriers that limit the adoption of the BIM methodology in technologically undeveloped contexts.

4.2 BIM Uses

Before starting any work on the model, it is necessary to define which activities and processes will require the implementation of the BIM methodology. For the definition of BIM Uses, it is necessary to analyse a series of variables such as the purpose of the project, the scope of the contract in which it will be used, the phase of implementation, the level of development required, and the design discipline (or disciplines) involved. Once the analysis is completed and the screening of the client's needs is done, it is necessary to arrange the information according to the detailed outline of the Bim Execution Plan (BEP). The drafting of the BEP requires the identification of the objectives to be pursued and the definition of the specific BIM Uses. In the BEP, the objectives to be achieved will be defined and above all, it must be explained how the BIM methodology is used to achieve them. The objectives definition also sets out what the fields of application of BIM will be, and for each identified BIM Uses, a leading party (there can also be more than one figure) will have to be identified, who will have to show his or her level of competence in executing the assigned action by presenting experience and acquired skills (Resume).
Defining and understanding the model's use is a significant step in the Information Requirement phase, which differs according to the use of the model and the phase in which the BIM working method is applied. The information requirement required for the design phase of a traditional building is different from that required for working with a building constructed from prefabricated components. The BIM Uses must be detailed by making explicit the characteristics that identify them: a description of the activity must be produced; its value; the required resources; the individual skills and skills of the working group involved; bibliographic and regulatory references; what the workflow positioning will be and which information will be produced during its realisation. Defining the possible purposes of BIM methodology applied to the construction sector is a vast subject. Indeed, there are many possible combinations between the methodology's application stages and

Model Uses - Categories BimExcellence.org (Succar, 2015)

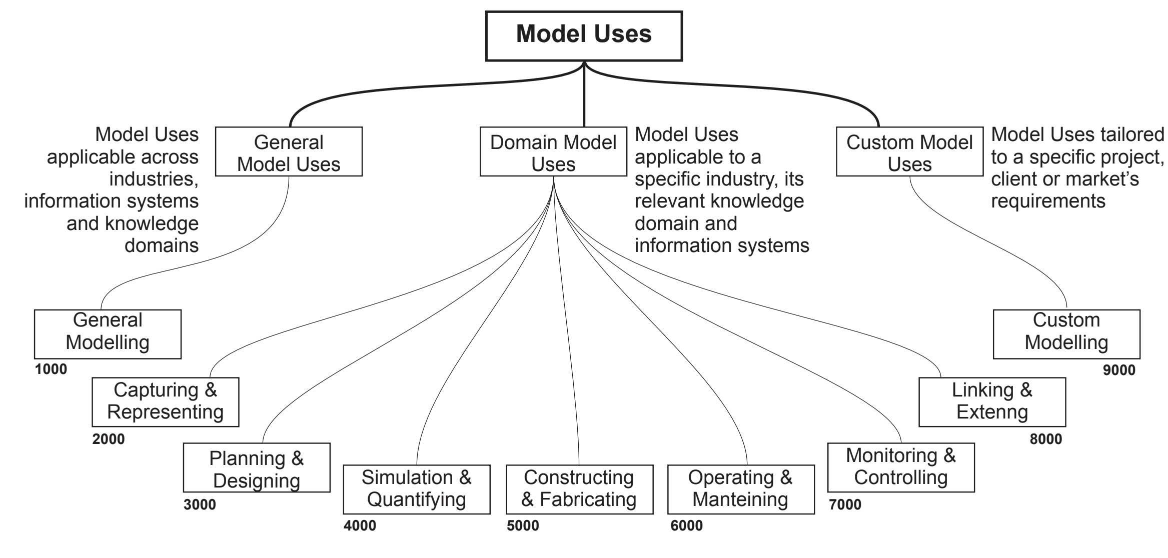


Fig. 034 - The schematization of the Model Uses categories identified by Penn University.

the activities performed. Penn University[1] has listed 21 possible fields of application of the BIM methodology. In their publication, they analyse the potential value of each case study, the required resources for the implementation, the skills to be implemented, as well as a list of references for further investigation. Particularly useful among these are “Design reviews”, “Cost estimation” (5D), 3D Coordination, Phase planning (4D) and Record modelling.

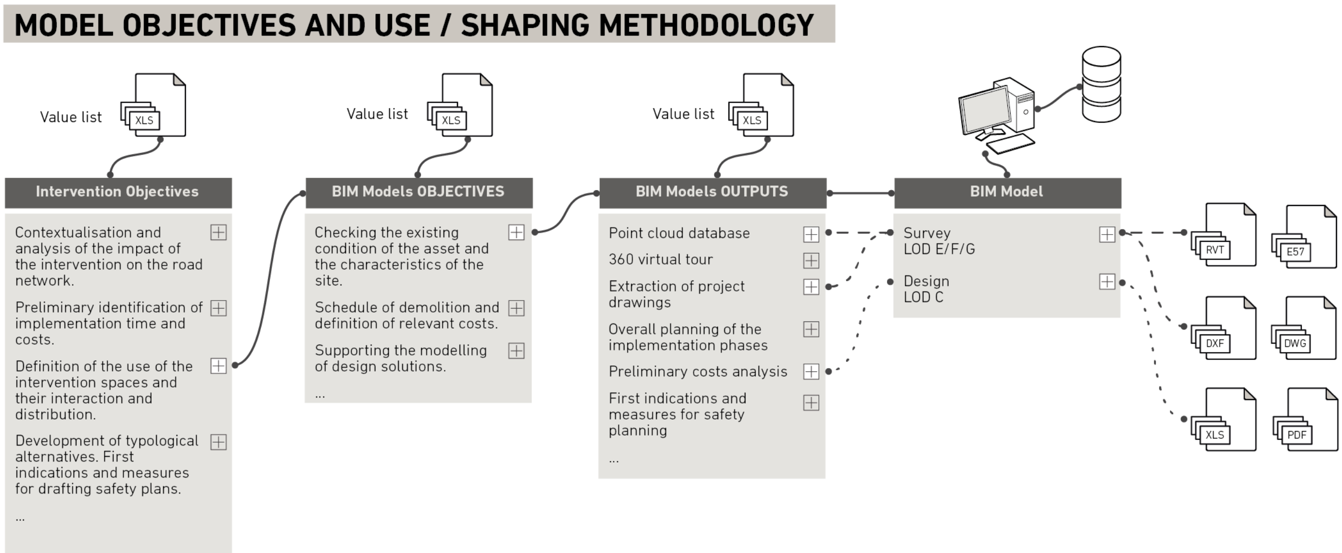


Fig. 035 - Composition system of the required specifications according to the selected BIM Use. It represents one of the tools developed to support the simplification of building intervention.

1 Kreider, Ralph G. and Messner, John I. (2013). “The Uses of BIM: Classifying and Selecting BIM Uses”. Version 0.9, September, The Pennsylvania State University, University Park, PA, USA. http://bim.psu.edu.

4.3 Record Modeling (As-Built)

Appendix B-6 of the handbook[2] framed by Penn University describes 'Record Modelling' as the process used to define an accurate representation of the physical conditions, environment and components of a work. The definition states that the representation must include the main architectural, structural and MEP aspects as minimum information. It then lists criteria of potential value such as: The possibility of using the model for the coordination of future activities; Maintaining an up-to-date documentation source integrated into the model; Providing an information base for decision-making; Enabling the possibility of creating a database for maintenance management; Providing the client with an accurate model that can be used with other BIM Uses; Reduce the dispersion of information management related to the building and its components; Facilitate the development of future interventions on the same building or with the same client; Quickly access useful information for the client, such as room surface or environmental performance data. Record Modeling implementation requires resources qualified to create and manage the 3D model, resources equipped to provide models that comply with the requirements, tools that allow the use of informative models and annexes in digital format, and tools useful for creating databases to manage the assets.
Therefore, the necessary skills foreseen for the implementation are those related to 3D data management, the skills required to implement the geometries with the collected alphanumeric information and keep the model up-to-date. Furthermore, knowledge of building construction processes is required to ensure the correct input of information. To complete the skills section, it is necessary to communicate effectively between the construction's design, implementation and management phases. The descriptive drafting of the model's purpose is done in a schematic form using a chart that allows for an immediate and comprehensive reading of the above-listed features. A brief description of the activity should be provided, showing in list form its potential value, the required resources to carry it out, and the required skills. The BIM Uses are identified by analysing the task and the scope that the data created within it will have in the asset's life cycle. This analysis will allow us to identify the data management strategy, which of this information will have a punctual use and cyclical use, outlining an intervention strategy that includes a focused effort on managing the most important data.
The guide from Penn University provides a useful worksheet for schematising the process of defining BIM Uses. The BIM Selection Worksheet schematises the process starting from choosing one or more BIM Uses. Of these, we will have to provide an impact assessment, defining in what way it will be conducive to the objective of the assignment. We will then indicate the subjects involved and with what priority. Once the subjects have been identified, we will assess the skills and competencies of the working groups, schematising with a value ranging from one to three with increasing qualitative criteria, the level of competence already acquired or to be implemented in the working groups. The schematisation then leads us to

2 Messner, J., Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Leicht, R., Saluja, C., and Zikic, N. (2019). BIM Project Execution Planning Guide, Version 2.2. Computer Integrated Construction Research Program, The Pennsylvania State University, University Park, PA, USA (Pp. 88-90)

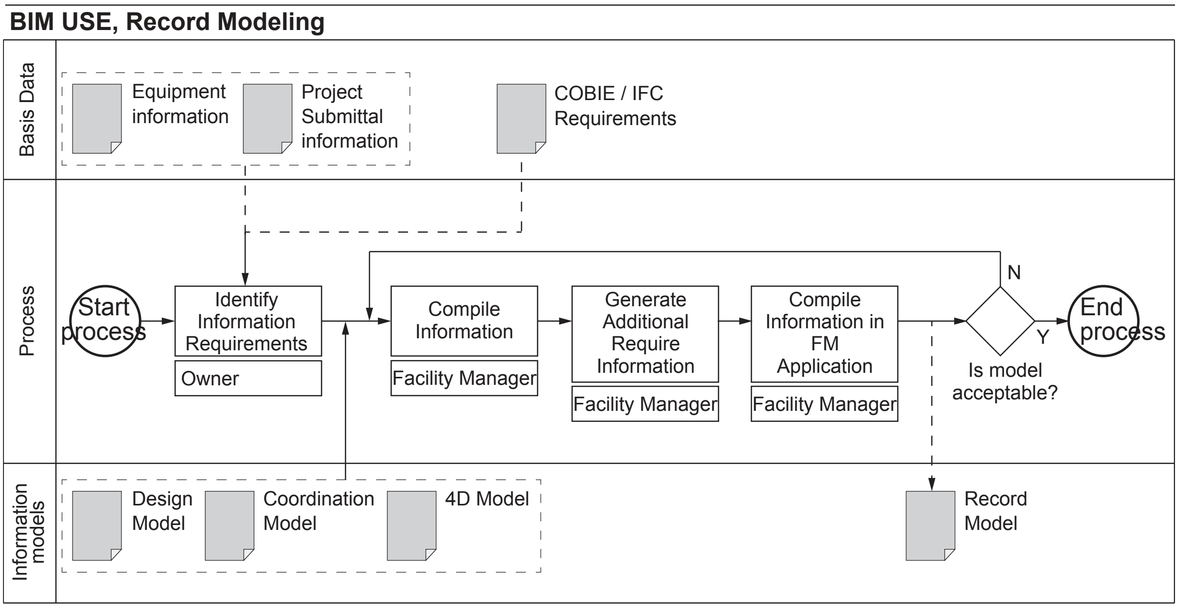


Fig. 036 - Record Modeling process diagram.

the need to define the identified weaknesses in the processes, work groups or necessary equipment. Of the identified weaknesses, we will have to identify possible solutions. The process ends with the evaluation (YES/NO) of the applicability of BIM Uses in a specific project phase. The decision-making group reaches the assessment by investigating the problems and the possible strategies for their resolution. If the measurable benefits from adoption outweigh the costs required to adapt the process, the adoption phase can proceed.

BIM Use	**Value to Project**	**Responsible Party**	**Value to Responsible Party**	**Capability Rating**			**Additional resources / competencies Required to implement**	**Notes**	**Proceed with Use**
	High/Med/Low		High/Med/Low	Scale 1-3					
				Resource	Competence	Experience			
Record Modeling	HIGH	Contractor	MED	2	2	2	Requires training and software		YES
		Facility Manager	HIGH	1	2	1	Requires training and software		
		Designer	MED	3	3	3			
Cost Estimation	MED	Contractor	HIGH	2	1	1			NO

Tab. 005 - Table identifying responsible figures and priorities related to BIM Use Record Modeling

4.4 Information Content Organization

The information content organization follows an asset-based criterion. Each asset may consist of several elements (buildings). These are catalogued as compositional elements belonging to the asset. These elements are then split into functional blocks. For each functional block, the necessary disciplinary models are created (Architectural, Structural, Plant, Furniture, etc.).
The number and characteristics of functional blocks are defined according to the complexity of the case study. The generated models are named using a coding system that allows them to be recognized. Federated models providing an overview of the model are also created to simplify the reading of the positioning of individual portions.

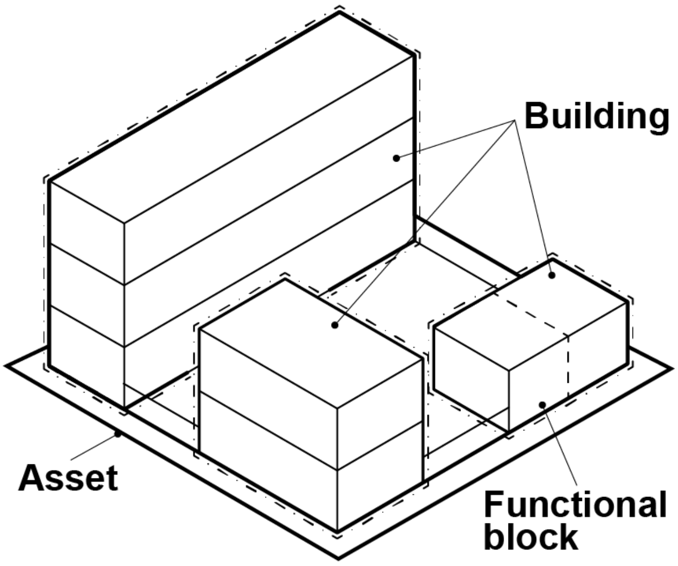


Fig. 037 - Diagram of the breakdown of elements that make up an asset.

The models' organization, therefore, follows a pre-established hierarchy that is fundamental for the federation phase of disciplines. According to the type of federated model (Asset, Building, Functional block), a structured organization is created. Model breakdown's organization directly affects the ACDat (CDE) structure.

4.5 Model location

Survey point

The survey point represents the origin to be used for model federation. Latitude, longitude and altitude values are requested. The angle of north rotation supplements the origin. The survey point coordinates embed assets in GIS spatial georeferencing systems. The identified coordinates will be entered into the model using the appropriate tools provided by BIM authoring software. The necessary instructions for identifying the on-site point through a survey campaign should also be provided.
For the As-built or those buildings that have already been the subject of intervention, a survey point must be provided to allow the model to overlap with the existing one.
The information required will therefore be the coordinates expressed in WGS84, the true north angle (in degrees) and the altitude (metres).

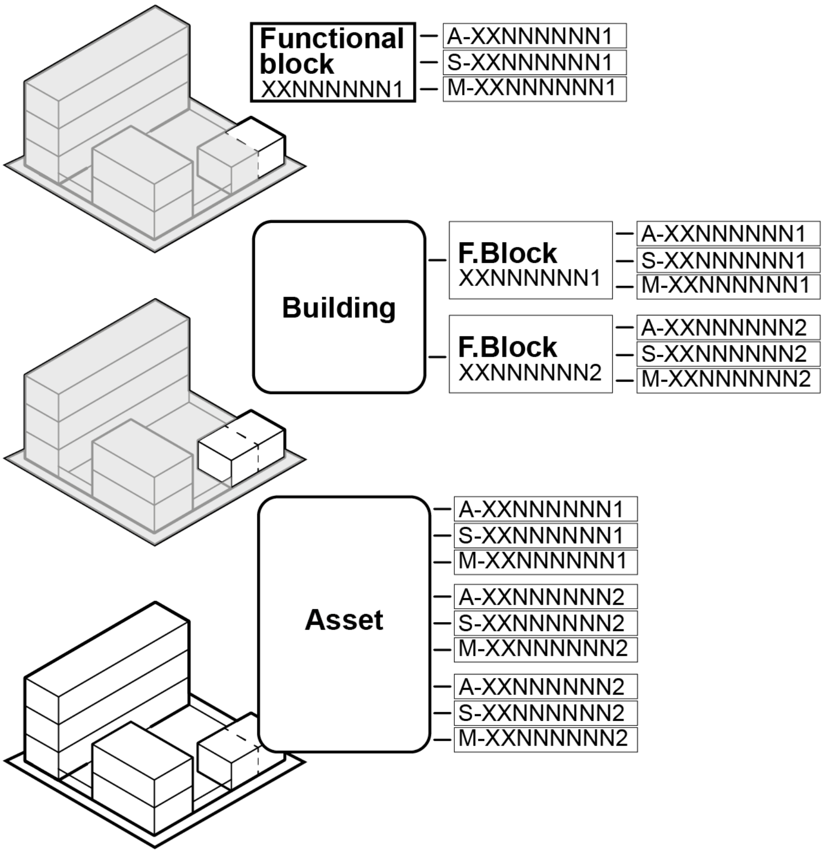


Fig. 038 - Schematisation of the coding system of federated models by disciplines

Reference grid

To optimize the breakdown of the asset, it is necessary to set up a system of reference axes that allows the correct positioning of individual portions. The reference grid is essential to organize the breakdown of disciplinary models and to coordinate the variants of the same model. The grid must therefore have an extension that allows coverage of the entire asset. The survey point must fall at a defined point on the reference grid, and base points must also be identified to be used as local origins for the individual models of the buildings that compose the asset.

The base point (relative origin)

For each building in the asset, the model’s relative point (relative origin) and the point to be used as a reference for the federation must be indicated. The base point must correspond with the intersection of two axes of the asset’s federated model reference grid to facilitate overall positioning. Model positioning information must be expressed in such a way that it can be exported in the IFC format. The IFC format provides IfcSite group values to host model positioning information.

4.6 Building breakdown

Reference levels

Buildings should be analysed to identify the most effective reference levels (floors) to be used for the 3D modelling phase. Asset models composed of several buildings may have reference levels at different heights, but they must be recognisable in the final model of the asset. For each level, the coding related to the name (G1, GF, 01, 02), the floor level

(expressed in metres) and the inter-floor height (expressed in metres) must be specified. For the parametric modelling phase in the BIM environment, the correct use of levels is crucial, as it is on these levels that the geometric elements representing the spaces and components are hooked. The inserted elements are positioned at a defined height relative to their reference level; as the level changes, the values of the elements are automatically updated by the software. Due to their design, special elements extending over several storeys must be assigned to the lowest level.
The storey elevations must be consistent with zero elevation of the project and must keep this value during the subsequent development phases.

Relative Reference System	
Object	**Specification**
External horizontal partitions	External horizontal partitions are to be associated with the reference level on which they lie and are bounded above and below by the floor top.
Internal horizontal partitions (Floor Slabs)	Slabs are to be positioned on the reference level to which they belong and entered at the top level. (From floor level to bottom)
Ceiling finish layers	Ceiling finish layers are associated with the room above.
Suspended ceilings	Ceiling finish layers are associated with the level below.
Exterior vertical partitions	External vertical partitions will be positioned on the reference level on which they lie and will be limited by the extrados of the ceiling at both the upper and lower points.
Internal vertical partitions	Internal vertical partitions will be positioned on the reference level on which they lie and limited by the ceiling at both the upper and lower points.
Vertical structural elements (load bearing)	Vertical load-bearing structures will be limited by the bottom surface of the beam above them or by the bottom surface of the floor slab. At the bottom, they will be limited by the top surface of the load-bearing element on which they rest.
Horizontal structural elements (Beams)	Beams are associated with the reference level below and are limited by the top surface of the upper floor.
Vertical systems	The systems are associated with the level below and are limited by the top surface of the upper floor.
Horizontal systems	Horizontal systems are associated with the level to which they belong.
Furniture	Furnishings are associated with the level to which they belong.

Tab. 006 - Table listing the compositional elements of the building with their descriptions.

Model Elements (Families)

All the elements that will represent the components in the building should be broken down according to the scheme proposed by the standard to ensure uniformity between models created by different teams. Each element inserted in the model shall be associated with its IFC class to organise the model components ontologically.

Coordination levels

The regulations provide checking tools to achieve the coordination consistency standards necessary for managing the BIM process. These steps are carried out to identify any clashes between elements or information inconsistencies between disciplinary or federated models. The steps are: LC1, Data coordination of elements produced by a single working group; LC2, Data coordination of elements created by different working groups or disciplines; LC3, Data and information check generated by graphical and data models and non-model generated content.

Information organisation

The methodology used to organise information within the model must meet the requirements of the model's function. The geometric detail, information and document level shall be appropriate to the function. The information content will follow the organisational methodology foreseen for the geometric structure, organised in: Asset; Building; Room; Plant; Element (2D or 3D object).

Geometrical content of models

The level of definition of the geometric component of the models will follow the indications provided for the information level.
The geometric development requirements follow the requirements for the shape and positioning of elements.
The shape is defined as the set of metric characteristics of the components that define an element. Shape may be articulated as Simple, Defined or Complex. The 'Simple form' is obtained by simplification and approximately describes the geometric components. The 'Defined form' is where the geometric part is expressed relatively accurately. On the other hand, 'Complex form' describes the components extremely accurately.
Positioning refers to the criteria used to place an element within the model. Positioning may be 'design' or 'actual'. Design positioning is identified during the design phase, while actual positioning is obtained through a survey campaign of the existing. The level of detail required for the elements is defined according to the needs of the intervention.

Documentary content

The data that can be associated with model entities can be of two types: Standard (system) parameters and design parameters. System parameters are those provided by

the authoring software by default and may be of various kinds. Specific parameters are those defined according to the purpose of the model and are structured in property sets. Property sets provide an essential tool in the BIM process, ensuring the interoperability of data and information between different software and working groups. The information contained in property sets are expressed through strings of alphanumeric values and conveys information of a heterogeneous nature. We can find parameters describing the discipline, the conformation of the property, the properties and the typology of the data being entered. The data that can be conveyed via IFC are of text type (IfcText), Boolean type (IfcBoolean), a real number (IfcReal) or an integer (IfcInteger).
Property sets are to be mapped to the 'ifcPropertySet' system, and properties are to be mapped to the 'IfcProperty' system to ensure a sufficient level of standardisation and interoperability.

Document Content

Information that does not have a place within the model must be digitised and included in special sheets stored in the Published repository within ACDat.

4.7 Information tools
Information exchange formats

Created models and deliverables must be delivered in the native format of the software that generated them and all project documentation. Models can be developed with any software that can export models in IFC format, respecting the mapping rules provided. Models will be delivered either in native format (specifically Revit) or in IFC format in the V2x3 Coordination View 2.0 version. To avoid any technical limitations , the individual files may not exceed 2GB.

ACDat (CDE)

The structure of ACDat is composed in such a way to accommodate the information related to the four phases of information management. Processing and Updating (WIP), Sharing (Shared), Publication (Published) and Archiving (Archive). Each Asset will have its own space in the ACDat, divided into folders organised according to the disciplinary hierarchical logic.
Sub-folders will be set up for each Asset containing the 'territorial co-ordination' data, valid for the federation of the buildings; the 'documentation' related to the model; and the folders related to the 'buildings' storing the models (CFNNNN), the graphic drawings and documents.
The folders relating to spatial coordination, documentation and buildings will be articulated within them by folders referring to the four processing phases.
The folders relating to buildings will have a further organisational level relating to the individual disciplines, in addition to the folder for federated models (Coordination).
Architectural Works (Architecture), contain the models, graphics and documents of the architectural discipline organised by working phases. The disciplines included are:

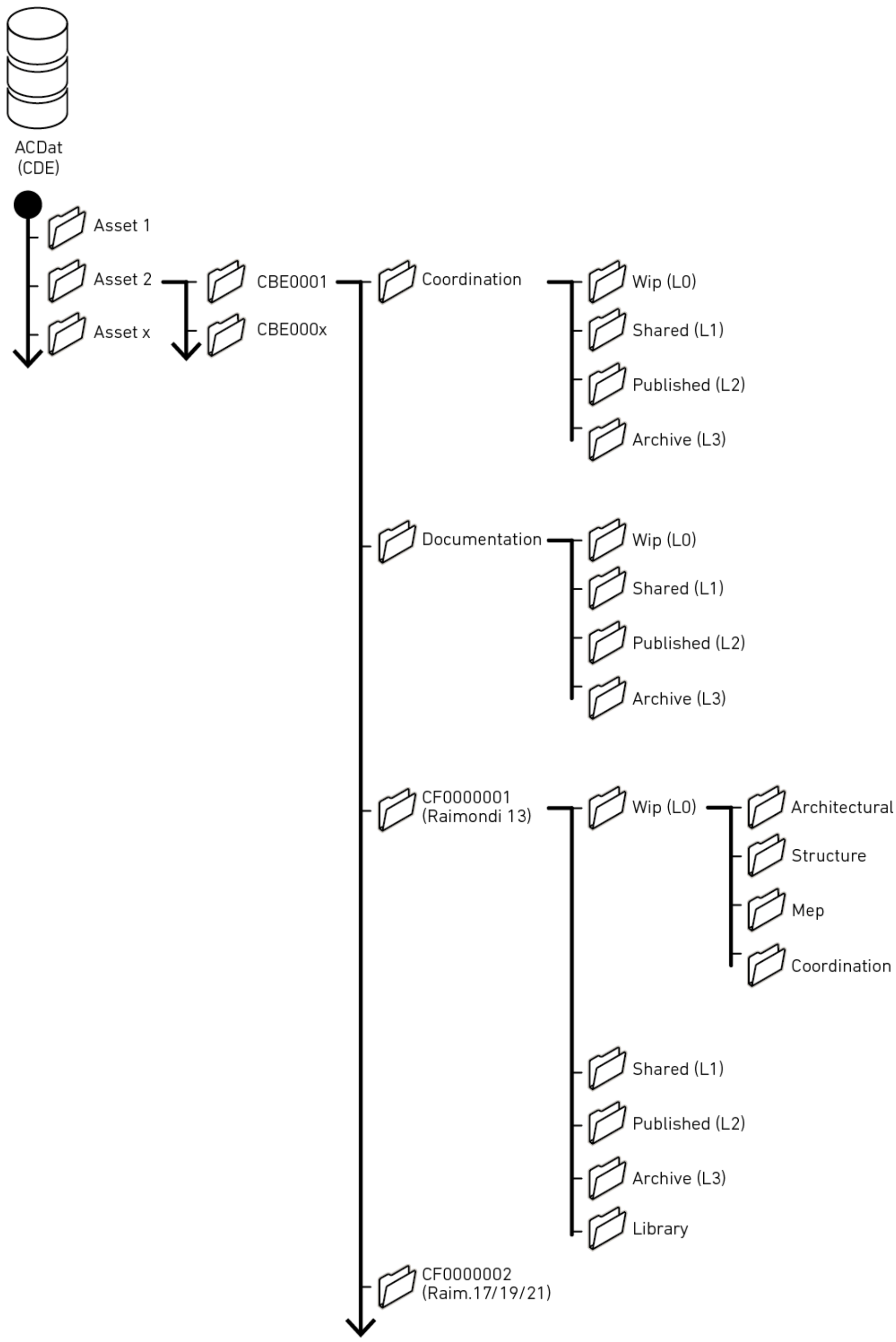


Fig. 039 - The schematization of the composition of the ACDat (CDE), the directory structure in which the assets are organized is visible in the diagram.

Architecture (A); Furnishings (F); Context (L); Urban planning (U); Facades (V); Virtual design (D).

Structural Works (Structures), contain the models, graphics and documents of the discipline organised by execution phases. The disciplines included are: Structures (S); Civil Works (O); Minor Works (Q) and Topography (T).

Plant Works (Impianti), contains the models, graphics and documents of the discipline organised by execution phases. The disciplines included are: Safety and Health (H); Mechanical Installations (M); Electrical Installations (E); Water Installations (P); Fire Prevention (I), and HAVC (N).

Coordination contains the federated model(s) of the building. The models may be Federated (C), Overall Federated (K) or Summary Federated (Y).

Work Phases

The building-related folders (CFNNNN) are divided into work folders to be used in a specific work phase.
Phase L0 (Wip) is the phase in which the material is processed and updated, the model is populated by discipline managers. When approved it passes into phase L1, and will no longer be editable. A model in need of editing will return to the L0 phase.

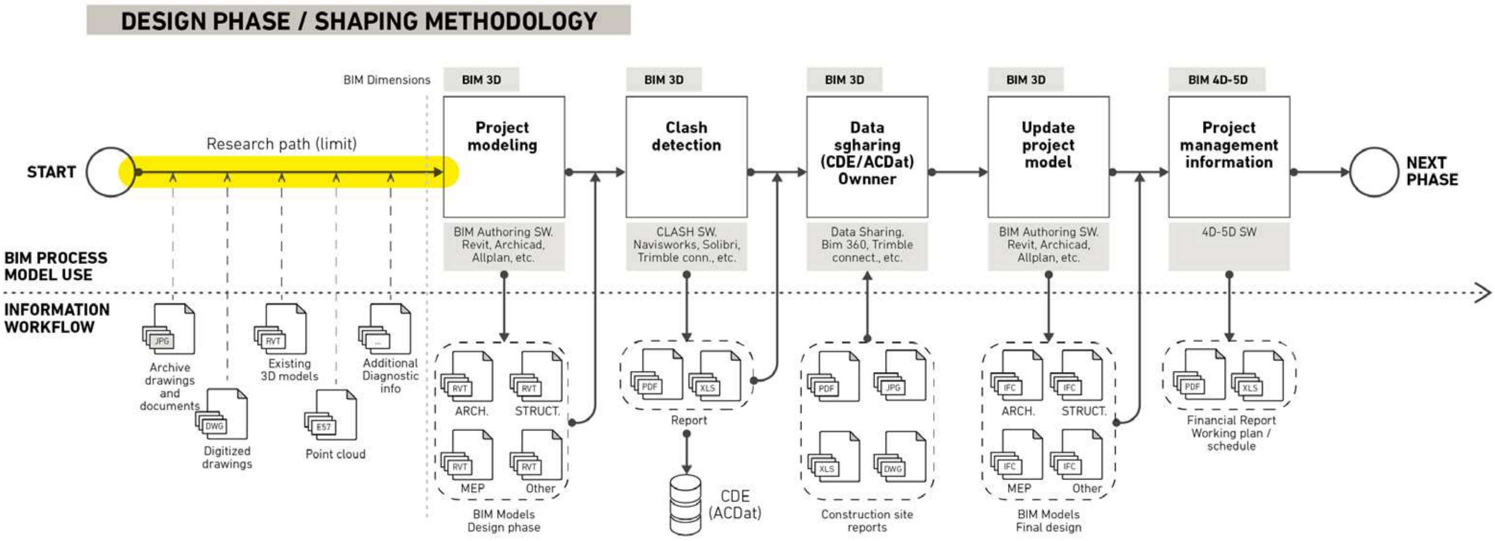
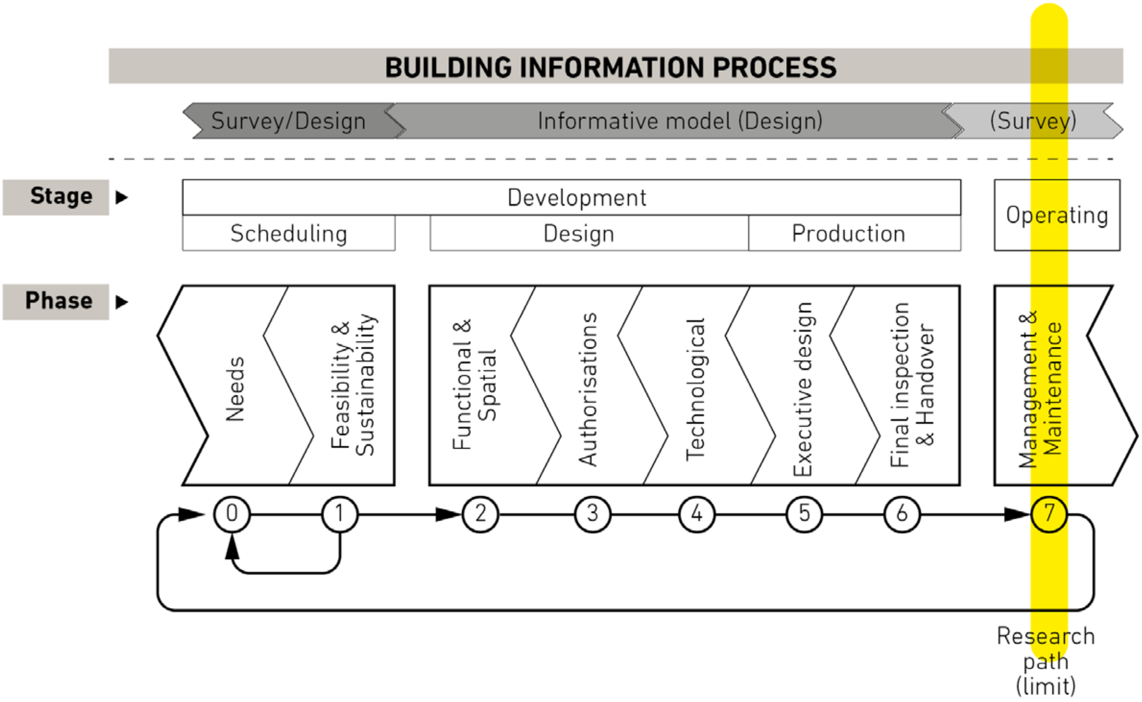


Fig. 040 - Flow chart of the activities carried out in the contract management through BIM methodology, the scope of the present research stands in the initial phase (As-Built) and in the phase of development of solutions for the intervention on the built environment (Smart Package).

Phase L1 (Shared) is the phase in which the BIM process manager and the asset owner check the information. The manager approves the models by passing them into L2, otherwise, they return to L0.
The L2 (Published) is the phase in which the asset owner verifies the consolidated models (proprietary format and IFC). If any errors are found, the model returns to L0. The verification phase can be carried out by an external figure commissioned by the asset owner.
Step L3 (Archive) concludes the process. This area is reserved for the asset owner, who stores the material produced (models, drawings and documents). The models stored in the ACDat will be used in the following stages of the asset life cycle. Valuable information for the Project information model (PIM) and the Asset information model (AIM) is extracted from the models.

Stages of Sharing and Approval of Deliverables

The four work phases match the steps of approval of deliverables and advancement to the next step. In the planning phase, the responsible persons for each development stage are identified for the L0 phase, the responsibility lies with the discipline managers, who pass the deliverables to the discipline managers for the L1 phase. In the L2 phase, a formal handover takes place, and the person responsible for managing the handover is the BIM process manager. The BIM process manager also handles the handover to the client by archiving the material in phase L3.



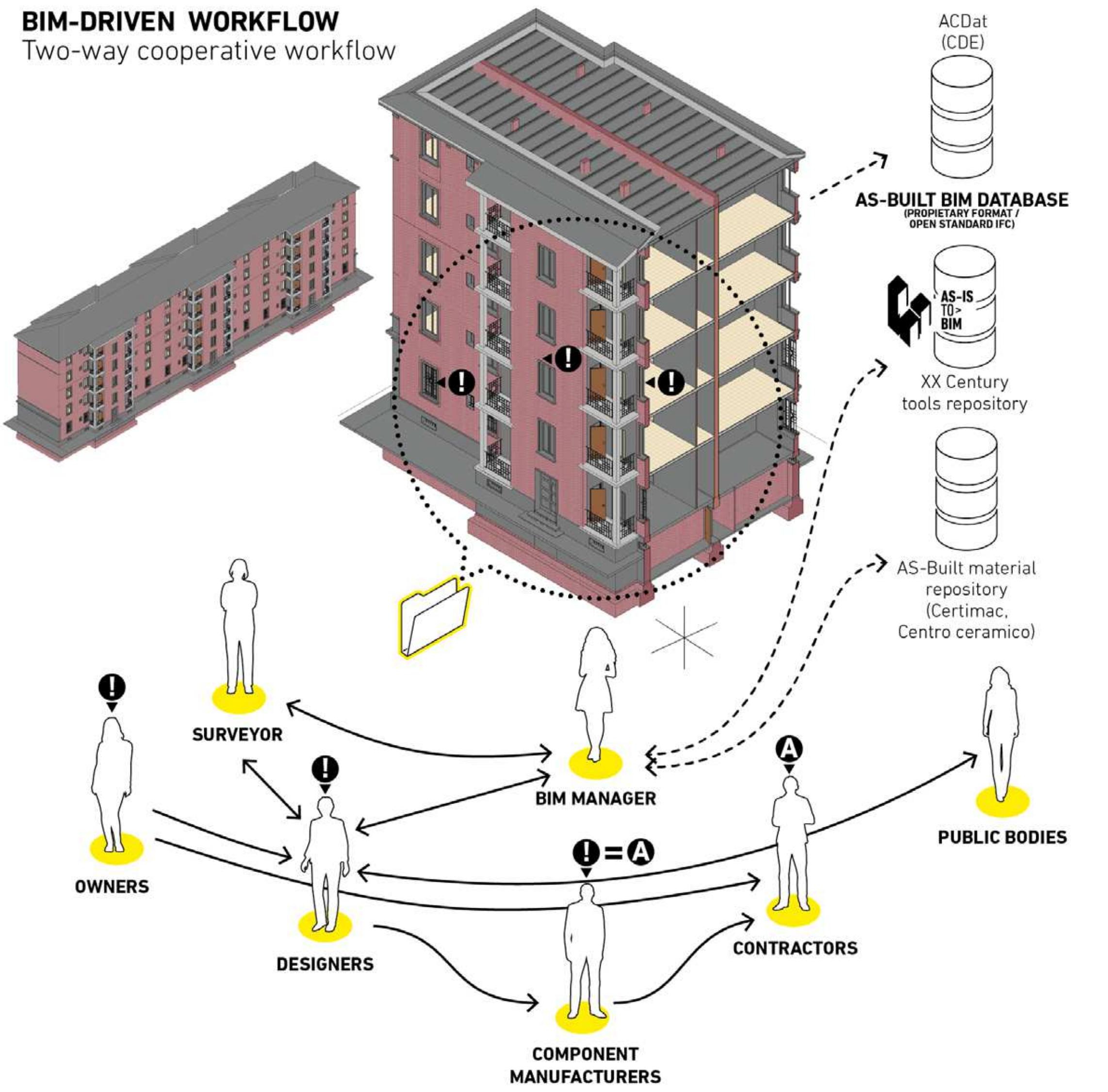


Fig. 041 - Schematization of the relationships between the actors involved in the management of the BIM information flow.

4.8 Methodological workflow

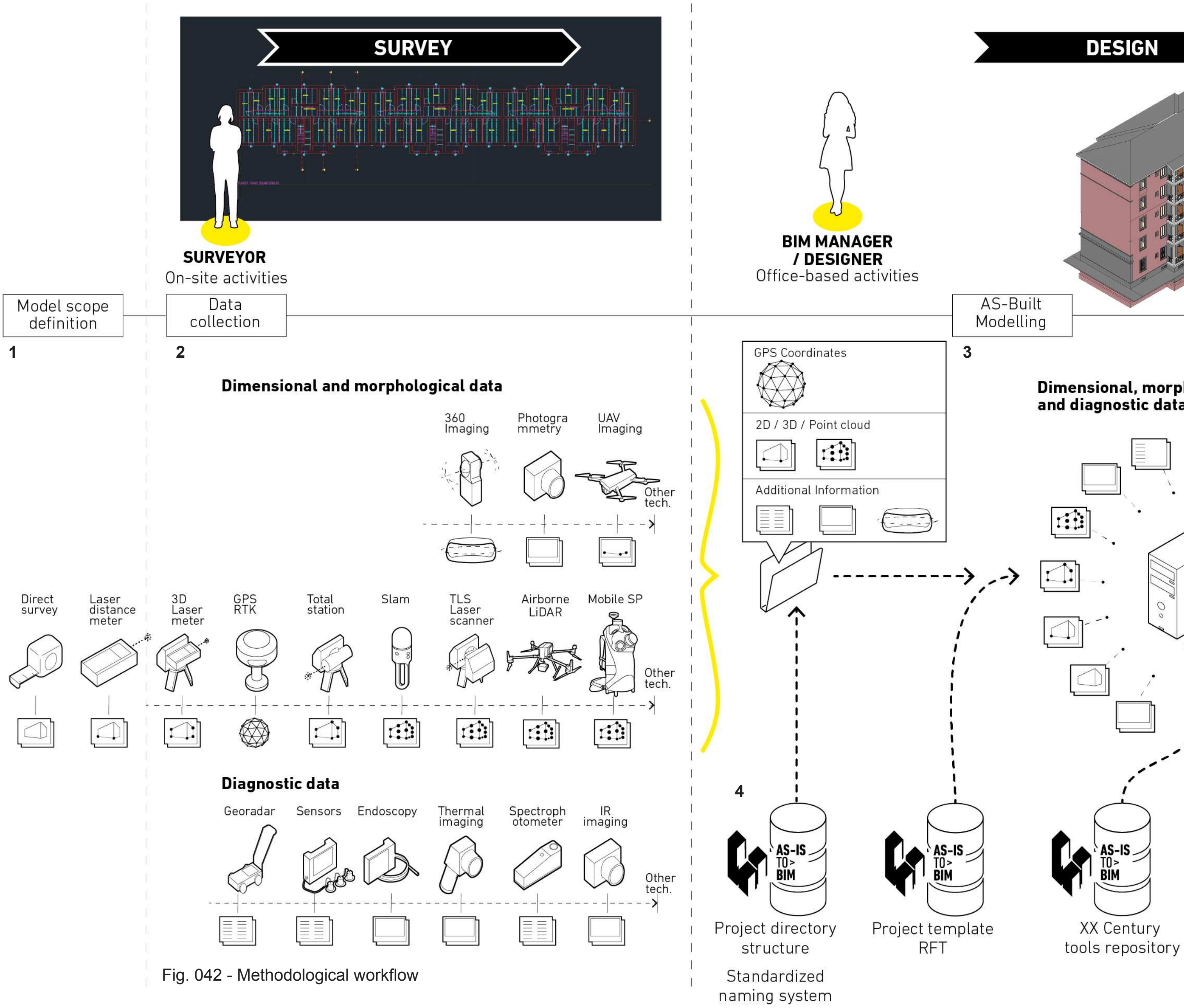


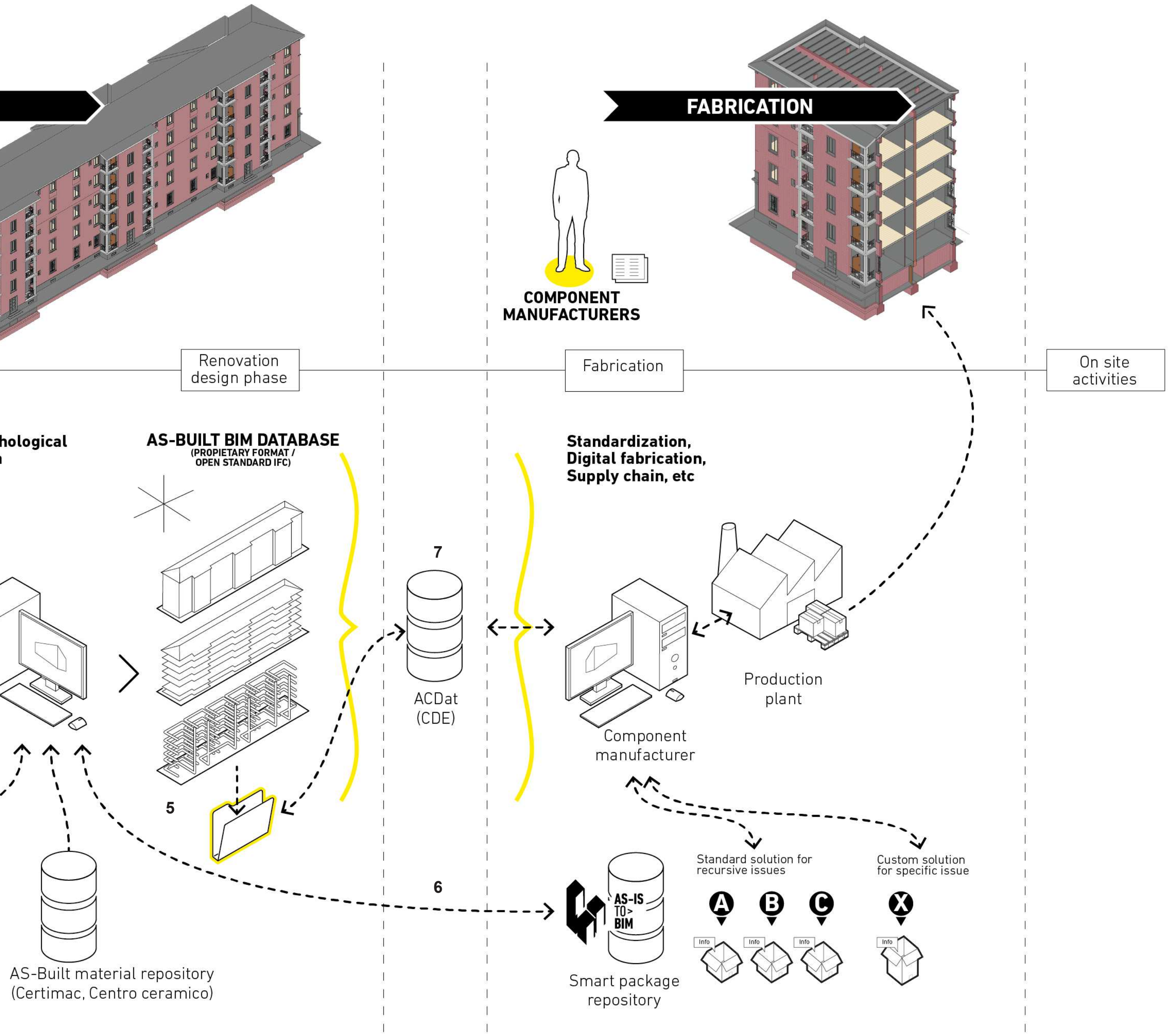
Fig. 042 - Methodological workflow

1 The proposed methodology includes, as an initial step, the definition of the model's scope. The necessary input data level and the structure required for the subsequent phases are defined depending on the scope.

2 The morphological and geometrical survey source is then defined, integrating the available data sources to provide an information set consistent with the needs identified in the planning phase. Diagnostic data are also provided to integrate the geometric data according to identified needs.

3 The information gathered during the survey phase is then processed and catalogued through an ACDat (CDE) in which a restricted access section for the asset is created. The ACDat will be the tool used for sharing information and deliverables in the various stages of development.

4 The modelling and information aggregation phase is supported by the use of pre-set digital tools that are customised to fit the asset's specific needs. Components composing the asset are crafted from pre-set elements already present in the library. In the case of elements not yet present, they are created on purpose and then added to the library (custom family library). The elements in the library include the necessary tools for sharing the information stored. There is a link to the existing material libraries for materials that are used to make components and stratigraphies. These libraries contain the performance data of many building materials used in the area from the 20th century to the present.



5 The disciplinary models created are then federated, and the geometric interference and information content are checked. The federated disciplinary models are then consolidated and shared in a proprietary format (.rvt) in addition to the IFC interchange format (.Ifc)

6 The models are then made available to the technicians working on the assets.
Technicians in charge will then be able to access the tools developed for intervention in the built environment by adding the intervention solutions proposed by the companies during the design phase, using the available models. If the package for the required solution is unavailable in the library, it is possible to request the development of a custom-developed package.

7 The workflow ends with the design model, which integrates the survey model with the performance enhancement solutions proposed by the designer. The developed model, templates, library components and databases are tools designed to support the intervention developed with the BIM methodology and to foster its adoption by promoting supporting and simplifying actions.

4.9 Coding methodology

The BIM working methodology requires working groups to develop their activities in a decentralised approach, operating on disciplinary models that are federated for the interference-checking phase. If we add to this the aspect of variable development phases, it is evident that a system is required that ensures the univocal nomenclature of models, components and materials. These nomenclature systems must be defined in the information management offer phase and used by all those involved in the process. Otherwise, different nomenclatures for the same element would be generated if each working group could define its nomenclature system. Defining a univocal coding system, and providing coding rules to the working groups, allows a very accurate level of standardisation, reducing the resources that would have to be allocated for conflict management.
The BIM methodology makes it possible to intervene on data models both in the order management phase and in the subsequent asset management phases. Implementing an effective coding system allows the property to provide those in charge of future maintenance work with both the information model and the tools to act and manage the components created during the modelling phase.
Three coding systems were therefore developed during the research, starting from systems already established by players active in extensive asset management. One system is dedicated to the coding of the nomenclature of models and deliverables, a second system is dedicated to the coding of components (families), and the third is dedicated to the coding of materials.

4.9.1 Coding methodology for models and deliverables

	A	B	C	D	E	F	G	H	I	J	K
1	Codifica dei modelli e degli elaborati / Coding of models and deliverables										Codifica/Code:
2	Manual selection										
3	Codifica bene	Proprietà	Codice fabbricato	Codice livello	Tipo elaborato	Codice disciplina	Stato costruttivo	Numeratore progerssivo			
4	Site code	Owner	Building code	Level codification	File tipology	Discipline	Constructive stage	Progressive number			
5	ACB0001	ACB	AB0000001	GF	CA	A	S	0000			ACB0001-ACB-AB0000001-GF-CA-A-S0000
6											
7											

Fig. 043 - The nomenclature system developed in MS Excel

In order to achieve a correct organisation of elements that compose the digital delivery, it is necessary to have a unique and codified nomenclature system that allows all the involved actors to read and identify the models, elements and deliverables produced.
The adopted nomenclature is used for the organisation of the elements in the CDE (ACDat) and is followed by all the stakeholders involved in the process during the realisation and management phase of the asset. To facilitate the elements' coding, special concatenators have been developed that allow the selection of specific items for each typology of coding, automatically composing the required code. The code created will be used to identify the model, the deliverable or the component being processed.
The coding for templates and elaborates consists of eight values that make up the final code. The selection of an entry in the previous column makes up the selectable values in the next column, which are related to the choice made.

Code	Description
Colonna1	Colonna2
ACB0001	Albero Mario, 6/8
ACB0002	Raimondi 13
ACB0003	Raimondi 17/19/21

Fig. 044 - Column A - Asset ID

Code	Description
Colonna1	Colonna2
ACB	Acer Bologna

Column B - Owner ID

Code
AB0000001
AB0000002
AB0000003
AB0000004
AB0000005
AB0000006

Column C - Building code

The first column (A) identifies the Asset referred to (Asset). The Asset referred to is the building or group of buildings subject to the intervention and is coded by a value composed of three letters and four numbers (LLLNN). In the example, AC stands for the owner (ACER), and B stands for the geographical location (Bologna). The progressive number identifies the individual assets available to the owner in the area.

The code ACB0001 identifies the Asset located in Via Alberto Mario, the code ACB0002 identifies the Asset located in Via Raimondi 13, while the code ACB0003 identifies the Asset located in Via Raimondi 17/19/21.

The second column (B) identifies the ownership. In this case, ACB represents the code for ACER Bologna, the public housing company of the province of Bologna.

The third column (C) identifies a variable value composed of two letters and seven numbers (LLNNNNNNN). This value can be the building code, the code of a document or the code used for the model federation. The example shows the coding relative to the Building Code, where the value AB0000001 identifies the first building belonging to the asset ACB0001. If the Asset is composed of several buildings, the coding would increase the numeric value.

Code	Descrizione	Description
Colonna1	Colonna2	Colonna3
ZZ	Livello multiplo	Multiple level
XX	Nessun livello	None level
GF	Piano terra	Ground floor
01	Piano primo	First floor
02	Piano secondo	Second floor
03	Piano terzo	Third floor
04	Piano quarto	Fourth floor
05	Piano quinto	Fifht floor
06	Piano sesto	Sixth floor
M1	Piano mezzanino 1	Mezzanine 1
M2	Piano mezzanino 2	Mezzanine 2
G1	Piano interrato 1	Underground floor -1
G2	Piano interrato 2	Underground floor -2

Fig. 045 - Column D - Elevation level

Code	Descrizione	Description
Colonna1	Colonna2	Colonna3
BQ	Computo delle quantità	Quantities documentation
CA	Relazioni di calcolo	Structural documentation
CM	Construction management	Construction management
CP	Analisi dei costi	Cost analysis
DR	Tavole 2D	2D Drawings
HS	Sicurezza	Safety
MI	Report delle riunioni	Meetings report
MS	Procedura metodologica	Method Satement
M2	Modello con contenuti 2D	Model with 3D elemments
M3	Modello con contenuti 3D	Model with 2D elemments
MR	Modello da utilizzare per scopi diversi	Mixed use model
PH	Materiale fotografico	Pictures
PR	Programma dei lavori	Task planning
RT	Relazione tecnica	Tecnical report
RP	Report e similari	Report
SM	Specifica metodologica	Methodological specification
SO	Specifica operativa	Operational specification
SN	Elenco delle non conformità	List of non-conformity
VS	File per la visualizzazione del Modello	Model displayng files

Column E - Information typology

The fourth column (D) identifies the reference elevation levels, and the coding is composed of a pair of letters (LL).

The fifth column (E) identifies the information typology, identified by a pair of letters it can be for example a report (RP), a model with three-dimensional attributes (M3) or a methodological specification (SM).

The sixth column (F) identifies the reference discipline, characterised by a single letter in the coding, it may belong to architecture (A), structures (S), or federation of models (C) to mention a few examples.

The last column (G) identifies the constructive stage with a letter. It can be related to As-Built (A), final design (D), detailed design (E), or construction documentation (C) to name a few.

The encoding concludes with a progressive numerator element in column H, which allows the recording and versions of the file.

	A	B	C
1	Code	Descrizione	Description
2	Colonna1	Colonna2	Colonna3
3	A	Architettura	Architecture
4	C	Federazione	Federation
5	D	VDC-Virtual Design and Construction	VDC-Virtual Design and Construction
6	E	Impianti elettrici	Electrical system
7	F	Arredo	Forniture
8	H	H&S - Sicurezza	H&S - Health and safety
9	I	Prevenzione incendi	Fire safety
10	L	Contesto e paesaggio	Landscape
11	K	Modello federato complessivo	Overall federated model
12	M	Impianti meccanici	Mecanical system
13	N	Impianti HVAC	HVAC
14	O	Opere civili	Civil engineering works
15	P	Impianti idirci	Water system
16	Q	Opere minori	Minor works
17	R	Restauro	Restoration
18	S	Strutture	Structural
19	T	Topografia	Topography
20	U	Pianificazione urban	Urban planning
21	V	Facciate	Facade
22	Y	Modello federato di sintesi	Syntetic federated model
23	Z	Generico	Generic

Fig. 046 - Column F - Discipline

	A	B	C
1	Code	Descrizione	Description
2	Colonna1	Colonna2	Colonna3
3	S	Stato di fatto	As-Is
4	P	Progetto di fattibilità tecnica ed economica	Tecnical and economical feasability project
5	D	Progetto definitivo	Final design
6	E	Progetto esecutivo	Detailed design
7	C	Costruttivo	Construction documentation
8	A	As Built	As Built
9	G	Generale	General planning
10			

Column G - Constructive stage

The resulting code (ACB001-ACB-AB000000001-GF-CA-A-S0000) uniquely identifies the content of the deliverable, simplifying the modelling and information management operations at all stages of the information model.

4.9.2 Coding methodology for model components.

	A	B	C	D	E	F
1	Codifica degli Elementi / Element encoding:					Codifica/Code:
2	Manual selection					
3	Funzione tipo	Funzione sottotipo	Descrizione	Numero progressivo		
4	Element Tipology	Element sub-tipology	Description	Progressive number		
5	TRV	TTT	MattoneBolognese_140x280x55mm	01		TRV-TTT-MattoneBolognese_140x280x55mm-01
8	Automatic selection					
9	Funzione tipo	Funzione sottotipo	Descrizione	Numero progressivo		Codifica/Code:
10	Element Tipology	Element sub-tipology	Description	Progressive number		
11	MUR	EST	MattoneBolognese_UnaTesta_140mm	01		MUR-EST-MattoneBolognese_UnaTesta_140mm-01

Fig. 047 - The nomenclature system for model components developed in MS Excel

The same coding methodology is also used to code the elements (families) that make up the model. In this case, in addition to naming the deliverable, it also defines the classification of the elements in the authoring software and how they will be classified for export through IFC.

	A	B	C	D
1	Code	Categoria	Category	IFC Class
2	Colonna1	Colonna2	Colonna3	Colonna4
3	TRV	Trave	Beam	*IfcBeam*
4	GEN	Elemento Generico	Building Element Proxy	*IfcBuildingElementProxy*
5	CLN	Colonna	Column	*IfcColumn*
6	FNT	Finitura	Covering	*IfcCovering*
7	FCO	Facciata Continua	Curtain Wall	*IfcCurtainWall*
8	POR	Porta	Door	*IfcDoor*
9	FON	Fondazione	Footing	*IfcFooting*
10	ELM	Elemento Strutturale	Member	*IfcMember*
11	APR	Apertura	Opening Element	*IfcOpeningElement*
12	PLF	Palificazione	Pile	*IfcPile*
13	PST	Piastra	Plate	*IfcPlate*
14	CRR	Corrente	Railing	*IfcRailing*
15	RMP	Rampa	Ramp	*IfcRamp*
16	RMP	Sviluppo Rampa	RampFlight	*IfcRampFlight*
17	ELR	Elemento Rinforzo	Reinforcing Element	*IfcReinforcingElement*
18	TET	Tetto	Roof	*IfcRoof*
19	SOL	Solaio	Slab	*IfcSlab*
20	SCA	Scala	Stair	*IfcStair*
21	SCA	Rampa Scala	StairFlight	*IfcStairFlight*
22	MUR	Muro	Wall	*IfcWall*
23	FIN	Finestra	Window	*IfcWindow*
24	ECD	Elemento Controllo Distribuzione	Distribution Control Element	*IfcDistributionControlElemen*
25	EFD	Elemento Flusso Distributivo	Distribution Flow Element	*IfcDistributionFlowElement*
26	ECA	Elemento Camera Distribuzione	Distribution Chamber Element	*IfcDistributionChamberElem*
27	ACE	Apparecchio Conversione Energia	Energy Conversion Device	*IfcEnergyConversionDevice*

Fig. 048 - Column A - Element categorization

Funzione sottotipo

Codice funzione tipo	Categoria Category ENG	Categoria Category ITA	IFC Class	Codice funzione sottotipo	Sottocategoria Sub-category ENG	Sottocategoria Sub-category ITA	IFC Type Enum
TRV	Beam	Trave	*IfcBeam*	-TRV			
				TTT	Joist	Travetto	JOIST
				ARC	Lintel	Architrave	LINTEL
				TRT	T Beam	Trave T	T_BEAM
FNT	Covering	Finitura	*IfcCovering*	-FNT			
				SOF	Ceiling	Soffitto	CEILING
				PAV	Floring	Pavimentazione	FLOORING
				RIV	Cladding	Rivestimento	CLADDING
				COP	Roofing	Copertura	ROOFING
				ISO	Insulation	Isolamento	INSULATION
				MEM	Membrane	Membrana	MEMBRANE
				GUA	Sleeving	Guaina	SLEEVING
				INV	Wrapping	Involucro	WRAPPING
POR	Door	Porta	*IfcDoor*	-POR			
				ASB	Single Swing	Anta Singola Battente	SINGLE_SWING_LEFT; SINGLE_SWING_RIGHT
				ADB	Double Swing	Anta Doppia Battente	DOUBLE_DOOR_SINGLE_ SWING; DOUBLE_DOOR_SINGLE_ SWING_OPPOSITE_LEFT; DOUBLE_DOOR_SINGLE_ SWING_OPPOSITE_RIGH T; DOUBLE_SWING_LEFT; DOUBLE_SWING_RIGHT; DOUBLE_DOOR_DOUBLE _SWING
				LIB	Folding	Ante a Libro	FOLDING_TO_LEFT; FOLDING_TO_RIGHT; DOUBLE_DOOR_SLIDING
				FIX	Fixed	Anta Fissa	
				SCO	Pocket	Scomparsa	
				PIV	Pivoting	Bilico	
				AVV	Rolling Up	Avvolgibile	ROLLINGUP
				BSS	Revolving	Bussola	REVOLVING
				SCR	Sliding	Anta Scorrevole	SLIDING_TO_LEFT; SLIDING_TO_RIGHT; DOUBLE_DOOR_SLIDING
ELM	Member	Elemento strutturale	*IfcMember*	-ELE			
				BRE	Brace	Bretelle	BRACE
				GIU	Chord	Giunzione	CHORD
				COL	Collar	Collare	COLLAR
				ELE	Member	Elemento	MEMBER
				MNT	Mullion	Montante	MULLION
				PTT	Plate	Piatto	PLATE
				SST	Post	Sostegno	POST
				PRL	Purlin	Perlinatura	PURLIN
				TTT	Rafter	Travetto	RAFTER
				TRS	Stringer	Traverso	STRINGER
				PNT	Strut	Puntone	STRUT
				PER	Stud	Perno	STUD
PST	Plate	Piastra	*IfcPlate*	**-PST**			
				PFC	Curtain Panel	Pannello Facciata Continua	CURTAIN_PANEL
				FGL	Sheet	Foglio	SHEET
CRR	Railing	Corrente	*IfcRailing*	-CRR			
				CRM	Handrail	Corrimano	HANDRAIL
				CRM	Guardrail	Corrimano	GUARDRAIL
				BAL	Balustrade	Parapetto	BALUSTRADE
RMP	Ramp Flight	Sviluppo della rampa	*IfcRampFlight*	**-RMP**			
				RET	Straight	Rettilinea	STRAIGHT
				SPL	Spiral	Spirale	SPIRAL
ELR	Reinforced Element	Elemento di rinforzo	*IfcReinforcingElement*	**-ELR**			
			IfcReinforcingBar	**BAR**	Reinforcing Bar	Barra armatura	
			IfcReinforcingMesh	**REM**	Reinforcing Mesh	Rete elettrosaldata (Metallica)	
			IfcTendon	**TIR**	Tendon	Tirante	
			IfcTendonAncor	**ATR**	Tendon Anchor	Ancoraggio tirante	
SOL	Slab	Solaio	*IfcSlab*	**-SOL**			
				STR	Structural	Strutturale	STRUCTURAL
				SOL	Floor	Soletta	FLOOR
				TET	Roof	Copertura	ROOF
				BAL	Landing	Ballatoio	LANDING
				SOT	Baseslab	Sottofondo	BASESLAB
SCA	Stair Flight	Rampa scala	*IfcStairFlight*	**-SCA**			
				RET	Straight	Rettilinea	STRAIGHT
				CHI	Winder	Chiocciola	WINDER
				SPL	Spiral	Spirale	SPIRAL
				CRV	Curved	Curvilinea	CURVED
				LIB	Free form	Forma libera	FREE FORM
MUR	Wall	Muro	*IfcWall*	**-MUR**			
				INT	Internal	Partizione Interna	
				EST	External	Muro Esterno	
FIN	Window	Finestra	*IfcWindow*	-FIN			
				SCR	Sliding	Anta scorrevole	Single panel
				ASI	Single Panel	Anta singola	SinglePanel
				ADV	Double Panel Vertical	Doppia anta verticale	DoublePanelVertical
				ADO	Double Panel Horizontal	Doppia anta orizzontale	DoublePanelHorizontal
				TPV	Triple Panel Vertical	Triplo pannello verticale	TriplePanelVertical
				TPO	Triple Panel Horizontal	Triplo pannello orizzontale	TriplePanelHorizontal
				TPB	TriplePanelBottom	Due verticali; Una bassa orizzontale	TriplePanelBottom
				TPT	TriplePanelTop	Due verticali; Una alta orizzontale	TriplePanelTop
				TPS	TriplePanelLeft	Due orizzontali;Una sinistra verticale	TriplePanelLeft
				TPD	TriplePanelRight	Due orizzontali;Una verticale destra	TriplePanelRight
				PER	UserDefined	Personalizzata	UserDefined

Fig. 049 - Column B - Element Sub-categorization (Part A)

88	ACE	Energy conversion device	Apparato di conversione energia	IfcEnergyConversionDevice	-ACE			
89				IfcElectricGenerator	GEN	Electric Generator	Generatore elettrico	
90				IfcElectricMotor	MEL	Electric Motor	Motore elettrico	
91				IfcTransformer	TRS	Transformer	Trasformatore	
92				IfcAirToAirHeatRecovery	REC	Air to Air Heat Recovery	Recuperatore di calore	
93				IfcBoiler	CAL	Boiler	Caldaia	
94				IfcChiller	REF	Chiller	Refrigeratore	
95				IfcCoil	BOB	Coil	Bobina	
96				IfcCondenser	CON	Condenser	Condensatore	
97				IfcCooledBeam	TRR	Cooled Beam	Travi raffreddate	
98				IfcCoolingTower	TRF	Cooling Tower	Torre di raffreddamento	
99				IfcEvaporativeCooler	REV	Evaporative Cooler	Raffreddatore evaporativ	
100				IfcEvaporator	EVR	Evaporator	Evaporatore	
101				IfcHeatExchanger	SCA	Heat Exchanger	Scambiatore di calore	
102				IfcHumidifier	UMD	Humidifier	Umidificatore	
103				IfcSpaceHeater	RIS	Space Heater	Riscaldatore	
104				IfcTubeBundle	TUB	Tube Bundle	Fascio tubiero	
105				IfcUnitaryEquipment	EQU	Unitary Equipment	Equipagiamento unitario	
106	CFL	Flow controller	Controllo di flusso	IfcFlowController	-CFL			
107				IfcElectricDistributionPoi	PDE	Electric Distribution Point	Punto distribuzione elettrica	
108				IfcElectricTimeControl	TIM	Electric Time Control		
109							Timer elettrico	
110				IfcProtectiveDevice	DPR	Protective Device	Dispositivo di protezione	
111				IfcSwitchingDevice	DCM	Switching Device	Dispositivo di commutazione	
112				IfcAirTerminalBox	BOX	Air Terminal Box	Scatola terminale aria	
113				IfcDamper	AMM	Damper	Ammortizzatore	
114				IfcFlowMeter	MFL	Flow Meter	Misuratore di flusso	
115				IfcValve	VLV	Valve	Valvola	
116	RAC	Flow Fitting	Raccordo	IfcFlowFitting	-RAC			
117				IfcCableCarrierFitting	MPC			
118				IfcJunctionBox	SCA			
119				IfcDuctFitting	CON			
120				IfcPipeFitting	TUB			
121	AMF	Flow Moving Device	Apparecchio Movimentazione Fluidi	IfcFlowMovingDevice	-AMF			
122				IfcCompressor	CMP	Compressor	Compressore	
123				IfcFan	VEN	Fan	Ventilatore	
124				IfcPump	PMP	Pump	Pompa	
125	SEG	Flow Segment	Segmento	IfcFlowSegment	-SEG			
126				IfcCableSegment	CAV	Cable Segment	Cavidotto raccordo	
127				IfcDuctSegment	CON	Duct Segment	Conduttura	
128				IfcPipeSegment	TUB	Pipe Segment	Tubazione	
129	A	Flow Storage Device	Apparecchio immagazzinamento fluidi	IfcFlowStorageDevice	-A			
130				IfcElectricFlowStorageDe vice	SFE	Electric Flow Storage Device	Stoccaggio flusso elettrico	
131				IfcTank	SRB	Tank	Serbatoio	
132	TER	Flow Terminal	Terminale	IfcFlowTerminal	-TER			
133				IfcLightFixture	LAM	Light Fixture	Lampada	
134				IfcLamp	LMP	Lamp	Lampadina	
135				IfcElectricHeater	STU	Electric Heater	Stufa elettrica	
136								
137				IfcOutlet	PRE	Outlet	Presa	
138				IfcAirTerminal	ARI	Air Terminal	Terminale Aria	
139				IfcGasTerminal	GAS	Gas Terminal	Terminale Gas	
140				IfcFireSuppressionTerminal	ANT	Fire Suppression Terminal	Terminale antincendio	
141				IfcSanitaryTerminal	SAN	Sanitary Terminal	Sanitari	
142				IfcStackTerminal	COM	Stack Terminal	Copertura comignoli	
143				IfcWasteTerminal	COL	Waste Terminal	Collettore scarichi	
144	DTF	Flow Treatment Device	Dispositivo di trattamento del flusso	IfcFlowTreatmentDevice	-DTF			
145				IfcDuctSilencer	SIL	Duct Silencer	Silenziatore condotto	
146				IfcFilter	FIL	Filter	Filtro	
147	TRA			IfcTrasportElement	-TRA			
148					ASC	Elevator	Ascensore	ELEVATOR
149					MOB	Escalator	Scala mobile	ESCALATOR
150					PAS	Moving Walkway	Passerella mobile	MOVINGWALKWAY

Fig. 050 - Column B - Element Sub-categorization (Part B)

The coding system for these elements is designed in a dual composition mode, both Manual and Automatic. Manual composition allows the operator to manually set values in sections, allowing the possibility of enabling non-standardised concatenations.

In the automated mode, the choices made in the previous column set the options available in the next one. The element coding (families) consists of four columns, where the first one identifies the class of architectural element to be created (e.g. Beam, Column, Door), while the second one defines the subcategory to which it belongs (e.g. MUR, Wall has Exterior and Interior as subcategories).

The third column descriptively identifies the element's characteristics (in the example, we see the code for the compositional elements of masonry).

A double-digit numerator concludes the coding to record the versions or variants of the file.

	A	B	C
1	Funzione / Function	Sottotipo / Sub-category	Description:
2	MAT		
3		EST	
4			BologneseSolidBrick_Header_140x280x55mm
5			BologneseSolidBrick_Gothic_140x280x55mm
6			BologneseSolidBrick_Stretcher_140x280x55mm
7			BologneseSolidBrick_Flemish_140x280x55mm
8			UniSolidBrick_Stretcher_120x250x55mm
9			BologneseDoubleHollowBrick_140x280x120mm
10			UniDoubleHollowBrick_120x250x120mm
11			HollowBrick_70x200x200mm
12			HollowBrick_50x200x200mm
13			UniDoubleHollowBrick_BologneseSolidBrick_420mm
14			
15		INT	
16			BologneseSolidBrick_Header_140x280x55mm
17			BologneseSolidBrick_Gothic_140x280x55mm
18			BologneseSolidBrick_Stretcher_140x280x55mm
19			BologneseSolidBrick_Flemish_140x280x55mm
20			UniSolidBrick_Stretcher_120x250x55mm
21			BologneseDoubleHollowBrick_140x280x120mm
22			UniDoubleHollowBrick_120x250x120mm
23			HollowBrick_70x200x200mm
24			HollowBrick_50x200x200mm
25			UniDoubleHollowBrick_BologneseSolidBrick_420mm
26	SOL		
27		STR	
28			VaultedBrick
29			Cirex55_160mm
30	FIN		
31		ADV	
32			Cellar_1000x400mm
33			SlantedWindow_4side_1000x1900mm
34			SlantedWindow_4side_Decorated_1000x1900mm
35			SlantedWindow_3side_1000x1900mm
36			SlantedWindow_3side_Decorated_1000x1900mm
37			SlantedWindow_3side_1000x1700mm
38			SlantedWindow_3side_1000x1500mm
39			Window_1000x1900mm
40			BathWindow_500x800mm
41			BathWindow_Shaded_500x800mm
42			AboveDoorWindow_1000x500mm
43			
44			

Fig. 051 - Column C - Element Description

4.9.3 Coding methodology for construction materials

	A	B	C	D	E	F
1	Codifica Materiali / Material coding					Codifica/Code:
2	Manual selection					
3	Dettaglio	Categoria	Sottocategoria	Descrizione		
4	Detail	Category	Sub-category	Description		
5	0	CRT	PNL	LastraNomelastra_MisurelastraxMisurelastraxMisurelastra		0-CRT-PNL-LastraNomelastra_MisurelastraxMisurelastraxMisurelastra

Fig. 052 - The nomenclature system for construction materials developed in MS Excel

The coding system for materials has been developed to work with materials related to the existing building and with newly applied materials used in refurbishment and restoration work.

Materials of the existing built environment have as their source of information either an instrumental survey campaign or can be provided by specific databases that index many historic building materials such as those developed by Certimac[1] and Centro Ceramico[2]. In the case of materials that come from a diagnostic campaign, they can be coded according

1 Product Analysis, Certification and Research. Certimac. (2022, April 5). Retrieved February 17, 2023, from https://certimac.it/

2 Research, Testing, Training Centre. Centro Ceramico. (2022, November 3). Retrieved February 17, 2023, from https://www.centroceramico.it/

to the proposed specifications. For materials already present in specific databases, a further step of nomenclature conversion from the source to the target nomenclature is necessary. On the other hand, newly applied materials are entered directly into the system with the correct codification.

	A	B	C	D	E	F
1	**Code:**	**Description:**				
2		Identity	Aspect	Physical prop.	Thermal prop.	Manufacturer
3	0	v	v			
4	1	v	v	v	v	
5	2	v	v	v	v	v

Fig. 053 - Column A - Level of detail

	A	B	C
1	**Code:**	**Descrizione:**	**Description:**
2	CER	Ceramica	Ceramic
3	CLC	Calcestruzzo	Concrete
4	CRP	Carta da parati	Wallpaper
5	CRT	Cartongesso	Plasterboard
6	GAS	Gas	Gas
7	GEN	Generico	Generca material
8	INC	Intonaco	Plaster
9	ISO	Isolante	Insulation
10	LGN	Legno	Wood
11	LUC	Sorgente luminosa	Light source
12	MBR	Membrana	Menbrane
13	MRT	Muratura	Masonry
14	MSC	Miscellaneo	Miscellaneous
15	MTL	Metallo	Metal
16	PIE	Pietra	Stone
17	PLS	Plastica	Plastic
18	SIS	Materiale sistemi	System material
19	TER	Terra	Soil
20	TRR	Terracotta	Clay
21	TES	Tessuto	Textile
22	VER	Vernice	Paint
23	VNL	Vinilico	Vinyl finishes
24	VTR	Vetro	Glass

Column B - Categories

The coding system consists of four columns, of which the first (A) defines the level of detail in conformity with the regulations with an increasing value ranging from zero to two. For new materials, we can set level two as the standard, while for materials related to the built environment, we can take a value ranging from zero to one depending on the level of instrumental investigations they have undergone.

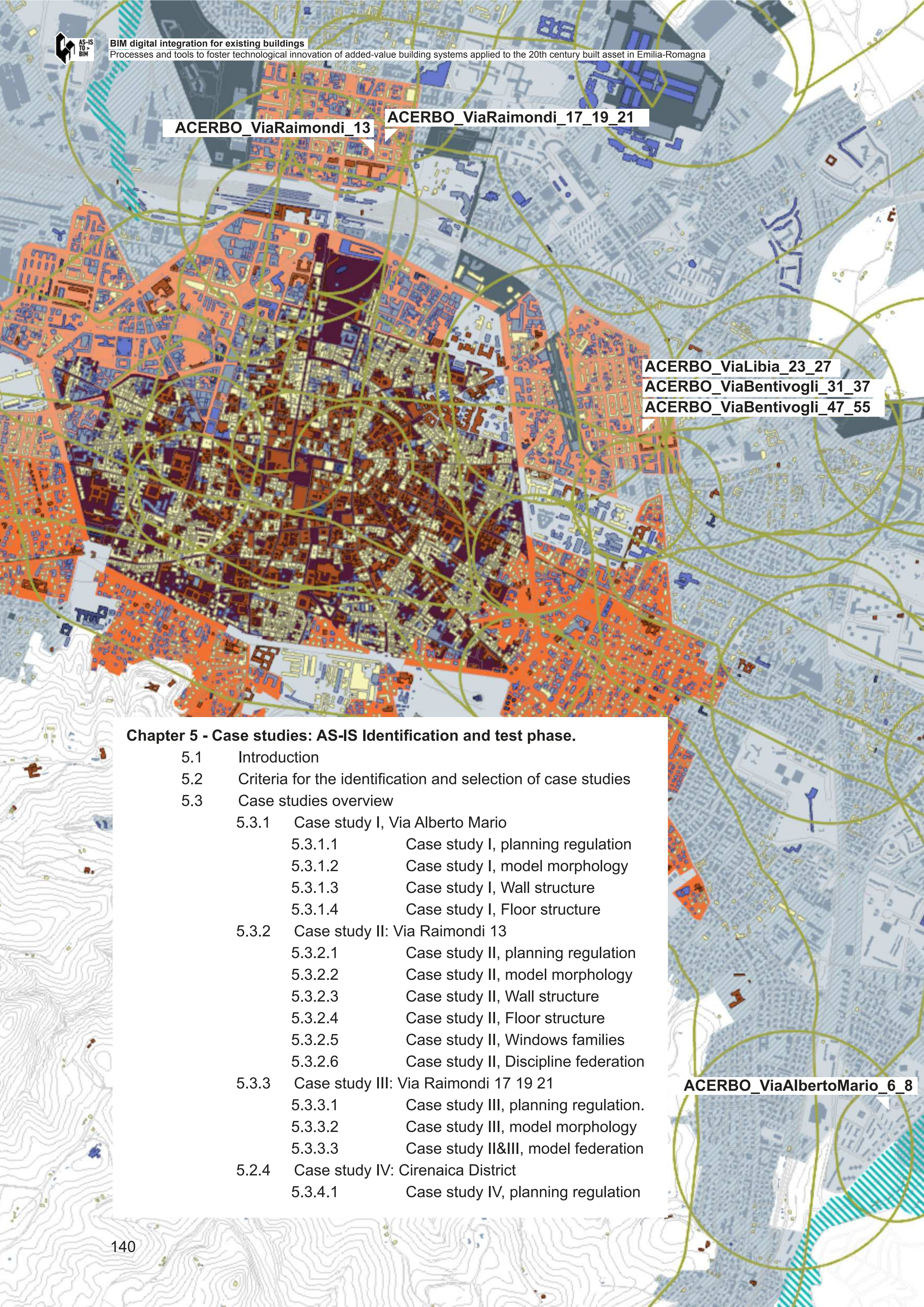
	A	B	C
1	**Code:**	**Descrizione:**	**Description:**
2	RTE	Rete	Mash
3	PNL	Pannelli	Panels
4	SRG	Stringhe	Strips
5	STR	Strutturale	Structural material
6	SUB	Sottostrato	Substrate
7	PIA	Piastrelle	Tiles

Fig. 054 - Column C - Sub-Categories

	A
1	**Descrizione:**
2	LastraNomelastra_MisurelastraxMisurelastraxMisurelastra

Column D - Description

The second column (B) defines the category to which it belongs. For example, we can have Ceramic materials, Concrete, and Plasterboard.
The third column (C) specifies the sub-category to which it belongs, going into more detail about the composition of the material. For example, we can have variants of technical performance and sheet formats for a new plasterboard material.
The fourth column (D) contains an extended description of the material, further detailing the information to support the operator.



Chapter 5 - Case studies: AS-IS Identification and test phase.

Chapter 5
Case studies: AS-IS Identification and test phase

5.1 Introduction

The construction industry has since long identified maintenance as a strategic function for the development of the supply chain aimed at reducing intervention costs, improving efficiency and increasing the life cycle of the built heritage (Di Giulio, 2007; Farida et al., 2019). Diagnostics and monitoring are tools that, when integrated, are more effective in analysing the behaviour and state of conservation of built heritage. However, these technologies are still scarcely applied and adopted within the value chain; moreover, within the value chain only the most up-to-date companies use monitoring solutions for ordinary monitoring, albeit mostly in critical operating conditions, if not in emergencies (Onat and Kucukvar, 2020). Commonly adopted monitoring systems focus on a few discrete parameters and their ability to detect a full range of potential problems is limited.
The InSPiRE[1] project aimed at implementing enabling technologies integrated into building components and systems for monitoring, also in real time, performance parameters (i.e. energy, structural, environmental health and indoor comfort, etc.). The result is an integrated

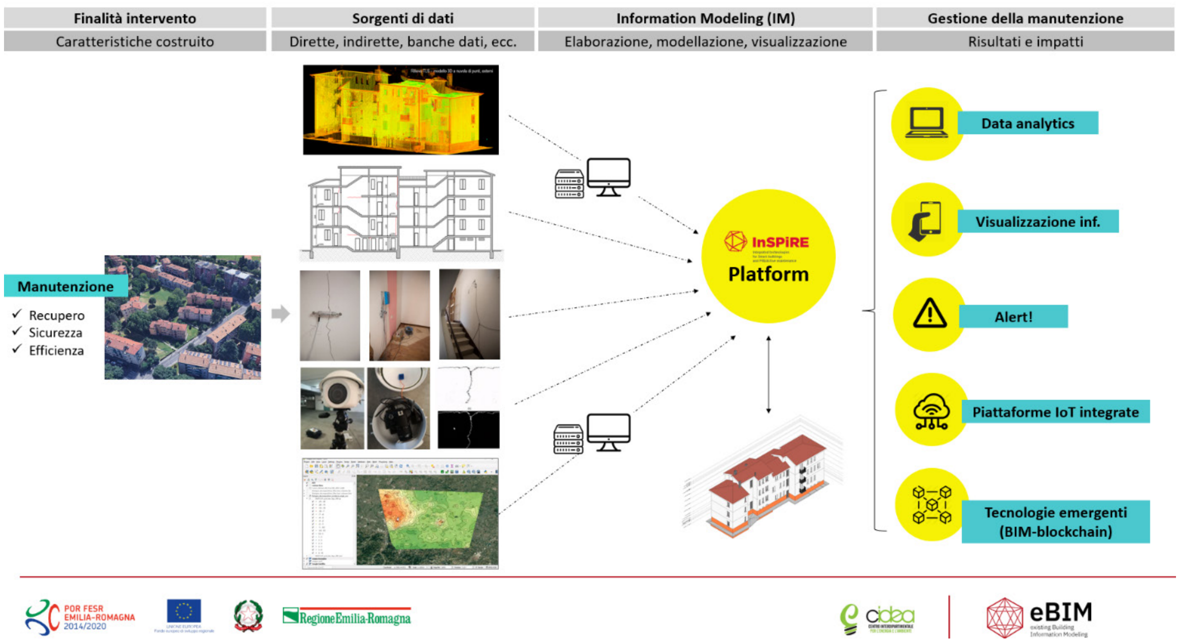


Fig. 055 - Conceptual outline of the workflow proposed by the Inspire research project. Source: Inspire Project

1 InSPiRE - Integrated technologies for Smart buildings and PREdictive maintenance is a project co-financed by the European Regional Regional Development Fund (POR FESR 2014 – 2020) and the Fund for Development and Cohesion (FSC). The project is coordinated by TechneHub Laboratory. Partners: CIRI EC - Centro Interdipartimentale di Ricerca Industriale Edilizia e Costruzioni dell'Università di Bologna; CRICT - Centro Interdipartimentale di Ricerca e per i Servizi delle Costruzioni e del Territorio dell'Università di Modena e Reggio-Emilia; Istec CNR - Istituto di Scienza e Tecnologia dei Materiali Ceramici di Faenza; Cifla - Centro per l'innovazione tecnologica e sociale - Fondazione Flaminia di Ravenna. Companies: ACER Azienda Casa Emilia-Romagna della Provincia di Bologna; ACER PRO.M.O.S. Programma di Manutenzione Ordinaria e Straordinaria; Fassa S.r.l. Spresiano, Treviso; Sestosensor S.r.l. Zola Predosa, Bologna; Finsoft S.r.l. Milano; Giancarlo Maselli S.r.l. Nonantola, Modena; ACSoftware Lamezia Terme, Catanzaro. Stakeholder: Clust-ER Build Associazione Clust-ER Edilizia e Costruzioni della regione Emilia-Romagna.

tool for the knowledge of the state of deterioration of buildings and decision support to predictive maintenance and management activities of the existing built heritage (Di Giulio et al., 2007), which provides for the implementation of a collaborative real-time monitoring platform based on a network of remote sensors and an innovative system architecture aimed at monitoring the state of conservation of the built heritage. The implementation of a modular diagnostic imaging platform that integrates the monitoring platform to promptly identify damages and ensure the sharing of images and reports is an additional project outcome.

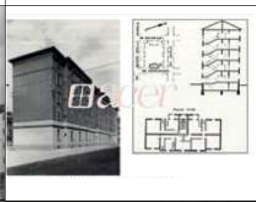
Acer Built asset	Court buildings	Tower buildings	Multi-storey buildings	Detached buildings
1901-1950				
1951-1975				
1976-1990				
1991-2000				

Fig. 056 - The composition of ACER Bologna’s built heritage, re-elaboration of the scheme proposed by the Inspire Project.

In the medium term, the impact of these results will contribute to the reduction of maintenance costs and the efficient management of resources, thus increasing the life cycle of the existing heritage by improving its accessibility and, in the long term, promoting a better quality of life. The project case studies were selected from the Acer Bologna building stock.

The selection criteria covered:
- Construction typologies
- Construction technologies
- Features of systems and components
- Materials properties

Recurrent building types were identified within the ACER Bologna building stock and preliminary simulations were carried out to estimate the energy performance of the buildings. Therefore, a repertory of maintenance interventions was created, linked to the main

building types belonging to the ACER Bologna stock by interfacing with the maintenance management system used by the agency.
In this way the most recurrent interventions were classified according to the technical elements involved, the methods of execution and the frequency, with respect to the different building types involved. From the data obtained, for each building under analysis, design hypotheses were made for energy upgrading and retrofitting, and energy simulations were conducted to estimate the effectiveness of the various hypothesised design strategies. Specifically, two levels of redevelopment of the typical building were analysed: a “typical

Acer Built asset	Structure	joisted floors	Roofing	Stairs	Courtain walls	Fixtures (Doors and windows)
Detached buildings	Load-bearing solid brickwork Load-bearing hollow brickwork	Wood-framed floors, Cast-in-place concrete floors, Concrete floors with prefabricated elements	Wooden roofing, Cast-in-place concrete roofing, Concrete roofing with prefabricated elements	Masonry stairs, Cast-in-place reinforced concrete stairs, Prefabricated reinforced concrete stairs	Solid brick curtain walling, Hollow brick curtain walling, Hollow core slab curtain walling, Pre-fabricated slab curtain walling, Glass block curtain walling	Wooden windows and doors, Iron windows and doors, Aluminium windows and doors
Multi-storey buildings Small	Load-bearing solid brickwork Load-bearing hollow brickwork Reinforced masonry structure	Wood-framed floors, Cast-in-place concrete slabs, Concrete slabs with prefabricated elements, Mixed slabs (slabs, vaults)	Wooden roofing, Cast-in-place concrete roofing, Concrete roofing with prefabricated elements	Masonry stairs, Cast-in-place reinforced concrete stairs, Prefabricated reinforced concrete stairs	Solid brick curtain walling, Hollow brick curtain walling, Hollow core slab curtain walling, Pre-fabricated slab curtain walling, Glass block curtain walling	Wooden windows and doors, Iron windows and doors, Aluminium windows and doors
Multi-storey buildings Large	Reinforced masonry structure, In situ reinforced concrete structure, Prefabricated reinforced concrete structure, In situ reinforced concrete wall, Other precast reinforced concrete structures	Cast-in-place concrete floors, Cast-in-place concrete floors with prefabricated elements, Precast reinforced concrete floors, Reinforced concrete and glass blocks	Cast-in-place concrete roofing, Concrete roofing with prefabricated elements	Cast-in-place reinforced concrete stairs, Prefabricated reinforced concrete stairs	Solid brick curtain walling, Hollow brick curtain walling, Hollow core slab curtain walling, Pre-fabricated slab curtain walling, Glass block curtain walling	Wooden windows and doors, Iron windows and doors, Aluminium windows and doors
Tower buildings	In situ reinforced concrete structure, Prefabricated reinforced concrete structure, In situ reinforced concrete wall, Other precast reinforced concrete structures	Cast-in-place concrete floors with prefabricated elements, Precast reinforced concrete floors, Reinforced concrete and glass blocks	Cast-in-place concrete roofing, Concrete roofing with prefabricated elements	Cast-in-place reinforced concrete stairs, Prefabricated reinforced concrete stairs	Hollow brick curtain walling, Hollow core slab curtain walling, Pre-fabricated slab curtain walling, Glass block curtain walling	Wooden windows and doors, Iron windows and doors, Aluminium windows and doors

Tab. 007 - The composition of ACER Bologna’s built heritage, re-elaboration of the scheme proposed by the Inspire Project.

redevelopment”, through the application of commonly used measures, and an “advanced redevelopment”, through the introduction of interventions reflecting the best available technologies.
After selecting buildings according to the above criteria, digital data sources were analysed and collected in order to manage available geometric and technical information, for some buildings CAD drawings, technical sheets, etc.; in other cases by acquiring digital data through laser scanner survey.
All the collected or acquired data were the basis to develop Information Modeling in BIM

environment, towards an informative implementation of HBIM (Heritage Building Information Modeling) and eBIM (existing Building Information Modeling) models of the built heritage for data analytics processes.

As part of the research developed within the thesis, a number of preliminary case studies were analysed, aimed at fine-tuning the overall methodology, and then focused on the BIM modelling of Acer case studies from the available data sources.

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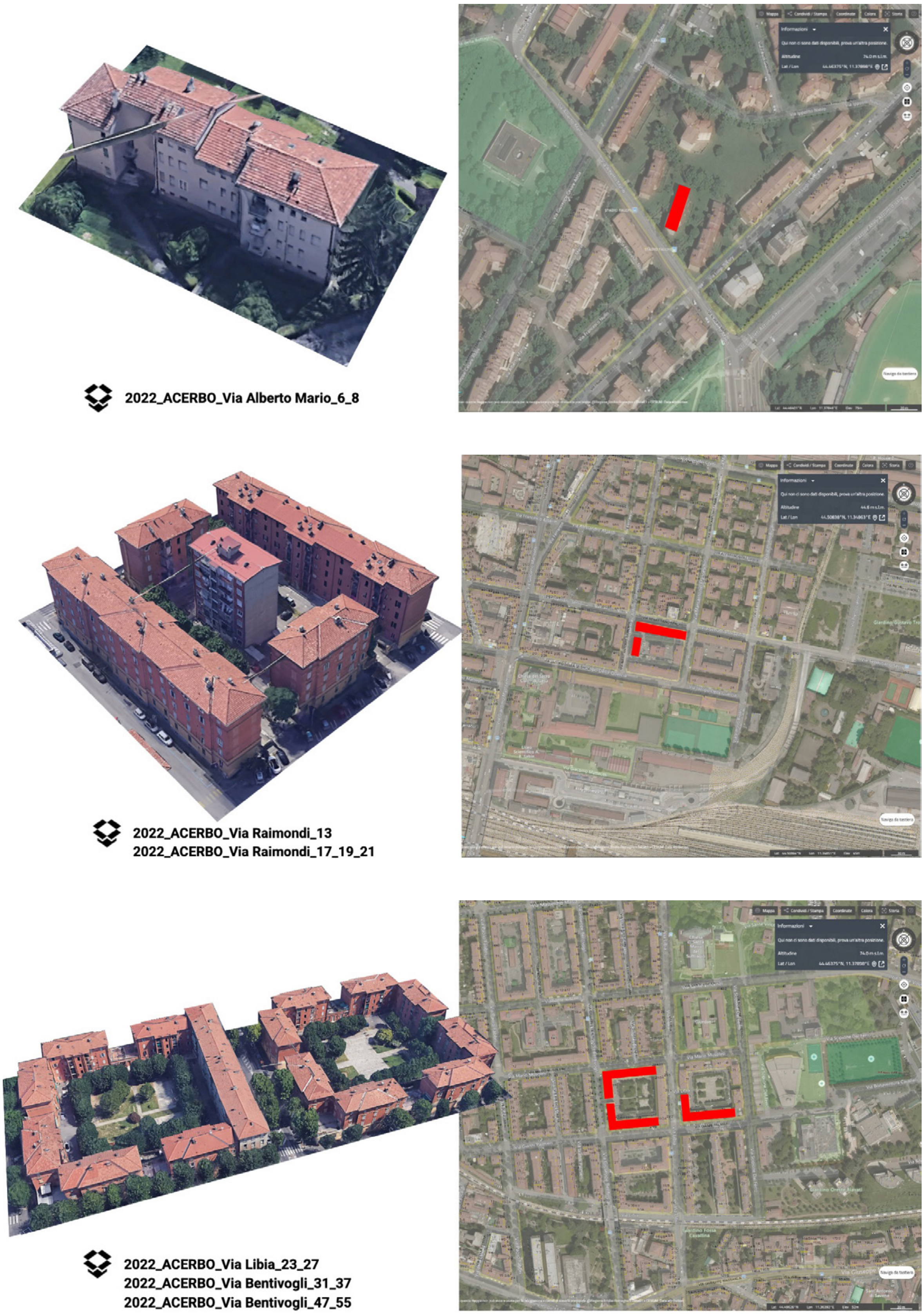


Fig. 057 - Schematization of the case studies' locations. The first is a building from the 1950s, included in an IACP housing lot that includes other buildings built with the same typology. The second includes case studies II and III, and identifies a building typology widely adopted at the beginning of the 20th century for social housing built by the IACP. The third example includes buildings of the same typology but aggregated with a different scheme.

5.2 Criteria for the identification and selection of case studies

The analysis of the regional building stock has highlighted the need to act and refurbish buildings be-longing to the existing building stock, with a particular focus on the residential sector. The residential sector represents, in quantitative terms, the primary component compared to the existing buildings. This makes the residential sector particularly suitable for wide-ranging refurbishment activities. As highlighted by the Gabetti Studies Centre report, the residential sector will require targeted interven-tions to reach the 2050 target set by the European community in terms of energy efficiency and anti-seismic safety.
By intervening in 20th-century buildings, it is possible to identify and promote intervention actions applicable to the broadest possible representative sample. Buildings belonging to the first part of the 20th century are those most affected by the issues related to the components with which they were built. In the area of Bologna, as is usual in many parts of Italy, handcrafted elements were still wide-spread, as these were made by companies derived from local standards.
Buildings were therefore identified that would respond to these problems and guarantee the widest margin of scalability. Selected case studies show recurring typologies widely exploited in the 20th century, allowing the proposed methodology to be applied to various potential interventions. The sca-lability of the proposed solutions is the key to the sustainability of the intervention, allowing the in-vestment to be spread over several similar interventions.
Buildings belonging to the selected typologies and owned by ACER (or in any case by undivided ow-ners) were identified to avoid fragmentation of ownership as the main limitation for upgrading the existing heritage. Selected buildings also belong to a property size that allows the economic sustai-nability of a redevelopment intervention, where the development of a digital model useful for future asset management has an acknowledged value.

5.3 Case studies overview

The selected case studies belong to the ACER heritage of the Bologna province. The buildings belong to two distinct types, Case Study I represents a typical building type from the mid-20th century, made of load-bearing masonry with horizontal partitions made of Cirex. The case study is located on a lot where the same building type has been replicated in some shape variations. The lot was built using similar technological solutions and materials.
Case studies II, III and IV are the same typology of social housing built in the 1920s. Based on the use of a modular housing concept, this typology is declined in some variants in the three case studies. Case study II is the one that is analysed in more detail and whose compositional elements (families) that define it are shown. Case study III is a variant of the second, in which the basic module is replicated in a linear series of three elements to form an in-line block. Case study IV is an aggregation variant of the basic element, in which a connecting element is introduced to enclose the plot that contains it and define the inner sphere.

Fig. 058 - Google. (n.d.). [Map of the city of Bologna]. Retrieved 10/01/2023, from earth.google.com

5.3.1
Case study I
Via Alberto Mario

SAVENA DISTRICT
2022_ACERBO_Via Alberto Mario_6_8

Model Code:
ACB0001-ACB-AB0000001-XX-M3-A-S0001

Model coordinates:
44.463715°N, 11.378933°W
74,1 m a.s.l.
North rotation 20°

The case study is located in the Savena district (San Lazzaro) in the southern part of the city and belongs to a more extensive intervention realised in 1955 by Arch. Francesco Santini on a public housing project commissioned by IACP. The building stands in an area classified by the municipality as specialised use, in which a mix of residential and productive activities coexist. The building is morphologically composed of "blocks" connected to shape the different typologies on the lot. The same constituent characters can also be found in the other ten buildings designed by architect Santini.
The building taken as a case study is articulated in elevation on three above-ground floors staggered between them and connected by a shared staircase every six residential units. The raised parts of the building host a basement where the cellars for the six flats are located.
The building has a strip of exposed masonry on the ground floor, used to mitigate rising dampness, and the remaining floors are plastered. The roof is made of a hollow slab and is covered with tiles.

Fig. 059 - Building view of the inner courtyard

The load-bearing structure is made of Bolognese-type bricks, a local standard widely used in the area until the middle of the 20th century. In the case study, we find six different masonry stratigraphies made of Bolognese bricks, UNI format bricks, and two kinds of hollow bricks. The floors are made with Cirex 55 technology, a variant of the hollow slab in which the load-bearing part consists of a reinforced hollow clay block system.
The original wooden window frames were replaced with single-chamber aluminium frames. All the replacement and modernisation work on the window frames is uneven, suggesting a certain level of randomness in the maintenance work by the tenants.
The case study is located on a vast property and shares large parts of public green spaces with the other buildings.
The planning instruments foresee for the area where the building stands regeneration actions that limit land consumption, the adoption of solutions that mitigate climate change risks and support energy transactions and the circular economy. The planning instruments foresee actions that favour the increase of units for social housing, support services and green areas.

Fig. 060 - The data acquired from the survey campaign carried out by using a terrestrial laser scanner (TLS) was exported in E57 format and processed using Autodesk ReCap. The point cloud was linked to the Revit project for the modelling process.

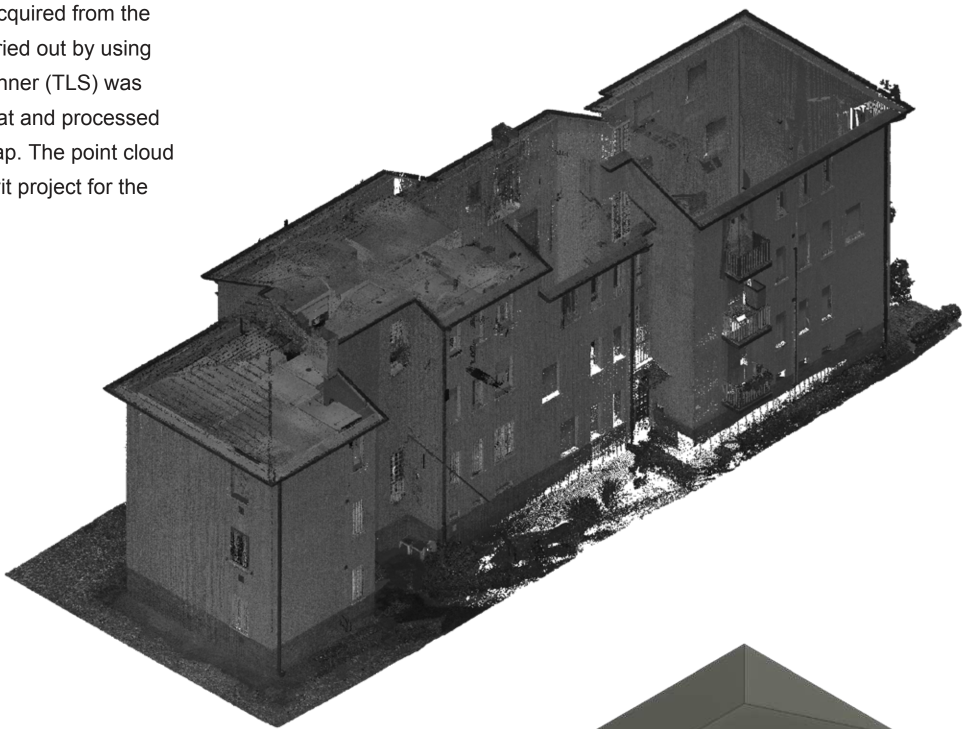


Fig. 061 - The point cloud was used as the basis for modelling the building, cross-referencing the extracted information with the technical drawings of the building.

Fig. 062 - The model was overlaid and compared with the point cloud to check its reliability.

5.3.1.1 Case study I, planning regulation

The table collects information on the cadastral identification of the asset in addition to the indications provided in the general urban plan (PUG). The PUG lists the planned development activities and constraints for the real estate in the municipal area of Bologna.

CS_Alberto Mario			
House number	Via Alberto Mario 6, 8		
Distrct	Savena		
Cadastral number	Sheet 298, map 350		
Distrct	Lungo savena		
PUG - Local strategies (PUG Piano Urbanistico Generale, General town plan)			
Plan Regulations (General Urban Plan effective from 29/09/2021)	4 Local strategies	4.1 References for the Implementation of Local Strategies	Lungo savena
PUG - Plan discipline - Resilience and environment			
Plan Regulations (General Urban Plan effective from 29/09/2021)	1.1 Promoting the regeneration of anthropised soils and counteracting soil consumption	1.1a Fostering the recovery and efficiency of the existing building stock	Parts of the city planned with an implementation planning instrument, Existing building stock
		1.1d Reinforcing already established functions and fostering de-sealing interventions	municipal area
	1.2 Developing the urban eco-network	1.2b Enhancing urban green infrastructure	Boundary of urbanised territory
		1.2c Building an urban blue infrastructure	municipal area
		1.2d Maintaining natural flow rates in the riverbed and reducing groundwater withdrawals	municipal area
		1.2e Improve surface water quality	municipal area
	1.3 Preventing and mitigating environmental risks	1.3a Containing natural hazards	Slope stability - Water resources and hydrogeological structure - Seismic risk
		1.3c Mitigating the heat island effect in urban areas and introducing measures for climate adaptation in buildings	Microclimatic fragility - low fragility
		1.3d Reducing population exposure to pollution and anthropogenic hazards	Accessibility to the local public transport network, Perimeter of urbanised territory, Municipal territory
	1.4 Supporting energy transaction and circular economy processes	1.4a Promoting and prompting different forms of energy efficiency and fair accessibility to energy services with a low environmental impact	municipal area
		1.4b Planning the deployment of energy production plants from renewable sources by creating local distribution networks	municipal area
		1.4c Stimulating the circular economy of construction and excavation materials	municipal area
		1.4d Encouraging recycling and reducing waste production	municipal area
PUG - Plan discipline - Housing and social inclusion			

Plan Regulations (General Urban Plan effective from 29/09/2021)	2.1 Extend access to housing	2.1a Promoting the growth and innovation of rental housing offer	Boundary of urbanised territory
		2.1b Promoting the growth of social housing supply	Areas to increase Social Housing supply
		2.1c Experimenting new forms of housing	municipal area
		2.1e Involving communities through participatory processes	Boundary of urbanised territory
	2.2 Ensuring the deployment of a balanced network of quality facilities and services	2.2a Promoting the redevelopment and realisation of territorial facilities	municipal area
		2.2b Supporting a balanced spread of cultural spaces	Boundary of urbanised territory
		2.2c Promoting services and proximity commercial activities	Boundary of urbanised territory, municipal area
		2.2d Supporting sustainable logistics	Boundary of urbanised territory, municipal area
		2.2e Experimenting new forms of temporary management of brownfield sites	municipal area
	2.3 Ridisegnare gli spazi e le attrezzature	2.3a Making the city universally accessible	municipal area
		2.3b Developing open spaces and public buildings of high architectural and environmental quality	Boundary of urbanised territory
		2.3c Renovating street space in terms of formal and environmental quality, accessibility and safety	Accessibility to the local public transport core network, Municipal area
	2.4 Preserving the character of the historic urban landscape by renewing its role	2.4d Enhancing the architecture and agglomerations of cultural and testimonial interest of the second half of the 20th century	Clusters of Cultural and Testimonial Interest in the Second Twentieth Century
PUG - Plan discipline - Attractiveness and employment			
Plan Regulations (General Urban Plan effective from 29/09/2021)	3.1 Supporting an overall urban re-infrastructure	3.1a Reconstruct the unique map of infrastructure networks, nodes and intersections, operators	Boundary of urbanised territory
		3.1b Ensuring the improvement of urban infrastructure with urban transformation interventions	Boundary of urbanised territory
		3.1c Facilitating the deployment and coordination of digital infrastructures	Boundary of urbanised territory
		3.1f Creating the urban tram network	Boundary of urbanised territory
		3.1g Extend and integrate the backbone of the urban and suburban cycle network	municipal area
	3.2 Fostering the widespread settlement of economic activities under environmentally compatible conditions	3.2a Ensuring regulatory and procedural flexibility for existing companies	Boundary of urbanised territory
		3.2b Targeting new production needs by orienting them towards the reuse and regeneration of urbanised territory	Boundary of urbanised territory
		3.2d Promoting the establishment of innovative companies and the promotion of innovation centres	Boundary of urbanised territory
Strategy: (ITA)			
http://sit.comune.bologna.it/alfresco/d/d/workspace/SpacesStore/66da2392-1e51-4382-9444-2a45f2982a16/SL_LungoSavena_20210807.pdf			
Data source:			
shorturl.at/acd26			

Tab. 008 - The table summarises the main regulatory strategies foreseen in the Regional Urban Plan (PUG) for the case study.

5.3.1.2 Case study I, model morphology

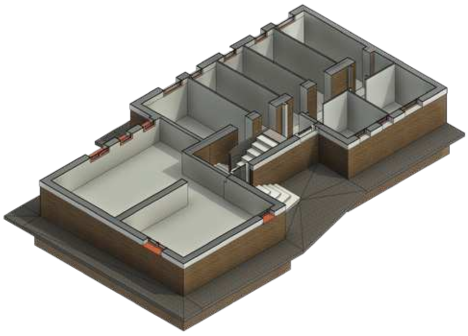


Fig. 063 - Level G1/GF - The case study is characterised by staggered floors connected by a shared stairwell.

Fig. 064 - Level 01/02 - The building consists of two types of flats per level, two smaller ones at the ends and two larger ones adjacent to the central part.

Fig. 065 - Level 02/03 -
four rooms, while the mo
six. The largest apartme
view on the front opposi

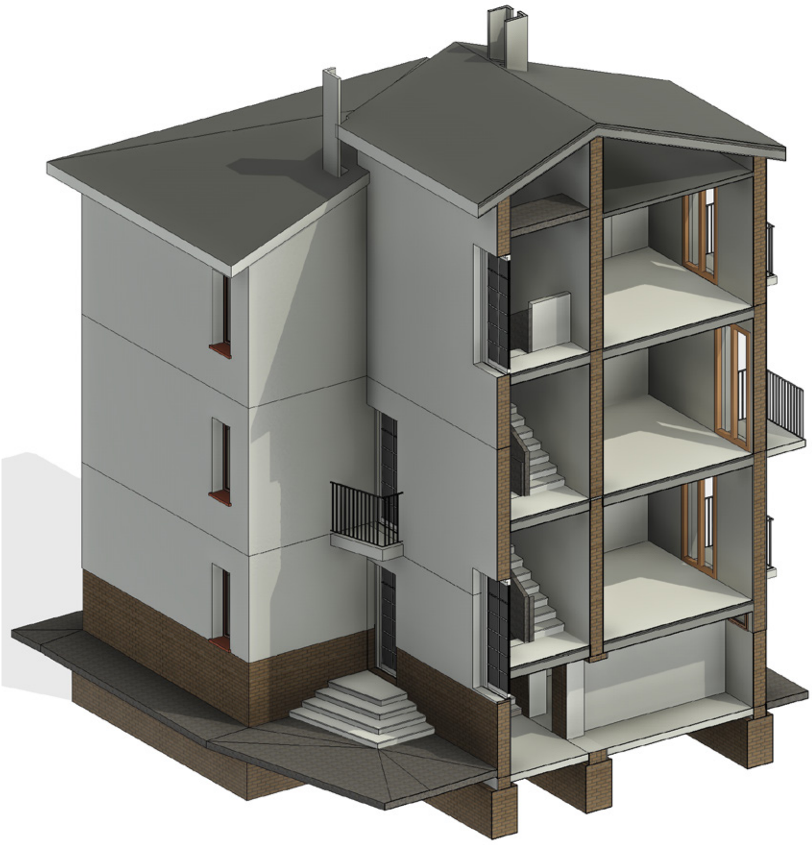


Fig. 068 - Cutaway of the model on the stairwell, the concrete staircase leading to the raised first-floor level is visible. There is a small balcony on the first-floor landing that serves as a cover for the entrance.

The smaller flats have
ore extensive ones have
ents have an external
te the entrance.

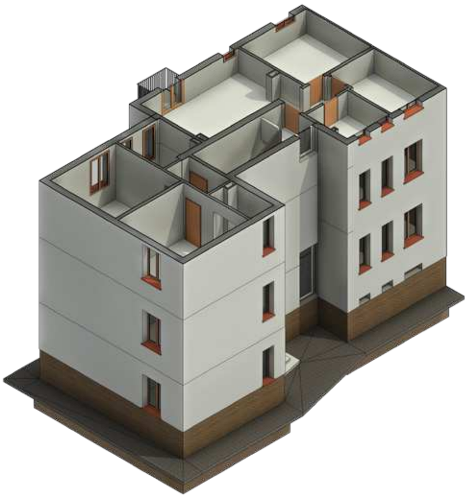


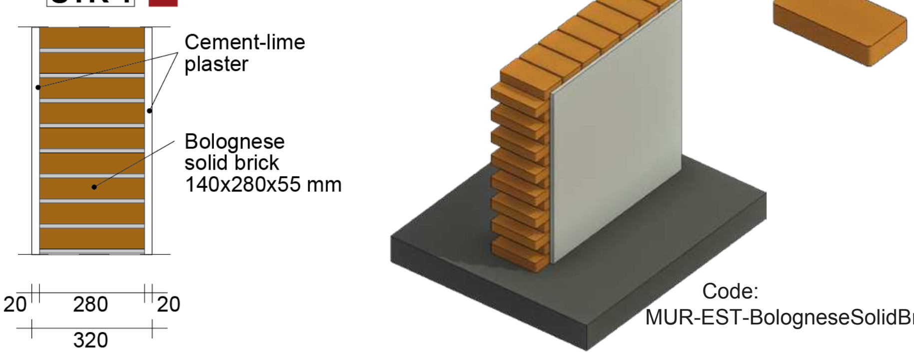
Fig. 066 - Level 03/04

Fig. 067 - Roofing view

Fig. 069 - Cutaway of the model of the two fronts of the building.

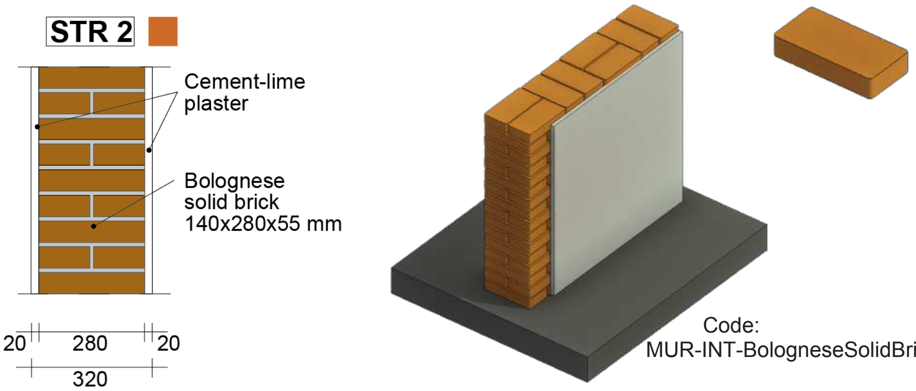
5.3.1.3 Case study I, Wall structure

STR 1



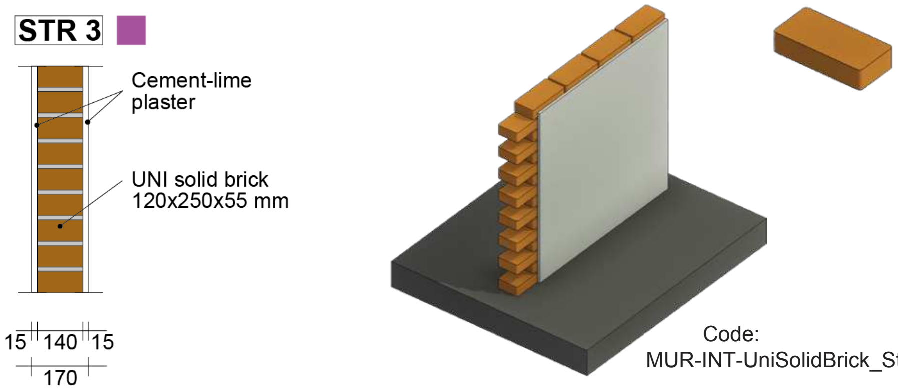
Code:
MUR-EST-BologneseSolidBrick_Header_140x280x55mm-01

STR 2



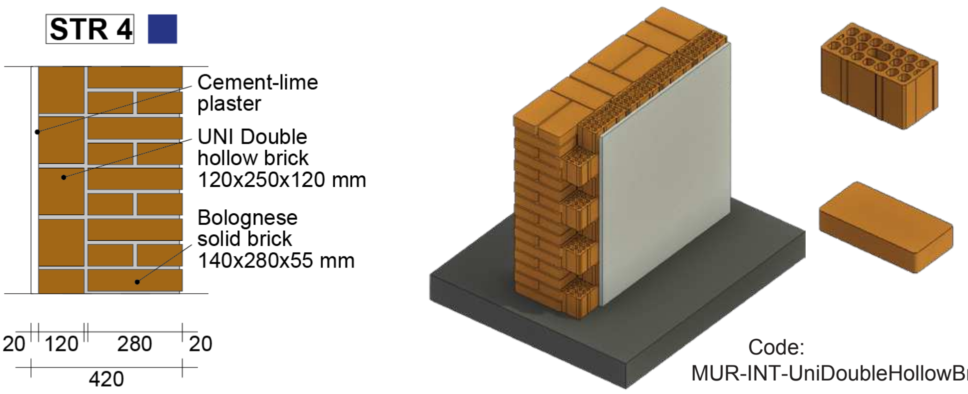
Code:
MUR-INT-BologneseSolidBrick_Gothic_140x280x55mm-02

STR 3



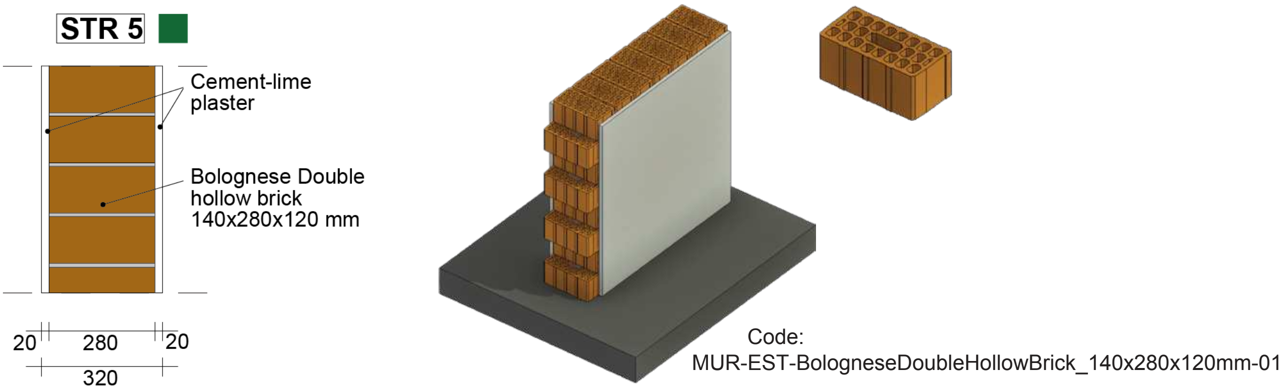
Code:
MUR-INT-UniSolidBrick_Stretcher_120x250x55mm-03

STR 4

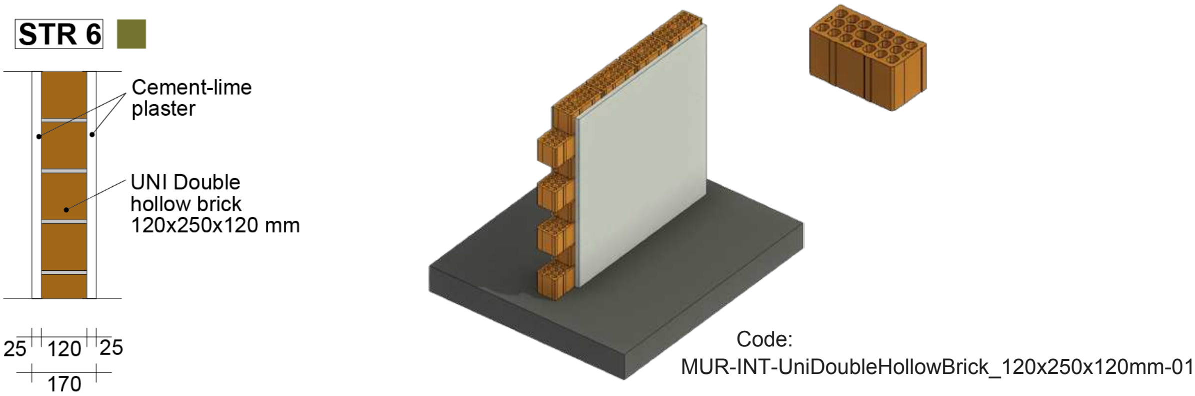


Code:
MUR-INT-UniDoubleHollowBrick_BologneseSolidBrick_420mm-01

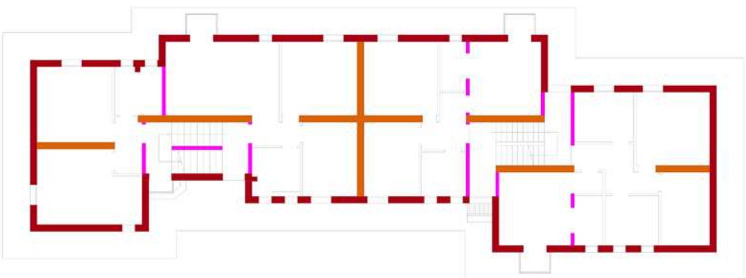
STR 5



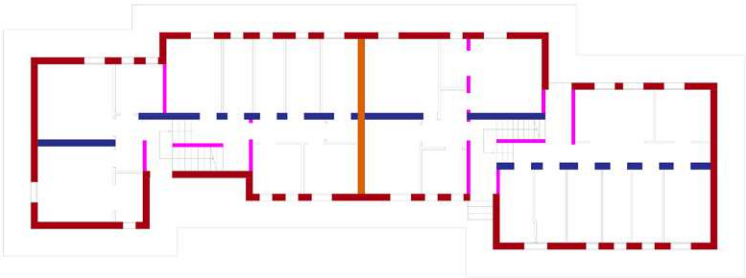
STR 6



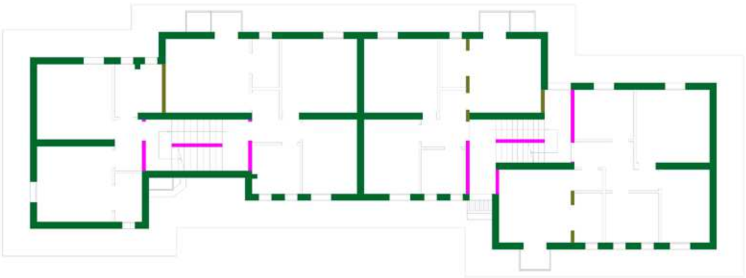
Wall composition



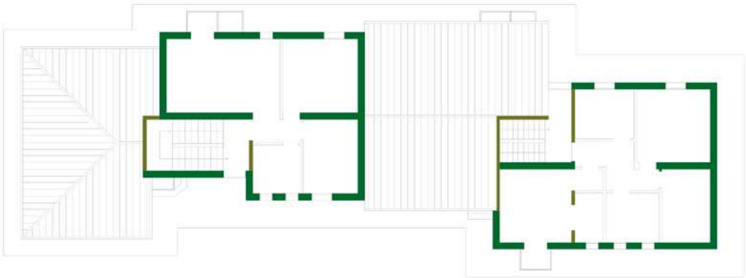
Ground floor



First floor

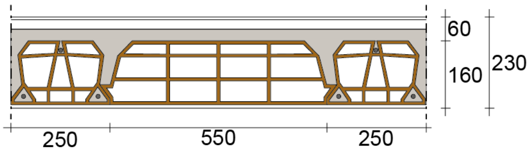


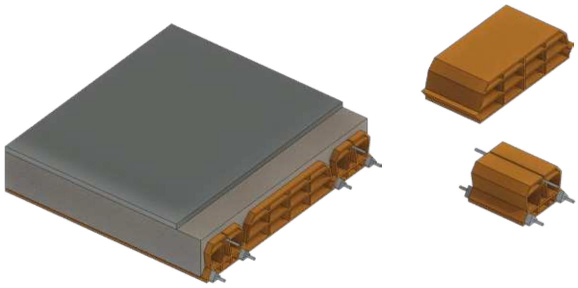
Second floor



Third floor

5.3.1.4 Case study I, Floor structure

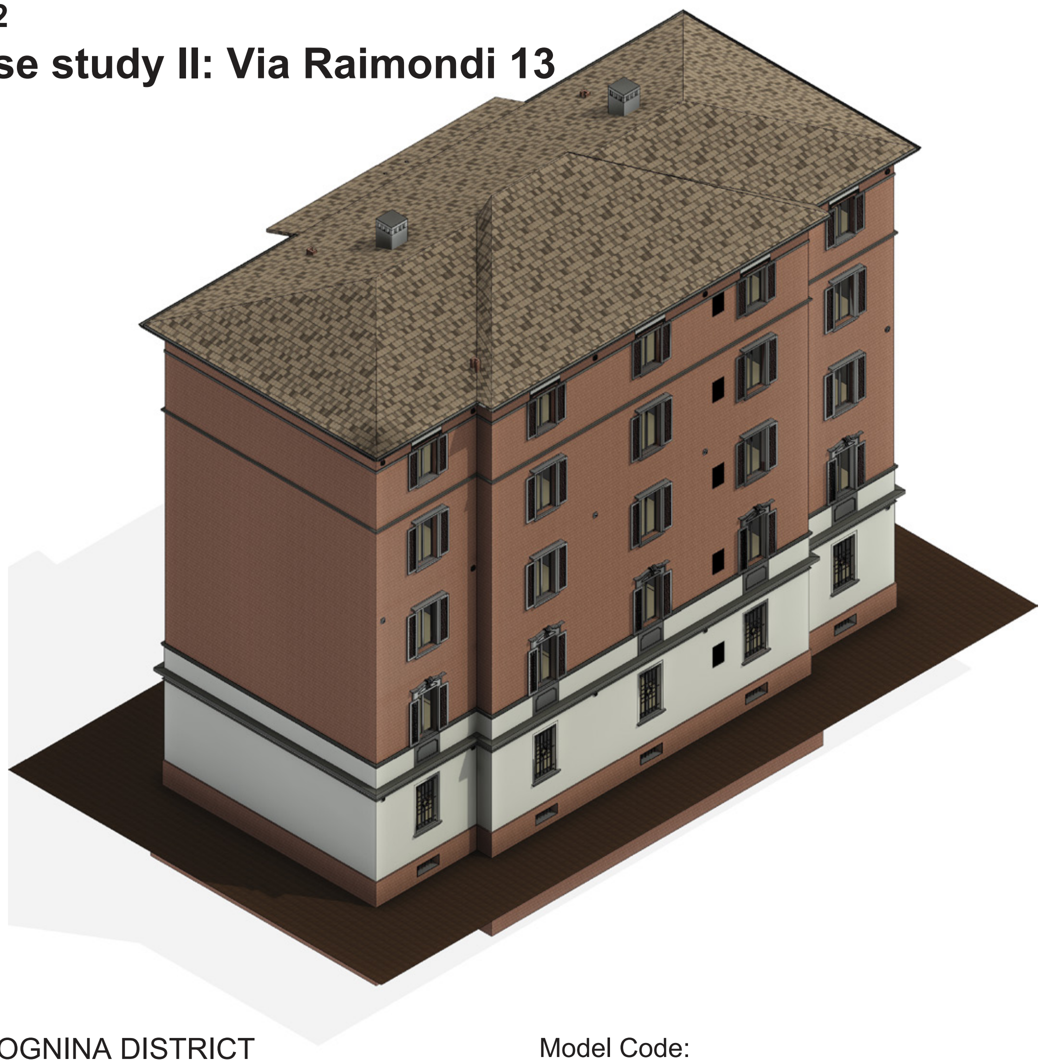




Code:
SOL-STR-Cirex55_160mm-01

Fig. 070 - Google. (n.d.). [Map of the city of Bologna]. Retrieved 10/01/2023, from earth.google.com

5.3.2
Case study II: Via Raimondi 13



BOLOGNINA DISTRICT
2022_ACERBO_Via Raimondi_13

Model Code:
ACB0002-ACB-AB0000001-XX-M3-A-S0001

Model coordinates:
44.50838°N, 11.34863°W
44.6 m a.s.l.
North rotation 10°

The case study is in the Bolognina district, close to Bologna’s railway station and is one of the first buildings built by the IACP as part of the expansion planned in 1889 outside the medieval walls to the north of the city. The building was built in 1924 by the Cooperativa Costruzione e Risanamento on a design by Engineer Ildebrando Tabarroni.
In terms of design, the building is conceived as a basic modular element used individually or aggregated to create larger and more articulated structures. Part of the same complex is a building resulting from the linear concatenation of the module to form the building facing Via Raimondi at numbers 17, 19, and 21 (case study III). The same module, joined at an angle, makes up the solution adopted for the complex in the Cirenaica district (case study IV). The level of modularity adopted to keep costs low during construction also becomes a driver for cost reduction when digitising the heritage, allowing components to be reused in more than one case study.
The building stands in an area classified by the municipality as ‘compact fabric’, in which the buildings are characterised by continuous fronts that outline the lot on which they stand.

The buildings ar-ranged around the perimeter form a curtain that marks the enclosed semi-private area. In this specific case, a new building was constructed in the centre of the block later, thus sacrificing the courtyard space. The inner courtyard is delimited by gate sections connecting the buildings and letting the cour-tyard be closed off to the outside.
The case study comprises five above-ground floors connected by a shared stairwell for the fifteen resi-dential units. In the basement, which is accessible from the same stairwell, there are utility spaces.
On the main front, the building has a portion of exposed masonry overlaid by a plastered portion that reaches the fixtures sills on the first floor. The following levels are in exposed masonry. Decorative string-course elements run horizontally at the level of the first-floor and fifth floors decks. The ope-nings are regular and have a decreasing level of decoration from the first floor, which is richly decora-ted, to the fifth floor where the openings have no decorative elements. There are ventilation ope-nings in the basement and service openings on the external front. These openings are masked by gra-ting to limit introspection.
The rear front is not decorated, and the decorative elements on the main front and side walls are in-terrupted to cover the thickness of the side walls. On the rear front is located the access point to the stairwell. The openings on the rear front are undecorated and have grating elements on the ground floor. On the rear façade, a volume protrudes from the outline of the building that hosts part of the stairwell and acts as a support for the units' balconies facing the internal courtyard.
The load-bearing structure is made of Bolognese-type solid bricks and has a variable thickness ranging from three heads for the basement to two heads for later storeys. The partition walls are made of hol-low brick with thicknesses ranging from 17 cm for internal partition walls between flats to 8-10 cm for inner walls. The interior floors are made of vaulted brick with variable structural spans.
The original window frames have been replaced with modern frames and show uniformity of design and colour, highlighting a refurbishment intervention carried out on the entire building on both the main and secondary fronts.
The planning instruments provide for the building to be protected as a building of cultural interest, referring to the municipal building regulations to identify which kinds of intervention are admissible.

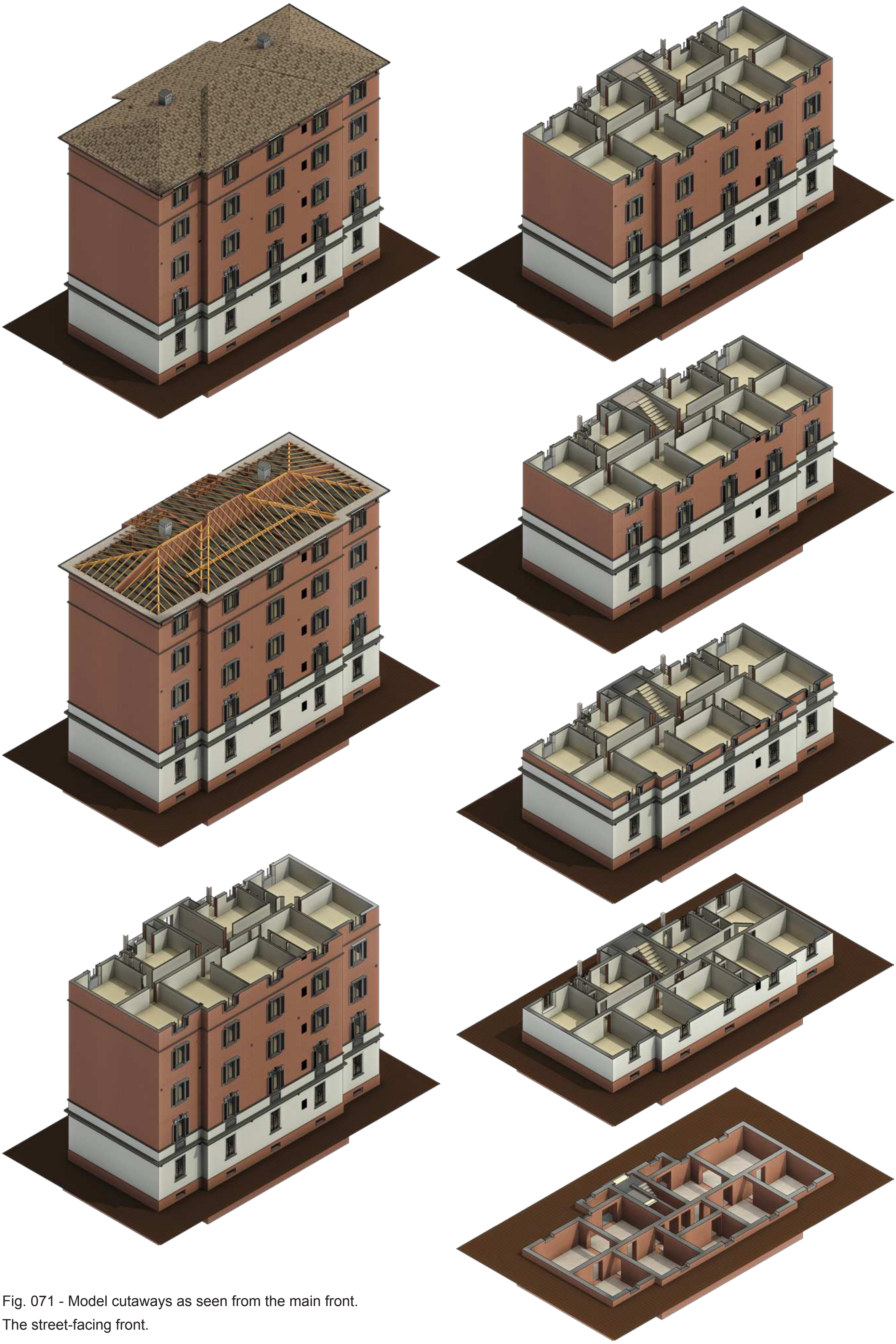


Fig. 071 - Model cutaways as seen from the main front.
The street-facing front.

5.3.2.1 Case study II, planning regulation

The table collects information on the cadastral identification of the asset in addition to the indications provided in the general urban plan (PUG). The PUG lists the planned development activities and constraints for the real estate in the municipal area of Bologna. Information on restrictions on feasible architectural interventions on the asset, as provided by the competent superintendency, is also listed.

CS_Raimondi 13		
Unit numb.	Via Marcantonio Raimondi 13	
District	Navile	
Cadastral number	Sheet 119, map 221	
District	Bolognina	
Construction restrictions (Vincoli in rete, http://vincoliinrete.beniculturali.it)		
ID	500489	
Designation	via Marc'Antonio Raimondi n. 13	
Schedule type	Architecture	
Legal status	Non-territorial public body ownership	
Purpose of use	Residential	
Cultural interest	Declared cultural interest	
Hierarchy	Complex	
Region	Emilia-Romagna	
Province	Bologna	
Municipality	Bologna	
Competent body (ECP)	S261 (SABAP-BO)	Superintendence of Archaeology, Fine Arts and Landscape for the metropolitan city of Bologna and the provinces of Modena, Reggio Emilia and Ferrara
Filing body (ESC)	S143 (SBAP-BO)	Superintendence for Architectural and Landscape Heritage for the Provinces of Bologna Modena and Reggio Emilia
Historical period	1924	
Source systems		
SigecWeb	No	
Risk chart	32966	
Listed element	3804	
VirApp	No	
ICCD	No	
Cadastral data		
Cadastral code	sheet	number
A944	119	221
A944	119	221
A944	119	48
A944	119	223
Data source		
http://vincoliinrete.beniculturali.it/VincoliInRete/vir/bene/dettagliobene500489		
PUG - Plan discipline (Piano Urbanistico Generale - Disciplina del piano, http://sitmappe.comune.bologna.it/pugviewer)		
PUG - Table of restrictions - Protection of Water Resources and Hydrogeological Structure		

Restrictions (Table of restrictions effective 23/11/2022)	Protection	Areas potentially affected by rare flooding - Main reticulum
	Protection	Areas potentially affected by infrequent flooding - Main reticulum
PUG - Table of restrictions - Protection of Natural and Landscape Elements		
Restrictions (Table of restrictions effective 23/11/2022)	Protection	Forests and assimilated areas within the meaning of Legislative Decree 34/2018
PUG - Table of restrictions - Protection of Historical and Archaeological Evidence		
Restrictions (Table of restrictions effective 23/11/2022)	Protection	Cultural Heritage - Cultural Heritage subject to declaration (Legislative Decree 42/2004, Art. 13)
	Protection	Low archaeological potential areas
	Protection	Buildings of interest - Buildings of cultural and testimonial interest
PUG - Table of restrictions - Seismic Risk Protection		
Restrictions (Table of restrictions effective 23/11/2022)	Protection	Homogeneous macro-zones in seismic perspective - Liquefaction Attention Zones 2A
PUG - Table of restrictions - Constraints Infrastructure, land and easements		
Restrictions (Table of restrictions effective 23/11/2022)	Restriction	Streets
PUG - Table of restrictions - Constraints for aviation infrastructure		
Restrictions (Table of restrictions effective 23/11/2022)	Restriction	Obstacle delimitation specifications - conical surface - Slope 1:20
	Restriction	Air Navigation Obstacles - Areas Affected by Variable Height Obstacle Boundary Surfaces (Annex A)
	Restriction	Air navigation hazards - Typology 1 (Table PC01A); Typology 2 (Table PC01A); Typology 3 - Limits laser projector sources (Table PC01B); Typology 4 - Wind power plants - Area of absolute incompatibility (Table PC01C)
PUG - Table of restrictions - Constraints Electromagnetism		
Restrictions (Table of restrictions effective 23/11/2022)	Restriction	Areas where the location of fixed mobile telephony installations is prohibited - buffer zone for sensitive receptors
	Restriction	Radio/TV Broadcasting - Area of Prohibition of Plant Location
Strategy:		
Data source:		
shorturl.at/cuAT3		

Tab. 009 - The table summarises the main regulatory strategies foreseen in the Regional Urban Plan (PUG) for the case study.

5.3.2.2 Case study II, model morphology

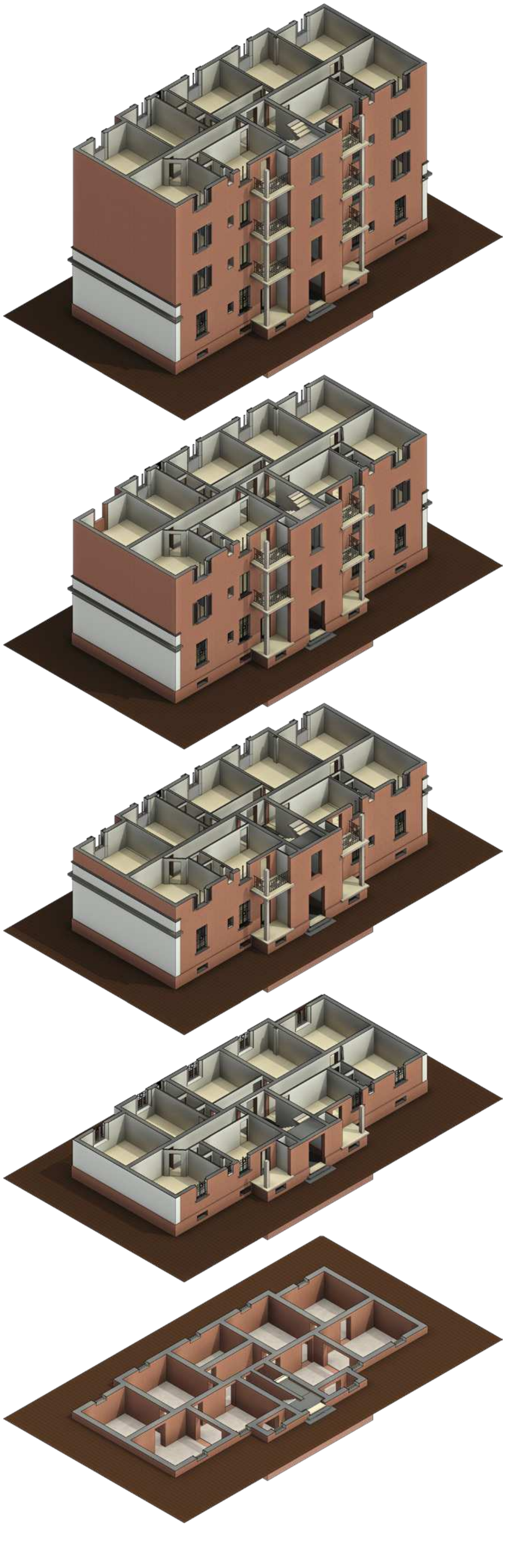


Fig. 072 - Model cutaways as seen from the rear front.
The courtyard-facing front.

Fig. 073 - Model cutaways sectioned on the stairwell.

Model structure, Levels, Woksets and custom families

Levels relative height	
Level name	Height (cm)
G2 (P_Fond)	-330
G1 (P-1)	-210
GF (L0_Pianerottolo)	0
M1 (P_Rialz)	60
01M (L1_Pianerottolo)	270
01 (P1)	435
02M (L2_Pianerottolo)	610
02 (P2)	785
03M (L3_Pianerottolo)	960
03 (P3)	1135
04M (L4_Pianerottolo)	1310
04 (P4)	1485
RL (Quota copertura SUD)	1765
Quota_Ctrsf_P4	1795
05 (Sottotetto)	1803
RL (Quota copertura NORD)	1817
RL (Colmo copertura)	2066

Tab. 010- The table shows the identified levels for the model breakdown and their relative elevations.

Worksets

ACERBO_Raimondi 13_Site
ACERBO_Raimondi 13_Arch_Copertura
ACERBO_Raimondi 13_Arch_P-1
ACERBO_Raimondi 13_Arch_PRialz_Exteriors
ACERBO_Raimondi 13_Arch_PRialz_Floors
ACERBO_Raimondi 13_Arch_PRialz_Walls
ACERBO_Raimondi 13_Arch_P1_Exteriors
ACERBO_Raimondi 13_Arch_P1_Floors
ACERBO_Raimondi 13_Arch_P1_Walls
ACERBO_Raimondi 13_Arch_P2_Exteriors
ACERBO_Raimondi 13_Arch_P2_Floors
ACERBO_Raimondi 13_Arch_P2_Walls
ACERBO_Raimondi 13_Arch_P3_Exteriors
ACERBO_Raimondi 13_Arch_P3_Floors
ACERBO_Raimondi 13_Arch_P3_Walls
ACERBO_Raimondi 13_Arch_P4_Exteriors
ACERBO_Raimondi 13_Arch_P4_Floors
ACERBO_Raimondi 13_Arch_P4_Walls
ACERBO_Raimondi 13_Arch_PFond
ACERBO_Raimondi 13_Arch_Scala
ACERBO_Raimondi 13_Str_Copertura
ACERBO_Raimondi 13_Str_P-1
ACERBO_Raimondi 13_Str_P1
ACERBO_Raimondi 13_Str_P2
ACERBO_Raimondi 13_Str_P3
ACERBO_Raimondi 13_Str_P4
ACERBO_Raimondi 13_Str_P4_Ctrsf
ACERBO_Raimondi 13_Str_PRialz
ACERBO_Raimondi 13_Str_Scala
ACERBO_Raimondi 13_Str_Sottotetto
ACERBO_Raimondi 13_Str_PFond

Custom families, Vertical structures

Number	Name	Format	Size
	Exterior		
001	ACERBO_Raimondi_13_EXT_StrWall_p-1_45.rfa	RFA	412,0 KB
002	ACERBO_Raimondi_13_EXT_StrWall_p-1_55.rfa	RFA	684,0 KB
003	ACERBO_Raimondi_13_EXT_StrWall_p-1_100.rfa	RFA	684,0 KB
004	ACERBO_Raimondi_13_EXT_StrWall_P_Rialz_32.rfa	RFA	528,0 KB
005	ACERBO_Raimondi_13_EXT_StrWall_P_Rialz_30.rfa	RFA	772,0 KB
006	ACERBO_Raimondi_13_EXT_StrWall_P1_5.rfa	RFA	520,0 KB
007	ACERBO_Raimondi_13_EXT_StrWall_P1_30.rfa	RFA	416,0 KB
008	ACERBO_Raimondi_13_EXT_StrWall_P1_32.rfa	RFA	828,0 KB
009	ACERBO_Raimondi_13_EXT_StrWall_P1_15.rfa	RFA	580,0 KB
	Interior		
010	ACERBO_Raimondi_13_INT_StrWall_P1_7.rfa	RFA	416,0 KB
011	ACERBO_Raimondi_13_INT_StrWall_P1_14.rfa	RFA	608,0 KB

Tab. 011- The table lists the families created for masonry typologies. The list is subdivided by Exterior and Interior walls.

Custom families, Floor slabs

	Structural floor		
001	ACERBO_Raimondi_13_StrFloor_5_Generico.rfa	RFA	692,0 KB
002	ACERBO_Raimondi_13_StrFloor_Voltine_80_2.rfa	RFA	708,0 KB
003	ACERBO_Raimondi_13_StrFloor_Voltine_80_5.rfa	RFA	424,0 KB
004	ACERBO_Raimondi_13_StrFloor_Voltine_92_25.rfa	RFA	520,0 KB
005	ACERBO_Raimondi_13_StrFloor_Voltine_93_5.rfa	RFA	424,0 KB
006	ACERBO_Raimondi_13_StrFloor_Voltine_97.rfa	RFA	424,0 KB
007	ACERBO_Raimondi_13_StrFloor_Voltine porzioni_56_4.rfa	RFA	416,0 KB
008	ACERBO_Raimondi_13_StrFloor_Voltine porzioni_55_9.rfa	RFA	708,0 KB
009	ACERBO_Raimondi_13_StrFloor_20.rfa	RFA	424,0 KB
010	ACERBO_Raimondi_13_StrFloor_10_Balcone PRialz.rfa	RFA	416,0 KB
011	ACERBO_Raimondi_13_StrFloor_15_Balcone P1234.rfa	RFA	436,0 KB
012	ACERBO_Raimondi 13_StrTrave_26x15.rfa	RFA	956,0 KB
013	ACERBO_Raimondi_13_StrFloor_Cirex_20.rfa	RFA	684,0 KB
	Architectural floor		
014	ACERBO_Raimondi_13_ArcFloor_4.5.rfa	RFA	424,0 KB

Tab. 012 - The table lists the families created for floor slabs, subdivided by Structural elements and Architectural elements.

Custom families, Stair component

	Profiles:		
001	ACERBO_Raimondi 13_Str_Profilo pianerottolo interno.rfa	RFA	708,0 KB
002	ACERBO_Raimondi 13_Str_Profilo pianerottolo esterno.rfa	RFA	424,0 KB
003	ACERBO_Raimondi 13_Arc_Rivestimento Pedata.rfa	RFA	416,0 KB
004	ACERBO_Raimondi 13_Arc_Rivestimento Pianerottolo sinistro.rfa	RFA	436,0 KB
005	ACERBO_Raimondi 13_Arc_Rivestimento Pianerottolo destro.rfa	RFA	464,0 KB

Tab. 013 - The table lists the families created to compose the stairs element.

Custom families, Drywall structures

Number	Name	Format	Size
001	Fassa_Str_GuidaU40x100x300.rfa	RFA	404,0 KB
002	Fassa_Str_GuidaU40x150x300.rfa	RFA	404,0 KB
003	Fassa_Str_GuidaU40x50x300.rfa	RFA	404,0 KB
004	Fassa_Str_GuidaU40x75x300.rfa	RFA	404,0 KB
005	Fassa_Str_GuidaUCTRSF28x16x28x300.rfa	RFA	400,0 KB
006	Fassa_Str_GuidaUCTRSF28x30x28x300.rfa	RFA	400,0 KB
007	Fassa_Str_MontanteC50x149x47x300.rfa	RFA	404,0 KB
008	Fassa_Str_MontanteC50x49x47x300.rfa	RFA	404,0 KB
009	Fassa_Str_MontanteC50x74x47x300.rfa	RFA	404,0 KB
010	Fassa_Str_MontanteC50x99x47x300.rfa	RFA	404,0 KB
011	Fassa_Str_MontanteCCTRSF15x48x15x300.rfa	RFA	620,0 KB
012	Fassa_Str_MontanteCCTRSF27x48x27x300.rfa	RFA	620,0 KB
013	Fassa_Str_Tavolato.rfa	RFA	400,0 KB

Tab. 014 - The table lists the families created as a support for the To-Be developement of Smart Packages,

Custom families, Structural beams

Number	Name	Format	Size
001	ACERBO_Raimondi 13_Str_Architrave laterocemento_B120xH75xL1200.rfa	RFA	676,0 KB
002	ACERBO_Raimondi 13_Str_C120_L2000_II.rfa	RFA	412,0 KB
003	ACERBO_Raimondi 13_Str_C120_L2000.rfa	RFA	408,0 KB
004	ACERBO_Raimondi 13_Str_IPE120_L2000_II.rfa	RFA	404,0 KB
005	ACERBO_Raimondi 13_Str_IPE120_L2000.rfa	RFA	788,0 KB

Tab. 015 - The table lists the families of structural elements improved to describe the structure of vaulted floor slabs.

Custom families, Doors

Number	Name	Format	Size
001	ACERBO_Raimondi 13_Porta ingresso_Finitura1_140x250.rfa	RFA	464,0 KB
002	ACERBO_Raimondi 13_Porta ingresso_Finitura2_140x250.rfa	RFA	488,0 KB
003	ACERBO_Raimondi 13_Porta ingresso appartamenti_120x250.rfa	RFA	388,0 KB
004	ACERBO_Raimondi 13_Porta interna_70x200.rfa	RFA	375,0 KB
005	ACERBO_Raimondi 13_Porta interna_80x200.rfa	RFA	420,0 KB
006	ACERBO_Raimondi 13_Porta interna_65x200.rfa	RFA	389,0 KB

Tab. 016 - The table lists the custom door families.

Custom families, Windows and Vertical structural openings

Number	Name	Format	Size
001	ACERBO_Raimondi 13_Arch_Bucatura Finestra Sguinciata 3 lati_148x264.rfa	RFA	412,0 KB
002	ACERBO_Raimondi 13_Arch_Bucatura Finestra Sguinciata 3 lati_148x314.rfa	RFA	684,0 KB
003	ACERBO_Raimondi 13_Arch_Bucatura Finestra Sguinciata 4 lati_148x238.rfa	RFA	684,0 KB
004	ACERBO_Raimondi 13_Arch_Finestra 50x80 con grata.rfa	RFA	528,0 KB
005	ACERBO_Raimondi 13_Arch_Finestra 50x80 con lamiera forata.rfa	RFA	772,0 KB
006	ACERBO_Raimondi 13_Arch_Finestra 50x80.rfa	RFA	520,0 KB
007	ACERBO_Raimondi 13_Arch_Finestra Arch_100x190.rfa	RFA	416,0 KB
008	ACERBO_Raimondi 13_Arch_P-1_Finestra cantina 100x40 con grata.rfa	RFA	828,0 KB
009	ACERBO_Raimondi 13_Arch_P1_Finestra corte con scuri_90x150.rfa	RFA	1.032,0 KB
010	ACERBO_Raimondi 13_Arch_P1_Finestra corte con scuri_90x180.rfa	RFA	864,0 KB
011	ACERBO_Raimondi 13_Arch_P1_Finestra corte senza inferriata no sguinci_90x180.rfa	RFA	580,0 KB
012	ACERBO_Raimondi 13_Arch_P1_Finestra decorata con fregio e inferriata_90x180.rfa	RFA	1.456,0 KB
013	ACERBO_Raimondi 13_Arch_P2_P3_Finestra fronte con oscuranti_90x180.rfa	RFA	1.872,0 KB
014	ACERBO_Raimondi 13_Arch_P4_Finestra corte senza inferriata no sguinci_90x150.rfa	RFA	584,0 KB
015	ACERBO_Raimondi 13_Arch_Portafinestra_90x200_2 ante balconi.rfa	RFA	464,0 KB
016	ACERBO_Raimondi 13_Arch_PRialz_Finestra corte con inferriata no sguinci_100x190.rfa	RFA	624,0 KB
017	ACERBO_Raimondi 13_Arch_PRialz_Finestra corte con inferriata_100x190.rfa	RFA	628,0 KB
018	ACERBO_Raimondi 13_Arch_PRialz_Finestra fronte strada con inferriata_90x180.rfa	RFA	636,0 KB
019	ACERBO_Raimondi 13_Arch_Scala_Finestra corte scala_100x200.0001.rfa	RFA	584,0 KB
020	ACERBO_Raimondi 13_Arch_Scala_Finestra corte scala_100x200.rfa	RFA	584,0 KB
021	ACERBO_Raimondi 13_Str_P-1_Finestra cantine_100x40.rfa	RFA	440,0 KB
022	ACERBO_Raimondi 13_Str_P-1_Portale strutt_161x200.rfa	RFA	424,0 KB
023	ACERBO_Raimondi 13_Str_P1_Finestra bagni_50x80.rfa	RFA	416,0 KB
024	ACERBO_Raimondi 13_Str_P1_Finestra sguincio 3 lati_100x155.rfa	RFA	608,0 KB
025	ACERBO_Raimondi 13_Str_P1_Finestra sguincio 3 lati_100x190_v2.rfa	RFA	608,0 KB

026	ACERBO_Raimondi 13_Str_P1_Finestra sguincio 3 lati_90x180.rfa	RFA	608,0 KB
027	ACERBO_Raimondi 13_Str_P1_Finestra sguincio 3 lati_90x180_v3.rfa	RFA	920,0 KB
028	ACERBO_Raimondi 13_Str_P1_Finestra_100x190.rfa	RFA	692,0 KB
029	ACERBO_Raimondi 13_Str_P1_Finestra_90x150.rfa	RFA	664,0 KB
030	ACERBO_Raimondi 13_Str_P1_Finestra_90x180.rfa	RFA	684,0 KB
031	ACERBO_Raimondi 13_Str_P2_Finestra sguincio 3 lati_90x180_v3.rfa	RFA	608,0 KB
032	ACERBO_Raimondi 13_Str_P3_Finestra sguincio 3 lati_90x180_v3.rfa	RFA	608,0 KB
033	ACERBO_Raimondi 13_Str_P4_Finestra sguincio 3 lati_90x180_v3.rfa	RFA	1.068,0 KB
034	ACERBO_Raimondi 13_Str_PRialz_Bucatura finestra sguinciata 4 lati_100x190.rfa	RFA	608,0 KB
035	ACERBO_Raimondi 13_Str_PRialz_Finestra_100x190.rfa	RFA	692,0 KB
036	ACERBO_Raimondi 13_Str_PRialz_Portale strutt_100x200.rfa	RFA	708,0 KB
037	ACERBO_Raimondi 13_Str_PRialz_Portale strutt_120x305.rfa	RFA	424,0 KB
038	ACERBO_Raimondi 13_Str_PRialz_Portale strutt_140x250.rfa	RFA	520,0 KB
039	ACERBO_Raimondi 13_Str_PRialz_Portale strutt_70x190.rfa	RFA	424,0 KB
040	ACERBO_Raimondi 13_Str_PRialz_Portale strutt_75x190.rfa	RFA	424,0 KB
041	ACERBO_Raimondi 13_Str_PRialz_Portale strutt_80x190.rfa	RFA	416,0 KB
042	ACERBO_Raimondi 13_Str_PRialz_Portale strutt_90x190.rfa	RFA	708,0 KB
043	ACERBO_Raimondi 13_Str_PRialz_Portale strutt_90x200.rfa	RFA	424,0 KB
044	ACERBO_Raimondi 13_Str_PRialz_Sovraporta ingresso_100x50.rfa	RFA	416,0 KB
045	ACERBO_Raimondi 13_Str_Scala_Finestra_100x200.rfa	RFA	436,0 KB
046	ACERBO_Raimondi 13_Arch_PSottotetto_Finestra fronte strada 100x150.rfa	RFA	956,0 KB
047	ACERBO_Raimondi 13_P1_Finestra con sguincio semplice_str_100x190_ v2.rfa	RFA	568,0 KB
048	ACERBO_Raimondi 13_Arch_Finestra 100x40 con grata_Test.rfa	RFA	544,0 KB
049	ACERBO_Raimondi 13_Arch_Finestra 50x80 con grata_Test.rfa	RFA	528,0 KB
050	ACERBO_Raimondi 13_Arch_Finestra 50x80 senza grata_Test.rfa	RFA	508,0 KB
051	ACERBO_Raimondi 13_Arch_Finestra con sguincio semplice a terra_ Decorazione tipo secondo piano_intonaco interno_90x150.rfa	RFA	844,0 KB
052	ACERBO_Raimondi 13_Arch_Finestra con sguincio semplice a terra_ Decorazione tipo secondo piano_intonaco interno_90x180.rfa	RFA	1.172,0 KB
053	ACERBO_Raimondi 13_Arch_Finestra con sguincio semplice a terra_intonaco esterno_inferriata_90x180.rfa	RFA	944,0 KB
054	ACERBO_Raimondi 13_Arch_Finestra con sguincio semplice_100x150_Ultimo piano_Corte interna.rfa	RFA	628,0 KB
055	ACERBO_Raimondi 13_Arch_Finestra con sguincio semplice_100x190_primo piano.rfa	RFA	608,0 KB
056	ACERBO_Raimondi 13_Arch_Finestra con sguincio semplice_100x190_primo piano_v2.rfa	RFA	612,0 KB
057	ACERBO_Raimondi 13_Arch_finestra con sguincio_V2.rfa	RFA	464,0 KB
058	ACERBO_Raimondi 13_Arch_Portafinestra_90x200_2 ante balconi.rfa	RFA	448,0 KB

Tab. 017 - The table lists the windows families created to describe the characterisitcs of custom decorated elements.

Custom families, Generic components

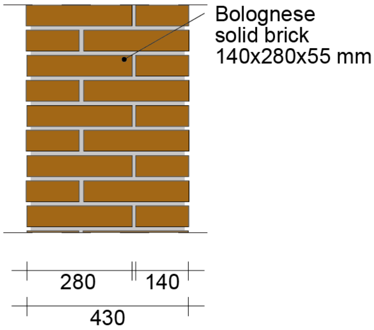
Number	Name	Format	Size
001	ACERBO_Raimondi 13_Arch_Decorazione aggettante_Finestra P1.rfa	RFA	424,0 KB
002	ACERBO_Raimondi 13_Arch_Decorazione sagomata finesta P1.rfa	RFA	684,0 KB
003	ACERBO_Raimondi 13_Arch_Decorazione superiore finestra P1.rfa	RFA	440,0 KB
004	ACERBO_Raimondi 13_Arch_P1_Pannello oscurante finestra_40x150.rfa	RFA	504,0 KB
005	ACERBO_Raimondi 13_Arch_P1_Pannello oscurante finestra_40x180.rfa	RFA	500,0 KB
006	ACERBO_Raimondi 13_Arc_Canna fumaria_Tipo 1.0001.rfa	RFA	432,0 KB
007	ACERBO_Raimondi 13_Arc_Canna fumaria_Tipo 1.rfa	RFA	432,0 KB
008	ACERBO_Raimondi 13_Arc_Rivestimento Pedata.0001.rfa	RFA	404,0 KB
009	ACERBO_Raimondi 13_Arc_Rivestimento Pedata.rfa	RFA	424,0 KB

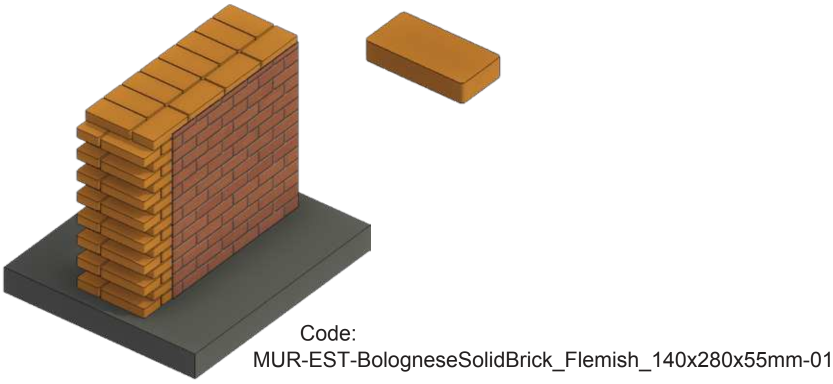
010	ACERBO_Raimondi 13_Arc_Rivestimento Pedata_Sinistro.rfa	RFA	424,0 KB
011	ACERBO_Raimondi 13_Arc_Rivestimento Pianerottolo destro.rfa	RFA	424,0 KB
012	ACERBO_Raimondi 13_Arc_Rivestimento Pianerottolo sinistro.rfa	RFA	408,0 KB
013	ACERBO_Raimondi 13_Arc_Rivestimento Pianerottolo sinistro_PT.rfa	RFA	408,0 KB
014	ACERBO_Raimondi 13_Profilo parapetto corto.rfa	RFA	648,0 KB
015	ACERBO_Raimondi 13_Profilo parapetto.rfa	RFA	948,0 KB
016	ACERBO_Raimondi 13_Str_Pianerottolo esterno.rfa	RFA	392,0 KB
017	ACERBO_Raimondi 13_Str_Pianerottolo interno.rfa	RFA	404,0 KB
018	ACERBO_Raimondi 13_Str_Piastra rinforzo strutturale_Ext.rfa	RFA	404,0 KB
019	ACERBO_Raimondi 13_Str_PRialz_Pianerottolo esterno.rfa	RFA	392,0 KB
020	ACERBO_Raimondi 13_Str_PRialz_Pianerottolo interno.rfa	RFA	392,0 KB
021	ACERBO_Raimondi 13_Str_Rampa corta_PT_PRialz.rfa	RFA	504,0 KB
022	ACERBO_Raimondi 13_Str_Rampa destra_PRialz_P1.rfa	RFA	508,0 KB
023	ACERBO_Raimondi 13_Str_Rampa_P-1_PT.rfa	RFA	692,0 KB
024	ACERBO_Raimondi 13_Str_Rampa_P1_Pianerottolo.rfa	RFA	588,0 KB
025	ACERBO_Raimondi 13_Str_Rampa_PT-Pianerottolo.rfa	RFA	500,0 KB
026	ACERBO_Raimondi 13_Travetto soffitto sottotetto_1000.rfa	RFA	400,0 KB
027	ACERBO_Raimondi 13_Travetto soffitto sottotetto_930.rfa	RFA	636,0 KB
028	ACERBO_Raimondi_13_StrFloor_Voltine porzioni_55.9.rfa	RFA	392,0 KB
029	ACERBO_Raimondi_13_StrFloor_Voltine porzioni_56.4.rfa	RFA	676,0 KB
030	ACERBO_Raimondi_13_StrFloor_Voltine porzioni_97.rfa	RFA	636,0 KB
031	ACERBO_Raimondi_13_StrFloor_Voltine_80.5.rfa	RFA	392,0 KB
032	ACERBO_Raimondi_13_StrFloor_Voltine_80.rfa	RFA	392,0 KB
033	ACERBO_Raimondi_13_StrFloor_Voltine_80_Long 505.rfa	RFA	392,0 KB
034	ACERBO_Raimondi_13_StrFloor_Voltine_89.2.rfa	RFA	624,0 KB
035	ACERBO_Raimondi_13_StrFloor_Voltine_92.5.rfa	RFA	676,0 KB
036	ACERBO_Raimondi_13_StrFloor_Voltine_93.5.rfa	RFA	676,0 KB
037	ACERBO_Raimondi_13_Decorazione a rilievo_Finestra primo piano.rfa	RFA	780,0 KB
038	ACERBO_Raimondi_13_Scalinata ingresso.rfa	RFA	404,0 KB
039	ACERBO_Raimondi_13_Travetto soffitto sottotetto_1000.rfa	RFA	676,0 KB
040	ACERBO_Raimondi_13_Travetto soffitto sottotetto_930.rfa	RFA	636,0 KB
041	FASSA_ELIWALL.rfa	RFA	416,0 KB
042	FASSA_Malta strutturale 790_iniezione.rfa	RFA	456,0 KB
043	FASSA_Malta strutturale NHL 712.rfa	RFA	432,0 KB

Tab. 018 - The table lists of generic model families created as a support for the As-Is developement of the model.

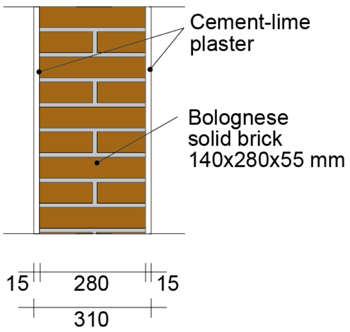
5.3.2.3 Case study II, Wall structure

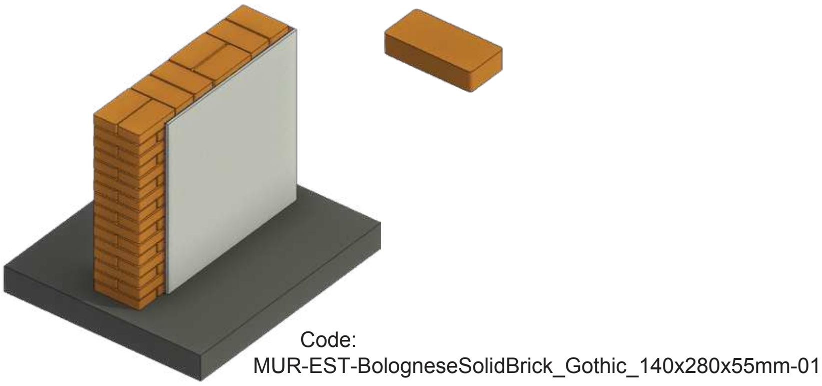
STR 1



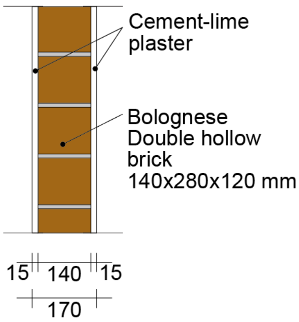


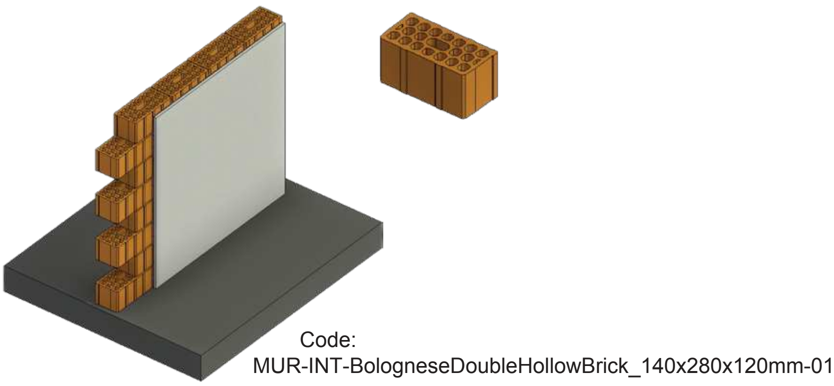
STR 2



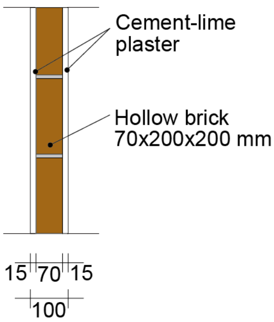


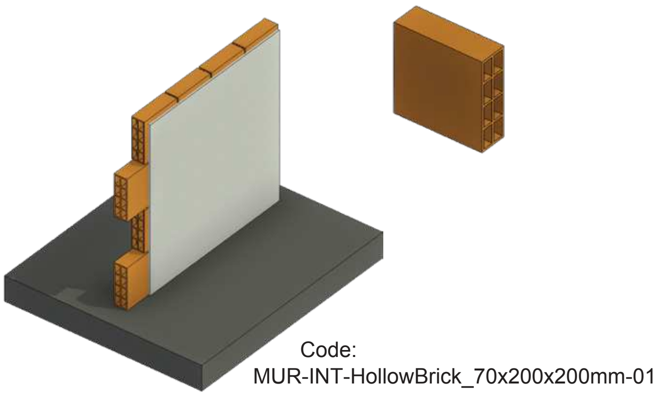
STR 3



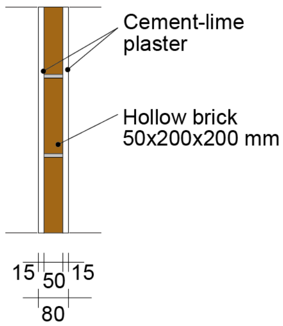


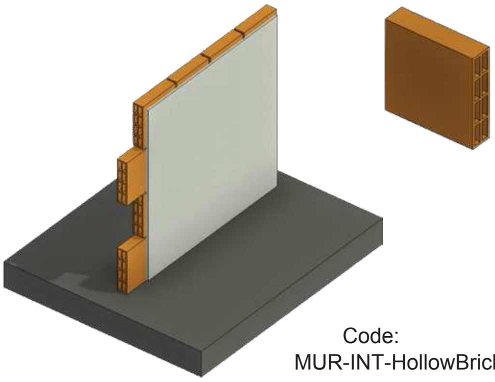
STR 4





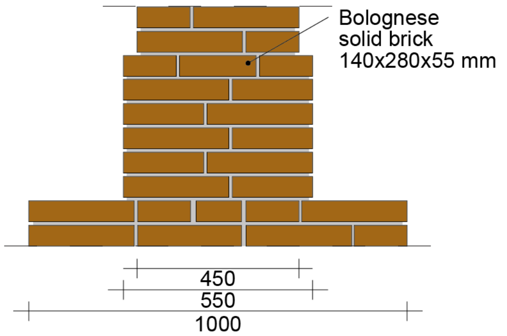
STR 5

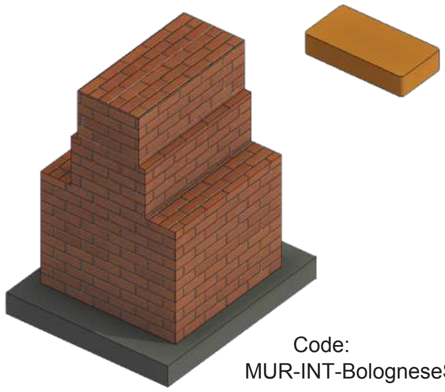




Code:
MUR-INT-HollowBrick_50x200x200mm-01

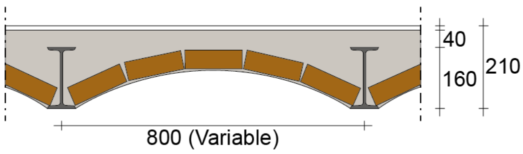
STR 6





Code:
MUR-INT-BologneseSolidBrick_Foundation-01

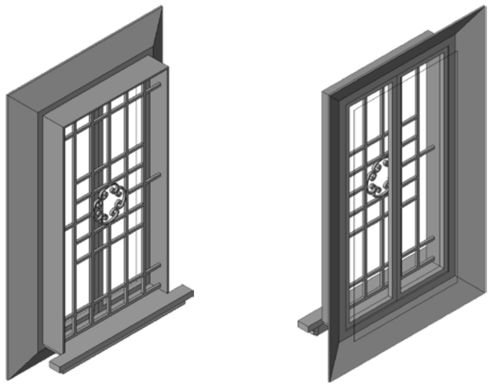
5.3.2.4 Case study II, Floor structure



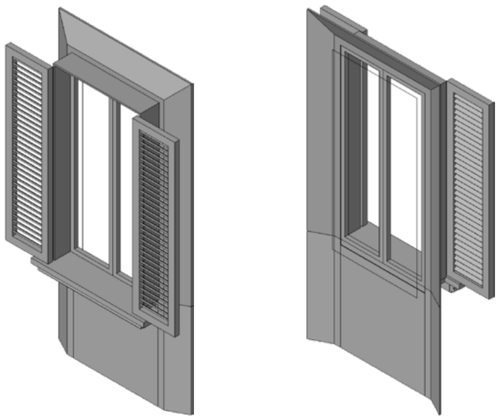
Code:
SOL-STR-VaultedBrick-01

5.3.2.5 Case study II, Windows families

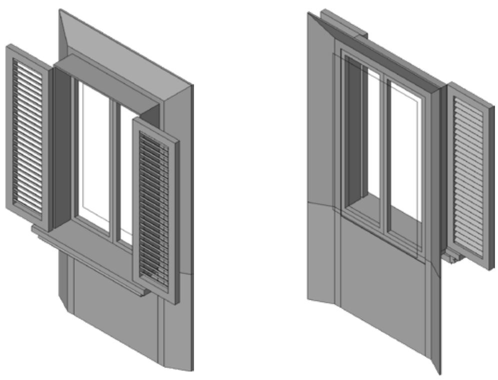
Summary table of window nested families. The frames have varying levels of complexity, more elaborate on the main face and less on the internal façade. Each family consists of the wall trim, the fixed frame and the pivoting components. There are also elements that describe the decorative elements and the external shutters.



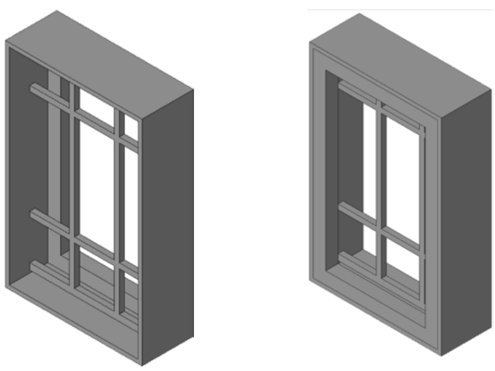
Code:
FIN-ADV-SlantedWindow_4side_1000x1900mm-01



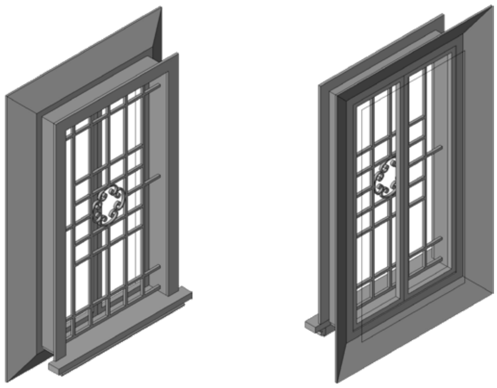
Code:
FIN-ADV-SlantedWindow_3side_1000x1900mm-01



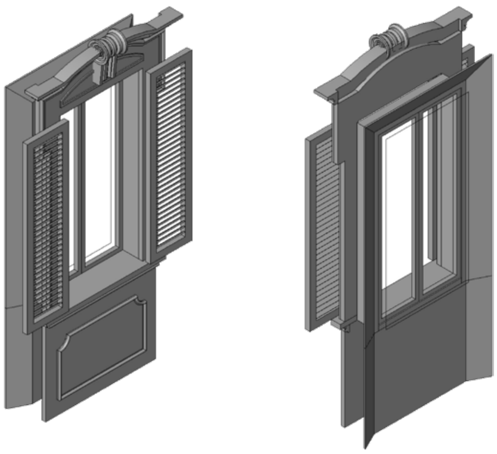
Code:
FIN-ADV-SlantedWindow_3side_1000x1500mm-01



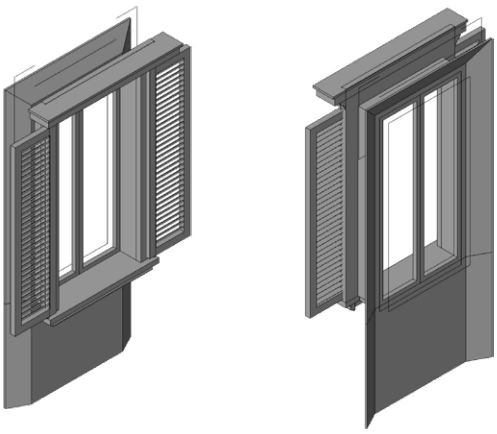
Code:
FIN-ADV-BathWindow_500x800mm-01



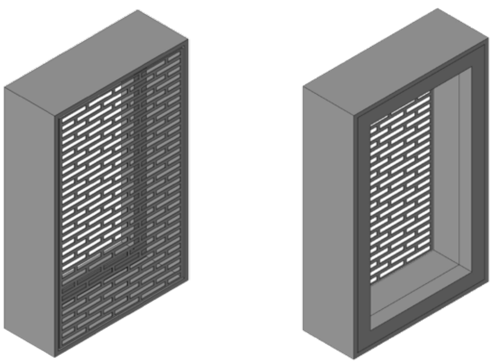
Code:
FIN-ADV-SlantedWindow_4side_Decorated_1000x1900mm-01



Code:
FIN-ADV-SlantedWindow_3side_Decorated_1000x1900mm-01



Code:
FIN-ADV-SlantedWindow_3side_Decorated_1000x1700mm-01



Code:
FIN-ADV-BathWindow_Shaded_500x800mm-01

5.3.2.6 Case study II, Discipline federation

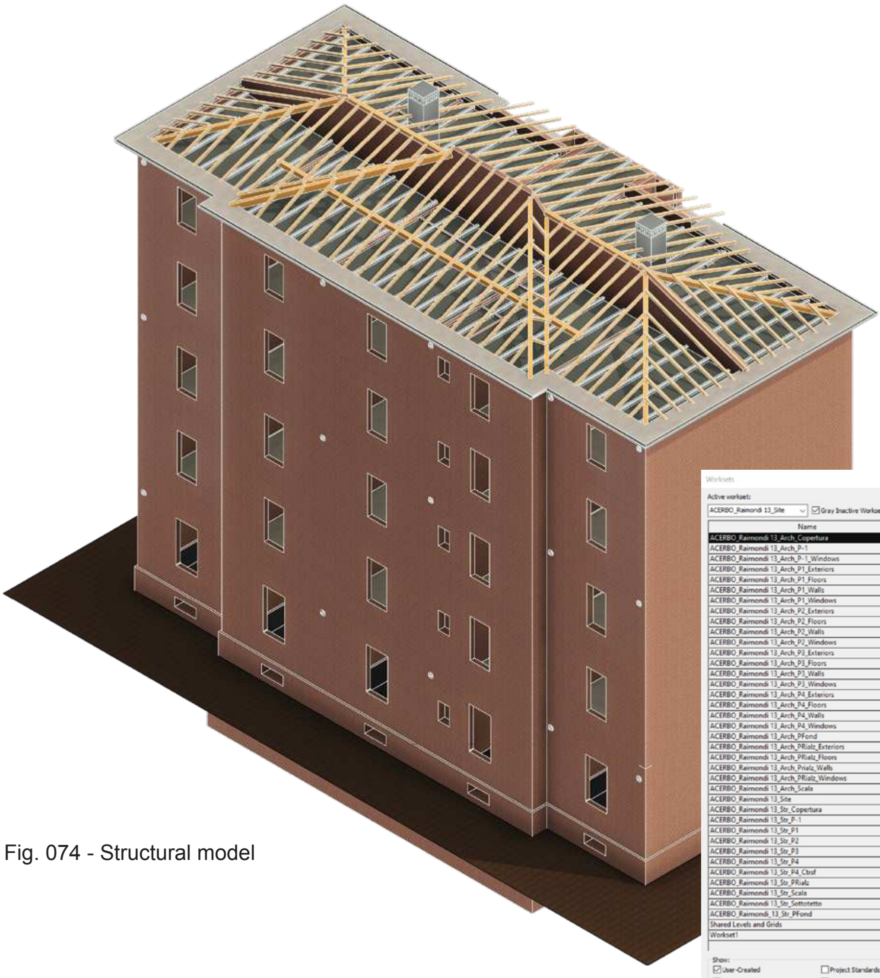
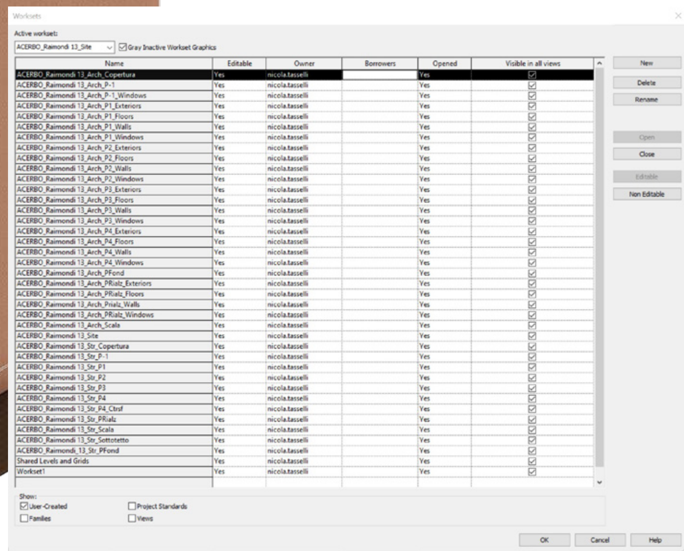
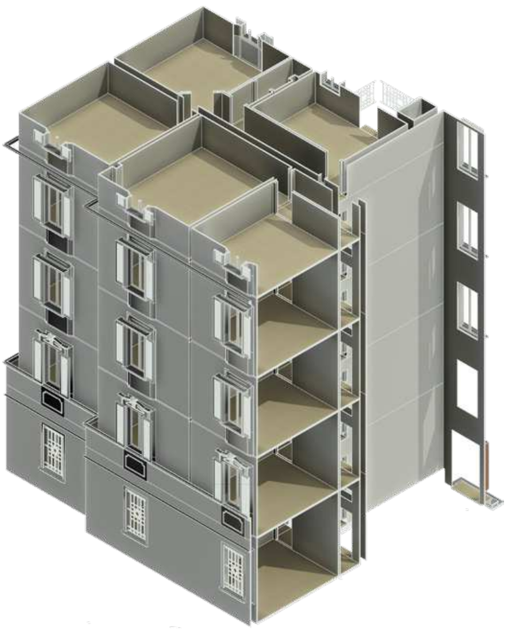


Fig. 074 - Structural model

Fig. 075 - The BIM Authoring software screen where the worksets used to decompose the model's subject areas are listed.





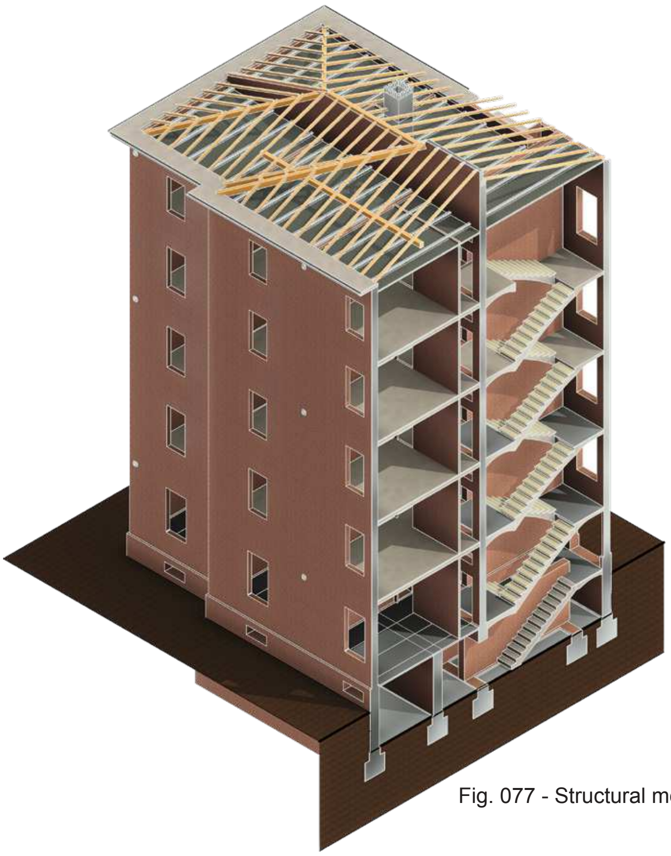


Fig. 076 - Architectural model (cutaway)

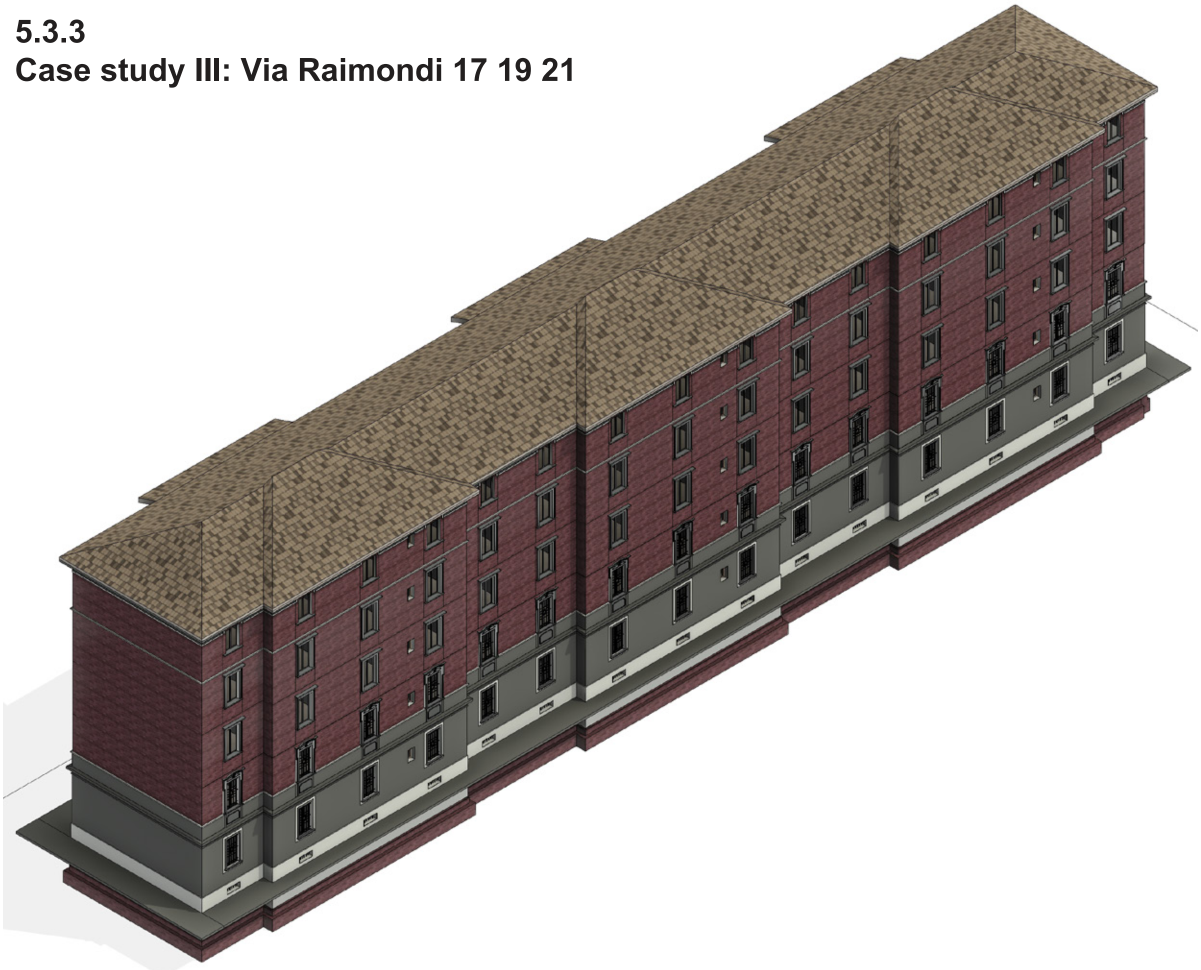
Fig. 077 - Structural model (cutaway)

Fig. 078 - Main external façade

Fig. 079 - Façade on the courtyard

Fig. 080 - Google. (n.d.). [Map of the city of Bologna]. Retrieved 10/01/2023, from earth.google.com

5.3.3
Case study III: Via Raimondi 17 19 21



BOLOGNINA DISTRICT
2022_ACERBO_Via Raimondi_17_19_21

Model Code:
ACB0003-ACB-AB0000001-XX-M3-A-S0001

Model coordinates:
44.50859°N, 11.34868°W
44.6 m a.s.l.
North rotation 10°

The case study is located in the Bolognina district, close to Bologna's railway station and is part of a complex of in-line buildings that outline the block containing them. This block is one of the first lots built by the IACP as part of the expansion planned in 1889, outside the medieval walls north of the city. The building was constructed in 1924 by the Cooperativa Costruzione e Risanamento according to the design of Engineer Ildebrando Tabarroni.
As mentioned in the description of case study II (Via Raimondi, 13), whose technical morphological report it shares, the building is composed of the linear repetition of the same module thrice. The resulting structure is therefore composed of 45 flats, 15 of which face the external front and 30 on the internal front, served by three independent stairwells.
The components of the building remain stylistically identical to Case Study II, while a much lower level of maintenance can be observed. On the main façade, deteriorated elements can be seen. Marks left by the closure of two windows on each floor, also present in other buildings of the same kind but not on all of them, are visible in the end wall on the left side of the building.

5.3.3.1 Case study III, planning regulation

The table collects information on the cadastral identification of the asset in addition to the indications provided in the general urban plan (PUG). The PUG lists the planned development activities and constraints for the real estate in the municipal area of Bologna. Information on restrictions on feasible architectural interventions on the asset, as provided by the competent superintendency, is also listed.

CS_Raimondi 17, 19, 21		
Unit number	Via Marcantonio Raimondi 17, 19, 21	
District	Navile	
Cadastral number	Sheet 119, map 220	
District	Bolognina	
Construction restrictions (Vincoli in rete, http://vincoliinrete.beniculturali.it)		
ID	500474	
Designation	via Marc'Antonio Raimondi nn. 17-19-21	
Schedule type	Architecture	
Legal status	Non-territorial public body ownership	
Purpose of use	Residential	
Cultural interest	Declared cultural interest	
Hierarchy	Complex	
Region	Emilia-Romagna	
Province	Bologna	
Municipality	Bologna	
Competent body (ECP)	S261 (SABAP-BO)	Superintendence of Archaeology, Fine Arts and Landscape for the metropolitan city of Bologna and the provinces of Modena, Reggio Emilia and Ferrara
Filing body (ESC)	S163 (SBAP-BO)	Superintendence for Architectural and Landscape Heritage for the Provinces of Bologna Modena and Reggio Emilia
Historical period	1924	
Source systems		
SigecWeb	No	
Risk map	82541	
Listed assets	3768	
VirApp	No	
ICCD	No	
Cadastral data		
Cadastral code	sheet	number
A944	119	220
A945	119	220
A946	119	48
A947	119	223
Data source		
http://vincoliinrete.beniculturali.it/VincoliInRete/vir/bene/dettagliobene500474		

PUG - Plan discipline (Piano Urbanistico Generale - Disciplina del piano, http://sitmappe.comune.bologna.it/pugviewer)		
PUG - Table of restrictions - Protection of Water Resources and Hydrogeological Structure		
Restrictions (Table of restrictions effective 23/11/2022)	Protection	Areas potentially affected by rare flooding - Main reticulum
	Protection	Areas potentially affected by infrequent flooding - Main reticulum
PUG - Table of restrictions - Protection of Natural and Landscape Elements		
Restrictions (Table of restrictions effective 23/11/2022)	Protection	Forests and assimilated areas within the meaning of Legislative Decree 34/2018
PUG - Table of restrictions - Protection of Historical and Archaeological Evidence		
Restrictions (Table of restrictions effective 23/11/2022)	Protection	Cultural Heritage - Cultural Heritage subject to declaration (Legislative Decree 42/2004, Art. 13)
	Protection	Low archaeological potential areas
	Protection	Buildings of interest - Buildings of cultural and testimonial interest
PUG - Table of restrictions - Seismic Risk Protection		
Restrictions (Table of restrictions effective 23/11/2022)	Protection	Homogeneous macro-zones in seismic perspective - Liquefaction Attention Zones 2A
PUG - Table of restrictions - Constraints Infrastructure, land and easements		
Restrictions (Table of restrictions effective 23/11/2022)	Protection	Streets
PUG - Table of restrictions - Constraints for aviation infrastructure		
Restrictions (Table of restrictions effective 23/11/2022)	Restriction	Obstacle delimitation specifications - conical surface - Slope 1:20
	Restriction	Air Navigation Obstacles - Areas Affected by Variable Height Obstacle Boundary Surfaces (Annex A)
	Restriction	Air navigation hazards - Typology 1 (Table PC01A); Typology 2 (Table PC01A); Typology 3 - Limits laser projector sources (Table PC01B); Typology 4 - Wind power plants - Area of absolute incompatibility (Table PC01C)
PUG - Table of restrictions - Constraints Electromagnetism		
Restrictions (Table of restrictions effective 23/11/2022)	Restriction	Areas where the location of fixed mobile telephony installations is prohibited - buffer zone for sensitive receptors
	Restriction	Radio/TV Broadcasting - Area of Prohibition of Plant Location
Strategy:		
Data source:		
shorturl.at/dG034		

Tab. 019 - The table summarises the main regulatory strategies foreseen in the Regional Urban Plan (PUG) for the case study.

5.3.3.2 Case study III, model morphology

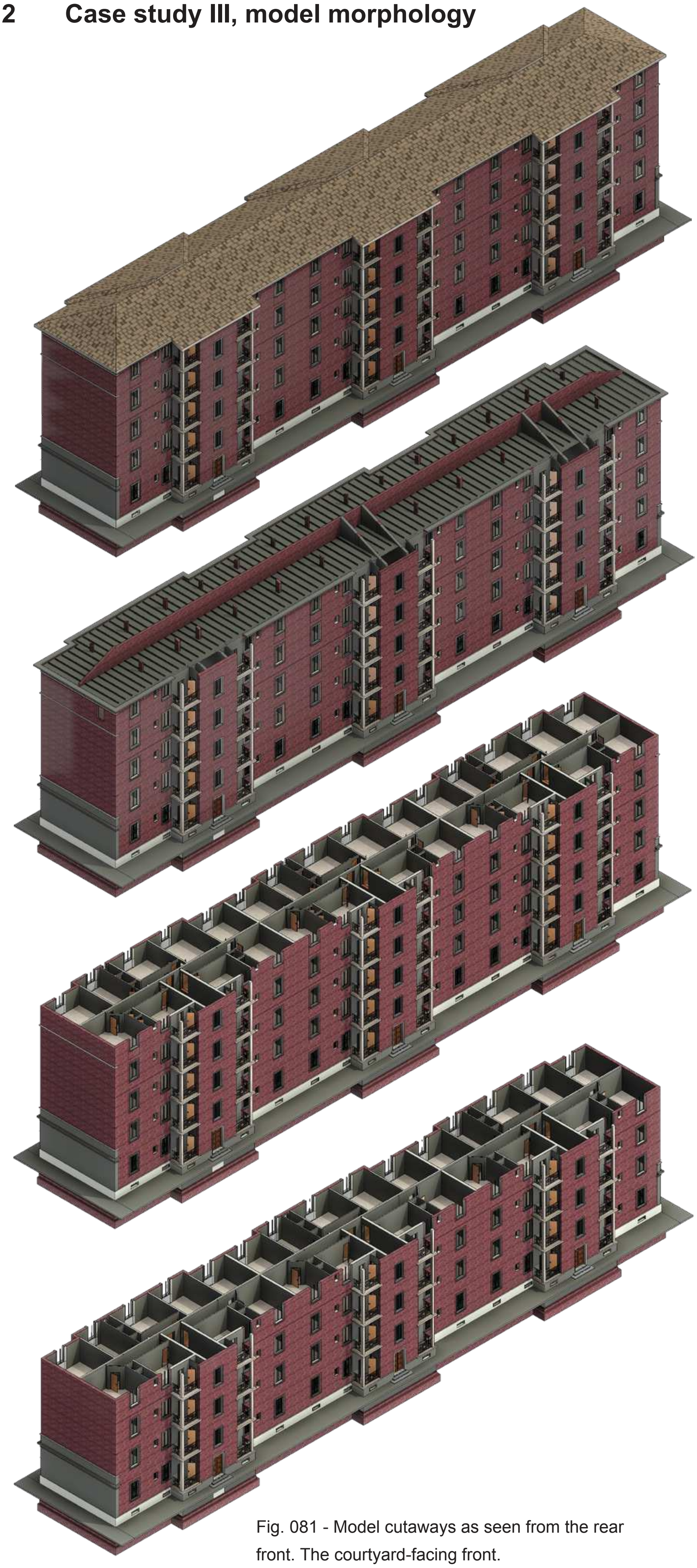
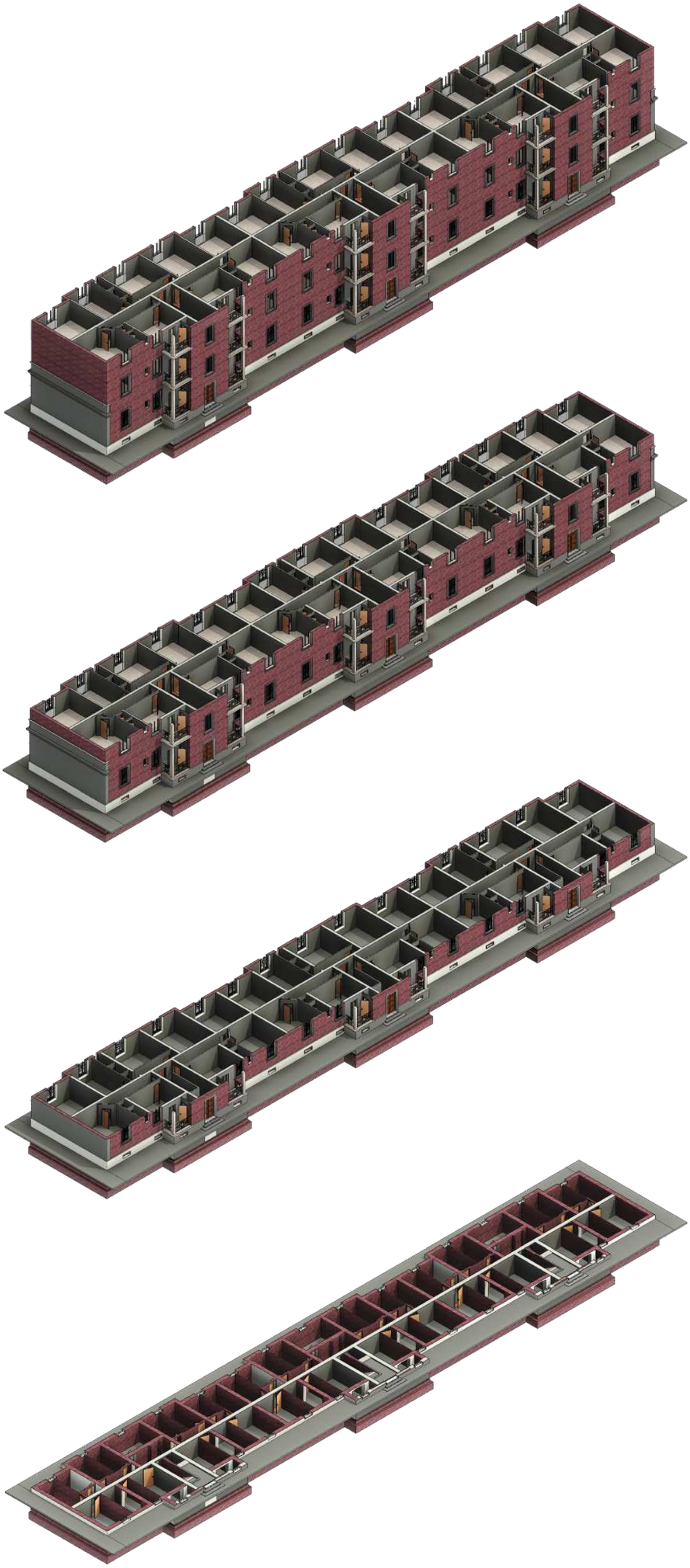


Fig. 081 - Model cutaways as seen from the rear front. The courtyard-facing front.



5.3.3.3 Case study II&III, model federation

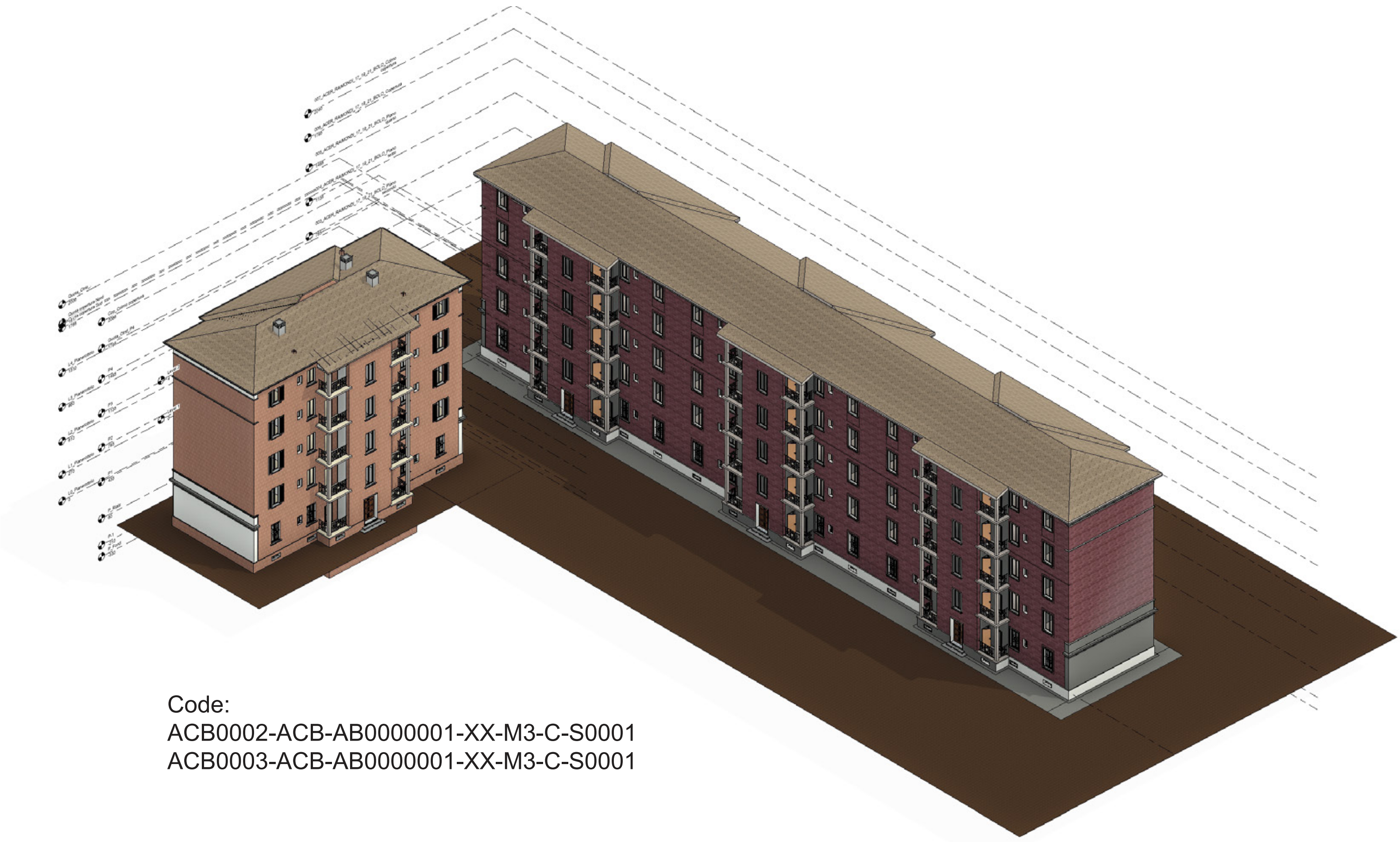


Fig. 082 - View of the federated model contains the disciplines' architecture and structure of case studies II and III.

Level of information development

The level of information development of components frames the data model and defines the quantity and quality of the information component conveyed. These values are functional to the objectives set for each phase set in the model. The development level of an object is the result of geometric and non-geometric information, which may be represented in either graphic or alphanumeric form. This information, and the level of complexity at which it is represented, provides the basis for a correct evaluation of the content.
The elements constituting the model must be accurately represented in terms of size, shape, position and quantity in relation to their location in the project.
The standard defined by the client does not impose a "minimum level" to be reached for each PBIM (Product Building Information Modelling) product or data model, but delegates to the model maker the definition of the requirements necessary to achieve the objectives.

Architectural Model

The definition of the architectural data model consists of a geometric and an information component. The level of geometric development represents the digital version of the as-built, developed from the survey information. This model will match the real in terms of quantity, size, shape, and orientation of the constituent components. Each architectural element will be represented by creating a three-dimensional component of equal dimensions, accurate

in stratigraphy and thickness. For buildings of historical-architectural value (Lots identified as “valuable”), a 2D restitution (plans, elevations and sections) shall be produced, and elaborated at a higher level of detail, in accordance with valuable elements. (mouldings, frames, string courses, architraves, columns, rosettes). The level of information developed represents the information component included in the data model. This component is the result of data collection on the specific asset and is necessary to develop in-depth knowledge of the technological systems and materials. Such data may also be the result of specific thematic investigations, such as energy verification or seismic vulnerability.
Each element should contain information on its constituent materials, finishes, thermal and physical characteristics, fire resistance class, the floor to which it belongs and its exposure.

Structural Model

The structural survey shall be carried out taking into consideration the characteristics required to carry out the seismic vulnerability check and to define the seismic risk class.
At the geometric development level, the model will have to represent all the compositional elements of the structure, both horizontal and vertical, creating components that display the real dimensions using the reference standards. At the level of information development, the model shall contain the information found on site, in addition to the information obtained from specific diagnostic investigations. Each element shall contain information on technical performance, materials, and mechanical properties. The information regarding the compositional aspects of the structure shall be integrated with two-dimensional elaborations extracted from the BIM model (crack picture, technological details of the nodes, etc.).
The level of approximation concerning dimensions and quantities obtained from the BIM data model shall not be less than that used for the elaborations drawn up with a traditional methodology. The levels of development envisaged for the individual thematic models are to be indicated in the information management offer.

System models (HAVC)

In addition to the disciplinary models of architecture and structures, models relating to heating, plumbing and electrical systems may be required.
Each system disciplinary model should conceptually represent all elements. Therefore, the spaces and overall dimensions of the main components and the holes required for the plant layouts should be defined.
At the information development level, the model shall contain the surveyed information of the existing system necessary for in-depth knowledge of the system. Each modelled element will have the performance information that identifies it and enables its functional analysis. (Type, flow rate, power, etc.). The information on the compositional aspects of the system will be supplemented with two-dimensional drawings extracted from the BIM model (plant paths on plan or section).

Fig. 083 - Google. (n.d.). [Map of the city of Bologna]. Retrieved 10/01/2023, from earth.google.com

5.2.4
Case study IV: Cirenaica District

CIRENAICA DISTRICT

—
2022_ACERBO_Via Libia_23_27
(Geoportale referencing id 23,25,27,29)

Model coordinates:
44.49466°N, 11.36605°W
52.9 m a.s.l.
North rotation 176°

—
2022_ACERBO_Via Bentivogli_47_55
(Geoportale referencing id 47,49,51,53,55,59)

Model coordinates:
44.49509°N, 11.36474°W
52.7 m a.s.l.
North rotation 174°

—
2022_ACERBO_Via Bentivogli_31_37
(Geoportale referencing id 31,29/2,29/2A,29/2B,22,35,37,24,24/A,24/B)

Model coordinates:
44.49458°N, 11.36482°W
52.9 m a.s.l.
North rotation 174°

Case Study IV represents the first lot in which the modular system used in Case Studies II and III was employed. The first buildings were constructed in 1913, followed by others at the end of the First World War from 1920 to 1923. The housing development was executed by the Cooperativa Costruzione e Risanamento based on the project of Engineer Ildebrando Tabarroni.
The Cyrenaica complex is protected as an element of declared cultural interest.

5.3.4.1 Case study IV, planning regulation

The table collects information on the cadastral identification of the asset in addition to the indications provided in the general urban plan (PUG). The PUG lists the planned development activities and constraints for the real estate in the municipal area of Bologna. Information on restrictions on feasible architectural interventions on the asset, as provided by the competent superintendency, is also listed.

CS_Libia		
Unit numb.	Via Gianni Palmieri 22, 24, 24/A, 24/B; Via Giuseppe Bentivogli 29/2, 29/2A, 29/2B, 31, 33, 35, 37, 47, 49, 51, 53, 55, 59; Via Libia 20/2, 20/2A, 20/3, 20/4, 20/5, 20/5A; Via Musolesi 23, 23/A	
District	San Donato . San Vitale	
Cadastral numb.	Sheet 192, map 591	
District	Cirenaica-Massarenti-Scandellara	
Construction restrictions (Vincoli in rete, http://vincoliinrete.beniculturali.it)		
ID	430289	
Designation	via Giuseppe Bentivogli n. 35	
Schedule type	Architecture	
Legal status	Non-territorial public body ownership	
Purpose of use	Residential	
Cultural interest	Declared cultural interest	
Hierarchy	Complex	
Region	Emilia-Romagna	
Province	Bologna	
Municipality	Bologna	
Competent body (ECP)	S261 (SABAP-BO)	Superintendence of Archaeology, Fine Arts and Landscape for the metropolitan city of Bologna and the provinces of Modena, Reggio Emilia and Ferrara
Filing body (ESC)	S143 (SBAP-BO)	Superintendence for Architectural and Landscape Heritage for the Provinces of Bologna Modena and Reggio Emilia
Historical period	1920	
Source systems		
SigecWeb	No	
Risk chart	157319	
Listed element	5494	
VirApp	No	
ICCD	No	
Cadastral data		
Cadastral code	sheet	number
A944	192	591
A945	192	591
Data source		
http://vincoliinrete.beniculturali.it/VincoliInRete/vir/bene/dettagliobene430289		

PUG - Plan discipline (Piano Urbanistico Generale - Disciplina del piano, http://sitmappe.comune.bologna.it/pugviewer)			
PUG - Local strategies			
Plan Regulations (General Urban Plan effective from 29/09/2021)	4 Local strategies	4.1 References for the Implementation of Local Strategies	Areas affected by man-made hazards - electromagnetism; Cirenaica-Massarenti-Scandellara; Green and blue infrastructure; Recognisable places
PUG - Plan discipline - Resilience and environment			
Plan Regulations (General Urban Plan effective from 29/09/2021)	1.1 Promoting the regeneration of anthropised soils and counteracting soil consumption	1.1a Encouraging the renovation and efficiency of the existing building stock	Existing built heritage
		1.1d Strengthening already established functions and promoting de-sealment interventions	municipal area
	1.2 Developing the urban eco-network	1.2b Enhancing urban green infrastructure	Boundary of urbanised territory
		1.2c Building an urban blue infrastructure	municipal area
		1.2d Maintaining natural flow rates in the riverbed and reducing groundwater withdrawals	municipal area
		1.2e Improving surface water quality	municipal area
	1.3 Preventing and mitigating environmental risks	1.3a Containing natural hazards	Slope stability - Water resources and hydrogeological structure - Seismic risk
		1.3c Mitigating the heat island effect in urban areas and introducing measures for climate adaptation in buildings	Microclimatic fragility - medium to low fragility
		1.3d Reducing population exposure to pollution and anthropogenic hazards	Accessibility to the local public transport carrier network, Mobile telephony installations - area 200 metres away, Perimeter of urbanised territory, Municipal territory
	1.4 Supporting energy transaction and circular economy processes	1.4a Promoting and incentivising different forms of energy efficiency and fair accessibility to energy services with low environmental impact	municipal area
		1.4b Planning the deployment of energy production plants from renewable sources by creating local distribution networks	municipal area
		1.4c Stimulating the circular economy of construction and excavation materials	municipal area
		1.4d Encouraging recycling and reducing waste production	municipal area
PUG - Plan discipline - Housing and inclusion			
Plan Regulations (General Urban Plan effective from 29/09/2021)	2.1 Enhancing housing access	2.1a Promoting the increase and innovation of rental housing supply	Boundary of urbanised territory
		2.1b Promoting an increase in social housing supply	Aree in cui aumentare l'offerta di ERS
		2.1c Testing new forms of housing	municipal area
		2.1e Involving communities through participatory processes	Boundary of urbanised territory
	2.2 Ensuring the deployment of a balanced network of quality facilities and services	2.2a Fostering the redevelopment and realisation of territorial endowments	municipal area

		2.2b Supporting a balanced spread of spaces for culture	Boundary of urbanised territory
		2.2c Promoting services and neighbourhood commercial activities	Boundary of urbanised territory, municipal area
		2.2d Supporting sustainable logistics	Boundary of urbanised territory, municipal area
		2.2e Experimenting with new forms of temporary management of brownfield sites	municipal area
	2.3 Re-designing spaces and equipment	2.3a Making the city universally accessible	municipal area
		2.3b Realising open spaces and public buildings of high architectural and environmental quality	Boundary of urbanised territory
		2.3c Renovating street space in terms of formal and environmental quality, accessibility and safety	Accessibility to the local public transport core network, municipal area
	2.4 Preserving the character of the historic urban landscape by renewing its role	2.4a Defending the habitability and character of the historic city	Buildings of interest - Buildings of historical-architectural interest, Buildings without special interest in the historic city fabric - ES, Historic city fabric - compact fabric
		2.4c Ensuring the preservation of heritage of historical architectural and cultural witnessing interest	Buildings of interest - Buildings of historical and architectural interest
PUG - Plan discipline - Attractiveness and work			
Plan Regulations (General Urban Plan effective from 29/09/2021)	3.1 Supporting comprehensive urban re-infrastructure	3.1a Reconstruct the unique map of infrastructure networks, nodes and intersections, operators	Boundary of urbanised territory
		3.1b Ensuring the improvement of urban infrastructure with urban transformation interventions	Boundary of urbanised territory
		3.1c Facilitating the deployment and coordination of digital infrastructures	Boundary of urbanised territory
		3.1f Building the urban tram network	Boundary of urbanised territory
		3.1g Extend and integrate the backbone of the urban and suburban cycle network	municipal area
	3.2 Favouring the widespread settlement of economic activities under environmentally compatible conditions	3.2a Ensuring regulatory and procedural flexibility for existing companies	Boundary of urbanised territory
		3.2b Intercepting new production needs by orienting them towards the reuse and regeneration of urbanised territory	Boundary of urbanised territory
		3.2d Promoting the establishment of innovative companies and the promotion of innovation centres	Boundary of urbanised territory
Strategy:			
http://sit.comune.bologna.it/alfresco/d/d/workspace/SpacesStore/c88d9f39-4d2a-4456-8f59-23065061b265/SL_Cirenaica-MassarentiScandellara_20210807.pdf			
Data source:			
shorturl.at/hMZ13			

Tab. 020 - The table summarises the main regulatory strategies foreseen in the Regional Urban Plan (PUG) for the case study.

Chapter 6 - Smart packages: TO-BE Digital tools for the innovation of components, systems and materials (Digital fabrication)

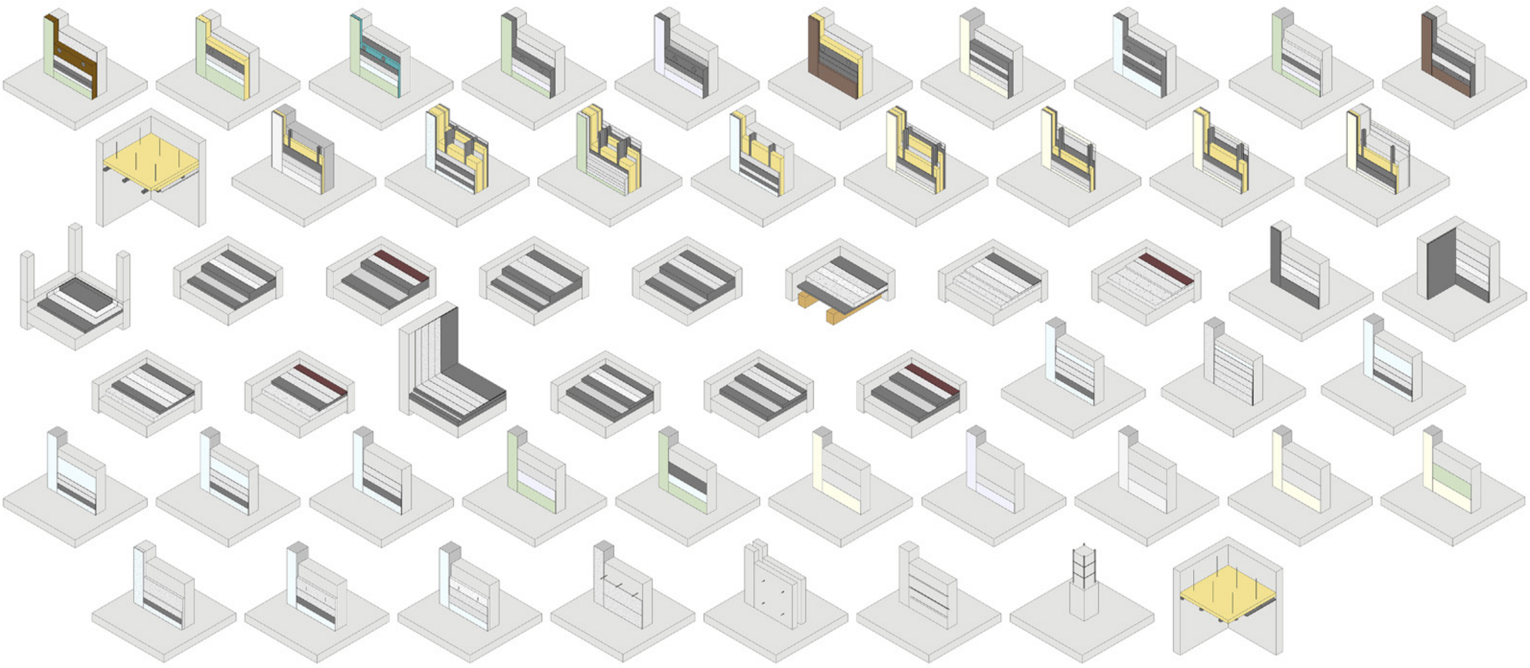


Fig. 084 - The library of standard smart packages developed for the first production batch.

Chapter 6
Smart packages: TO-BE Digital tools for the innovation of components, systems and materials (Digital fabrication)

6.1 BIM smart package

Following the analysis phase, a set of key indicators for the intervention on the existing buildings was defined. The identified needs are related to the building owner (or manager), professionals involved in the intervention design (architectural and structural designer, building process managers), operational workers (construction companies and contractors) and components producers (building product manufacturers). One of the research objectives is to involve all actors in developing and managing the BIM model.

The BIM methodology is considered a widely diffused standard for new constructions. If applied to the intervention on the built environment, the path towards an extensive adoption is still far to come. Small and medium-sized companies, or those that are less open to technological advances, struggle to organise themselves in such a way as to find and employ the necessary skills to implement a BIM workflow.

If the design world is already oriented towards this transaction fairly uniformly, this cannot be said for the other stakeholders. A quite significant difference in technological receptiveness to computer-aided project management (Travaglini et al., 2014) is quite evident when the different players are examined.

The main challenge is the complexity of the process managed through BIM, which requires a planned, coordinated, and synchronised effort from all the involved actors.

To foster an inclusive approach to the process, the research methodology proposes simplified tools and procedures, designed to allow a gradual transition into the world of parametric BIM methodology.

The research investigates the topic of digitisation through the BIM methodology of a sample of digital “technological systems”. These technological systems are layered materials designed to solve specific intervention problems in the existing built environment (Becerik-Gerber et al., 2012).

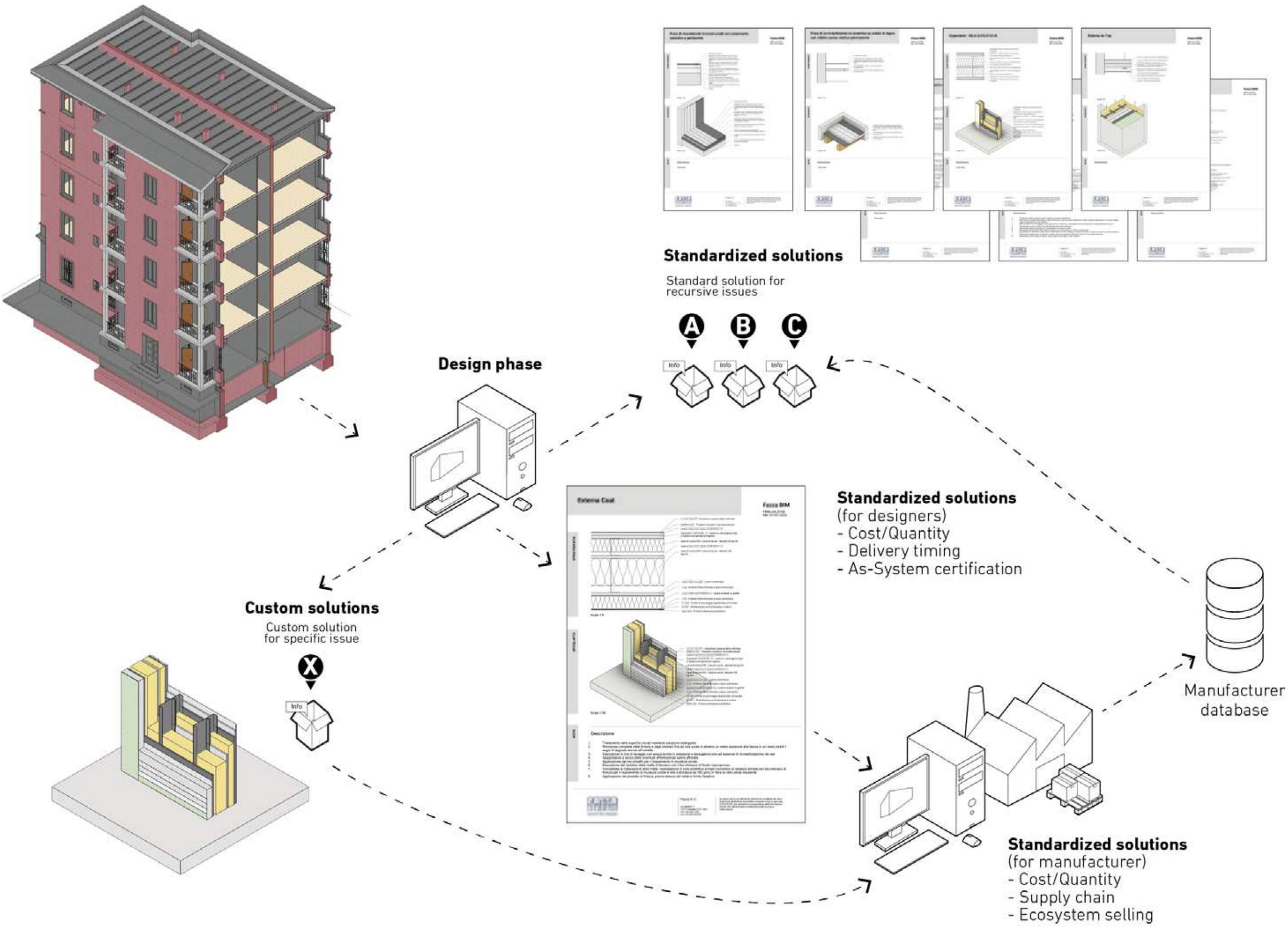


Fig. 085 - Workflow of the smart package development methodology, the designer can choose between library solutions or propose a custom solution that will be produced on demand.

The product packages represent a solution developed by the manufacturer to provide the most effective product system, considering the compatibility between the individual elements of which they are composed.
The problem-solution approach means that a range of sufficiently comprehensive developable solutions can be identified to cover a significant amount of the designers' requirements.
The packages represent an initial development batch to start covering the most statistically recurrent intervention cases. Therefore, it was decided to define a first batch of sixty technological solutions, divided into six macro-areas of intervention.
The areas of development concern: thermal insulation of the envelope, surface finishes, dehumidification packages, consolidation packages, drywall and the installation of coatings. Since the main focus of the work was on the building envelope, it was decided to develop envelope-oriented packages. However, it was also decided to include a minor number of interior renovation packages in the first development phase. This second line of development was created to verify that the features implemented in the development phase were exhaustive and would guarantee the scalability and application of the methodology in other areas.
Given the number and variety of materials involved in creating the packages and the

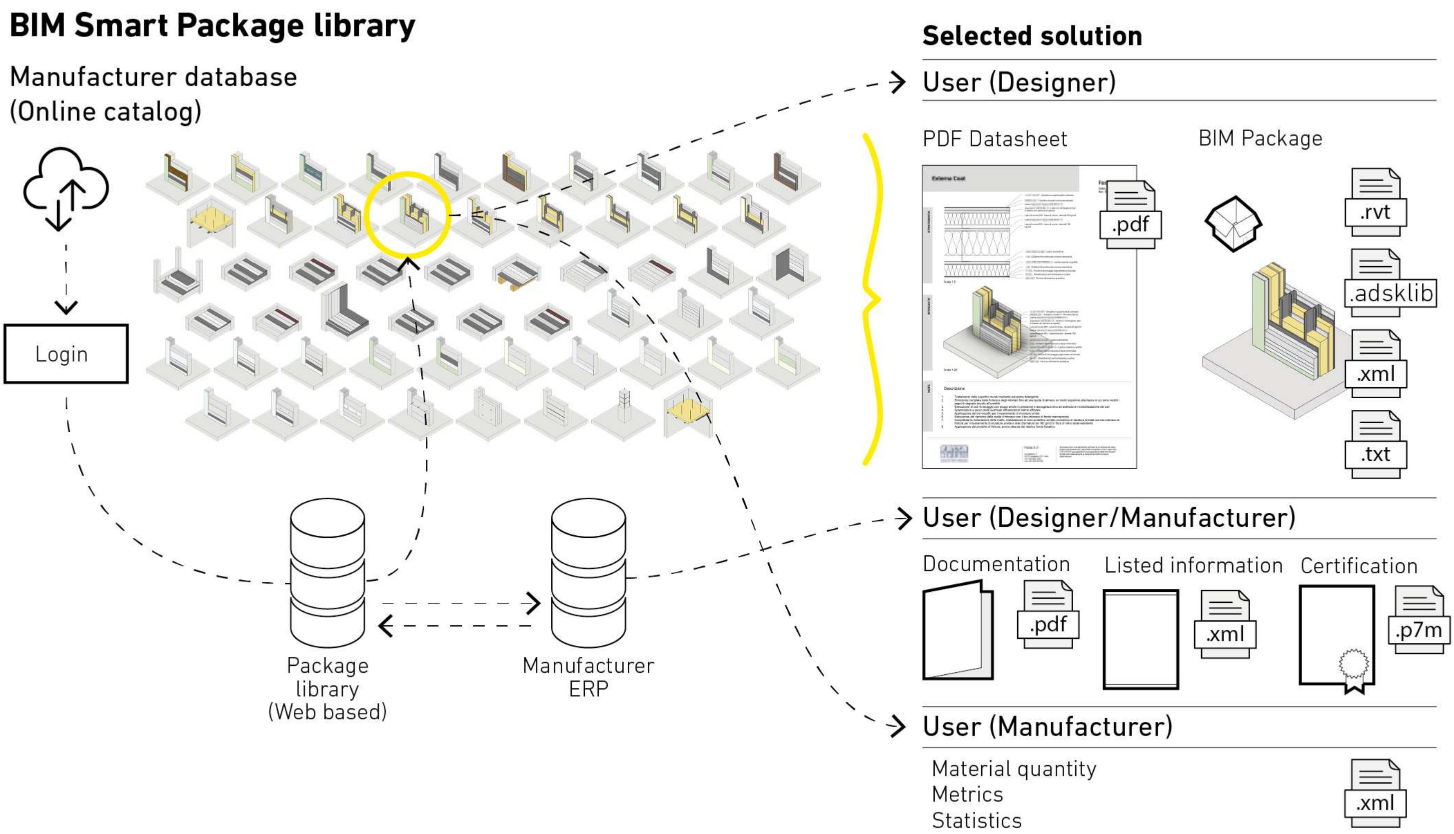


Fig. 086 - How to access and composition of the information content linked to smart packages.

possible variables of each material, it was decided to integrate an index file (XML) into the development process that records and indexes the reference values, simplifying the data entry phase and their updating.
The values that characterise the materials are to be considered variables; these values need to be updated periodically, following the changes made during production.
The project structure takes into account further developments, implementing the possibility of modifying and expanding the information included.
The workflow for the information layer is vertically structured, i.e. the information about the individual materials and the rules that aggregate them into packages are indexed by the manufacturer, who transfers them to the operator who deals with their parameterisation in the BIM environment. The created packages are validated and available to users through the manufacturer's web portal or specialised portals.
These packages are made uniquely identifiable through coding consisting of the package's name, the date of development and the version (e.g. FBIM_A4_GY01_2022v1).
The file supplied to the user (Smart package) is a compressed archive named by its coding.
The compressed file contains three elements: a PDF document in A4 layout showing the information contained in the parametric file; the parametric BIM file containing the developed family and the material library.

	Fassa System:	Company code - Cycle Name:	Lotto produzione-Production ID:	BIM Library:	RVT Sheet title Number:	RVT Sheet title Name:
	FASSATHERM					
FT01		Resphira	Primo/First	Y	FBIM_A4_FT01	FBIM_Resphira_2022v1
FT02		Silver Classic	Primo/First	Y	FBIM_A4_FT02	FBIM_Silver Classic_2022v1
FT03		Impact Classic	Primo/First	Y	FBIM_A4_FT03	FBIM_Impact Classic_2022v1
FT04		Mastro Classic	Primo/First	Y	FBIM_A4_FT04	FBIM_Mastro Classic_2022v1
FT05		Mineral fire plus	Primo/First	Y	FBIM_A4_FT05	FBIM_Mineral fire plus_2022v1
FT06		Mastro plus	Primo/First	Y	FBIM_A4_FT06	FBIM_Mastro plus_2022v1
FT07		Fire eco	Primo/First	Y	FBIM_A4_FT07	FBIM_Fire eco_2022v1
FT08		Wood eco	Primo/First	Y	FBIM_A4_FT08	FBIM_Wood eco_2022v1
FT09		IN-Therm	Primo/First	Y	FBIM_A4_FT09	FBIM_In-Therm_2022v1
FT10		Termointonaco	Primo/First	Y	FBIM_A4_FT10	FBIM_Termointonaco_2022v1
	COLORE					
CL01		Finitura per esterni con sistema acril-silossanico e idrosiliconico	Primo/First	Y	FBIM_A4_CL01	FBIM - Finitura per esterni con sistema acril-silossanico e idrosiliconico
CL02		Finitura per esterni con sistema idrosiliconico	Primo/First	Y	FBIM_A4_CL02	FBIM - Finitura per esterni con sistema idrosiliconico
CL03		Finitura per interni con decorativa alla calce	Primo/First	Y	FBIM_A4_CL03	FBIM - Finitura per interni con decorativa alla calce
CL04		Finitura per interni "solvent free" traspirante	Primo/First	Y	FBIM_A4_CL04	FBIM - Finitura per interni "solvent free" traspirante
CL05		Finitura lavabile per interni	Primo/First	Y	FBIM_A4_CL05	FBIM - Finitura lavabile per interni
CL06		Finitura mascherante per cartongesso	Primo/First	Y	FBIM_A4_CL06	FBIM - Finitura mascherante per cartongesso
CL07		Finitura effetto velatura per esterni (Non in elenco?)			FBIM_A4_CL07	FBIM - Finitura effetto velatura per esterni
	DEUMIDIFICANTE					
DE01		Intonacatura deumidificante - a base di calce aerea	Primo/First	Y	FBIM_A4_DE01	FBIM_Intonacatura deumidificante - a base di calce aerea
DE02		Intonacatura deumidificante - a base di calce idraulica naturale e cocciopesto	Primo/First	Y	FBIM_A4_DE02	FBIM_Intonacatura deumidificante - a base di calce idraulica naturale
DE03		Intonacatura deumidificante - 2 in 1	Primo/First	Y	FBIM_A4_DE03	FBIM_Intonacatura deumidificante - 2 in 1
DE04		Riparazione e rasatura armata di facciate finite con finiture minerali - a base di calce idraulica naturale (NHL)	Primo/First	Y	FBIM_A4_DE04	FBIM_Facciate finite minerali - a base di calce idraulica
DE05		Riparazione e rasatura armata di facciate finite con finiture minerali - a base di calce aerea	Primo/First	Y	FBIM_A4_DE05	FBIM_Facciate finite minerali - a base di calce aerea
DE06		Intonacatura di murature di nuova realizzazione - a base di calce aerea	Primo/First	Y	FBIM_A4_DE06	FBIM_Intonacatura di murature di nuova realizzazione - a base di calce aerea
	CONSOLIDAMENTO					
CN01		Intonaco armato con malta cementizia e rete in acciaio elettrosaldata	Primo/First	Y	FBIM_A4_CN01	FBIM - Intonaco armato con malta cementizia e rete in acciaio elettrosaldata
CN02		Placcaggio diffuso con sistema ad alto spessore (CRM) con rete e connettore in fibra di vetro	Primo/First	Y	FBIM_A4_CN02	FBIM - Placcaggio diffuso con sistema ad alto spessore (CRM) con rete e connettore in fibra di vetro
CN03		Placcaggio diffuso con sistema a basso spessore (FRCM) con rete e connettore in fibra di vetro	Primo/First	Y	FBIM_A4_CN03	FBIM - Placcaggio diffuso con sistema a basso spessore (FRCM) con rete e connettore in fibra di vetro
CN04		Iniezioni consolidanti con legante a base di calce idraulica naturale	Primo/First	Y	FBIM_A4_CN04	FBIM - Iniezioni consolidanti con legante a base di calce idraulica naturale
CN05		Connessione di pannelli murari scollegati	Primo/First	Y	FBIM_A4_CN05	FBIM - Connessione di pannelli murari scollegati
CN06		Ristilatura armata	Primo/First	Y	FBIM_A4_CN06	FBIM - Ristilatura armata
CN07		Ripristino strutturale - ricostruzione di pilastri e travi con malta colabile	Primo/First	Y	FBIM_A4_CN07	FBIM - Ripristino strutturale - ricostruzione di pilastri e travi con malta colabile
	GYPSOTECH					
GY01		Externa Wall	Primo/First	Y	FBIM_A4_GY01	FBIM - Externa Wall
GY02		Externa Coat	Primo/First	Y	FBIM_A4_GY02	FBIM - Externa Coat
GY03		Externa Over	Primo/First	Y	FBIM_A4_GY03	FBIM - Externa Over
GY04		Externa on Top	Primo/First	Y	FBIM_A4_GY04	FBIM_Externa on Top_2022v1
GY05		Gypsotech - WLA 2x75/215 LR	Primo/First	Y	FBIM_A4_GY05	FBIM - Gypsotech - WLA 2x75/215 LR
GY06		Gypsotech - WLA 2x50/VAR LR	Primo/First	Y	FBIM_A4_GY06	FBIM - Gypsotech - WLA 2x50/VAR LR
GY07		Gypsotech -WLA 75-125 LR	Primo/First	Y	FBIM_A4_GY07	FBIM - Gypsotech -WLA 75-125 LR
GY08		Gypsotech - WLA 100-150 LR	Primo/First	Y	FBIM_A4_GY08	FBIM - Gypsotech - WLA 100-150 LR
GY09		Gypsotech - SLA 50-75 LR	Primo/First	Y	FBIM_A4_GY09	FBIM_SLA 50-75 LR_2022v1
GY10		SAZ 50-75 LR	Primo/First	Y	FBIM_A4_GY10	FBIM - SAZ 50-75 LR
GY11		Gypsotech - CL 2x48-27/VAR LR	Primo/First	Y	FBIM_A4_GY11	FBIM - Gypsotech - CL 2x48-27/VAR LR
	POSA					
PO01		Posa di un rivestimento in ceramica su massetto radiante con isolamento acustico a pavimento	Primo/First	Y	FBIM_A4_PO01	FBIM - Posa di un rivestimento in ceramica su massetto radiante con isolamento acustico a pavimento
PO02		Posa di un rivestimento in legno su massetto radiante con isolamento acustico a pavimento	Primo/First	Y	FBIM_A4_PO02	FBIM - Posa di un rivestimento in legno su massetto radiante con isolamento acustico a pavimento
PO03		Posa di un rivestimento resiliente su massetto radiante con isolamento acustico a pavimento	Primo/First	Y	FBIM_A4_PO03	FBIM - Posa di un rivestimento resiliente su massetto radiante con isolamento acustico a pavimento
PO04		Posa di un rivestimento in marmo su massetto radiante con isolamento acustico a pavimento	Primo/First	Y	FBIM_A4_PO04	FBIM - Posa di un rivestimento in marmo su massetto radiante con isolamento acustico a pavimento
PO05		Posa di un rivestimento in ceramica su solaio in legno con ridotto carico statico permanente	Primo/First	Y	FBIM_A4_PO05	FBIM - Posa di un rivestimento in ceramica su solaio in legno con ridotto carico statico permanente
PO06		Posa di un rivestimento in ceramica su massetto radiante a bassa inerzia termica	Primo/First	Y	FBIM_A4_PO06	FBIM - Posa di un rivestimento in ceramica su massetto radiante a bassa inerzia termica
PO07		Posa di un rivestimento in parquet prefinito su massetto radiante a bassa inerzia termica	Primo/First	Y	FBIM_A4_PO07	FBIM - Posa di un rivestimento in parquet prefinito su massetto radiante a bassa inerzia termica
PO08		Posa in facciata di un rivestimento in ceramica	Primo/First	Y	FBIM_A4_PO08	FBIM - Posa in facciata di un rivestimento in ceramica
PO09		Posa di rivestimento in mosaico vetroso per piscina	Primo/First	Y	FBIM_A4_PO09	FBIM - Posa di rivestimento in mosaico vetroso per piscina
PO10		Ciclo per l'impermeabilizzazione di un terrazzo	Primo/First	Y	FBIM_A4_PO10	FBIM_Impermeabilizzazione terrazzo_2022v1
PO11		Rivestimento di ceramica su grande superficie	Primo/First	Y	FBIM_A4_PO11	FBIM - Rivestimento di ceramica su grande superficie
PO12		Posa legno prefinito su grande superficie	Primo/First	Y	FBIM_A4_PO12	FBIM - Posa legno prefinito su grande superficie
PO13		Posa di rivestimenti in locali umidi con isolamento acustico a pavimento	Primo/First	Y	FBIM_A4_PO13	FBIM - Posa di rivestimenti in locali umidi con isolamento acustico a pavimento
PO14		Posa di lastre di grande formato in interno con isolamento acustico a pavimento	Primo/First	Y	FBIM_A4_PO14	FBIM - Posa di lastre di grande formato in interno con isolamento acustico a pavimento
PO15		Posa di marmi, graniti e pietre naturali con isolamento acustico a pavimento	Primo/First	Y	FBIM_A4_PO15	FBIM - Posa di marmi, graniti e pietre naturali con isolamento acustico a pavimento
PO16		Posa di rivestimento in legno con isolamento acustico a pavimento	Primo/First	Y	FBIM_A4_PO16	FBIM - Posa di rivestimento in legno con isolamento acustico a pavimento

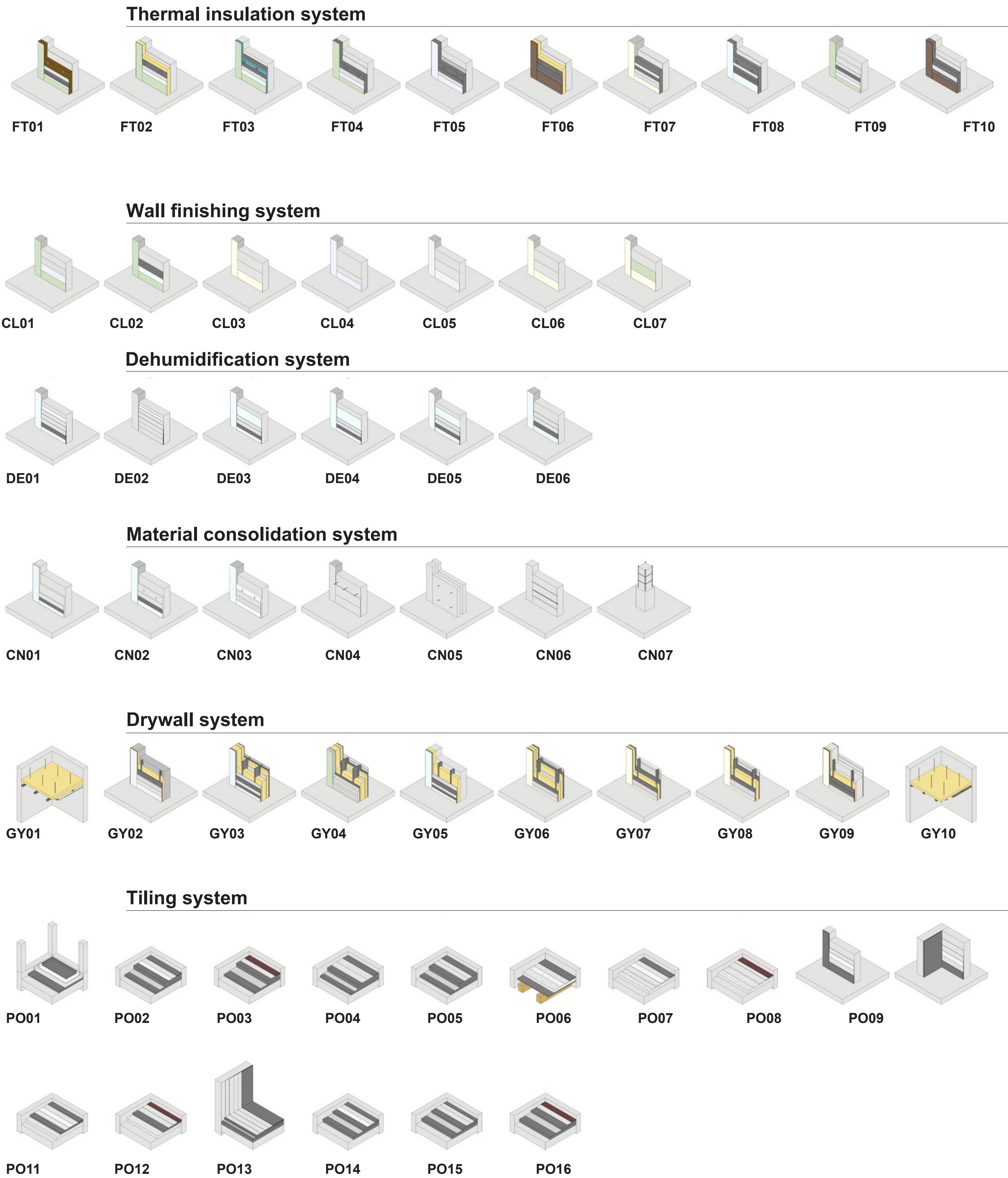


Fig. 087 - Information control mask and encoding of library elements. The library consists of six development lines with a total of approximately sixty package.

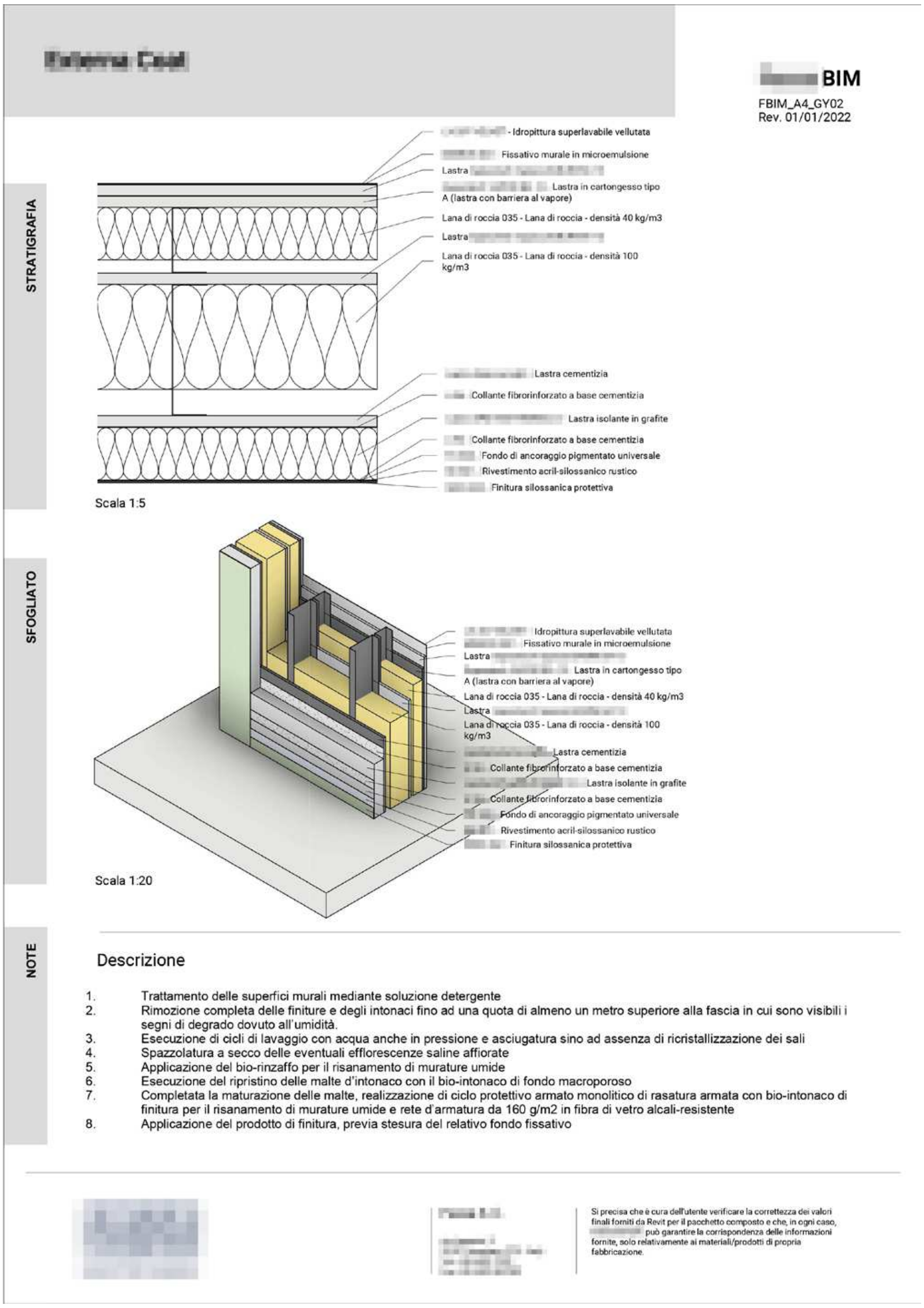
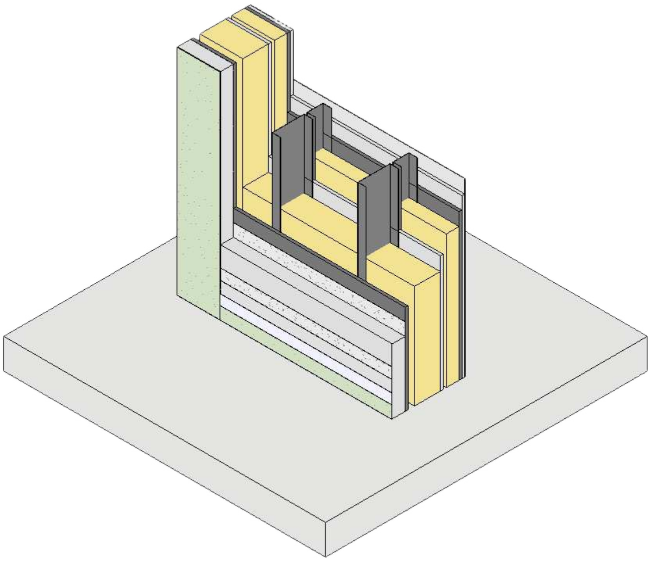


Fig. 088 - The smart package comes with an A4 table that conveys the main information. In addition to the information allowing identification of the solution, there is a diagram of the composition and a three-dimensional cutaway.

The PDF document is used as a synoptic index, allowing a quick overview of the contents of the package without having to open the file within the BIM software.
The hierarchical composition of the contents works on the principle of successive levels of detail. It starts with the extended title of the package in which the function for which it was developed is identified. At the same level, the unique coding of the file is displayed with an indication of the development version.
The next level shows the two-dimensional stratigraphy represented on a scale of 1:5, in which the names of the products inserted are shown in order of application.
The in-depth view continues with a representation in axonometric cut-out (scale 1:10/20). A sample of one metre by one metre is displayed in which the materials making up the package

are cut out in succession to illustrate their composition.This view also includes accessory elements shown in a simplified way, such as fixing elements for insulating boards.
The last level is made up of a notes field. The package description is shown in text form, as well as the application procedure and the indications provided by the company in terms of existing substrate preparation and potential incompatibilities.



The parametric file contains the developed family, together with the material library and the nested families developed for the correct composition of the package.
For instance, a package made up of rigid insulating panels will also include a series of nested families that represent the required mechanical supports. On the other hand, a package created to represent insulating drywall will include the boards and the underlying metal profiles.

6.2 Material library

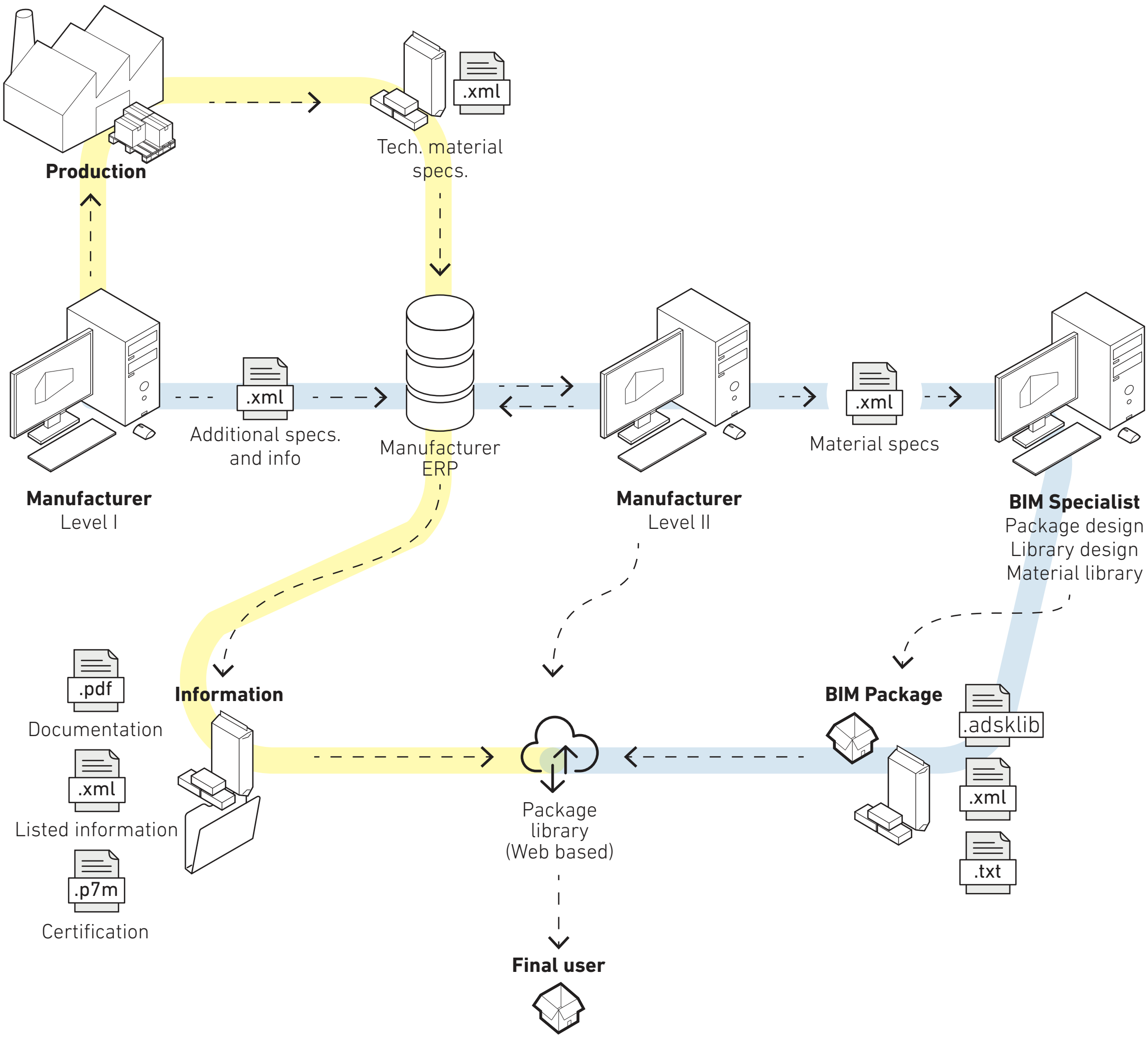


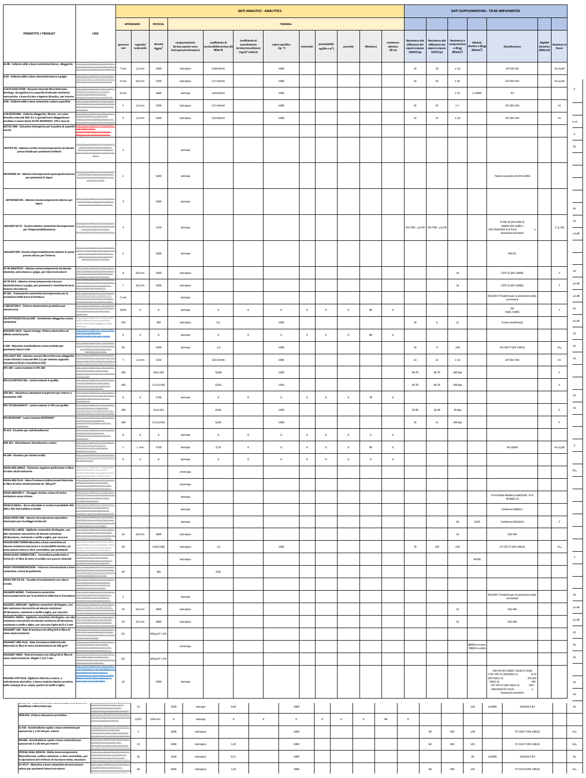
Fig. 089 - Information management process schematisation. The two flows used for updating data are highlighted.

A feature collection and management system was implemented to define materials to be used for the composition of BIM packages, allowing technicians to extract data from the company's management system (ERP). The extracted data must be conveyed using a human-readable coding system that allows it to be spot-checked; to do this, XML coding of data was chosen, using XLSX as a file format. The specific format was identified because of its widespread use, which guarantees many users can exploit it.

The information interchange starts from the manufacturer (Manufacturer Level I), which provides the desired product specifications to the production plant (Production). The production plant, responsible for producing the goods, determines the final product specifications. These specifications update those defined theoretically by the company and are updated in the management system. Final specifications deviate from the theoretical ones by often negligible values and are influenced by the variable nature of the raw materials of which they are composed. Values can also be updated according to performance changes required by the market, and in this case, the information process is essentially the same.

The updated information from the production plant are verified by the appointed technicians (Manufacturer II) responsible for providing it to the BIM specialist in charge of translating it into BIM format. The information conveyed through XML are used to populate the characteristics of individual materials in the BIM environment. Specifically, at this stage of

DATI ANALITICI - ANALYTICS												DATI SUPPLEMENTARI - TO BE IMPLEMNTED						
APPEARANCE		PHYSICAL	THERMAL															
spessore mm	rugosità/ scabrosità	densità Kg/m^3	comportamento (le due opzioni sono isotropico/ortotropico)	coefficiente di conducibilità termica (λ) W/m·K	coefficiente di assorbimento termico/assorbanza (kg/m^2·min0,5)	calore specifico J/g· °C	emissività	permeabilità ng/(Pa·s·m^2)	porosità	riflettanza	resistenza elettrica (Ω·m)	Resistenza alla diffusione del vapore acqueo UMIDO (μ)	Resistenza alla diffusione del vapore acqueo SECCO (μ)	Resistenza a compressione a 28 gg (N/mm^2)	Modulo elastico a 28 gg (N/mm^2)	Classificazione	Rigidità dinamica (MN/m3)	Reazione al fuoco



Analytical data		
	Material thicncess	mm
	Surface graining	μm
	Density	Kg/m^3
	Isotropic/ortrophic	
	Thermal conductivity	W/mm•K
	Heat absorption coefficient	Kg/m^2•min 0,5
	Specific heat	J/g•°C
	Emissivity	W/m2
	Permeability	ng/(Pa•s•m$^{2)}$
	Porosity	0-1
	Reflectance	1-100
	Electrical resistance	Ω•m

Additional data		
	Resistance to moisture diffusion - Humid	μ
	Resistance to moisture diffusion - Dry	μ
	Compression resistance	N/mm^2
	Elastic modulus	N/mm^2
	Classification	
	Dynamic stiffness	MN/m^3
	Fire reaction	REI 10-360

Fig. 90 - A portion of the XML used for the management of material characteristics to be inserted into library elements. This file updates the features that are subsequently implemented in the libraries.

development, materials populate a corporate material library developed in Autodesk Revit. The chosen format is the one that allows covering the largest share of users, but further development is planned to expand the offer by developing the libraries also for other BIM authoring applications.

The information carried by the elements are those relating to identity, appearance, physical and thermal properties.

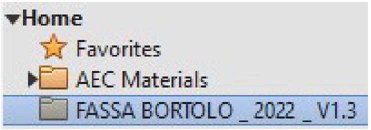
Identity properties define the product name, the description (Class, Keyword), manufacturer information (Manufacturer, Model, URL) and annotations.

Appearance-related properties provide the material's characteristics within the BIM authoring software. This set of information are for illustrative purposes only.

The properties relating to physical and thermal characteristics are the most important and are filled in as completely as possible. The information entered is produced by the company engineer, who identifies each material class's most relevant technical characteristics.

Material characteristics are liable to change during their lifecycle, to keep track of these changes, variations are recorded through the package versioning record. A special file (change log) collects information on modifications and can be used to determine whether or not the material package needs to be updated by end users.

The .adsklib library can also be used independently from the BIM package library to compose custom solutions.



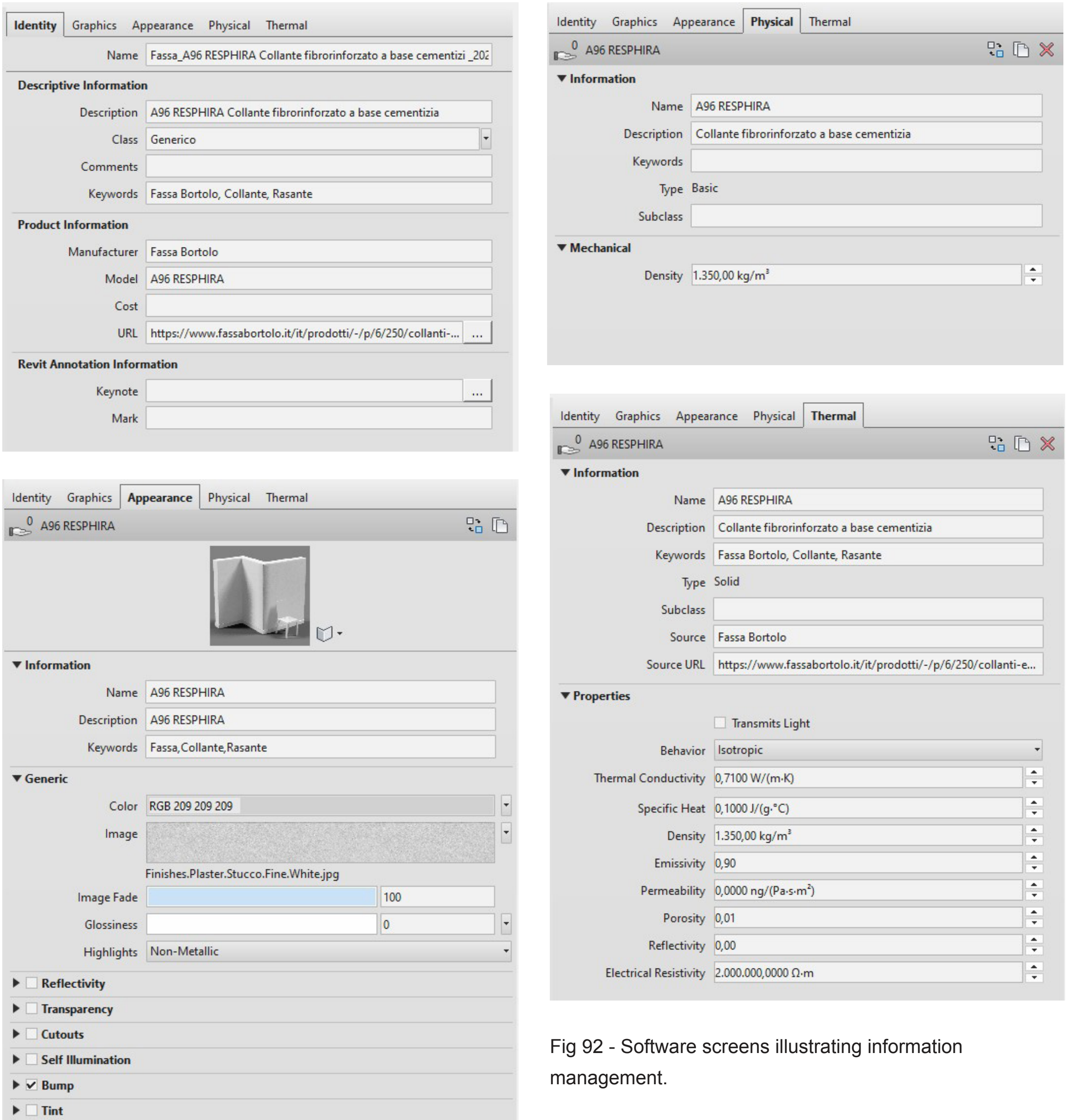


Fig 92 - Software screens illustrating information management.

Materials stored in the library convey informative, physical and thermal characteristics. Each material is marked with a unique code that allows the individual product to be identified in the company's trade portal. The characteristics are indexed through an XML file. There is a versioning record for the products created, characteristics are updated over time and changes are recorded.

Fig 91 - View of the Revit library organising the digitised materials for the first production batch.

The materials library is the file that contains all the digitised materials. Instead of fragmenting it, it has been chosen to create a single library to detach the library from the single package. In this way, the material library file can also be used stand-alone, providing operators with a tool that is not linked to individual ready-made solutions.

The digitised materials include the commercial name, descriptive information and manufacturer information. Graphic information representing the material is also included, along with physical and thermal properties where available.

The project identification code is always reported within each document, package, family, or material, with the web link to the reference portal. The code for the aggregated package is shown where available, with the relative update date and version.

The information is updated in a semi-automated manner using an XML import script. The XML format was chosen because of the possibility of extracting the information directly from the company's ERP (Enterprise Resource Planning) system. As a further development, the possibility of creating a dynamic link via database has been planned.

The update phase ends with exporting and publishing packages, renamed to the latest version.

Due to the kind of changes that the manufacturer can make and their frequency, it is unnecessary to provide end-users with a record of previous versions. The release history is always stored by the developer and may be made available if required in the future.

The proposed system is organised in several consecutive development phases. The aim is to provide tools that can be immediately adopted by investing in technologies and processes with high TRL (Technology Readiness Level). Once the users are familiar with the BIM working methodology, it will be possible to start the following phases characterised by the increase of the offer (number of packages), the development for different platforms (Archicad, Allplan, Tekla, etc.) and higher process automation (Dynamo, Python, etc.).

In the first phase, the packages are developed exclusively for Autodesk Revit, which covers a considerable part of the market share of the applications currently used in the region.

The dialogue between the Enterprise Resource Planning platform (ERP), in which the product datasheets including all information and characteristics are created, and the BIM platform takes place in a first phase through export in XML format. This choice is due to the need to simplify the content update process.

The created materials are grouped and compressed in a digital archive and made available to the end-user through a duly developed section within the company website.

The files are accessible through a login, allowing the user to record the downloaded solutions. This helps to check quickly for updates on previously downloaded packages.

Proposed solutions are indexed according to the technological system to which they belong. A specific function of the web portal manages the link between the selected BIM package and the related technical documentation developed by the company (Data Sheet, Application Manual, Certifications).

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Chapter 7 - Results and future development

Chapter 7
Results and future development

7.1 Definition of an applied methodology

In the field of digital data representation and management, BIM is today considered the last frontier, being a methodology where interoperability is one of the central attributes.
The use of the BIM methodology is also becoming essential in existing building interventions, and in conservation and restoration interventions (Chiabrando et al. 2019), thanks to its ability to integrate different information and characteristics in relation to the geometric shapes of the model. Therefore, there is a need to link the survey and data interpretation processes with an advancement of the IFC, able to describe and connect different data and information related to existing heritage buildings within the BIM process.
From this comes the centrality of the topic of representation through digital tools able to connect different knowledge, different levels of information, and representing the complexity of the process of knowledge and intervention project (Vernizzi 2017).
The research defined an overall methodological approach, by analysing the main framework within the current state of the art. The methodological value and the assessment of the knowledge and interpretation process to be undertaken to reach the BIM digital integration for existing buildings intervention guided the most technical steps, defined under a critical approach in the application of the current tools for integrated surveying and representation. The interdisciplinary levels involved in the research opens up to new digital applications and new approaches in data sharing.
According to this main research view, one of the main results is the improvement of BIM modeling as an information "collector" of integrated data supporting the innovation in interventions on the built assets. The research investigated the integration of applicable and reliable digital tools on different project phases by using case studies able to be representative of specific features related to the intervention on the existing buildings, considering the social housing as one of the main drivers in building refurbishment. As an additional outcome reached by the research, the definition of methodologies and tools strictly focused on the requirements for refurbishment and management of the existing building stock can be considered as a valuable support to help bringing innovation on the built environment.
The identification of parameters for accessible databases aimed at managing the intervention in the different project phases (documentation, project, management, programming, etc.) allows gathering several levels of information (energy, structural, environmental, etc.). This makes also possible the integration of BIM models into existing multidisciplinary platforms (Fassi et al., 2015), allowing many professionals to work in an integrated and coordinated way. The advancement in the management competencies for BIM tools according to the evolution of the current legislation is an additional target. The aim is to work in the direction

of introducing the information modelling and management as a key factor in the public works' sector while aiming at the competitiveness of SMEs as well as professionals to operate in an international framework with a digital-driven perspective, towards a progressively mandatory use of BIM tools.

The research actively contributed in defining operational tools for the refurbishment of the widespread existing building stock in Emilia-Romagna, setting up a methodology and a set of digital tools widely replicable and applicable. New forms of accessibility to data aggregated into 3D models (interoperable and open access) for an interdisciplinary use of digital tools is a current need shared by different stakeholders, both in research, academic and professional environment.

The research aimd to develop, on one hand, an optimized procedure, a methodology able to develop BIM modeling as an information "collector" of integrated data to support the innovation of the intervention on the existing built. On the other hand, an integration of digital tools applicable and replicable on different sections of the project, developed starting from case studies able to provide all the complexities of the intervention on existing buildings.

In this scenario, the research proposes the development of digital tools in BIM environment for a better readability of the framework of the regenerative interventions of the regional built heritage, the definition of new integrated technological solutions and of protocols for intervention and monitoring.

7.2 Test on functionalities

Through the case studies digitisation, it was possible to investigate the construction characteristics that emerged from analysing the existing 20th-century building stock in the region. The knowledge process developed is structured in such a way as to allow a constant evolution of the digitised elements. It has been limited to the building typologies identified during the analysis phase. The selected typologies provide a representative sample of the heritage under investigation in the metropolitan area of Bologna and give a relatively articulated initial package of features to be developed in the BIM framework. The construction characteristics identified through the analysis carried out on the case studies were useful for developing the features to be implemented in the packages designed for the intervention on the existing building. The solutions developed took into consideration the needs identified through the study of the construction solutions used, which included the presence of non-standard construction elements (or local standards), non-uniform construction technologies (built with available materials) and obsolete construction technologies (no longer in use).

The identified solutions, both methodological (as built) and instrumental (Smart Package), were conceived and tested, taking into account the development and use methods of the solutions produced to integrate the BIM working methodology with the problem-solution approach developed to make the digital tools set up through a library of standard packages usable.

The developed functionalities have been designed to foster the integration of building management through the BIM methodology, simplifying as much as possible the adoption modalities to allow the broadest possible number of operators to interface with advanced digital tools. The functionalities are tested on buildings that need retrofitting to reach energy efficiency and seismic standards and to extend their usability and functionality over time.

As-Built Modelling Testing and Verification Procedure

The functionality verification phase regarding the decomposition of building elements and their subsequent digitisation was carried out using a mix of instrumental survey technologies and archival documentary resources. The structural and architectural elements were modelled according to the specifications required by the regulations, integrating where required some additional specifications useful for the interaction of the existing components with the materials and technologies used for the refurbishment work. The models are therefore ready to be divided and modulated to host the integrations to be carried out in the later work phases.

Procedure for verifying the functionality of the developed packages

The content production system to be conveyed through a library of design solutions, developed jointly with the manufacturer, is divided into several development stages. The selected packages for the first development stage represent a batch of recursive solutions covering many operational cases. The system also includes a parallel development line to develop customised solutions requested by designers. This second 'custom' line is developed in collaboration with the R&D engineers of the partner company. The custom packages, developed for specific needs, are certified to provide the designers with a high standard of compatibility and effectiveness in solving the issue identified by the design team in charge of refurbishment. Custom packages are then applied and tested and, if found suitable, could become effective, increasing the standard library packages. The standard library, in order not to become over-extended, houses only the most frequently used packages. The standard library is kept specifically limited to avoid overloading the system for updating the materials and certifications that are produced for each library element.

The verification and evaluation steps are carried out in different production stages to check the effectiveness of the process; these stages involve several users with different roles. The roles are related to strategic development, which means the people in charge of identifying which packages are being developed and for what reasons, as well as the roles of developing the functionality of the packages in which the R&D experts who certify the assembled package and the specialists who develop its digital twin are involved.

The problem-solution approach used to develop the first package batch identifies recursive issues from analysing the company's intervention data. BIM technology is used to structure a targeted intervention methodology, which keeps track of the actions carried out on an asset and allows the planning of the maintenance phase to be managed. From the company's point of view, the management of the materials required to realise the proposed solutions (standard library or custom) is used for activity planning and warehouse management through the integration between BIM and the company's ERP (Enterprise resource planning). The automation of processes and methodologies is foreseen with a gradual adoption over time to allow departments to proceed with the implementation of the necessary tools as well as staff training.

7.3 Guidelines

Developing a methodology supported by tools specifically developed for this purpose represents the first step in adopting these tools within the supply chain. The construction components supply chain, and the sector of intervention on existing buildings, is a field of application in which the actors involved are particularly resilient to adopting innovative procedures that move away from the traditional operational methodology. The adoption of digital tools, which impact economically on the planning phase of interventions, is still perceived as a cost without an overall assessment of the actual impact on the management of the intervention.
Among the major difficulties identified in the applicability of the “BIM-driven” approach to the management of the refurbishment process is the aspect related to the implementation of the technologies underlying the digital site management process. These technologies, whether they digital surveying, digital twin management or information models on the construction site, represent a barrier to applicability that is difficult to solve. To provide a short-term feasible implementation strategy, it was decided to work by incremental levels of complexity, providing relatively simplified tools. The tools made available to the actors in the supply chain are therefore designed to be easy to use, providing models that can be modulated in terms of complexity and adapted to the specific needs of each stakeholder. The methodological aspect that rules the development of the proposed solutions envisages that the process that defines the steps will be supported by a series of guidelines developed according to the user’s needs. Thus, there will be guidelines specifically set for those involved in the management phase of the BIM process and others that define how to develop the package solutions to be provided to those responsible for digitising the proposed solutions on behalf of the building component companies.
However, the guidelines do not limit themselves to the practical aspects of the BIM process but provide instructions specifically designed to communicate the value of the digital approach to site management and also to those actors that are involved in the process, such as owners, administrators or managers of the property in question.
The Guidelines developed for the digitisation of the real estate heritage belonging to the regional territory built in the 20th century represent a research tool in constant evolution as a result of the integration of methodological information arising from other research projects that have previously investigated similar issues at the regional and national levels.

7.4 Further developments

The XX century buildings redevelopment is not only an essential target for the Emilia-Romagna region, but it also covers the main needs to meet the goals of emission reduction, energy saving and use of renewable energy sources throughout the building life cycle.

Therefore, the issue of digitisation processes or digital renovation workflows is a priority toward an efficient information and data collection (technical specifications, sensors, etc.), data management, and data archiving, conservation and sharing, to make the redevelopment process easily manageable and more effective.

The research also explored the growing trend of manufacturing companies to make their products available in IFC - Industry Foundation Classes models.

Possible future research developments can go in the direction to contribute to the definition of a shared ecosystem that will require the effort of both designers and manufacturers, triggering new forms of accessibility to data aggregated to 3D models (interoperable and open access) for an inter-sectoral and interdisciplinary use of digital tools.

Data is the most valuable raw material of the future. European projects such as Gaia-X[1] show how data sovereignty will be a commercial battlefield in the not-too-distant future, where Europe (Autolitano & Pawlowska, 2021) owns less than 5% of the companies involved[2]. The data created today are stored in facilities that operate outside the European regulatory framework and over which there is no jurisdiction whatsoever. Having established these first two points, it is still possible to consider it correct to operate towards digitising processes.

The current state of the construction industry in Italy, which has been in crisis for the last twenty years, does not allow to not take advantage of the digital revolution as a driver for the growth and relaunch of the entire sector.

Developing digital ecosystems, in which all stakeholders in the supply chain (public/private) can work together, acting on a shared model that connects all areas of the construction process, can be a privileged starting point to solve some of the critical issues in the construction process.

The methodology developed under the research thesis is limited to investigating the intervention needs supported by digital data sharing in the built environment. Likewise, it aims to provide operational tools for professionals who will have to evolve in methodology, adopting innovative technologies that allow a competitive advantage in a constantly evolving market.

Future research developments may see employing the created models as tools for collecting data (e.g., energy consumption, maintenance statistics) to be applied to automated management Blockchain protocols (Carson et al., 2018) or as digital bases for the more or less automated integration of construction technologies used in restoration processes based on digital fabrication, in a supply chain/industry 4.0/Supply chain perspective.

The effects of the digitization of the building process applied to the built assets can contribute

1 GAIA-X - Home. Available at: https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html (Accessed: 14 May 2021).

2 Market Trends: Europe Aims to Achieve Digital Sovereignty With GAIA-X. Gartner. Available at: https://www.gartner.com/en/documents/3988433/market-trends-europe-aims-to-achieve-digital-sovereignty (Accessed: 14 May 2021).

to the improvement of regeneration processes thanks to the implementation of innovations in building components and systems, increasing the exploitation of BIM potential for the renovation of existing buildings. The results achieved and tested on selected case studies within the regional heritage of the twentieth century can contribute to further development of procedures and application of integrated digital tools.
The research aimed to promote an integrated methodology based on digital tools to support technicians working on existing buildings using a BIM methodology. The methodology was designed and developed to operate on a specific field of intervention, trying to combine the aspects related to the digitalization of the building (As-Built) with the needs of the refurbishment intervention in an integrated supply chain perspective. Owners, designers, contractors and manufacturers represent the chain of stakeholders at which the project is aimed.
The progress in the application of BIM tools to the existing heritage, based on the evolution of the current legislation and in view of the progressive introduction of the mandatory nature of BIM tools, can contribute substantially to the definition of operational tools aimed at the redevelopment of the existing widespread heritage.
Starting from the structuring of accessible databases aimed at managing the intervention in the different phases (documentation, project, management, programming, etc.), in which different information levels (energy, structural, environmental, etc.) converge, a possible future development foresees the integration of BIM models in existing multidisciplinary platforms, allowing different professionals to work in an integrated and coordinated way.

7.5 Possible impacts

The expected impacts from applying the methodology and tools developed in the research pathway can be grouped according to the beneficiary subject. Possible impacts are to be classified according to whether the beneficiary is the property owner (or manager), public administration, a stakeholder in the built environment intervention chain, or one of the companies engaged in manufacturing building systems or components.

Expected impacts for asset owners
Property owners (or managers) can benefit from the potential offered by computerised management of building interventions. For an initial investment useful for digitising the asset, it will be possible to obtain a set of three-dimensional models that can be used to plan the refurbishment activities to be carried out, as well as to evaluate through simulation the effects in terms of energy savings and seismic safety.
For those who own or manage many properties, investing in the digitisation of assets is more convenient. It allows them to carry out planned maintenance activities by spreading fixed costs over several properties.
Landlords can finally use the developed models to keep a digitised archive of the activities carried out in the various maintenance actions, reaching even highly accurate levels of detail.

Expected impacts for Public Administrations

Public bodies can gather digitised building data sources and perform analyses and assessments on a large scale, being able to query data archives on a historical basis that can also be updated in real-time. In the short-term applicability, BIM information managers will be able to share a simplified version of the building model to convey the key information of the asset, providing information on the building's construction characteristics, the technological systems installed and the quality aspects that distinguish it.

When the level of automation will be mature and widespread enough, the models created will be used to become the basis for aggregating the information gathered in real-time from the sensors embedded in the adopted technological solutions. The aggregated and processed data can feed the digital strategies foreseen for activating smart cities.

Expected impacts on supply chain operators (Existing heritage refurbishment)

Operators in the supply chain will be able to take advantage of up-to-date digital models and use them when preparing the economic offer and in the subsequent phases of intervention on the property. The level of digitisation required and the necessary investment in instrumentation and on-site personnel are increasingly within reach of medium-sized players. Broader use of BIM technologies on construction sites will probably have to wait for a longer time horizon. The learning curve of the tools and the amount of investment required to train employees extensively is still a barrier that is difficult to overcome in the short term, and it will probably be necessary to wait for the generational change of employees to begin to achieve satisfactory results.

Among the benefits that can be achieved in the medium term, we can also include those resulting from the prior adaptation to the specific requirements in terms of digitisation of the process required by the regulations of Legislative Decree 36/2023, the 'New Procurement Code', published in the Italian Official Gazette[3], which will come in effect by 1 July 2023. The regulation provides for actions aimed at increasing the competitiveness of companies through the adoption of advanced digital tools to support design and tools (BIM) that foster the sharing of information (ACDat). The regulation focuses on technological advancement to support the development of the supply chain, taking into account the needs of small and medium-sized enterprises.

The standard foresees the extensive use of BIM in contract management, whereas previously, it suggested its adoption in exceptional cases. In addition, specific training actions are expected in all phases of project development for the employees involved, who must necessarily consolidate a package of knowledge that enables them to carry out digital activities correctly.

There are currently many initiatives supporting the digitisation of the construction process, developed by large companies operating internationally, which lead to hope for future applicability also to lower scales of intervention.

3 Ordinary Supplement No. 12 to the Italian Official Gazette No. 77 of 31 March 2023

Expected impacts on building component manufacturers

Companies producing building materials, components and systems can use digital models and tools to develop strategies for production control, process automation, raw material procurement and inventory management.

From the analysis of the data gathered from the IT platform that manages the use of smart packages, it is already possible to create specific metrics to assess trends in the use of aggregated systems and those of the individual products that comprise them. These metrics can then be further filtered to evaluate the individual site, territorial area or type of intervention. Utilisation trend analysis can be used to assess the material flow in and out of production facilities, enabling more efficient management of logistics, production and warehousing.

The development of pre-packaged solutions allows the definition of 'material packages' whose characteristics (quantitative and qualitative) are known, facilitating their management. The finished package is then manageable as an 'assembly of components' and can be used as a tool for simplified production management.

Companies can therefore develop and integrate BIM-based IT tools with the IT systems (ERP) they already use for managing their production facilities, facilitating the development of cost planning, production optimisation and warehouse management policies.

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Despite all these assumptions, I am here to write these last lines of a product that is not perfect, is still evolving, and with which I will certainly not be completely satisfied in the future, but which can be considered finished.
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Titolo della tesi (traduzione):

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Maietti Federica

Settore Scientifico Disciplinare (S.S.D.)

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