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ISS GIS BIM Lectures and notes for a digital integrated design

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Lectures and notes for a digital integrated design

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CITERA - the Interdepartmental Center for Territory, Building, Conservation and Environment of Sapienza University of Rome - has carried out intense international cooperation activities thanks to the support of the International Urban Cooperation (IUC) programme of the European Union.

Research agreements and collaborations between CITERA and Chinese universities have been signed and are being implemented.

The training on GIS & BIM was conducted thanks to the collaboration of the Department of Planning, Design, and Technology of Architecture of Sapienza, afferent to CITERA, with the construction cooperation of its Director Prof. Laura Ricci and the Scientific Coordinator Prof. Marco Casini.

This book is one of the concrete results that CITERA has achieved with Chinese cities and academic institutions within the IUC programme. It is the compilation of contributions presented by the professors who participated in the first edition of the International Summer School (ISS) GIS-BIM for Digital Integrated Design held online from 31 August to 11 September 2020 organised by the Department of Planning, Design, and Technology of Architecture of the Sapienza University of Rome.

Bilateral and Research Academic days
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CONTENTS

BIM-GIS integration towards Digital Twin: shaping smart for rethinking cities

Original article by: **Sofia Agostinelli** and **Elisa Pennacchia**
GIS, BIM and Digital Twins Laboratory
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Cities are complex systems connected to demographic, economic and ecological conditions and evolution. The progressive transformation of the *modus vivendi* and related needs of the population requires accurate analysis to understand the ever-increasing complexity of urban contexts.

Cities are the main sources of environmental pollutants on a global level and the places where vulnerability to climate risks and related upheavals can be tackled, as well as the major socio-economic and human health challenges. Therefore, they are the most appropriate places to start the transition towards sustainability, linking the sustainable development agenda with the ICT of pervasive digital research and development.

Trying to build a scientific and technological system allowing to analyze and predict future scenarios and events that may have a significant impact on communities is strategically important in order to develop and direct risk prevention interventions as well as sustainable management of buildings and urban agglomerations.

In fact, a deep understanding about relevant connections between the integration of urban planning with different enabling Information Communication Technologies - ICT[1] (such as modelling and simulations, Internet of Things, Artificial Intelligence for learning and reasoning) is becoming more and more related to a new paradigm based on approaching predictive scenarios in urban sustainability for the configuration of long-term policies. In fact, the development of Urban Intelligence[2] (UI) paradigms set out ecosystems of technologies aimed at improving quality of life and wellbeing, defining a new urban environment made up of Smart City systems.

The introduction of ICT-based dynamic strategies in urban development needs a deep focus on a user-approach including the interactions between people and infrastructures through the definition of a City Digital Twin, which is namely a cyber-physical counterpart of all the city systems and subsystems, combining advanced real-time multidisciplinary city modelling, simulation and learning tools with numerical optimization techniques.

Thus, Urban Intelligence environments are able to provide alternative strategies and scenarios supporting policy makers and stakeholders in designing sustainable and customized solutions. Then the main characteristics of a Urban Intelligence architecture are:

- fully multidisciplinary integration of city layers;
- real-time connection and evolution with the city;
- integration of participative strategies to include "human oriented" information;
- modularity of application.

[1] According to Ajayi, O. O (2009), ICT can be defined as a technological means of collecting (inputting/gathering), collating (processing/analyzing), and conveying (outputting/transferring) information via technology.

[2] Urban Computing and Intelligence can bridge the gap of pervasive computing, intelligent computing, cooperative communication, mass data management technologies and artificial intelligence to improve urban environments and quality of life in smart city systems.
Roche, S. Geographic Information Science II. Prog. Hum. Geogr. 2016, 40, 565–573. [1] describes the concept of urban intelligence as the urban stakeholders' ability to depict the connected complex urban places (i.e., platial urban dynamics). Hence, smart cities are not only continuous spaces crowded with quantitative data and sensors; they are also about complex place dynamics based on citizens interactions, for instance, with respect to places (sense of place (SoP)) or social relationships (social capital (SC)). G. White and S. Clarke, *Urban Intelligence With Deep Edges* in IEEE Access, 2020, vol. 8, pp. 7518-7530.

A City Digital Twin[3] based on a Urban Intelligence paradigm leverages crossovers between mobile networking (IoT - Internet of Things), process modelling, and Artificial Intelligence (AI), with the aim of learning, reasoning, and targeting a city (Smart City) where infrastructures and city assets are coordinated and integrated using digital technologies [1, 2].

The result is a digital eco-system of infrastructures and services that allows the creation of a Digital Twin (DT) of complex real/physical systems such as cities, including their systems and subsystems (e.g., transportation, energy distribution, water usage, population, education, health, cultural heritage, etc. [3]).

Some experiences of DT models have been implemented in India, Southeast Asia, and Europe [4, 5] always trying to solve very specific problems without a full common/global approach for UI providing effective generalizations [6].

This is why the evolution of Smart City approaches opens up new directions towards integrated and intelligent systems for the government of cities, using multiple integrated data sources (from sensors to data platforms for Citizen involvement) using a holistic approach. The objective is a real-time integration of heterogeneous data controlled by multidisciplinary optimization approaches in a flexible and adaptive digital model that learns from and evolves with the real city, being capable of anticipating future scenarios.

From this perspective, the integration between Building Information Models (BIM) and Geographic Information Systems (GIS)[4] becomes a crucial strategy aimed at increasing efficiency in information processes between building systems and subsystems analysis, urban planning applications, disaster management, cadastre and homeland security and so on.

Smart City applications need mass data, both static and dynamic, current and historical, geometrical and semantic, microscopic and macroscopic to integrate ICT and IoT solutions in a secure way to manage city assets etc. Therefore, BIM and GIS can be used to collect, manage and create lifecycle data of vertical facilities, as well as data describing the urban environment, which is horizontally distributed. Hence, integrated application of BIM and GIS is becoming essential in Smart City management applications where data of both facilities and urban environment are required.

The idea of Digital Smart City shapes such the creation, analysis and use of information about the urban environment in all its dimensions, managing to ensure the desired quality of life for its inhabitants, while achieving sustainable results in economic, social and environmental terms. In other words, a Digital Twin of a urban system can also be a key tool for the storage, visualization, analysis and creation of data useful for managing the urban lifecycle.

Given the absolute centrality of data in the configuration of full-digital processes, a significant development is the integrated use of GIS and BIM for information management and processing. Although they share the essential concept of describing the real world through the combination of representation and information, they are conceived and developed as belonging to different domains.

While BIM focuses on buildings and on the representation of construction details, i.e. micro-level data, often unrelated to context, GIS specializes in geospatial information defining the environmental level, and it is used to generate information at the macro-level, such as topographical data.

Their main differences can be summarized in different users, application focuses, development phases, spatial scales, coordinate systems, semantic and geometric representations, levels of granularity and methods of storing and accessing information. The need for a global vision of the city, both in width (house, neighbourhood, city) and in depth (architecture, structures, installations), is growing a general interest to deepen the overlapping nature of BIM and GIS. The integrated use of these technologies can bring benefits in both fields of action. Infact, information from a GIS can facilitate

[3] Digital Twins are an endeavor to create intelligent adaptive machines by generating a parallel virtual version of the system utilizing real time data and analytics for understanding the physical system. Information connectivity, analytical, and visualization capabilities enabled by Internet of Things (IoT) and emerging virtualization technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) allow for the creation of a digital twin of a building (to include residential, commercial, factories, etc.), a community (to include neighborhoods, corporate campuses, military installations), and a city.

[4] A BIM-GIS model requires a complex semantic framework. However semantic models are needed for different engineering and planning applications that require complex queries and analysis.

BIM applications such as site selection and on-site material placement, while BIM models can help generate detailed models in a GIS and lead to greater effectiveness in project management. While BIM systems focus on developing objects with the maximum level of detail in geometry, GIS is applied to analyse objects, which already exist in the physical environment, in the most abstract way.

That is why achieving interoperability between both domains will offer substantial benefits, as each domain brings information and services the other lacks.

For example, considering the information management of new construction projects, the integration of BIM and GIS can support applications such as supply chain management, getting a detailed takeoff in the early procurement phase, using GIS to perform geospatial analysis of the logistics delivery in a visualized construction supply chain management system, developed for tracking materials and providing warning for delivery accidents. This visualized method of digital monitoring and control reduces time and cost for logistics delivery. Even for building retrofit projects, the integration of BIM and GIS supports decision-making. Putting as-is geometric BIM data and other necessary data into GIS, it becomes possible to create a pre-retrofit simulation model to perform building data, mapping issues to be renovated and corresponding solutions for building renovations.

This development leads to an important design and process innovation for territorial information systems playing a fundamental role in addressing the development of built environment, providing both the congruity information management in GIS environment and the information produced through BIM processes. GIS systems are able to provide the context and the cartographic basis of any intervention and, at the same time, it extends the value of BIM design data through their visualization and geographical analysis that can be performed.

It can be observed even how the theme of overlapping models and their ability to interact without loss of information, (i.e. interoperability), represents the main aspect for the effective possibility of grouping models.

From a methodological development point of view, it is clear that the import and incorporation in a GIS of the geometries and data useful to computerize the entity in a timely manner, involves, on the one hand, a greater exploitation of the potential of BIM on different scales of representation, on the other hand, thanks to this context, the GIS technology can be consolidated to provide essential information to the organizations for managing the building heritage.

This capability becomes possible through the creation of geodatabases, identifying entities spatially related one to each other. In this regard, one of the most important drivers is sharing the information that must be entered only once into the database, giving the possibility to optimize information management, increasing accuracy through the addition of new information, not by iterative entry of the same data already entered.

However, researchers use different integration patterns and platforms still lacking enough practice and validation in different fields for the whole lifecycle. Therefore, for future research, it is suggested a focus on issues including using a unified model, better based on standard data format of Industry Foundation Classes (IFC)[5] and City Geography Markup Language (CityGML)[6] for Smart City applications on multiple purposes across the whole lifecycle, developing a corresponding data platform.

In addition, achieving a coherent collaboration between both domains will enable the creation of a continuity of

[5] IFC is defined as an object-based file format oriented specification for exchanging, sharing and re-using information throughout the building industry's life cycle. It is an open file format developed and maintained by International Alliance for Interoperability since 1995. El-Mekawy, M.; Östman, A.; Hijazi, I. *An Evaluation of IFC-CityGML Unidirectional conversion*. Int. J. Adv.Comput. Sci. Appl. 2012,3, 159–171

[6] CityGML, is a common information model and XML-based encoding for the representation, storage, and exchange of virtual 3D city and landscape models. It is realized as an opened data model and implemented as an application schema (Schema is the organization or structure of a database. The term is often used in relational databases and object-oriented databases) for the Geography Markup Language 3 (GML3), the extendible international standard for spatial data exchange issued by Open Geospatial Consortium (OGC) and ISO/TC211 Geographic information/Geomatics. It provides a standard model and mechanism for describing 3D objects in relation to their geometry, topology, semantics and appearance generalization of hierarchies between thematic classes,aggregations, relations between objects, and spatial properties. Gröger, G.; Plümer, L. *CityGML Interoperable semantic 3D city models.* ISPRS J. Photogramm. Remote Sens.2012,71, 12–33.

information on a multi-scale level that connects buildings and the urban environment.

It seems necessary to introduce different levels and approaches on interoperability, that is defined as the "capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units"[7].

Furthermore, existing standards identify three main levels of interoperability:

- Data interoperability concerns the creation, meaning, computation, usage, transfer and exchange of data (ISO/IEC 20944-1, 2013)[8];
- Syntactic Interoperability concerns information formats and the ability of two or more systems to exchange structured information (ISO 16678, 2014)[9];
- Semantic Interoperability concerns the ability of two or more systems or services to automatically interpret and use information that has been exchanged accurately (ISO 16678, 2014).

These information layers are connected and built upon each other, where the lower levels provide elements required by upper level functionalities and without all levels of interoperability, metadata cannot be shared effortlessly efficiently and profitably. Therefore, without data interoperability information would not be sent correctly from one device to another. Furthermore, without syntactic interoperability, data is not handled properly, which means it will not respect the formats, encoding, properties, values and data types. And finally, without Semantic interoperability, the meaning of the language, terminology and metadata values used cannot be exchanged or properly assumed. Hence, in regards to BIM and GIS interoperability levels, only the semantic level has not been yet solved. Therefore, ISO 11354 (ISO 11354-1, 2011[10]) proposes to achieve semantic interoperability between multiple systems through three semantic approaches: unification, integration and federation.

The final ambition is to configure a digital approach to UI basing on interoperability between BIM and GIS integration towards DT models of the city organized into layers that cooperate and reconfigure themselves to solve assigned problems. High level decisions can be provided through a coordinated multidisciplinary approach, leveraging fully multidisciplinary integration of city layers, connection and evolution with the city, and integration of participative strategies to include "human-oriented" information, as well as modularity of application. The proposed methodologies for a new digital urban planning could lead to some significant results at a strategic level (planning and intervention on city infrastructures, mobility systems, energy distribution, etc.) as well as at an operational level (urban planning in connection with services management, local mobility planning, building design and performance, site and settlement planning) and also on emergency levels (integrating resiliency and sustainability into emergency preparedness).

[7] ISO/IEC 2382-1:1993 Information Technology — Vocabulary — Part 1: Fundamental terms.

[8] ISO/IEC 20944-1:2013 *Information Technology — Metadata Registries Interoperability and Bindings* (MDR-IB) — Part 1: Framework, common vocabulary, and common provisions for conformance. The ISO/IEC 20944 series of International Standards provides the bindings and their interoperability for metadata registries, such as those specified in the ISO/IEC 11179 series of International Standards. ISO/IEC 20944-1:2013 contains an overview, framework, common vocabulary, and common provisions for conformance for the ISO/IEC 20944 series of International Standards.

[9] ISO 16678:2014 *Guidelines for interoperable object identification and related authentication systems to deter counterfeiting and illicit trade*, establishes a framework and outlines functional units used to achieve trustworthiness and interoperability of such systems. It does not specify any specific technical solutions, but instead describes processes, functions, and functional units using a generic model to illustrate what solutions have in common. Object identification systems can incorporate other functions and features such as supply chain traceability, quality traceability, marketing activities, and others, but these aspects are out of scope of ISO 16678:2014.

[10] The purpose of ISO 11354-1:2011 is to specify a Framework for Enterprise Interoperability (FEI) that establishes dimensions and viewpoints to address interoperability barriers, their potential solutions, and the relationships between them. ISO 11354 applies to manufacturing enterprises, but can also apply to other kinds of enterprises. It is intended for use by stakeholders who are concerned with developing and deploying solutions based on information and communication technology for manufacturing enterprise process interoperability. It focuses on, but is not restricted to, enterprise (manufacturing or service) interoperability.

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[10] Gröger, G.; Plümer, L. *CityGML Interoperable semantic 3D city models.* ISPRS J. Photogramm. Remote Sens.2012,71, 12–33.

[11] ISO/IEC 20944-1:2013 *Information Technology — Metadata Registries Interoperability and Bindings* (MDR-IB) — Part 1.

[12] ISO 16678:2014 *Guidelines for interoperable object identification and related authentication systems to deter counterfeiting and illicit trade.*

[13] ISO 11354-1:2011 *Advanced automation technologies and their applications — Requirements for establishing manufacturing enterprise process interoperability* — Part 1.

Foreword

Pablo Gandara

Team Leader IUC Asia

EU International Urban Cooperation (IUC) Project

It is a great pleasure for the International Urban Cooperation (lUC) Asia project team to have been able to support Sapienza University in the preparation of the international summer school on BIM and GIS, implemented online in September 2020. The IUC is a programme of the European Union's Foreign Policy Instrument (FPI) that boosts international urban cooperation with EU partners in Asia and the Americas.

As the areas in which most people live and work, cities are increasingly acknowledged as the arena in which solutions to major societal and environmental challenges must be developed and implemented. Cities are the world's primary hubs of economic and cultural activity, a fact which is causing the rate of urbanisation to increase at a rapid pace. This accelerated demographic change has put many cities under significant strain, with local governments often struggling to meet the higher demand for energy, water, health, education and transport services.

The IUC programme enables cities in different global regions to link up and share solutions to common problems. It is part of a long-term strategy by the European Union to foster sustainable urban development in cooperation with both the public and private sectors, as well as representatives of research and innovation, community groups and citizens. Through engaging in the IUC, cities have the chance to share and exchange knowledge with their international counterparts, building a greener, more prosperous future.

The IUC programme is an opportunity for cities to learn from each other, set ambitious targets, forge lasting partnerships, test new solutions, and boost their international profile IUC activities support the achievement of policy objectives as well as major international agreements on urban development and climate change, such as the Urban Agenda, the Sustainable Development Goals, and the Paris Agreement. Moreover, the IUC supports cities in the implementation of the European Green Deal, designed to make our economy more sustainable and to turn environmental and climate challenges into opportunities, while ensuring that transition to the new model of development is just and fair for all European citizens.

Within the IUC Asia programme, we have involved many cities from China and the European Union, with Rome as a great example commitment and excellence. We have promoted together a multi-stakeholder approach involving public authorities, the research community and the business sector. I am happy to see that - since the very beginning of Rome's IUC participation - Sapienza University has taken a leading role in this 'triple-helix' approach.

The summer school on BIM and GIS is a remarkable pilot project that has delivered deep insights into urban planning, which is the base for achieving a sustainable urban development. I am delighted to have seen such a wide range of applications for the digital tools in the planning and construction processes, which may enable cities' experts to achieve higher levels of energy efficiency and protect architectural heritage in China and Europe.

In times of complex issues such as the COVID pandemics, let me please congratulate the Sapienza team for implementing the summer school fully online and for reaching such a wider audience in China and Europe. I am happy to see that the IUC project team has been able to support this achievement, which is complemented by a digital platform for long-term cooperation between experts from European and Chinese cities.

Preface

Prof. Marco Casini

ISS Scientific Director

Faculty Advisor and Project Manager Team Sapienza SDME 2018

Department of Urban Planning, Design and Architecture Technology, SAPIENZA University of Rome

At the beginning of the 4th Industrial revolution, the advent of digitalization, innovative technologies and materials, and new construction techniques, have begun transforming the way that infrastructure, real estate and other built assets can be planned, designed, constructed and operated in order to create a more attractive, energy efficient, comfortable, affordable, safe and sustainable built environment. Developments in digital design, artificial intelligence, robotics, nanotechnology, additive manufacturing, have finally started to move the construction industry - traditionally reluctant to innovation and slow in adopting new technologies - towards a new era.

Massive changes are occurring as a result of the possibilities created by the synergic use over the entire life cycle of Building Information modelling (BIM) and Geographic Information system (GIS) in design at building and urban scale making building planning more efficient, rational, and standardized. BIM-GIS integration and its applications represent an active research topic for the future development of society, especially in the field of the sustainable built environment and a growing number of studies have shown that BIM-GIS integration has promising prospects in numerous applications.

The combined use of BIM and GIS is in fact establishing a comprehensive view of the built environment based on integrated data that can increase the quality and the productivity of the AEC industry and, at the same time, address emergent global challenges such as resource shortage, climate change and increase of global population.

The International Summer school "GIS-BIM for digital integrated design" of which I've been Scientific Director had the important objective of giving a comprehensive review on BIM-GIS integration in sustainable built environments in order to analyze the status quo and practical applications from the viewpoints of technologies for data integration, applications in the life cycle of AEC projects, building energy management, and urban governance, showing relevant case histories. The aim of this publication on the School lectures is to provide researchers with a roadmap for improving the integrated management of spatial information by using data analysis and visualization, employing new technologies in the traditional fields of construction and environmental engineering, devising more efficient methods of development, and facilitating sustainable urban development.

Why a digital integrated design?

Prof. Flavio Rosa
ISS GIS-BIM Coordinator and Book Editor
Professor in Environmental Building Physics,
Faculty of Architecture, SAPIENZA University of Rome

A Digital Twin is the fusion of a real-world system and virtual representation designed to control, monitor, and optimize a project's functionality. Digital Twin (DT) provides a promising way to alleviate the problem by bridging the physical space and virtual space.

The building sector, with 40%, is the largest end-energy user. Information and communication technologies (ICT) have been identified to play an important role in reducing energy intensity and increasing the energy efficiency of the building stock. The building process is in rapid and considerable transformation given the entry of BIM (Building Information Modeling) which is greatly modifying its workflow. These transformations are in place both at the level of energy planning on the urban scale and at the level of the single housing unit. The concept of Smart Cities has dramatically changed reading and urban planning. The basic unit, the atom of this complex structure, is not the building but the single housing unit. If we move towards reading from the point of view of energy flows, we arrive at the "elementary particles" of individual environments.

The urban scale, with GIS (Geographic Information System) and BIM tools for the single housing unit, infrastructures a highly interconnected workflow, flow of data and information. The amount of information to be processed must be managed with ICT methodologies and solutions. The integration process requires a "wide-scale" vision and design method: from Satellite-Land scale to the BIM-single electric Switch in a room. The solution is the continuum between representation and information.

The Design of Digital Integrated GIS and BIM has become paradigmatic therefore a necessary step in the management of urban and architectural complexity.

The International Summer School: GIS-BIM for digital integrated design, which I had the honour and pleasure of coordinating thanks to the support of the Scientific Director, Professor Marco Casini, and the Director of the DPDTA, Professor Laura Ricci, was conceived to train students all over the world on a subject as yet unexplored. A highly interconnected educational workflow between research and teaching activities for operational design and management applications in the construction industry.

Our initiative, thanks to the continuous and concrete support of the IUC international cooperation program of the European Union, has enabled us to develop transdisciplinary themes internationally in collaboration with Chinese professors at Tongji University in Shanghai.

Participation in the ISS of the Glodon Company, the first company that enrolled personnel in the field of construction engineering informationization in China as well as students from Liuzhou Vocational College, Yantai University, Northeastern University has allowed us to involve different user profiles. Without forgetting the Italian students and those from all over Europe.

Given the great interest and the positive feedback received at various levels and from all the figures involved, the realization of this publication has become a necessary act.

This work, with contributions from all the teachers whom we want to thank very much for their participation and the high quality of the submitted content, focuses on the concrete activities aimed at Bridging the GAP knowledge between academic institutions and professional and Italian ones worldwide.

List of contributors

Prof. Marco Casini Scientific director

Prof. Marco Casini is a leading academic in the Green and Smart Building sector with over 20 years' experience in Building Sciences. He is an environmental engineer, PhD in Environmental Engineering and Associate Professor in Architecture Technology at Sapienza University of Rome, where he also teaches in several Master's, PhD and Graduate schools. From 2016 to 2018 Prof. Casini has been the Faculty Advisor and Project manager of Sapienza University Team competing in Solar Decathlon Middle East 2018 Edition. Prof. Casini's research activities cover a wide spectrum of topics within sustainable architectural design and construction, focusing on advanced materials and technologies and innovative tools and methods for smart buildings and smart cities. He worked as scientific coordinator on major projects including the development of "Italian regional system for the certification of environmental sustainability of buildings - Protocollo ITACA Lazio" (2014) and the preparation of the "Sustainable Energy Action Plan of Rome" within the European Covenant of Mayors for Climate and Energy (2012). He has been member of several International Public Technical Working Groups for the development of specific standards on environmentally sustainable construction. Prof. Casini is Member of the Editorial Boards and Reviewer of several international scientific journals in the fields of Engineering and Architecture. He has authored over 80 scientific publications on energy and environmental efficiency of buildings, latest the book "Smart buildings: Advanced materials and nanotechnology to improve energy-efficiency and environmental performance" (Woodhead Publishing Elsevier, 2016).

Prof. Flavio Rosa ISS GIS-BIM Coordinator

Graduated in Environmental Engineering and Land Management at the Faculty of Engineering of La Sapienza Rome. He is a qualified engineer and is registered with the province of Rome. PhD in Energy at the Department of Nuclear Engineering and Energy Conversions (DINCE) with a thesis on the use of Biomass in protected natural areas. Research fellow: A.A. 2010/11 Study and Evaluation of Environmental Problems Related to the Maritime Transport of Dangerous Goods; AA.AA. 2011/12 2012/13 Implementation of Renewable Energy Within Port Areas. Adjunct Professor of Environmental Technical Physics at the Faculty of Architecture in Rome from 2014 to the present. Professor of 1st level BIM University Master - Building Information Modelling Faculty of Architecture Sapienza Rome and 1st level Master of Building Process Management - Project Management. Theses tutor and supervisor in the field of RES and their interaction with the built environment at the Faculty of Architecture at La Sapienza Rome. Reviewer of scientific articles in the field of sustainable architecture and systems integration in historic buildings. Author of publications in the field of renewable energy and energy retrofit within historic buildings. In charge of international relations for the SAPIENZA CITERA CENTER. International Summer School Coordinator with operations in China, Panama and Costa Rica.

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Prof. Tommaso Empler

BA Certificate of Higher Education in Architecture at Sapienza University of Rome in 1992. He obtaines PhD degree in 1998 and becomes research worker in 2010. Since 1998, as external lecturer, he teaches Computer Graphics at "Valle Giulia" Architecture Department of Sapienza University of Rome. From 2002 to 2004, as external lecturer, teaches Simulation techniques of landscape, at "Valle Giulia" Architecture Department of Sapienza University of Rome. From

2005 to 2010, as external lecturer, teaches Computer Graphics at the Faculty of Engineering of Trento. Since 2010 he is Assistant Professor at the Department of History, Design and Architecture Restoration teaching Computer Graphics 1, Computer Graphics 2, Atelier of Computer Graphics 3, Three-dimensional representation and dedicates it's studies and research activity on: how using and developing computer graphics to design and survey with particular attention to Open Source systems; studying wayfinding systems related to visual and non-visual perception. He is author of many scientific book on his research field.

Prof. Patrick Maurelli

PhD in Urban Planning Techniques in 2009, is Coordinator of the GIS BIM & Digital Twin Laboratory of the CITERA Research Centre - Sapienza University of Rome; Responsible for European Projects and International Initiatives of FEDERESCO; H2020 Expert Evaluator for EASME EU Commission. Former EU projects and Energy Expert at the Infrastructures and Public Works Councilor Office of Roma Capitale. Project Manager for ongoing H2020 funded projects in the energy efficiency sector: REFINE (CSA – E7 AT Lead) activities of Federesco, for PLATOON (IA – Engie FR Lead) activities of Risorse per Roma. Civil Environmental Engineer expert in project management, energy efficiency and auditing, renewable energy, information technology (GIS, DBMS, WebGIS, BIM), impact assessment, LCA/LCIA, evaluation techniques. As GIS expert has been researcher at INRETS (France) on Transportation Urban planning and Safety themes, at CesdRoma/ISTAT within international statistic activities (EUROSTAT) and is author of various publications. Lecturer and tutor within the master's degree courses in Environmental Engineering for Sustainable Development (Sapienza University, 2005-2016). Technical supervisor of the "Land and Urban Planning Laboratory"and "GIS and Numerical Modelling Laboratory" of the Environmental Engineering Faculty (Sapienza). From 2002 as program and project manager participates in many R&D projects (Sapienza, ISPESL, INAIL, Ecomedia), engineering projects (large RES plants; hydraulics and wastewater treatment), GIS and multimedia development projects.

Prof. Sofia Agostinelli

Master's Degree in Building Systems Engineering at Sapienza University of Rome, she is an Adjunct Professor of Project Management at the Faculty of Architecture of Sapienza University of Rome. She is involved in research activities at CITERA (Interdepartmental Research Centre for Building Territory Restoration Environment) participating in national and international work teams. She has authored several publications on the field of Digital Twin, digital project management and sustainability of construction processes.

Module 4a: Digital methods and tools in the construction process for an efficient project management workflow: case histories. The activity provides an analysis of methods and applications related to the use of digital methods and tools for the control and optimization of different phases in the construction process.

The opportunities deriving from the integration of information systems in the project workflow will be explored also through the analysis of specific thematic case studies about the interaction of Digital Twins & Artificial Intelligence systems aimed at optimizing processes.

Prof. Claudio Tomazzoli

Master's Degree in Information and Automation Engineering at the University of Padova. PhD in Computer Science at the University of Verona. He is Adjunct Professor at the Department of Computer Science of the University of Verona and he is involved in research activities in the field of Artificial Intelligence. He is inventor of patents including Energy Management System in at least one building and relative method.

Prof. Stefano Amista

Graduated in Business and Economics and specialized in Project Management for construction, he has been working for the last 20 years in STR - TeamSystem Group in different positions, gaining specific skills in the fields of Customer Care, Software Solutions Development and Marketing, and he is currently Sales Specialist for AEC and BIM companies.

He has been an Adjunct Professor in the Management Control Lab at the University of Turin since 2017, graduating with a master's degree in Accounting Professions.

Dr. Simone Di Biase

Simone Di Biase in an Architect with experience in complex building, infrastructure and TLC (mobile fixed and Data Center) projects, from preliminary design to construction phase. He joined DBA PRO. more then 10 years ago in 2007 involved in Real Estate projects and then in TLC sector. Since 2015 he is involved in BIM development for the Holding (DBA Group), as for develop BIM Projects and internal procedure for BIM development for Architecture, Infrastructure and TLC Business Unit. Due to his experience in complex projects and BIM procedure since 2018 is involved in BSI International as representative for DBA Group. With the experience acquired in standard projects and BIM Project the next step of research is to have a concrete approach to project development to the whole life cycle design and finally to facility management from BIM Models.

Dr. Claudio Mirarchi

Claudio Mirarchi is a postdoc researcher at Politecnico di Milano. He has a PhD in Building Engineering achieved at Politecnico di Milano and his research is focused on the introduction of digital processes in the construction sector with specific reference to the issues related to the knowledge management area. Founding partner of ConITeng s.r.l. an engineering company focused on innovative services in the construction sector, he is active in the research and practice about the implementation of BIM and digital processes and technologies in the construction sector. He is the project management work package leader of the DigiPLACE project aimed at creating the foundations for the future European platform(s) in the construction sector; he coordinates the development of the Italian standard about common data environment in the context of the UNI 11337 series (working group 4). He has held several courses and speeches at national and international level including the BIMA+ European master, the MSc Building Information Modelling program at the School of Architecture, University of Liverpool, the dissemination activities promoted by the Italian association of construction companies (ANCE) at Italian level, the LC3 conference, the ECPPM conference, the EC3 conference, the BIM world Paris, etc.

Prof. Xing Shi

Professor, College of Architecture and Urban Planning, Tongji University. Chair, Key Laboratory of Ecology and Energy-saving Study of Dense Habitat, Ministry of Education. Dr. Shi received his Bachelor degree from Tongji University in 1998. He then studied at the Pennsylvania State University in the U.S. and received his Ph.D. degree in 2005. From 2005 to 2008, he worked at Walter P Moore in Houston as a consulting engineer. In early 2008, Dr. Shi joined the Faculty of Architecture at Southeast University. In August 2020, Dr. Shi returned to his Alma Mater as the professor at College of Architecture and Urban Planning and the chair of the Key Laboratory of Ecology and Energy-saving Study of Dense Habitat, Ministry of Education.

Dr. Shi's research interests include green building performance and design optimization, urban energy systems and simulation, energy-efficient cities and design. He teaches 4 courses on both the undergraduate and graduate levels.

Dr. Shi has led and participated in more than 20 research projects, funded by the Natural Science Foundation of China, the Ministry of Science and Technology of China, the Ministry of Education of China, the National Science Foundation of the U.S., the ASHRAE, etc. He has published 4 books and more than 90 papers on academic journals and conferences. These journals include Energy, Renewable Energy, Applied Energy, Energy and Buildings, Building and Environment, Landscape and Urban Planning, Automation in Construction, Journal of Building Physics, Journal of Building Engineering, etc. Dr. Shi has extensive design and consulting experiences. One of his recent works is leading the project of green building design and technology integration of the National Cultural Center in Beijing.

Dr. Shi serves on the editorial board of 4 international journals. He is a member of several technical committees including the Green Building Evaluation Committee of the Ministry of Housing and Urban-Rural Development of China.

Organization and digitization of information on buildings and civil engineering works, including building information modelling (BIM).

Dr. Francesco Ruperto

Coordinator of Professional Higher Education Course and 3D Modeling & BIM Workshop
at the Faculty of Architecture of Sapienza University of Rome.

The digital transformation of public works project management. OpenCortina: Artificial Intelligence and cognitive services to support the customer's decision-making process.

The increasing use of digital technologies in the various production sectors has accelerated considerably due to the social distancing imposed by the measures to contain the COVID 19 pandemic. The need to maintain the operation of many public and private organizations is breaking down many factors of resistance to the change in established ways and working habits over the decades. The covid 19 negative event is at least returning an increased awareness of the potential of digital that obviously is not limited to the mere possibility of working remotely even if this is perceived as the most evident discontinuity compared to traditional working methods. The scope of the change taking place is much wider and involves a review of the organizational models of organizations including those in the construction sector. Business goals can be pursued through information that continuously provides data-driven decision support. A digital framework, designed for uses and objectives, returns value in terms of reliability and robustness of information by limiting the possibilities of ambiguity of interpretation and favoring a usable "knowledge" of the project.

From the perspective of public works clients, this is an opportunity to optimize the efficiency and effectiveness of their technical and administrative activity aimed at the realization of projects aimed at the community using digital technologies, including those of BIM.

Artificial intelligence and machine learning, cognitive services and business intelligence can be in the availability of the project manager of the public work and can return, if combined with a coherent organizational model, immediacy and reliability of information for different uses, technical, environmental, security, administrative etc. This potential becomes even more strategic when related to programmes of public works interventions that cannot be delayed, such as works related to major sporting events: world competitions, Olympic Games, etc. Digital information management makes it possible to extract value from containers information of different nature, structured and un structured making relationable and analyzable knowledge bases otherwise destined to be only evidence of documentary obligations.

In this scenario, the **OpenCortina project** was promoted in 2018 by Luigivalerio Sant'Andrea, Government Commissioner of the Cortina 2021 Alpine SkiIng World Championships and developed by Francesco Ruperto as senior project manager and Elisa Coletta as junior project manager. OpenCortina is aimed at the digital governance of an articulated Plan of Public Interventions of a predominantly sporting and mountain nature. OpenCortina, after two years of development, constitutes a digital organizational model, scalable and replicable even on events of greater impact in quantitative and qualitative terms.

The project is based, at the legislative level, on the preliminary obligations provided for by the decree of mandatory electronic methods and tools at Italian contracting stations and granting administrations: "The information flows concerning the contracting station and the related process take place within a common data environment, where the digital management of information processes takes place, explained through a process of correlation and optimization of digitized information flows and decision-making processes concerning the individual process". The statement of the legislative forecast emphasizes the need that, with a view to improving the performance of the public client in terms of cost-effectiveness, efficiency and effectiveness, key principles of public administrative action, it is possible to resort to digital technologies enabling better levels of knowledge, control and monitoring of the procedures and processes of implementation of public works. Very ambitious objectives whose achievement has forced in the case of OpenCortina, to a progressive but inevitable paradigm shift the entire supply chain of works and services of the construction industry; a transition that has gradually led to recognize Value in actions less and less based on documentary requirements and increasingly oriented to manage and monitor projects on data articulated in information containers. This digital transformation has allowed an optimization of public resources, imposing on the other a general strategy aimed at increasing the reliability and availability of data on the basis of rules previously shared within the organization and contracted in relations with external suppliers on individual procedures.

In this innovative scenario but always oriented by EUBIM HAndbook, from international standards on ISO 9000 quality management, ISO 55000 asset management, ISO 21500 project management, ISO 19650 information management and Information Security Management as well as national UNI 11337: 2017 main lines of action have developed:

1. Analysis and evaluation of the purchasing organization of the works "Cortina 2021" verifying their strategic objectives, main functions, multiannual planning, regulatory, legislative or related to particular acts of technical /administrative direction.
2. Structuring of the decision-making line, roles and responsibilities and approval processes and definition of the necessary needs and information flows in response useful for achieving the objectives;
3. Analysis and evaluation of the nature of the assets to be managed through the definition of the management, commercial and technical aspects of the production of information about fixed assets. The first two areas define the information standards and production methods and procedures that need to be implemented. The technical aspects define the information parts necessary to meet the information needs of the organization.
4. Analysis and evaluation of the methods of procurement of project and work services identifying the information requirements useful for the achievement of specific strategic objectives at each of the decision-making milestones in the various phases of realization of the work;
5. Alignment of the processes management systems of the evaluated organization in relation to the nature of the assets and the methods of supply, through audit activities aimed at identifying information deficiencies and structuring response information flows based on useful data and preferably structured in interoperable open formats necessary for the return of significant indicators;
6. Definition of contractual schemes that direct the action of the parties in terms of modalities and responsibilities, in the digital field, in the supply chain of the "Cortina 2021", and depending on the phase going so far as to structure even penalty metrics in case of non-compliance;
7. Verification of enabling digital technologies, acquisition and implementation of the same, evaluating the nature of the works, the type of projects, the competence of the staff and possibly structuring training plans consistent with the role played in the organization;
8. Surveillance, maintenance and continuous improvement of the platform and the data sharing environment in the life cycle of procedures and possible progressive development of artificial intelligence algorithms and cognitive services useful for improving the performance of the organization.

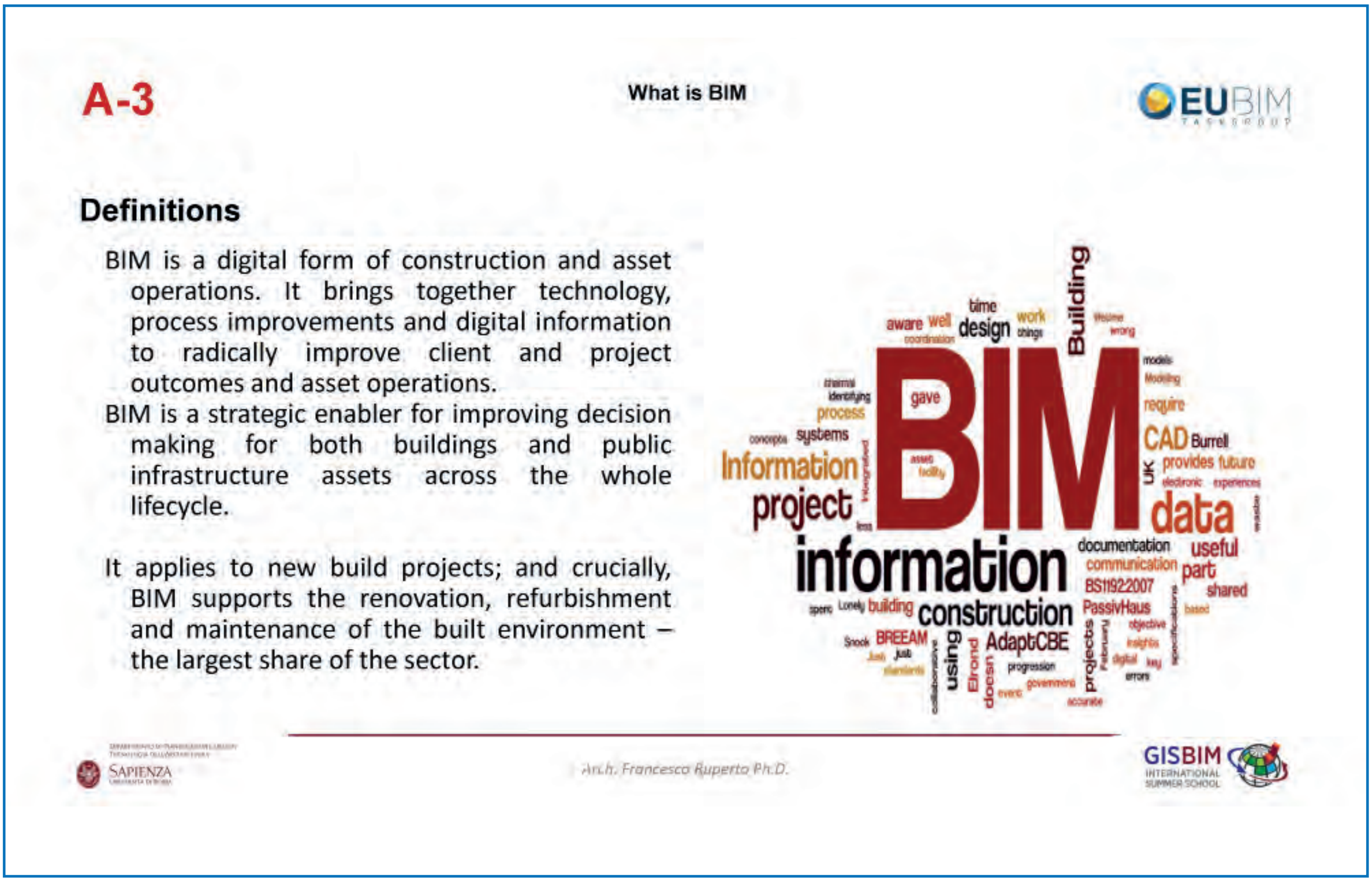
From the summary above, therefore, some initial derived considerations are evident, which are summarized below:

- OpenCortina is a Platform structured by Common Data Environments based on a cloud computing information resource in the availability of the Client part in which, independently of the different entrustors, it manages its projects and its real estate and infrastructure assets in all phases, with rules previously shared and contracted through information specifications / Information Management Plan;

- OpenCortina is the “place” of execution of the contract allowing to constantly monitor the performance of the internal working group and/or external suppliers of the Contracting Station and/or the Pubblic Administration;
- OpenCortina reflects the organizational structures of the appointing party and possibly enables better levels and on this must be tailored with scalar solutions and with costs previously estimated and calibrated on the objectives considered strategic.

In conclusion, OpenCortina has gradually become, itself, a strategic asset of the organization able to return value in terms of efficiency, effectiveness and cost-effectiveness, all the greater depending on the specificity of the solution adopted and the medium/long-term vision put in place, recognizing its value also in terms of improving environmental sustainability (supporting the optimization of resources and reducing waste), economic (limiting the risk of lengthening time and overruns of the budget), social (being able to enable higher levels of site safety), and ethics (favoring greater transparency and reducing the risk of moral hazard).

The slides that accompany this text are the synthesis of the principles on which the OpenCortina project was based, illustrating in depth the main regulatory and methodological references that can support a progressive digital transformation of public commission organizations useful to meet the needs of the national and international community.



A-4

What is BIM

EUBIM TASKGROUP

The Prize

BIM is not new, but it is a global trend that is growing. Reports forecast that the wider adoption of BIM will unlock 15–25% savings to the global infrastructure market by 2025. And it is the technology-led change most likely to deliver the highest impact to the construction sector.

The prize is large: if the wider adoption of BIM across Europe delivered 10% savings to the construction sector then an additional €130 billion would be generated for the €1.3 trillion market.

Even this impact could be small when compared with the potential social and environmental benefits that could be delivered to the climate change and resource efficiency agenda.

SAPIENZA

Arch. Francesco Ruperto Ph.D.

GISBIM INTERNATIONAL SUMMER SCHOOL

A-5

Digital Transformation

EUBIM TASKGROUP

Digitalisation

Digitalisation is the adoption or increase in the use of digital or computer technology by an entity such as an organisation, industry sector or country.

The introduction of Building Information Modelling (BIM) represents the construction sector's moment of digitalisation.

It is undisputed, that the wider use of technology, digital processes, automation and higher-skilled workers contribute greatly to our economic, social and environmental future.

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A-7

Digital transformation

Risk management

Several industry reports identify systemic issues in the construction process relating to its levels of collaboration, under-investment in technology and R&D; and poor information management.

These issues result in poor value for public money and higher financial risk due to unpredictable cost overruns, late delivery of public infrastructure and avoidable project changes.

Arch. Francesco Ruperto Ph.D.

A-10

What is 'BIM' to the public sector stakeholder?

A decision making enabler

For the public sector, BIM can be thought of as 'digital construction'.

It is similar to the technology and digital process revolution that entered the manufacturing sector in the 1980s and 1990s to improve productivity rates and output quality.

It combines the use of 3D computer modelling with whole life asset and project information to improve collaboration, coordination and decision-making when delivering and operating public assets. It also addresses long over-due changes in processes from the analogue into the digital world that enable us to control and manage an unprecedented volume of digital data and information.

Arch. Francesco Ruperto Ph.D.

A-13

Value proposition of BIM

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Value proposition of BIM

The public sector can benefit from the adoption of BIM in three distinct stakeholder roles:

- Public procurer or an infrastructure and estate owner concerned with the project phase (i.e. delivery of built assets)
- Public infrastructure and estate owner concerned with the operations and maintenance phase (i.e. use of public built assets)
- Public policy officer concerned with the development of legislation, policy, regulation or standards to improve performance of the sector or built environment (i.e. sector focus).

For the public sector, these benefits translate to economic benefits, such as better value for public money during the delivery phase and improved quality of public goods and services during the use of the built asset.

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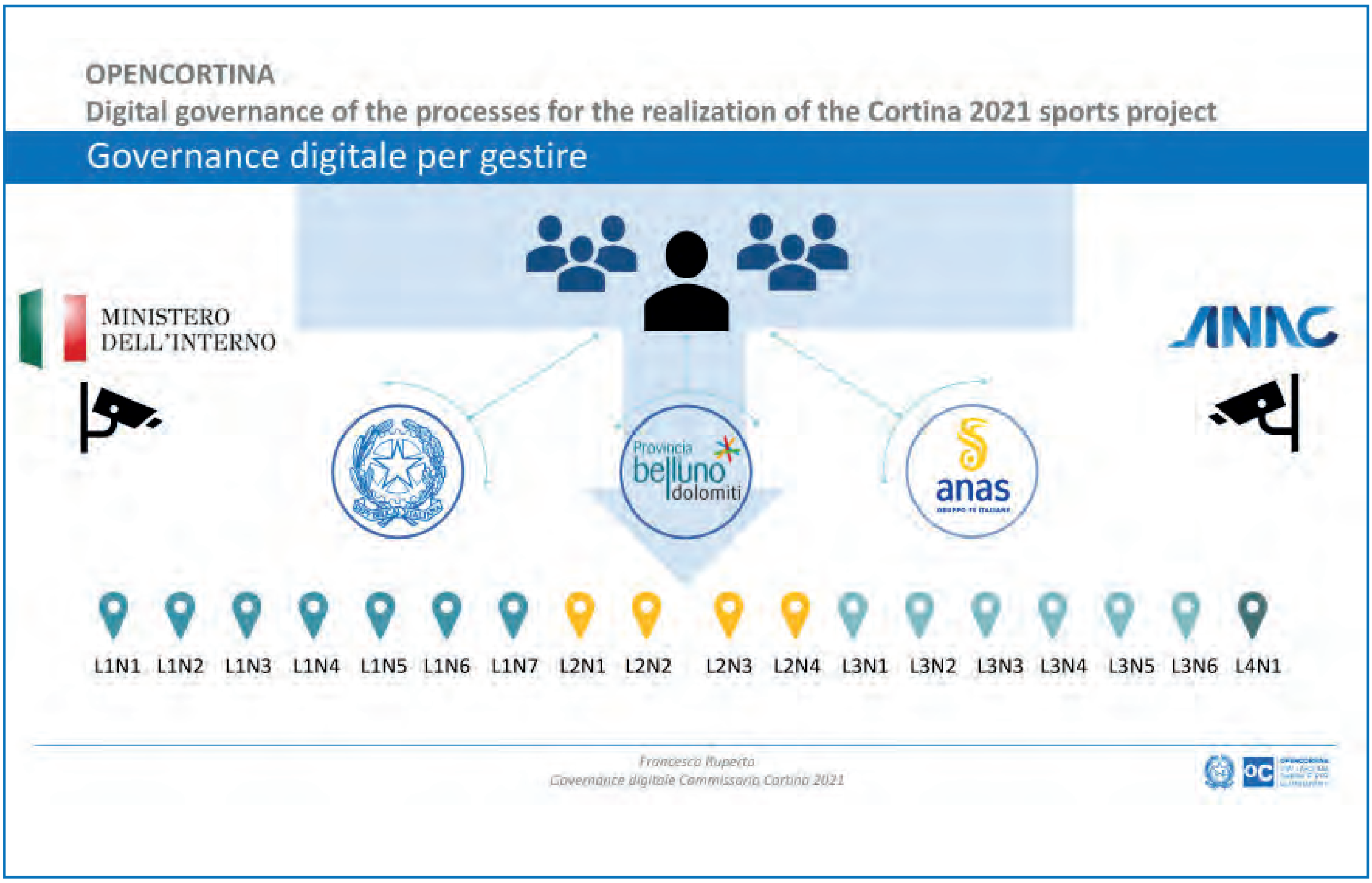
OPENCORTINA

Digital governance of the processes for the realization of the Cortina 2021 sports project


Championship numbers of the Alpine Skiing World
600
Athletes from more than 70 nations
14
Days of racing
1.200
Volunteers
20k
Spectators expected
500 mln
Live connected viewers
The numbers of OpenCortina
14
Works
95 mln
euros of Investments
3
Appointing parties
1
Digital Governance Project
30
Months to realize the works


OPENCORTINA
Digital governance of the processes for the realization of the Cortina 2021 sports project
Governance digitale per gestire
MINISTERO DELL'INTERNO
ANAC
Provincia belluno dolomiti
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L1N1 L1N2 L1N3 L1N4 L1N5 L1N6 L1N7 L2N1 L2N2 L2N3 L2N4 L3N1 L3N2 L3N3 L3N4 L3N5 L3N6 L4N1
Francesco Ruperto
Governance digitale Commissario Cortina 2021
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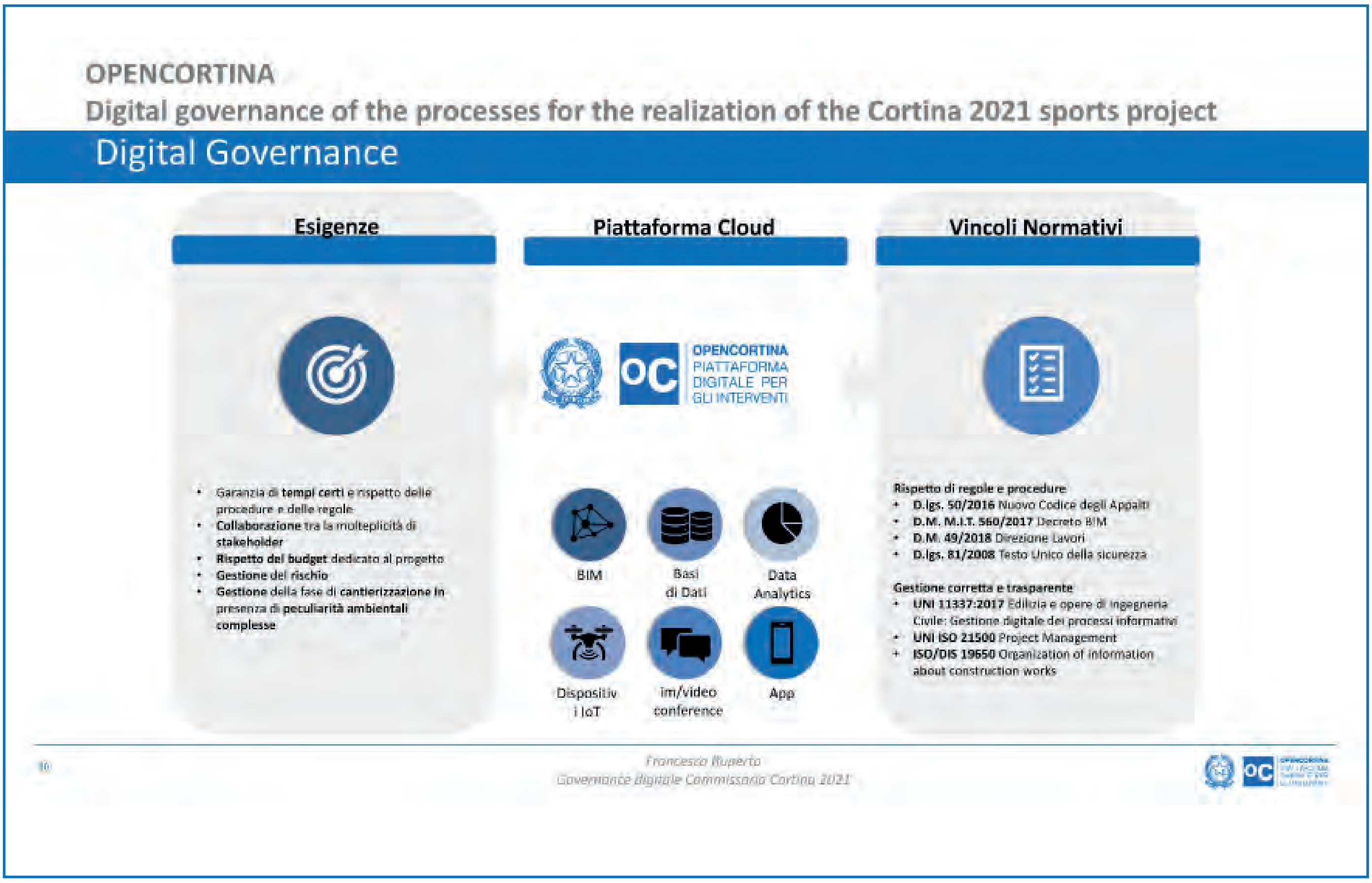
OPENCORTINA
Digital governance of the processes for the realization of the Cortina 2021 sports project
Digital Governance
Esigenze
Piattaforma Cloud
Vincoli Normativi
OPENCORTINA
PIATTAFORMA
DIGITALE PER
GLI INTERVENTI
Garanzia di tempi certi e rispetto delle procedure e delle regole
Collaborazione tra la molteplicità di stakeholder
Rispetto del budget dedicato al progetto
Gestione del rischio
Gestione della fase di cantierizzazione in presenza di peculiarità ambientali complesse
BIM
Basi di Dati
Data Analytics
Dispositivi IoT
im/video conference
App
Rispetto di regole e procedure
D.lgs. 50/2016 Nuovo Codice degli Appalti
D.M. M.I.T. 560/2017 Decreto BIM
D.M. 49/2018 Direzione Lavori
D.lgs. 81/2008 Testo Unico della sicurezza
Gestione corretta e trasparente
UNI 11337:2017 Edilizia e opere di ingegneria Civile: Gestione digitale dei processi informativi
UNI ISO 21500 Project Management
ISO/DIS 19650 Organization of information about construction works
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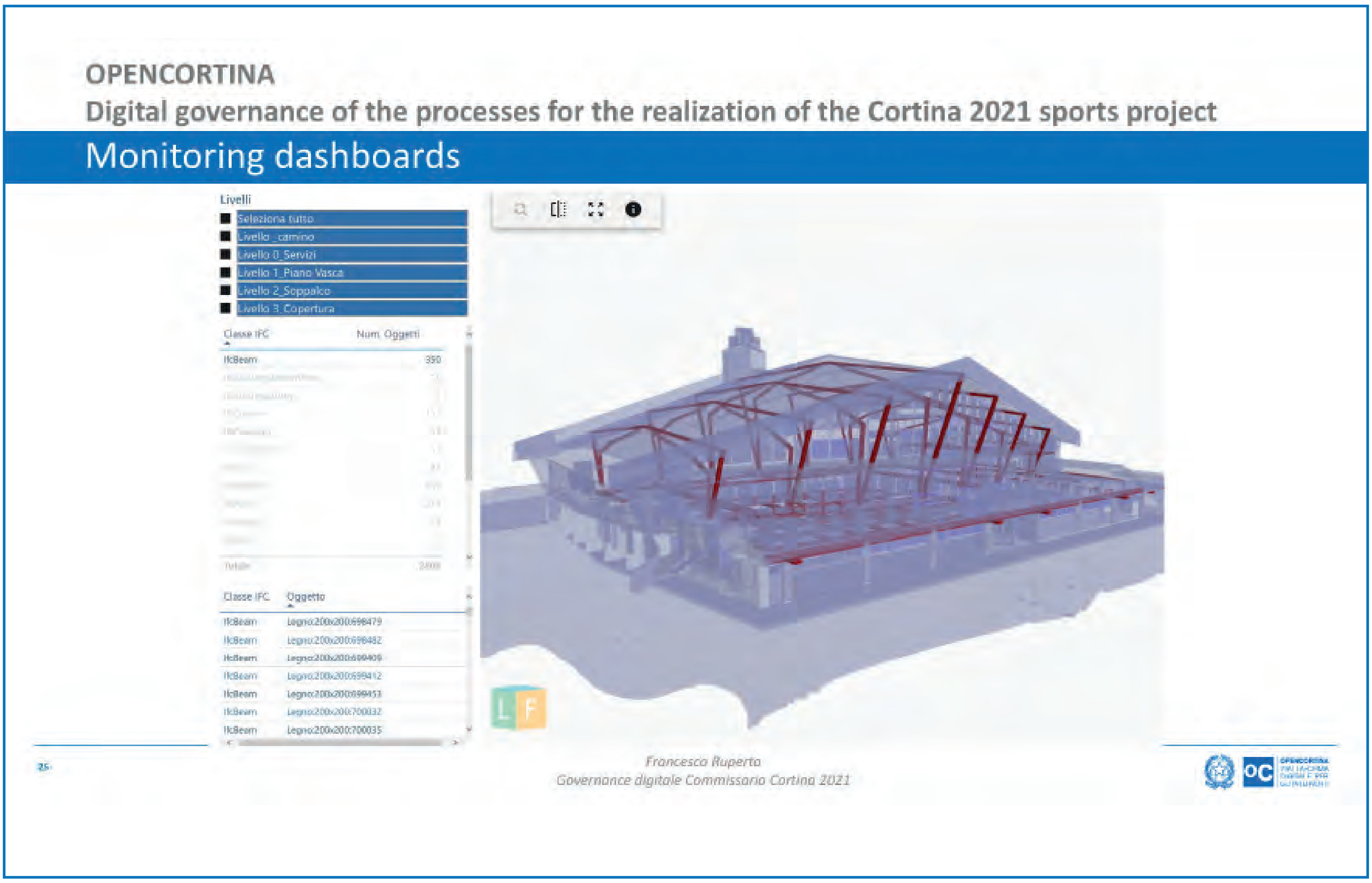
Governance digitale Commissario Cortina 2021


OPENCORTINA
Digital governance of the processes for the realization of the Cortina 2021 sports project
Monitoring dashboards
Livelli
Seleziona tutto
Livello_camino
Livello 0_Servizi
Livello 1_Piano Vasca
Livello 2_Soppalco
Livello 3_Copertura
Classe IFC
Num. Oggetti
IfcBeam
350
Classe IFC
Oggetto
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Monitoring dashboards

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Digital governance of the processes for the realization of the Cortina 2021 sports project

Galleria

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Common Data Environment(s) and Digital Platforms in the Construction Sector

Dr. Claudio Mirarchi,

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Data, information, and knowledge management represent fundamental areas of research and development in all sectors, including construction. On the one side, the spreading of Building Information Modelling (BIM) and the progressive development of technologies classified under the umbrella of Construction 4.0 are pushing the generation of data and information from different sources (information models, digital documents, data from sensors, etc.) highlighting the need to manage these assets. On the other side, the fragmented environment where data and information are generated poses a challenging framework.

The construction sector is a project base one and for every project a group of stakeholders is defined, and it evolves according to the different phases of the construction process. This group generates data, information, and knowledge during the development of the project on its own or in collaboration with one or more of the involved stakeholders. However, at the end of the project, or during the evolution of the group of stakeholders, this asset (i.e. data, information, and knowledge) is dispersed in different disconnected pieces. In the context of BIM, the concept of Common Data Environment (CDE) tries to limit this issue creating a collaborative environment where data and information can be shared and stored during the entire life of the project facilitating.

CDE is defined in the international standard ISO 19650-1 as an "agreed source of information for any given project or asset, for collecting, managing, and disseminating each information container through a managed process".

Common Data Environment (CDE) - Definitions

BS 1192-1:2007

"...a repository, for example a project extranet or electronic document management system."

BS PAS 1192-2:2013

"single source of information for any given project, used to collect, manage and disseminate all relevant approved project documents for multi-disciplinary teams in a managed process.
A CDE may use a project server, an extranet, a file-based retrieval system or other suitable toolset."

UNI 11337-1:2017

"An environment for an organized collection and sharing of data related to digital models and outputs for a single work or a single complex of works"

DIN SPEC 91391-1:2019

"Basically, a CDE is an agreed source of information for a given project or asset. In a CDE, information containers are collected, processed, and distributed by means of a controlled process."

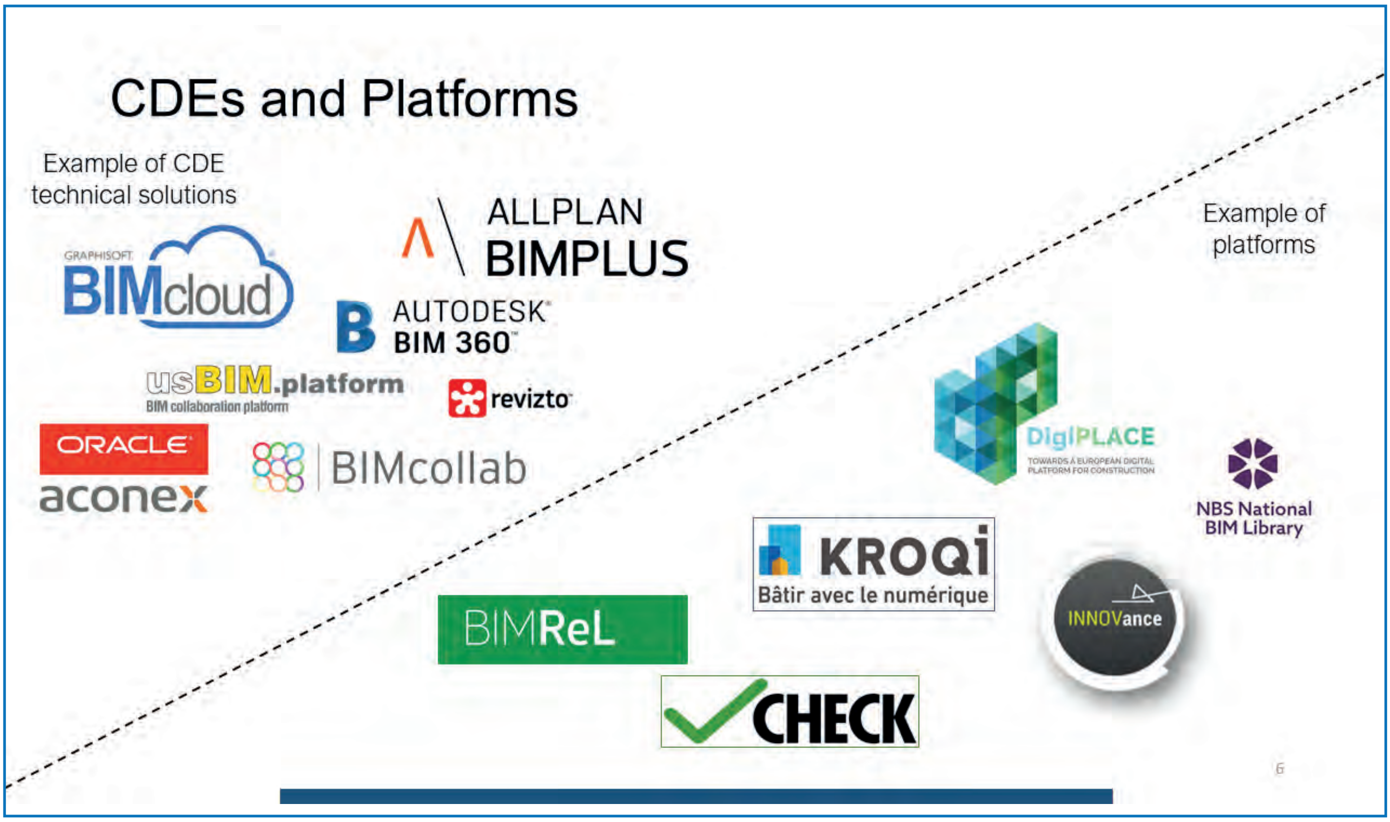
UNI EN ISO 19650-1:2019

"agreed source of information for any given project or asset, for collecting, managing, and disseminating each information container through a **managed process**."

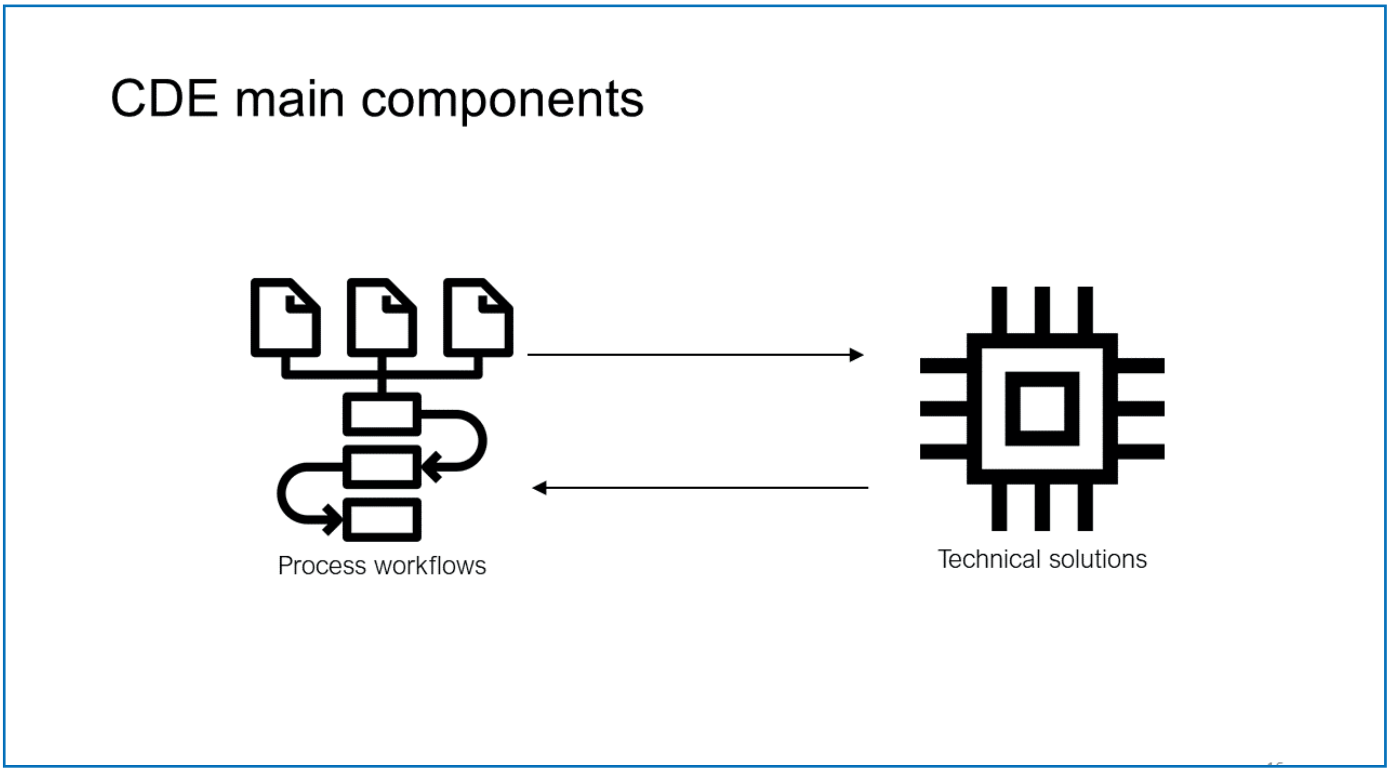
4

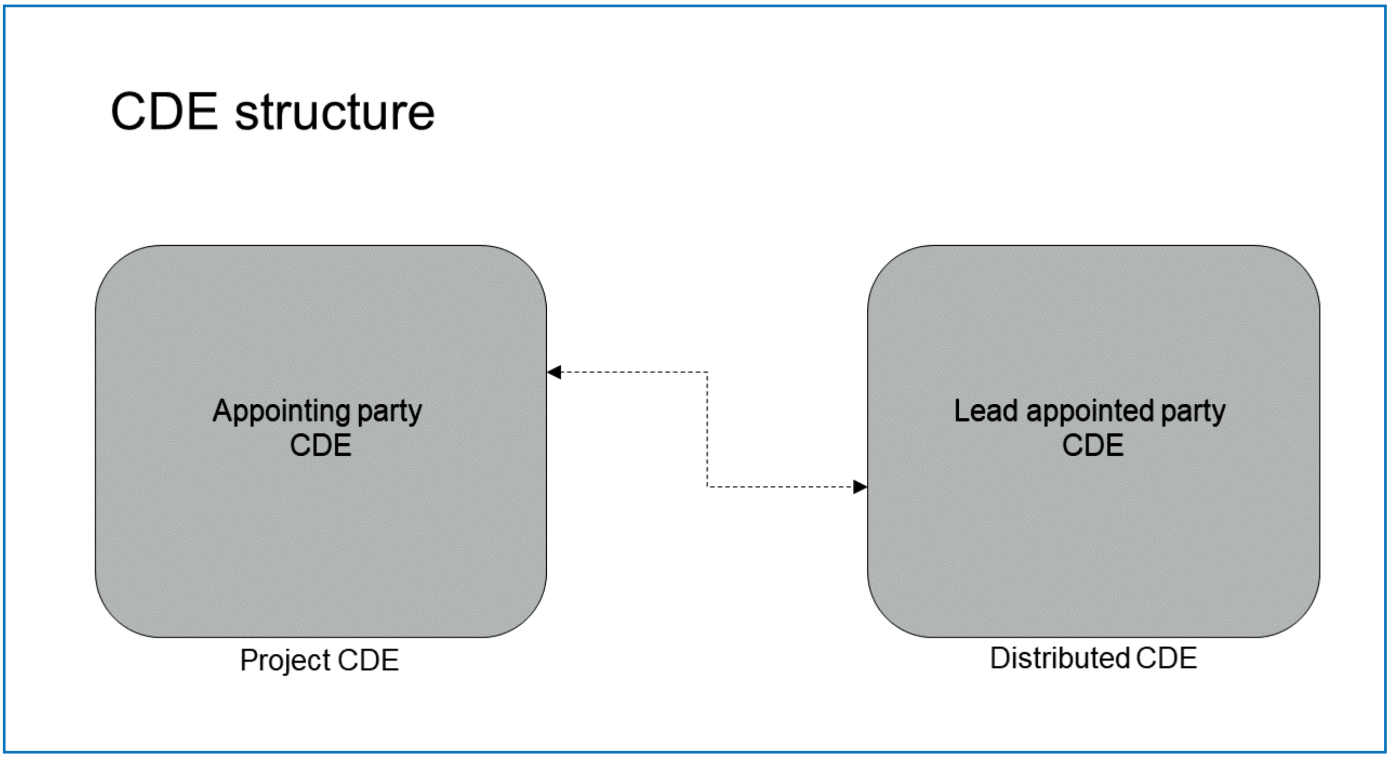
Starting from this definition there are at least three points that require attention. First, the CDE is defined for any given project or asset, that means that the CDE represents a project level concept and its requirements, rules, structure, etc. should be defined according to the needs and the context of the specific project or asset. Second, the CDE definition refers to the concept of "information container", i.e. "named persistent set of information retrievable from within a file, system or application storage hierarchy" (ISO 19650-1), opening the way to an effective data management in the CDE instead of a management based on file. Third, the content of the CDE should be managed through a managed process, that means that the CDE itself should be intended as the set of tools (technological solutions) and processes used to managed data and information in a specific project.

When thinking about construction products, i.e. buildings, infrastructures, etc., it is clear that each single project or asset is located in a bigger context (e.g. city, region, country, etc.) and the context itself may have specific needs and may generate a different set of data and information that needs to be analysed and used in an aggregated way therefore considering multiple projects or assets. From this perspective, that can be read as both the need to aggregate in a new environment the information about multiple projects and the need to create an interoperable level between different CDEs so that to create a network where information can be integrated, emerges the concept of platforms. Platforms development represents nowadays one of the main topic in research and the interest around this theme is rising at different levels, regional (e.g. the BIMRel project in Lombardy region – Italy), country (e.g. Kroqi platform in France and INNOVance project in Italy) and European (e.g. the DigiPLACE project).

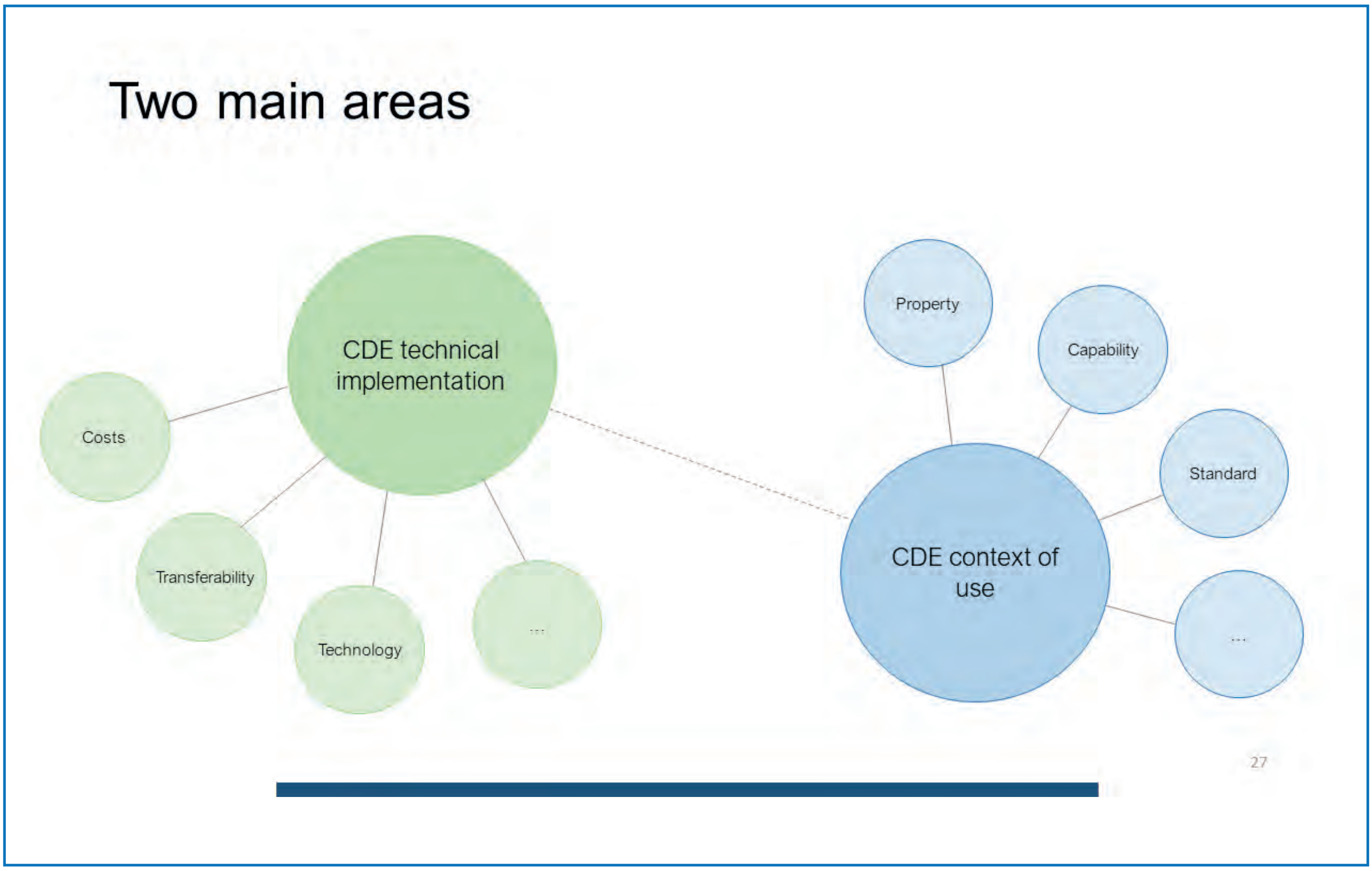


Focusing on CDEs, to enable the possibility to create dynamic environments able to satisfy the needs of both the stakeholders and the data and information management perspectives, it is crucial to understand the framework that can be applied. The market proposes several tools that can be used according to specific functions, services, performance, etc. that the solution provides. However, it may happen that an actor needs the integration of different tools to satisfy all the objectives of the project and develop all the intended uses that can be associated to the CDE. In the same way, it may happen that different stakeholders collaborating on the same project, have different needs in terms of required functions, services, etc. Hence the perspective about a distributed CDE framework that can represent how the CDE itself should be intended as a networks of tools (or better technological solutions) coordinated by structured workflows that can be defined in the specific tools (identifying for example review processes, issue notification, etc.) and between the different tools defined for the specific project (identifying what data and information are registered where, how data and information can flow from one tool to another, etc.).





The understanding of how common data environments and platforms can be defined, developed and related according to the different phases and the different needs of the stakeholders involved in the process represents a crucial point to allow the development of digital twins including not only the project dimension but also its integration in the country, i.e. its relation with the city and the related information model. CDEs represent the first point to integrate data and information that can be generated from different sources. However, to achieve an efficient integration and collaboration according to the different involved stakeholders, the evolution of the process and the different levels that can be considered (project, city, region, etc.) a deep understanding of CDEs and platforms framework is required to allow the design and the use of this solutions consistently with the overall context of application and use.



Of course, several issues and barriers still exist. The technologies, in terms of available tools, are still tied to a file base management even if enriched with metadata. As above mentioned, the existing standards open the way for new approaches and the research is extremely active on this side with the application of linked data and semantic web technologies. However, it is still difficult to find applicable solutions generally available in the market. The interoperability between different systems, that is between different CDEs, is still based on processes defined ad hoc that require dedicated developments (both on procedures and applications). About the context of use, the competencies of the stakeholders involved in the process is a critical point. The effective application of a CDE in a project requires that all the stakeholders are aligned in the use of the required tools (that may be different for the different stakeholders) and, with particular reference to the client, that the requirements for the definition and development of the CDE are well defined and integrated in the organization of the client itself. Unfortunately, this condition is not always satisfied creating possible issues in the starting point of the process that can impact on the entire development of the project requiring further adjustments and changes during the different activities. Nonetheless, the definition and use of CDE solutions at project level as well as their integration towards higher levels like cities, countries, etc. represent crucial points to enable better collaboration and information management.

Integrated management of sustainable processes of requalification and recovery in architectural and environmental heritage

Prof. Tommaso Empler

Department of History, Representation and Restoration of Architecture - Sapienza University of Rome

Abstract

The aim of the research is to identify method and operational references at different scales, urban and territorial, to be applied to territories affected by earthquakes, useful for defining prevention and reconstruction strategies. In particular, the activity focuses on Accumoli, placed in the central part of Italy, and takes concrete form in the construction of a pilot program for reconstruction, defining integrated and coordinated reconstruction actions based on resilience of the affected areas, with three specific features: addressing multiple scales (not just individual buildings, but settlements and territories); considering various topics and subjects (besides physical reconstruction, functional aspects and relationships and different actors involved); pursuing prevention purposes in relation to possible future events within a sustainable local development perspective. Proposals are defined through a process, where the involvement of various institutional actors and inhabitants does not want to be understood as a "formal" participation, but as an essential condition of joint work.

The research follows two correlated directions:

a) Definition of the guidelines for a path of virtuous reconstruction;

b) Identification of a BIM methodology applicable both in the reconstruction and prevention situation.

Keywords: risk assessment, reconstruction, prevention, BIM, sustainable territory

Research framework[1]

Research goals are directly connected to the "priorities for action" which emerge from the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan, on March 18, 2015, and published under the title of "Sendai Framework for Disaster Risk Reduction 2015 – 2030" by the United Nations Office for Disaster Risk Reduction (UNISDR).

The starting point is the development of a framework, based primarily on the construction and diffusion of knowledge, dedicated to territories. This knowledge should be based on survey and on a strong historical background for tackling restoration at the building, urban and territorial scales. Here follows a brief index of the main priorities intend to take into consideration:

Priority 1. Understanding disaster risk;

Priority 2. Strengthening disaster risk governance to manage disaster risk;

Priority 3. Investing in disaster risk reduction for resilience;

Priority 4. Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction.

[1] Members of the Research Unit "Urban Seismic Risk: Prevention and Reconstruction" are: DSDRA -Tommaso Empler (Scientific Coordinator), Carlo Bianchini, Piero Cimbolli Spagnesi, Stefania Portoghesi Tuzzi, Fabio Quici, Nicola Santopuoli; DIAP - Andrea Bruschi; PDTA - Barbara Pizzo; DISG - Paolo Franchin; DICEA - Carla Nardinocchi, Leonardo Paris; Seismic Group (Gruppo Sisma) - Giacomina Di Salvo, Francesco Fazzio, Margherita Giuffré, Roberto Parotto; PhD - Valentina Adduci, Adriana Caldarone, Claudia Calice, Michele Calvano, Alexandra Fusinetti, Maria Laura Rossi; Experts and scholars - Serena Bellinvia, Elisa Cecchetti, Giulia Cenciarelli, Teodora Compagnoni, Chiara Del Milo, Alberto Di Forte, Marius Dumitrache, Lucrezia Iannaci, Mario Sacco, Arianna Tiberti.

One of the main research aim is to improve an interdisciplinary methodology which allows and promotes a continue and long-lasting process which goes from territorial knowledge to planning and to management, which will serve both the usual- ordinary urban/territorial functions, and those emerging during a catastrophic event, helping at better facing the emergency and also the recovery phase. The objective of the research program is to define a methodology, applying it on the Central Italy territory, hit by the sequence of earthquakes started in the Summer 2016. The methodology has been sketched through the convergence of different discipline, their approaches and tools: architectural representation and design (computer-aided), representation and survey of historical buildings and urban complexes in particular, architecture and landscape restoration, history (architecture, urban and territorial history), urban and regional planning. The proposed research methodology is organized as follow:

Phase 1: Programming activities. Definition of reconstruction objectives within an urban-territorial seismic-oriented workflow.

Phase 2: Pre-Seismic cognitive framework (Figure 1), whose sub-articulation includes: urban and territorial surveys, archive documentation, structural surveys, geological surveys, survey, territorial reading. "Urban and territorial surveys" relate to the acquisition of the planning documents and other programming documents (regarding e.g. internal areas, etc.), emergency planning (Civil Protection Plan) and at the existing CLE (Limit Condition for the Emergence).

The acquisition of "archive documentation" follows two different paths: institutional sources, collecting and analyzing the existing cartographies at the various scales, and the historical documentation (cartography, cadastre, historical photos, etc.); non-institutional sources, where the material to be acquired derives from private archives (photos, videos, historical prints, etc.).

"Structural surveys", collecting studies and researches, data and documents, regarding the vulnerability of strategic buildings, cultural heritage sites, and infrastructures.

"Geological surveys", with the collection of existing surveys of seismic micro-zoning (MS), geological studies and hydrogeological plans.

"Survey stage", which provides a first distinction between "fast survey" and "detailed survey". Data from the "fast survey" comes from the web, those referring to "detailed survey" come from 3D laser scan or photomodeling campaigns. Collected data are decimated and organized for the realization of a 3D model of the pre-earthquake situation.

"Territorial reading" collects data from investigations such as socio-economic analysis, study of specific sites, identification of aggregates and areas for specific insights; are also investigated the histories of urban and territorial transformations.

Phase 3: Post-Seismic cognitive Framework defines the damage map and sub-articulation includes: survey, geological surveys, territorial surveys.

"Survey step", provides a distinction between "fast survey" and "detailed survey". Data from the "fast survey" comes from the web, those referring to "detailed survey" come from 3D laser scan or photomodeling campaigns. Collected data are decimated and organized for the realization of a 3D model of the post-earthquake situation.

"Geological surveys" include new seismic microzonations and the analysis of local seismic response.

"Territorial surveys" analyzes damage (physical damage, loss of functionality) in relation to a synthetic risk assessment of vulnerability, hazard and exposure.

Phase 4: Restoration Concept, sub-articulations are: territorial proposals, geological proposals, structural proposals, architectural proposals.

"Territorial proposals" deal with the main physical and functional transformations of the capital and the fractions (relocation of strategic functions, access system, temporary residential settlements, etc.), and the identification of SUMs. These actions include spatial development scenarios and references to overall planning and restoration/prevention goals.

"Geological proposals" concern the design and installation of a ground monitoring network and depth (about 30m).

"Structural proposals" define the safety standards in the choice of typologies, constructive methods and technologies.

In architectural proposals, compartments reconstruction hypotheses are provided, aggregates, widespread building, public spaces. Are also identified places and cultural assets of local memory.

Phase 5: Restoration Planning and Prevention, are articulated in: Territorial Proposals, Geological Proposals, Structural Proposals, Architectural Proposals.

"Territorial proposals" produce guidelines for reconstruction and prevention at the local and regional urban scale.

"Geological proposals" concern the design and installation of a ground monitoring network and depth (about 30m).

"Structural proposals" deal with the identification of case studies related to typical structures (or even strategic or of particular importance) and different damage situations, such as collapsed structure, heavily damaged structure, poorly damaged structure (bell tower, municipal building, precious building, etc.). Choice of more suitable seismic protection materials and techniques in the various cases (such as seismic isolation, energy dissipation systems, etc.), with particular reference to innovative solutions that meet costs, execution times, safety and durability, and can also be replicated in other municipalities damaged by the earthquake. Definition of security standards in the choice of typologies, of constructive methods and adopted technologies.

Architectural proposals concern the identification of case studies related to typical structures (or even strategic or of particular relevance). Elements to consider are culture, local buildings, materials at different scales of deepening. Will also be conducted a durable typological study and technical-constructive feasibility.

In the research is also developed an information systems named ARIM (Assessment Restoration Information Modeling) (Empler, 2017) (Figure 2), that might play a decisive role for reaching a deeper territorial knowledge, the capacity of monitoring territorial phenomena as well as the management of the built environment and of the urban and territorial context as wholes. Prevention, emergency management, post-seismic reconstruction and recovery must be finally and definitely intended as integrated actions and not as single, individual interventions.

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ARIM (Assessment Reconstruction Information Modeling)
A framework for reconstruction: collecting data, using data

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1. Introduction

The Department of History, Representation and Restoration of Architecture, Sapienza University of Rome, with a research unit called "Urban Seismic Risk: Prevention and Reconstruction", since 2016 is investigating a double BIM (Building Information Modelling) path connected to natural disasters: prevention and reconstruction.
The focus is to investigate how small towns (villages) – made up of vernacular buildings – can join a BIM procedure. We are no longer speaking of HBIM (Historic Building Information Modelling), but of ARIM (Assessment Reconstruction Information Modeling). The main topic is linked to "data fusion", where interdisciplinary skills meet up, ranging from historical sector, to surveying, urban planning, restoration, structures and design. How should data be organised?
What are the local regulations?
Where – and how – research and the professional world meet each other?
These are the topics of a seminar where different cultures and different research fields can be compared to find some common denominators.

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2. 2016 earthquake

2 municipalities have been affected by 2016 earthquake on the 24th of August and the 30th of October: Amatrice (138 km east of Rome) and Accumoli (145 km east of Rome)

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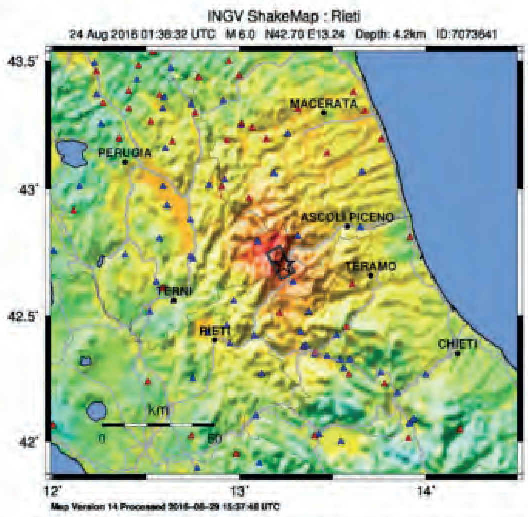
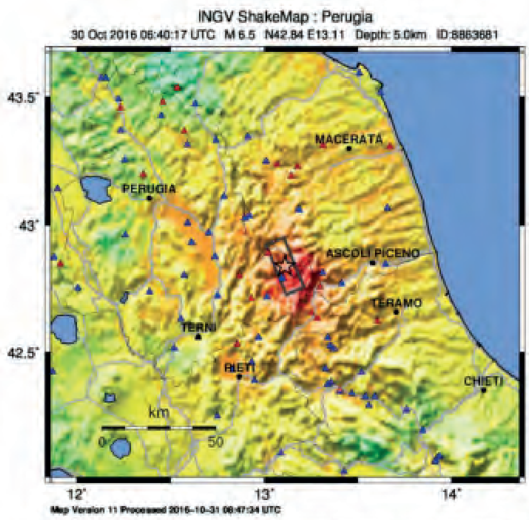
24th August 2016: Magnitude 6.0



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.2	0.8	2.0	4.8	12	29	70	>171
PEAK VEL.(cm/s)	<0.02	0.08	0.3	0.9	2.4	6.4	17	45	>120
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Faenza and Michelini, 2010, 2011

30th October 2016: Magnitude 6.5



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
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INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Faenza and Michelini, 2010, 2011


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3. Mapping: Accumoli
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4. BIM workflow

BIM workflow

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5. ARIM - Reconstruction

ARIM procedure integrates some BIM procedures, as GeoBIM, HBIM, LIM and seismicBIM; additionally, it presents further details and elaborations, specifically;
- GeoBIM allows to define the degree of vulnerability of a territory based on geological stratification;
- HBIM is associated to some buildings surveying methods, through laser scanning 3D procedures, use of thermographic cameras and the acquisition of historic documentation of the site of interest;
- LIM is responsible for the evaluation and study of the landscape components, where are located anthropic sites isolated;
- seismicBIM is responsible for the part of the survey and analysis of the structural component of the buildings.

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ARIM workflow

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ARIM procedure includes a flowchart, where the main variations from BIM's workflow are linked to the "design" sub-system, which can be reviewed as "reconstruction design", and it is organized as follows:

1 Scheduling activities. Definition of the reconstruction goals with a path oriented to seismic prevention at urban and territorial scale (Accumoli and territorial context).

2 Pre-Sisma framework, where sub-articulations includes: urban and territorial surveys, historical documentation, structural surveys, geological surveys, land reading.

3 Post-Sisma framework, defines the damage map and the subdivision includes: survey, geological surveys, urban and territorial surveys.

4 Development of concept, whose subdivisions are: urban and territorial proposals, geological proposals, structural proposals, architectural proposals.

5 Management and planning references for reconstruction and prevention, divided into: urban and territorial proposals, geological proposals, structural proposals, architectural proposals.

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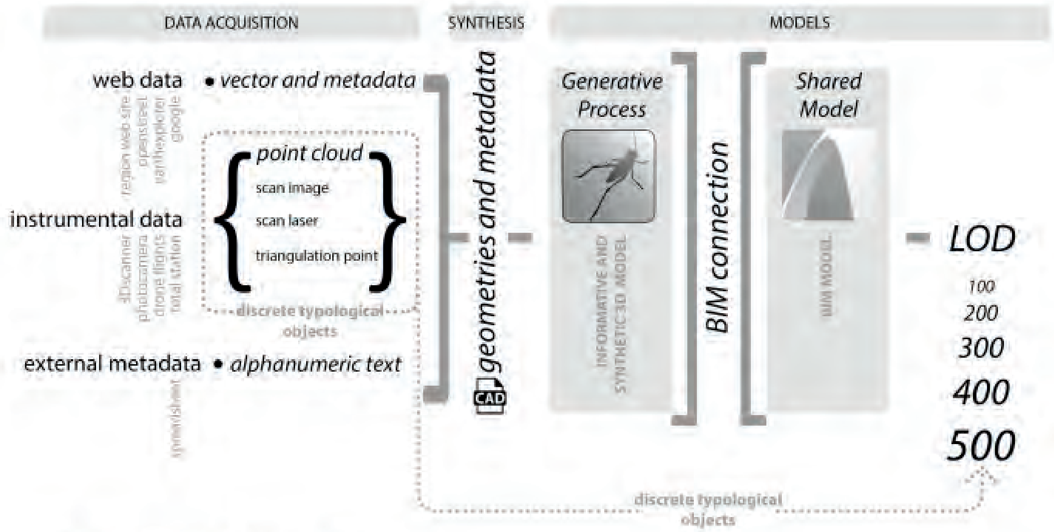

ARIM Framework (M. Calvano).

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Grisciano Village, Ortophoto from laser scanner survey (L. Paris).

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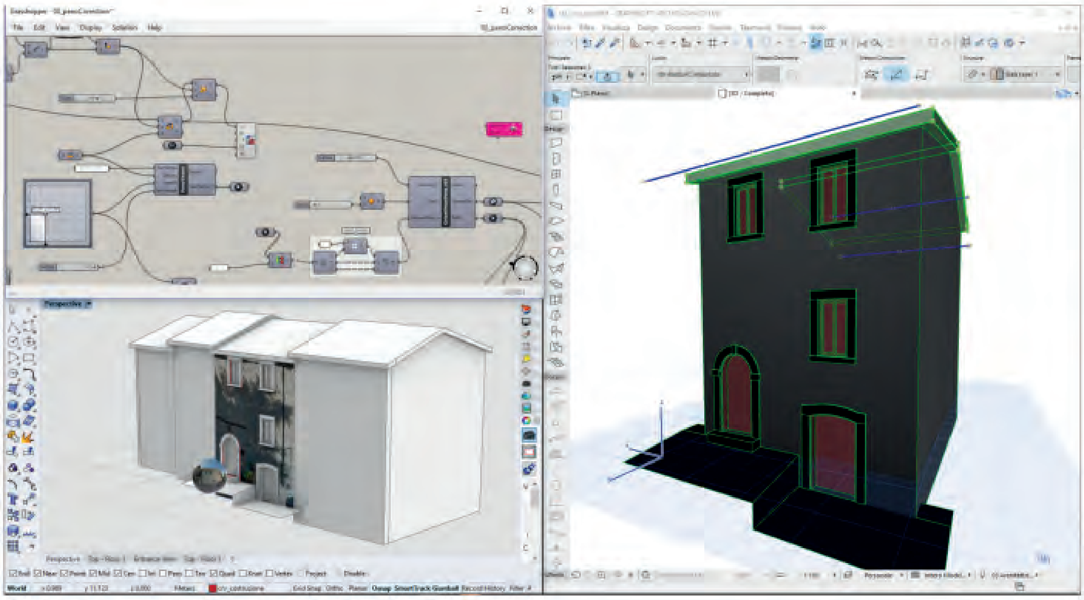

VPL procedure developed by M. Calvano and M. Sacco.

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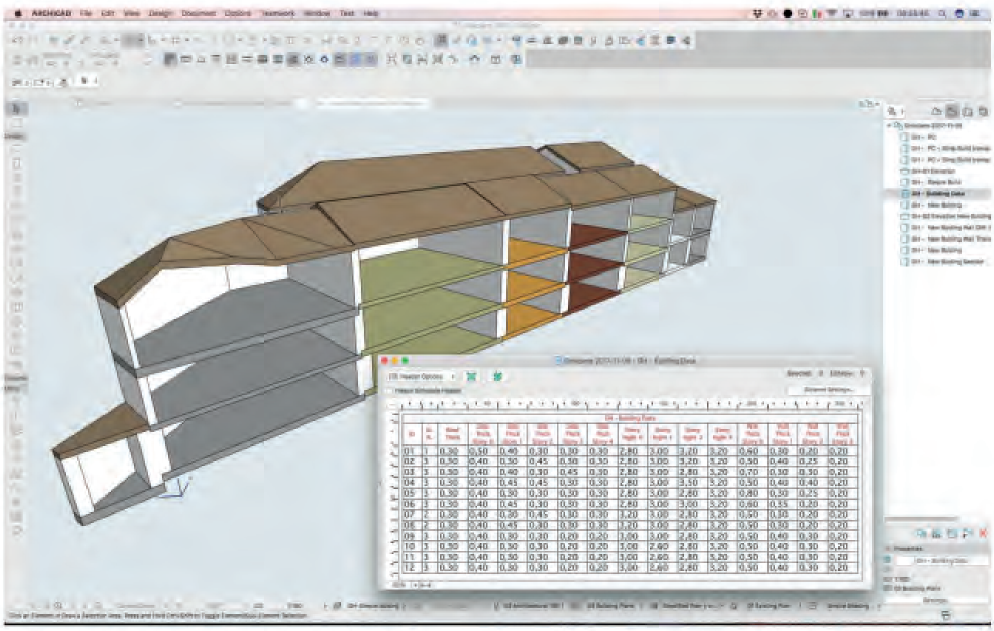

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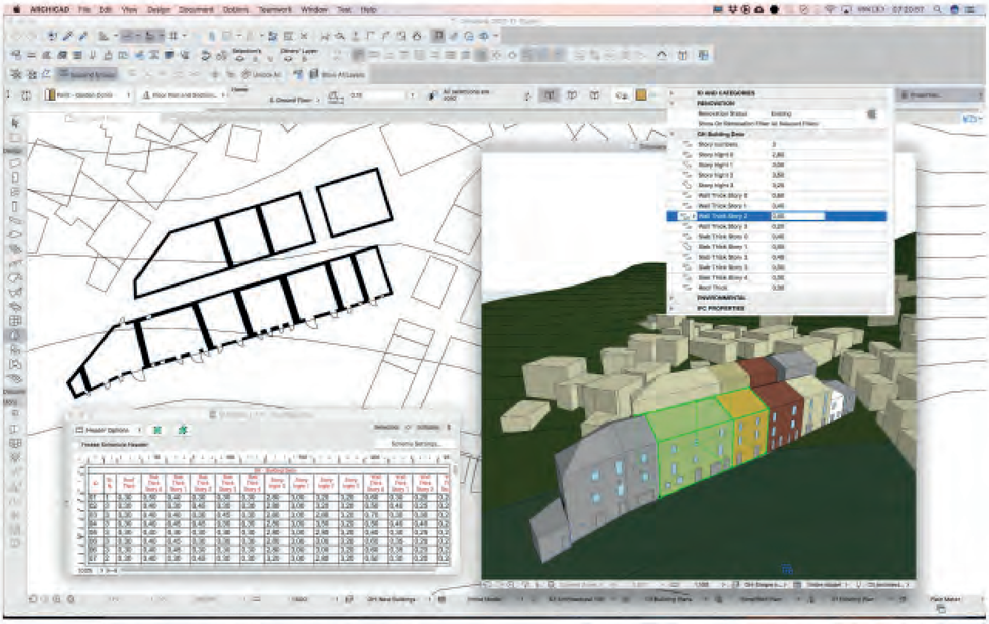

VPL procedure developed by M. Calvano and M. Sacco.

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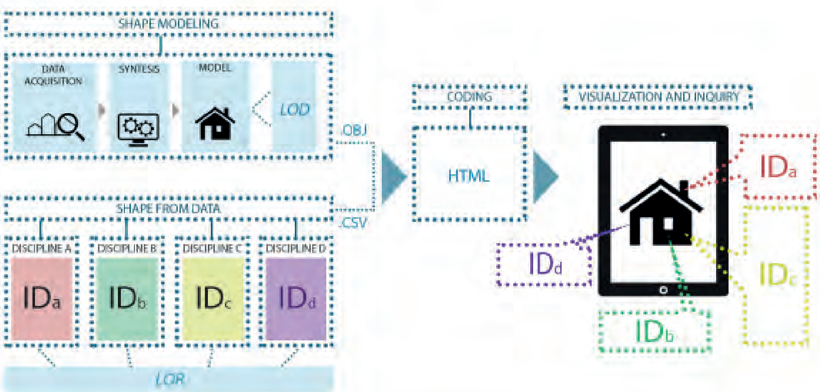
6. ARIM – Assessment



Elaborazione framework: Tommaso Empler, Michele Calvano, Adriana Caldarone

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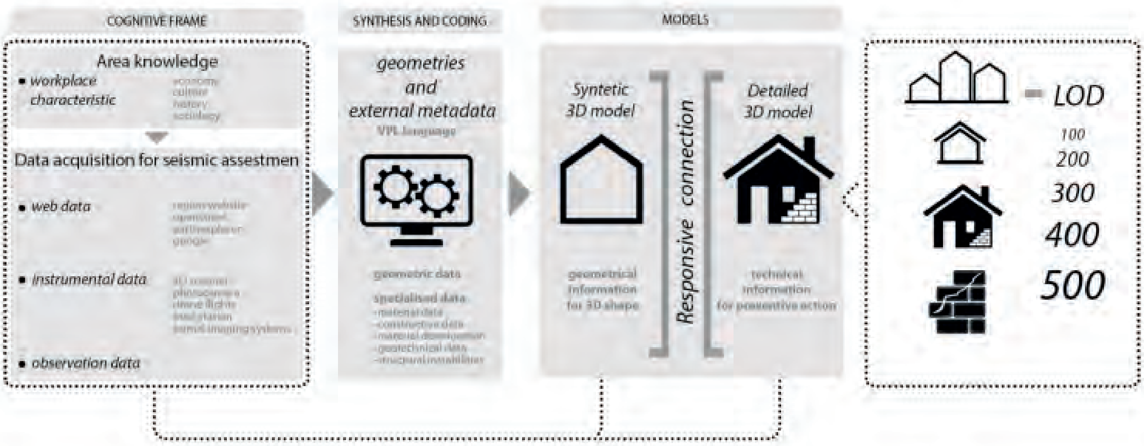
6. ARIM – Assessment



ARIM Framework for prevention (M. Calvano A. Caldarone)

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6. ARIM – Assessment

Activities to develop cognitive frame:

- Identification of the building, its location and the relationship with the surrounding urban context;
- Building's geometric survey in current state;
- Identification of building's historical evolution;
- Identification of building composing elements and its construction methods;
- Identification of materials, their deteriorating state, their mechanical behaviors;
- Knowledge of the subsoil, of the foundation structures and their instability.

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6. ARIM – Assessment

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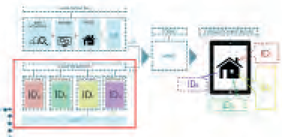
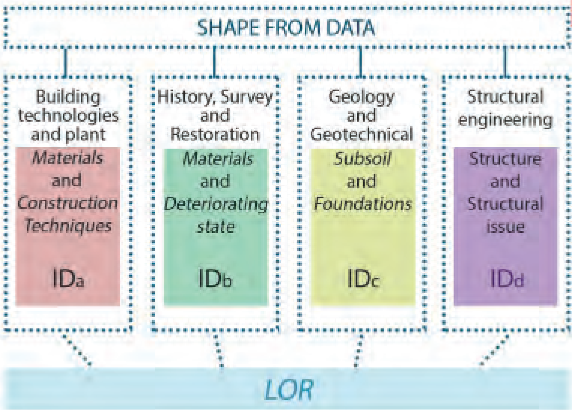
6. ARIM – Assessment





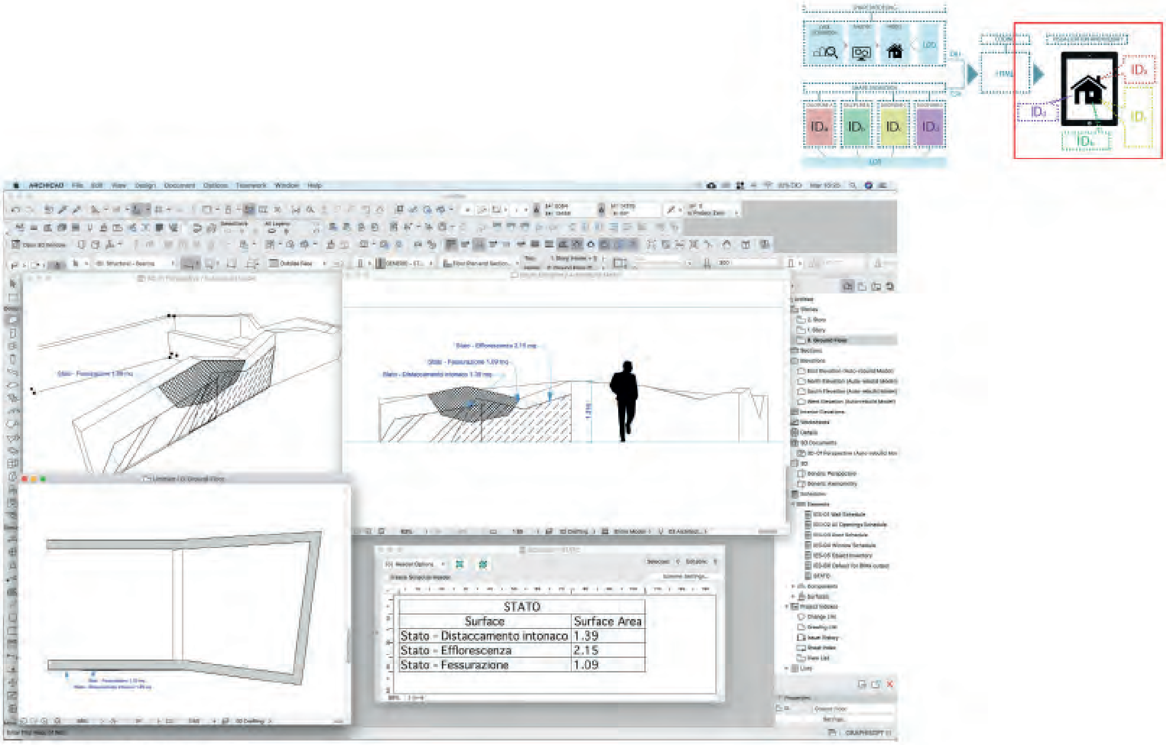
Elaborazione framework: Tommaso Empler, Michele Calvano, Adriana Caldarone

	Fase 1	Fase 2	Fase 3
Anno	1950	1980	1985
Struttura	continua	puntuale	puntuale
Strato 1	3	2	6
Strato 2	2	2	/
Strato 3	3	3	/
Attributo A	0.04	0.06	0.02
Attributo B	0.06	0.06	0.06
Attributo C	0.45	0.17	0.12

Elaborazione: Adriana Caldarone

Layers	Thickness	Core	Stato	Attributo 1	Attributo 2	...
_Tipo A			buono	aaa	bbb	
Pietra	0.5	1				
Intonaco I	0.02	0				
_Tipo B			buono	aaa	bbb	
Intonaco E	0.05	0				
Mattoni	0.25	1				
Intonaco I	0.02	0				
_Tipo C			discreto	aaa	bbb	
Intonaco E	0.05	0				
Mattoni	0.6	1				
Intonaco I	0.02	0				
_Tipo D			pessimo	aaa	bbb	
Intonaco E	0.05	0				
Forati	0.2	1				
Aria	0.05	0				
Forati	0.08	1				
Intonaco I	0.02	0				

Elaborazione: Adriana Caldarone



Elaborazione: Mario Sacco

Digital Innovation in the project and construction phases

Dott. Stefano Amista
Specialist in AEC & Bim Management Solutions TeamSystem SPA

Introduction. The activity explored the theoretical and applicative aspects of an integrated 4D/5D project modeling during the planning and then in the control phase.

It is possible starting from the analysis of a 3D model, proceeding to the realization of a 5D model up to the different levels of a 4D programming.

Whatever we build something always happens in space, in time and needs necessary resources. The basic concept of a 3-4-5D BIM model is that it would be a virtual representation, as a sort of time machine, of how, when, and how much a construction project will cost. To do this, it is necessary to build a model that can connect and integrate all the necessary information and in particular the fundamental elements to create a realistic representation. Therefore, starting from what I define "the relativity formula of BIM 3-4-5D" I make it clear what are the indispensable information and therefore the basic "properties" to create an integrated modeling between space (3D model), times (4D model) and costs (model5D) that allows to have a single model 3-4-5D.

The next step is to understand how the above 3D model integrates into the various processes of the project life cycle: design, estimating, planning, construction, and operation.

The estimating phase in a 5D modeling process takes place by associating an item taken from a price list and multiplying it by the quantity of selected objects. A Construction Project Management (CPM) software can do this with two methods:

a. IFC model imported
b. a connected Plug-in installed in the authoring software

In each method is possible estimate through Parametric Estimating Rules that are instructions to calculate the economic value (cost/revenue) of a project item through the multiplication between filtered objects quantities and an item of a selected price list. The parametric estimating method can also create an Estimated Bill of quantity organized by WBS or other parameter as level, materials, or property of the model. At the end, it is possible to have a real 5D model with 3D model and an estimated Budget of cost, revenues and income.

The third step is the planning phase. It is possible to obtain a 4D model in two different way. The assembly method means that you can create a 4D model in a BIM 4D software through a process of automatching based on the same WBS between the 3D model and a plan create with a Project Management solution as MS Project or Oracle Primavera. In the same way, if you import the same plan in a solution like TeamSystem CPM, you can create directly a 3-4-5D model without any more algorithm.

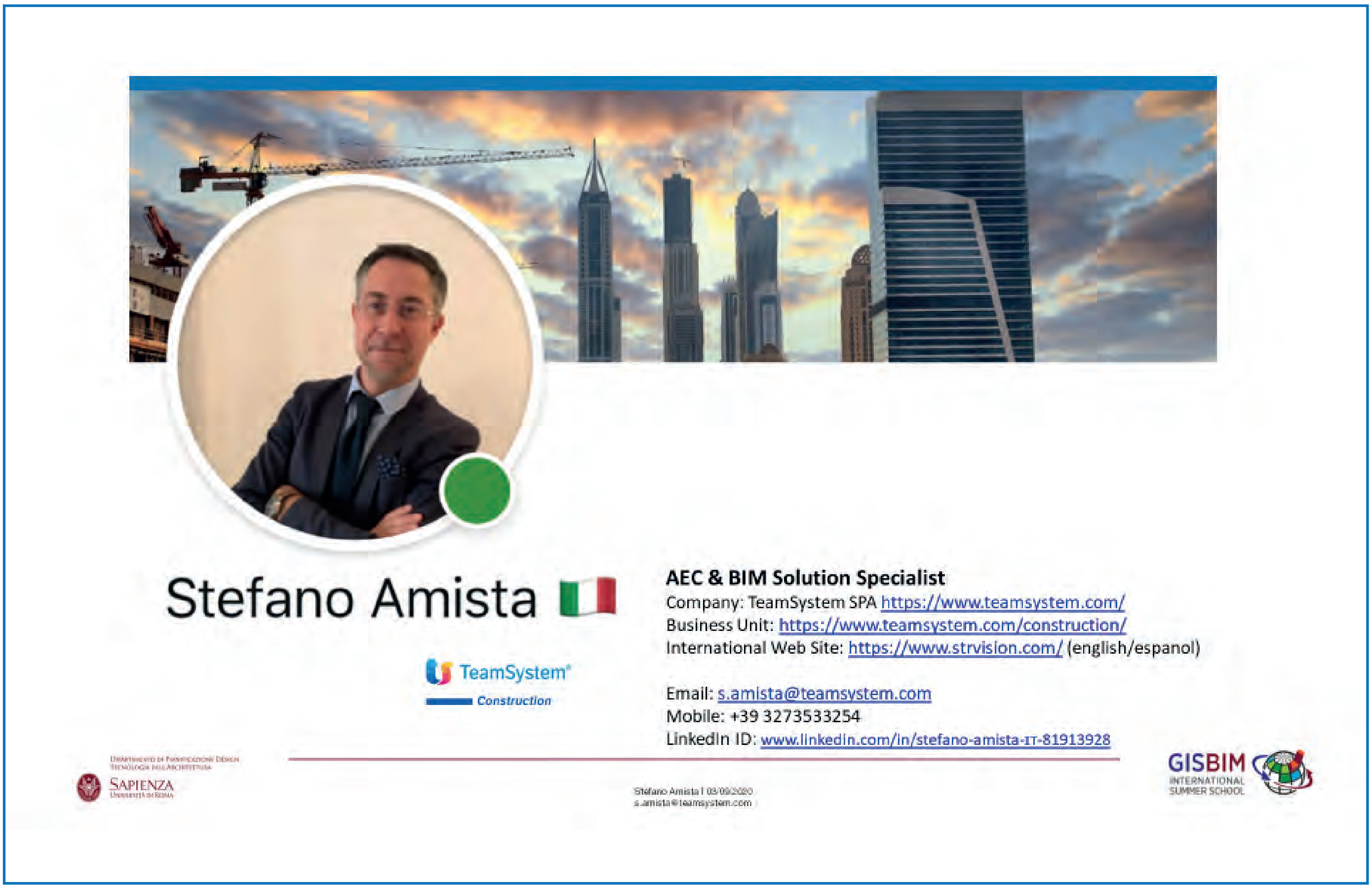
The Parametric method is based on the estimation of resource employment. Starting from a 5D model where the cost analysis was calculated by the estimation of resource incidence in the most item of a bill of quantity, you can calculate the time estimation, the duration, of any WBS element (WBE) that is yet connected with objects of the models.

This method so is based on a correct calculation of the durations starting from the number and the incidence of any resource it is necessary for the construction. The parametric method is a correct scheduling method to have a realistic 3-4-5D model representation. Otherwise, through software solution like Bentley Synchro you can create compared scenarios between the two kind of method or create new more efficient and advanced 3-4-5-D model.

In these slides I explain how is possible to combine the classic Project Management way to control a working in progress (WIP) of a construction through the Earned Value Analysis (EVA), with the field Bim solutions. Using a CPM software solution you can analyse a WIP starting from an As Built WIP 3D modeling that can give information about physical WIP of any object modelled, you can create also a 5D WIP model and compare with time and cost expected at the same time in the planned baseline budget.

Using EVA values and indexes you can verify and create a forecast situation that can permit to understand if your project is in late or in advance or you are spending much or less money.

In conclusion, it is important to understand that any kind of model, economic or Gantt representation, index or value amount are fundamental to keep a Project under control, but is also important to understand that we have to be able to read these information deeply. A negative value or index could be good or bad, but we must understand what, when, how and why.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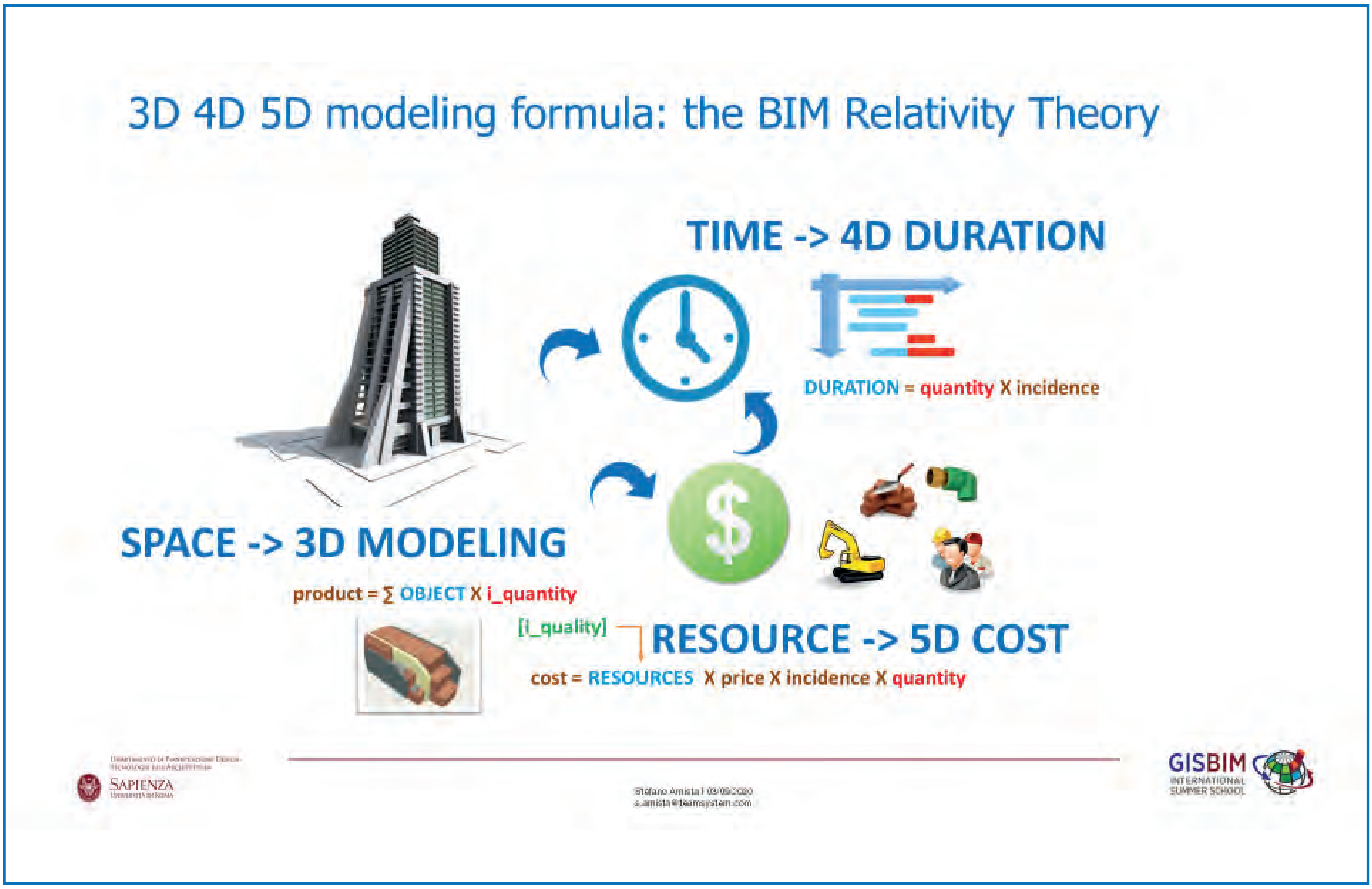
The 3 dimension of BIM
• SPACE
• TIME
• RESOURCE


3D 4D 5D modeling formula: the BIM Relativity Theory
TIME -> 4D DURATION
DURATION = quantity X incidence
SPACE -> 3D MODELING
product = ∑ OBJECT X i_quantity
[i_quality]
RESOURCE -> 5D COST
cost = RESOURCES X price X incidence X quantity
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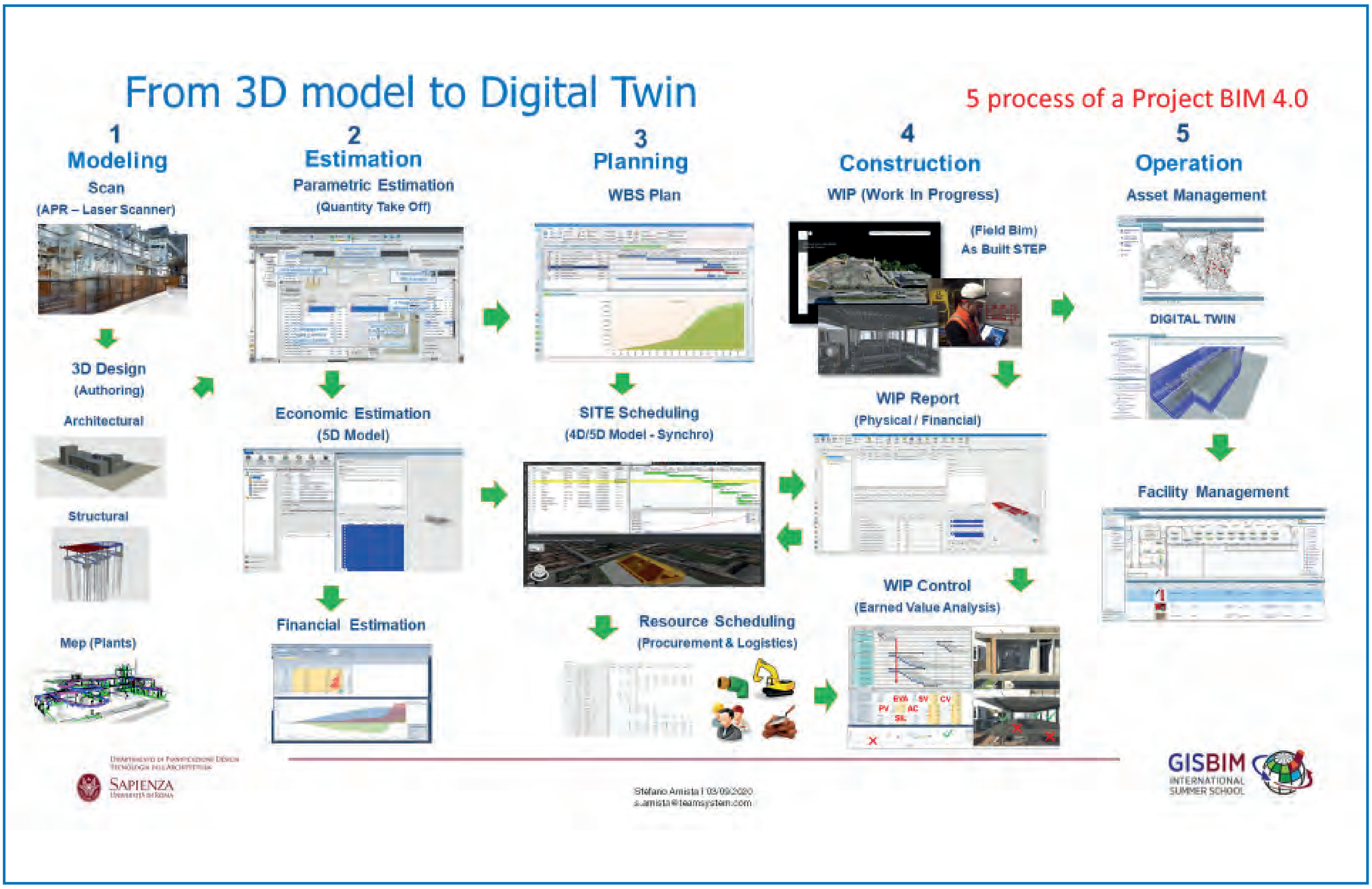
The 5 steps of BIM
• MODELING
• ESTIMATION
• PLANNING
• CONSTRUCTION
• OPERATION


From 3D model to Digital Twin
5 process of a Project BIM 4.0
1
Modeling
Scan
(APR – Laser Scanner)
3D Design
(Authoring)
Architectural
Structural
Mep (Plants)
2
Estimation
Parametric Estimation
(Quantity Take Off)
Economic Estimation
(5D Model)
Financial Estimation
3
Planning
WBS Plan
SITE Scheduling
(4D/5D Model - Synchro)
Resource Scheduling
(Procurement & Logistics)
4
Construction
WIP (Work In Progress)
(Field Bim)
As Built STEP
WIP Report
(Physical / Financial)
WIP Control
(Earned Value Analysis)
5
Operation
Asset Management
DIGITAL TWIN
Facility Management
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From the 3D model to the estimation

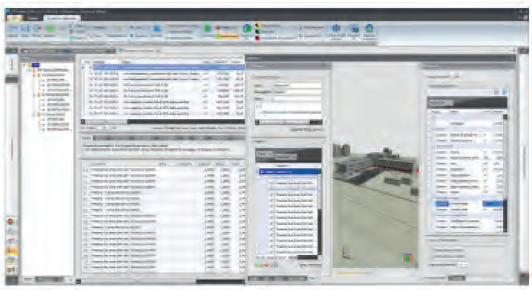
Step 2. Estimation

The evolution of estimation

2 Method

1. IMPORT FILE IFC
- a) Drag n Drop
- b) Parametric Estimation Rules
- c) Massive import

2. PLUG IN
- a) Parametric Estimation Rules
- b) Massive import



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The 5 steps of BIM

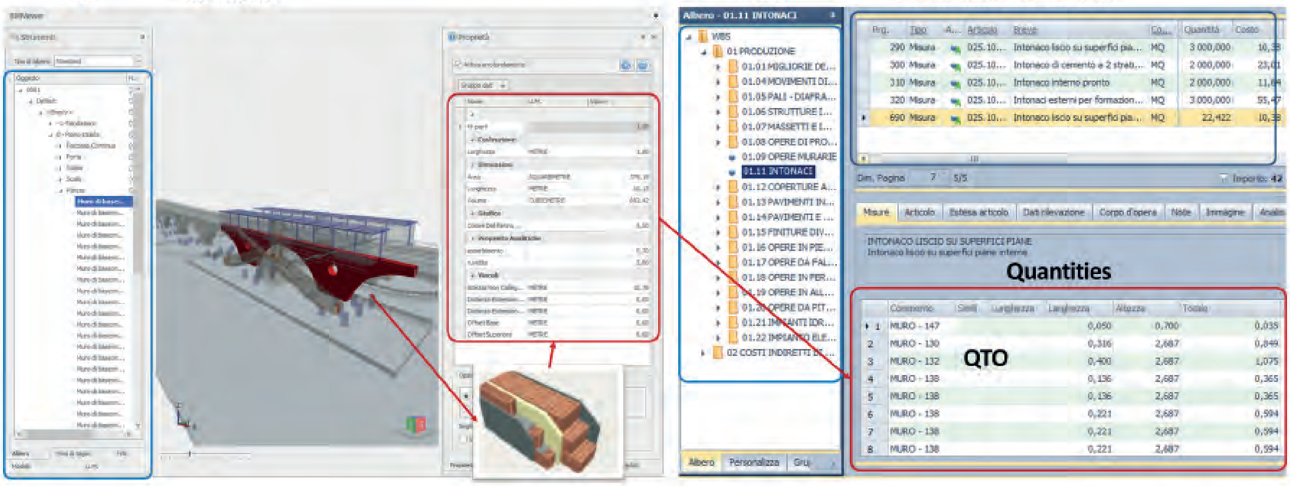
- MODELING
- ESTIMATION
- PLANNING
- CONSTRUCTION
- OPERATION

From the 3D model to the economic estimation

Step 2. Estimation

Quantity Take Off, from PBS to WBS

PBS | 3D model | WBS | Economic Estimation



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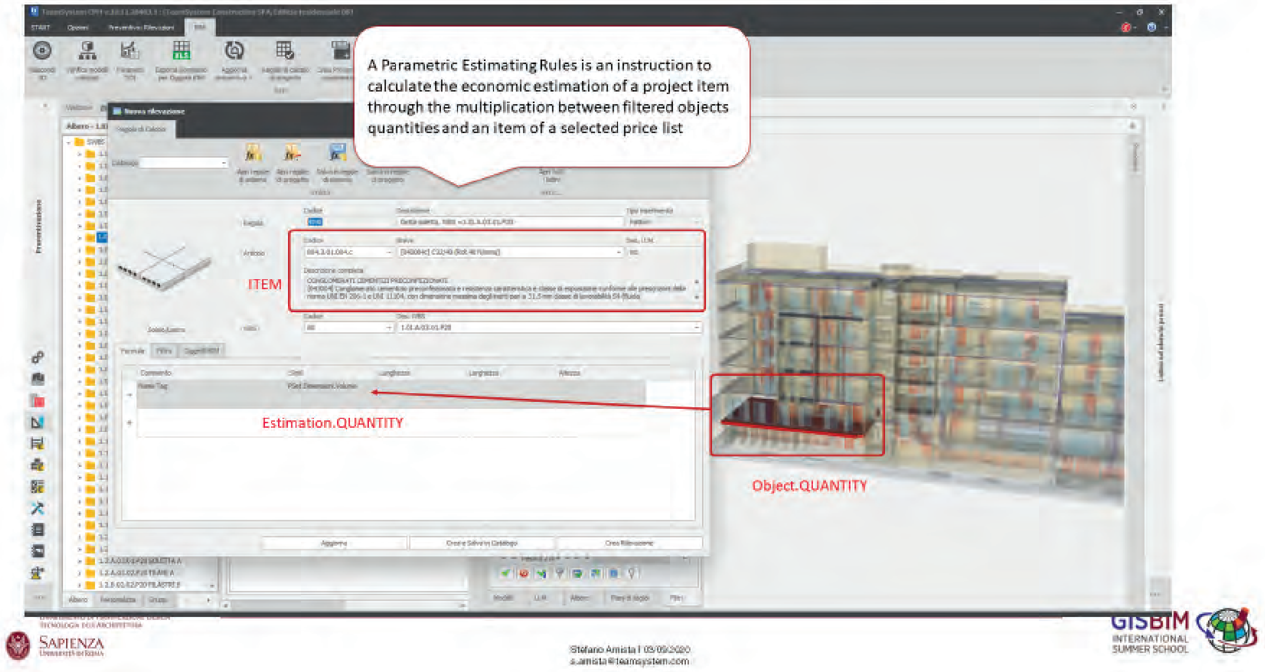
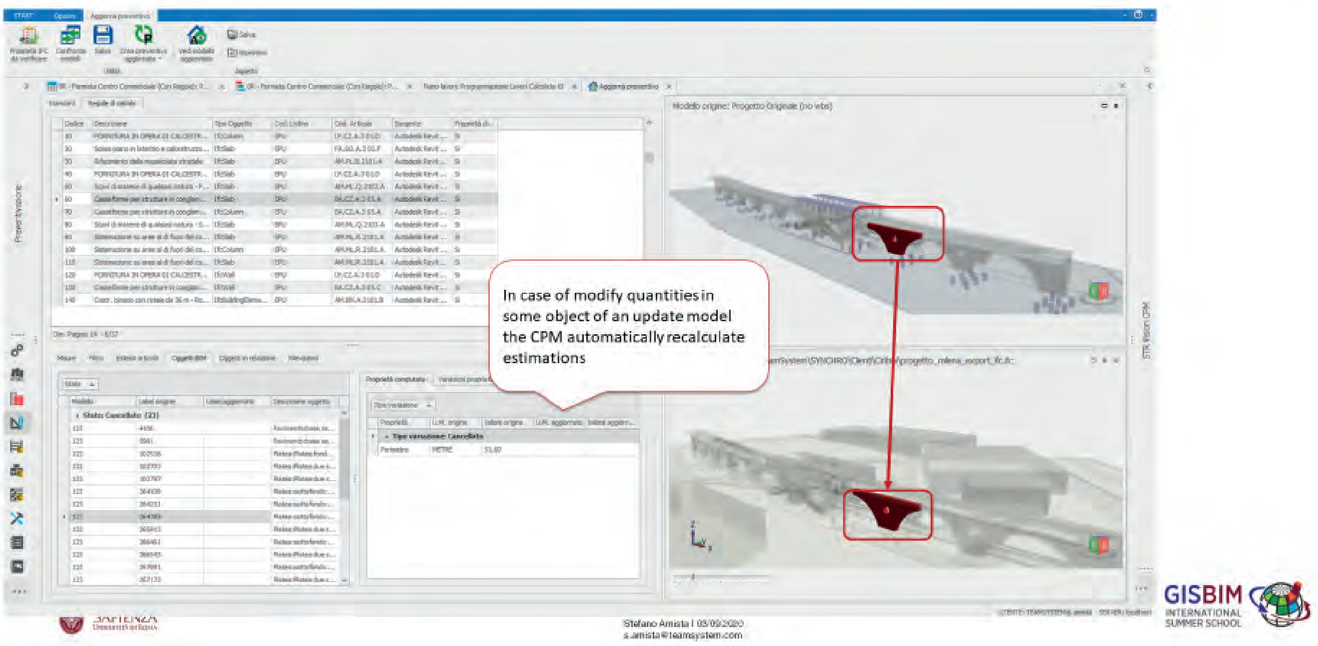
Quantity take off by Parametric Estimating Rules

Step 2. Estimation



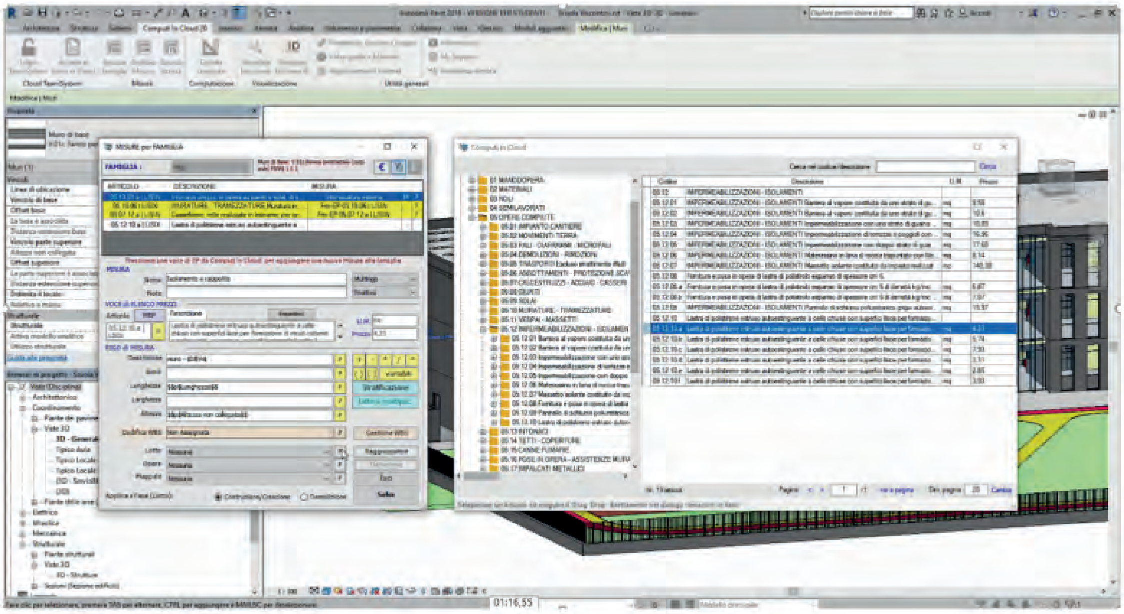
Upadting of estimation from ad updated 3D model

Step 2. Estimation



From 3D Model to estimation: the Plug-in method (Revit/Archicad)

Step 2. Estimation



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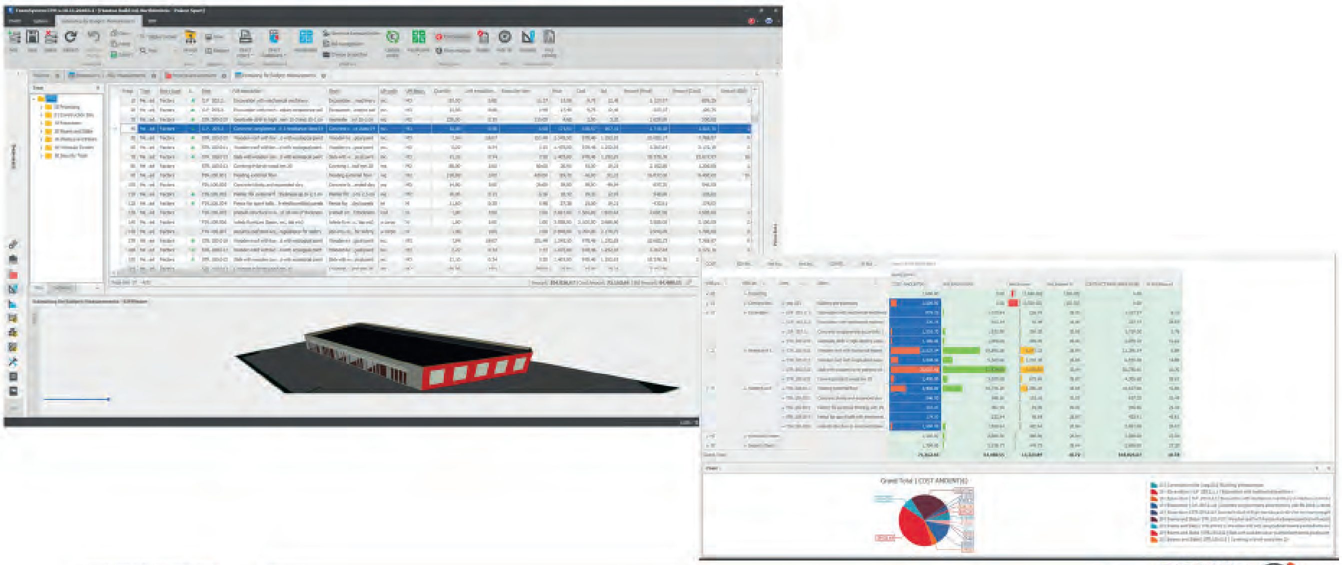
BIM 5D Economic Estimation

All in one: 3D model + cost, bid and income estimation



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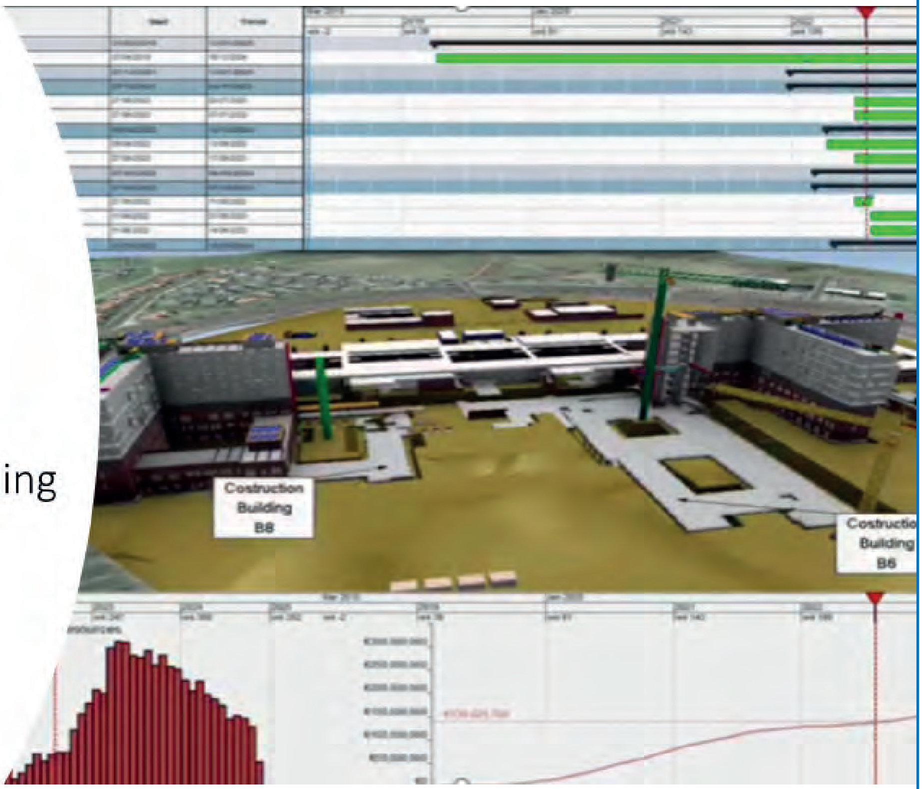
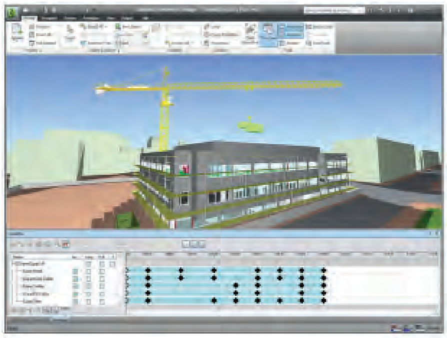
4D Planning & Scheduling



2 Method

Step 3. Planning

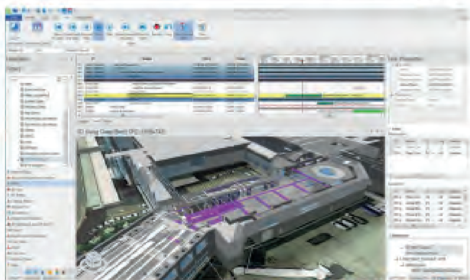


1. Assembly

a) Manual connection between model and wbs
b) Automatching through same parameter between WBS and PBS
c) Resource employment as result

2. Parametric

a) Based on resource employment
b) 4D depend from 5D
c) One 3D/4D/5D model integrated



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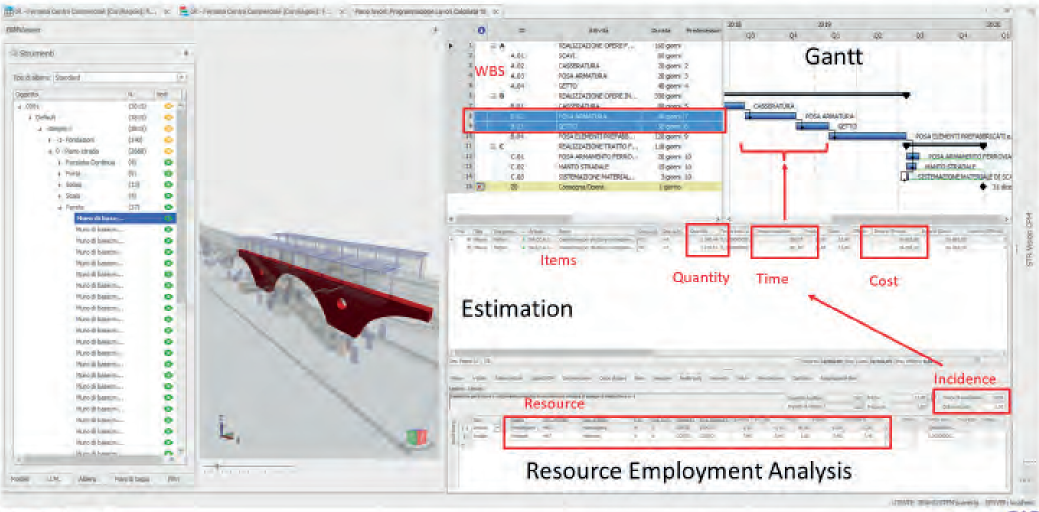
Step 3. Planning

4D Model. The Parametric Method

A 5D estimation based on a resource cost analysis is the right method to calculate the correct cost and duration for any item and related WBE (work breakdown element). In this way we can obtain a real 4D&5D model integrated



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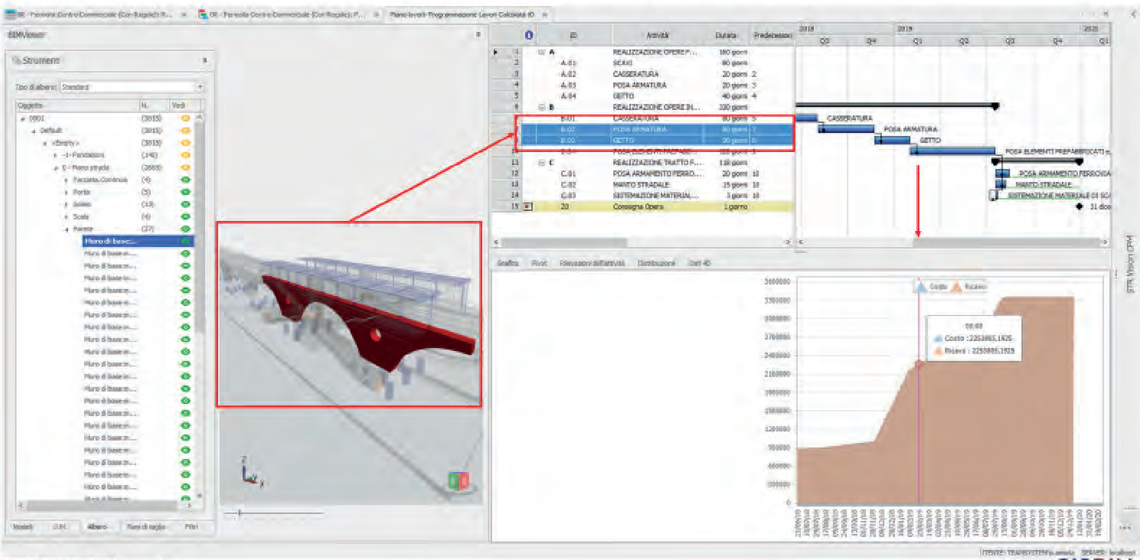
Step 3. Planning

4D/5D Planning

A 4D/5D model really integrated can show time and cost for any object or any WBE



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An integrated process from estimation to 4D model

Step 3. Planning

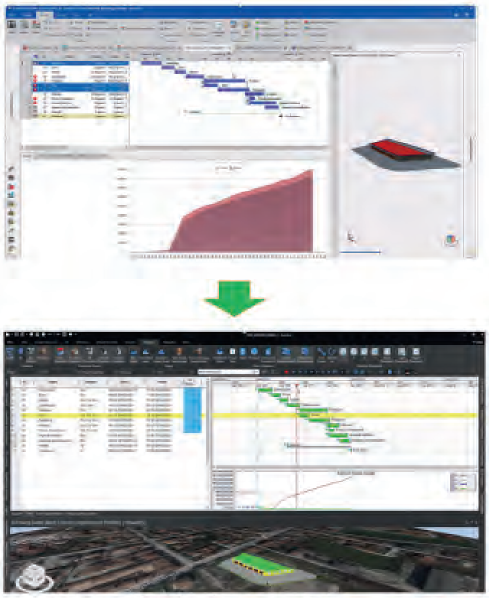
TeamSystem CPM + Synchro PRO

Advantages from integration

- ✓ Work Breakdown Structure of Gantt is automatically got from the estimation solution
- ✓ 3D model objects automatically connected with WBE
- ✓ Cost/Revenue automatically got from estimation model (5D)
- ✓ Actuals from the WIP reporting from CPM to Synchro
- ✓ Automatically comparison between Actuals and Planned

When

- ✓ Planning Phase: all in one BIM 3D/4D/5D model and reporting (MP4, 3D PDF)
- ✓ Lean Construction: clash and check detection to validate timing and logistic forecast
- ✓ Construction Phase: to have the best control of schedule and cost performance to better plan to finish



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From the execution plan to the site logistics scheduling

Step 3. Planning

An example of a solution for 4D modeling

Synchro PRO is a 4D advanced platform for the scheduling and simulation of a Project

Highlights

- ✓ It's not a movie maker solution
- ✓ Create a GANTT diagram integrated with 3D model
- ✓ Multiple connections between 3D object and WBE
- ✓ All kind of relationship between WBE (EE, SS, ES, SE), interruption and delay
- ✓ Possibilità di realizzare più baselines/scenari con analisi «What if»
- ✓ Interoperability with main BIM and Gantt solution (IFC, Primavera, MS Project, Bentley, Tekla, Naviswork, SketchUp, ASTA, Plug in - Revit)
- ✓ Clash Detection
- ✓ Resource Employment reporting (Procurement Plan, Security Plan)
- ✓ IRAY function (Rendering fotorealistico 3D Max)
- ✓ Augmented Reality with MS Hololens
- ✓ APP Mobile Synchro SITE
- ✓ Earned Value Analysis reporting

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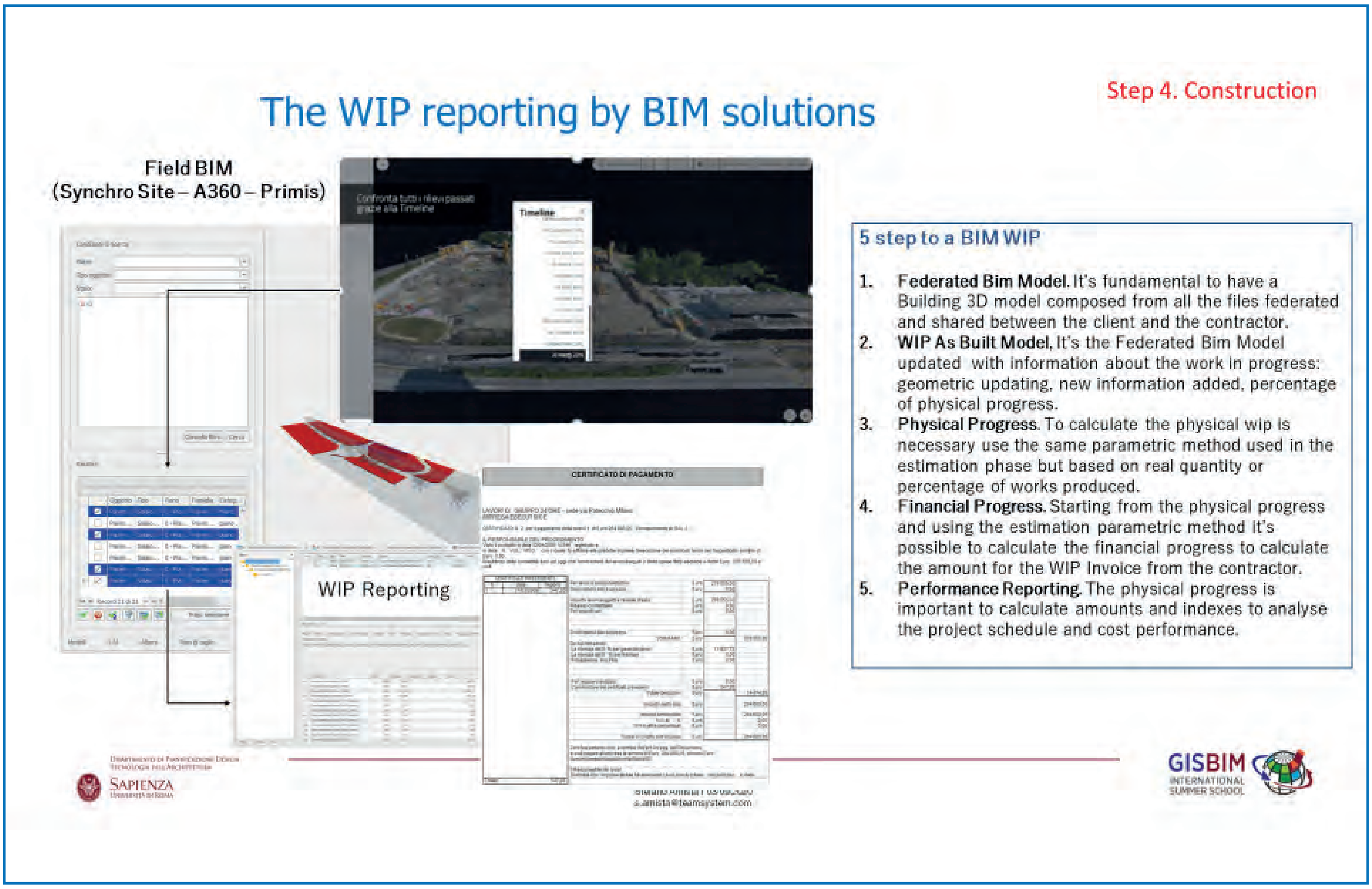
Construction and Control
grazie alla Timeline


The WIP reporting by BIM solutions
Step 4. Construction
Field BIM
(Synchro Site – A360 – Primis)
Timeline
WIP Reporting
CERTIFICATO DI PAGAMENTO
5 step to a BIM WIP
1. Federated Bim Model. It's fundamental to have a Building 3D model composed from all the files federated and shared between the client and the contractor.
2. WIP As Built Model. It's the Federated Bim Model updated with information about the work in progress: geometric updating, new information added, percentage of physical progress.
3. Physical Progress. To calculate the physical wip is necessary use the same parametric method used in the estimation phase but based on real quantity or percentage of works produced.
4. Financial Progress. Starting from the physical progress and using the estimation parametric method it's possible to calculate the financial progress to calculate the amount for the WIP Invoice from the contractor.
5. Performance Reporting. The physical progress is important to calculate amounts and indexes to analyse the project schedule and cost performance.
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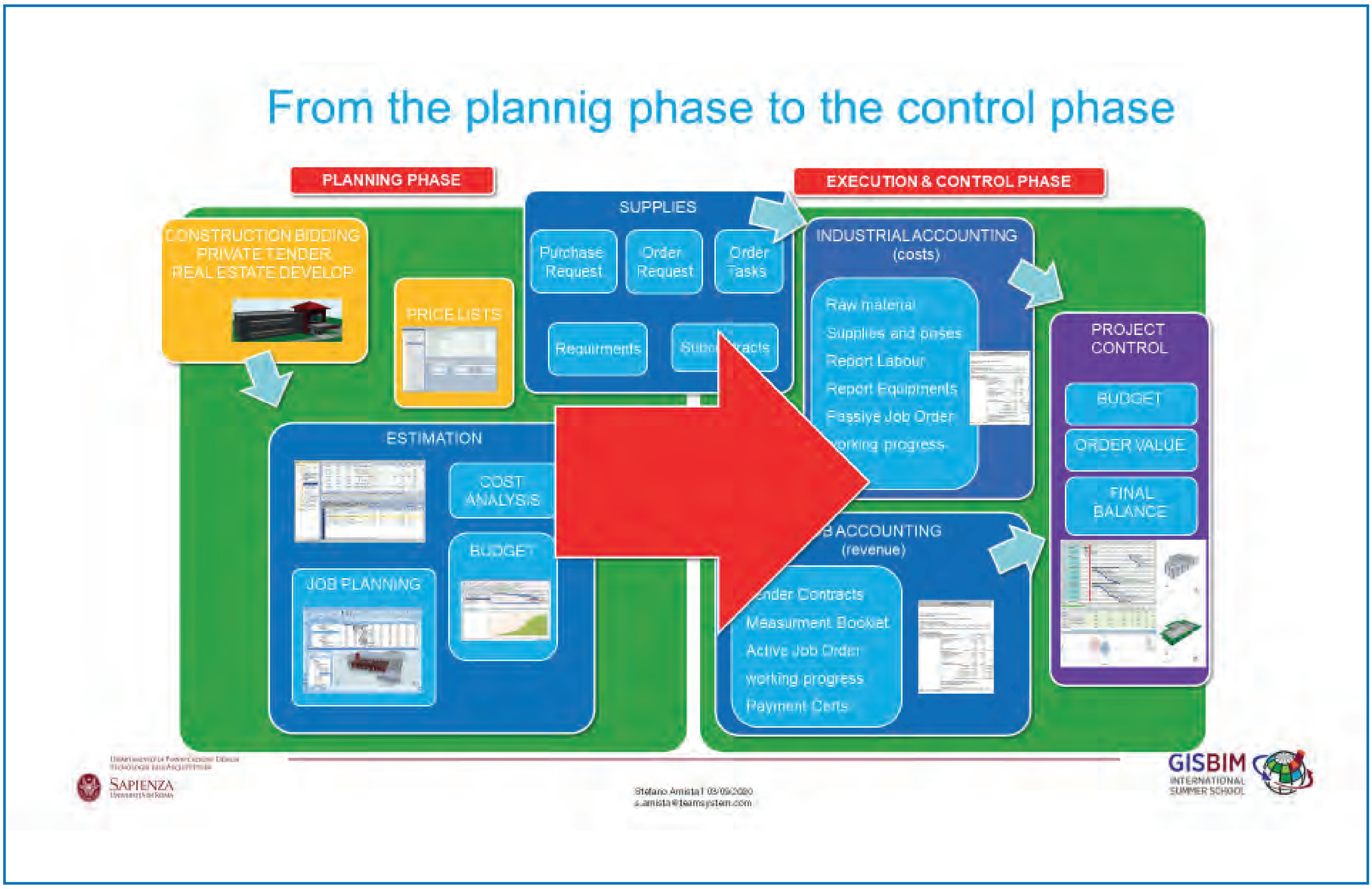
From the plannig phase to the control phase
PLANNING PHASE
EXECUTION & CONTROL PHASE
CONSTRUCTION BIDDING
PRIVATE TENDER
REAL ESTATE DEVELOP
PRICE LISTS
SUPPLIES
Purchase Request
Order Request
Order Tasks
Requirments
ESTIMATION
COST ANALYSIS
BUDGET
JOB PLANNING
INDUSTRIAL ACCOUNTING (costs)
Raw material
Supplies and bases
Report Labour
Report Equipments
Passive Job Order
Measurement Booklet
Active Job Order
working progress
Payment Certs
PROJECT CONTROL
BUDGET
ORDER VALUE
FINAL BALANCE
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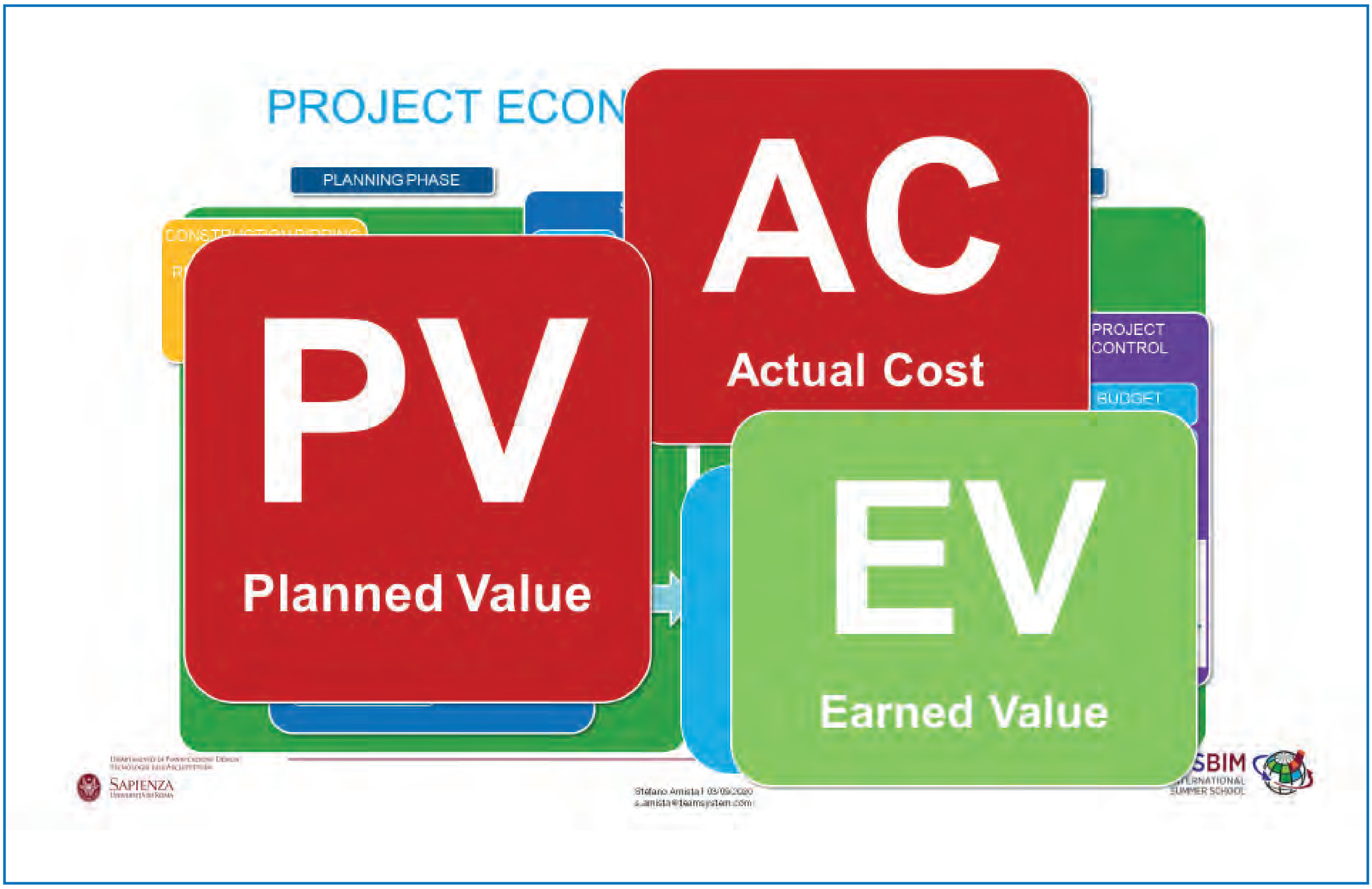
PROJECT ECON
PLANNING PHASE
AC
Actual Cost
PV
Planned Value
EV
Earned Value
PROJECT CONTROL
BUDGET
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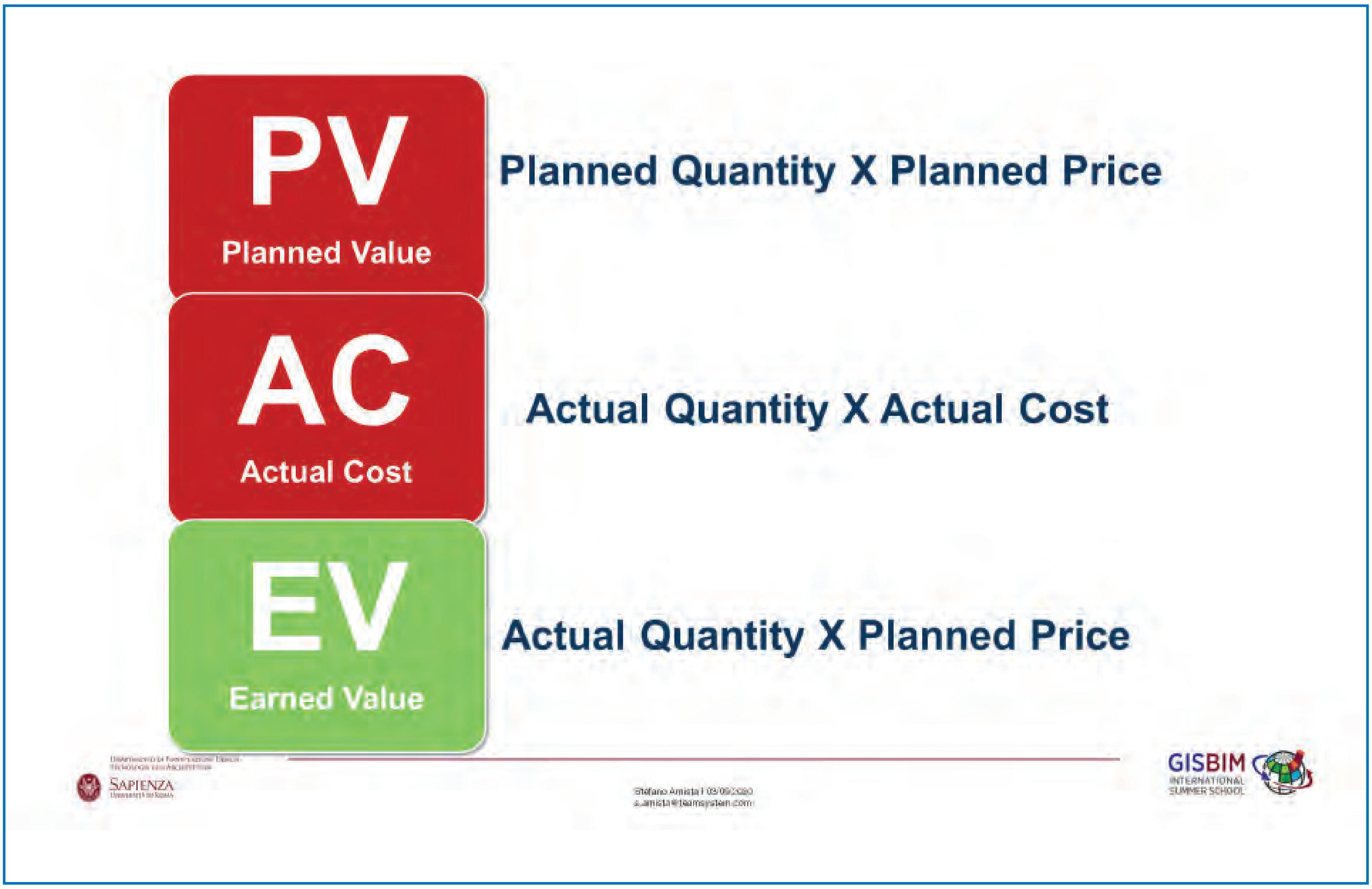
PV
Planned Value
Planned Quantity X Planned Price
AC
Actual Cost
Actual Quantity X Actual Cost
EV
Earned Value
Actual Quantity X Planned Price
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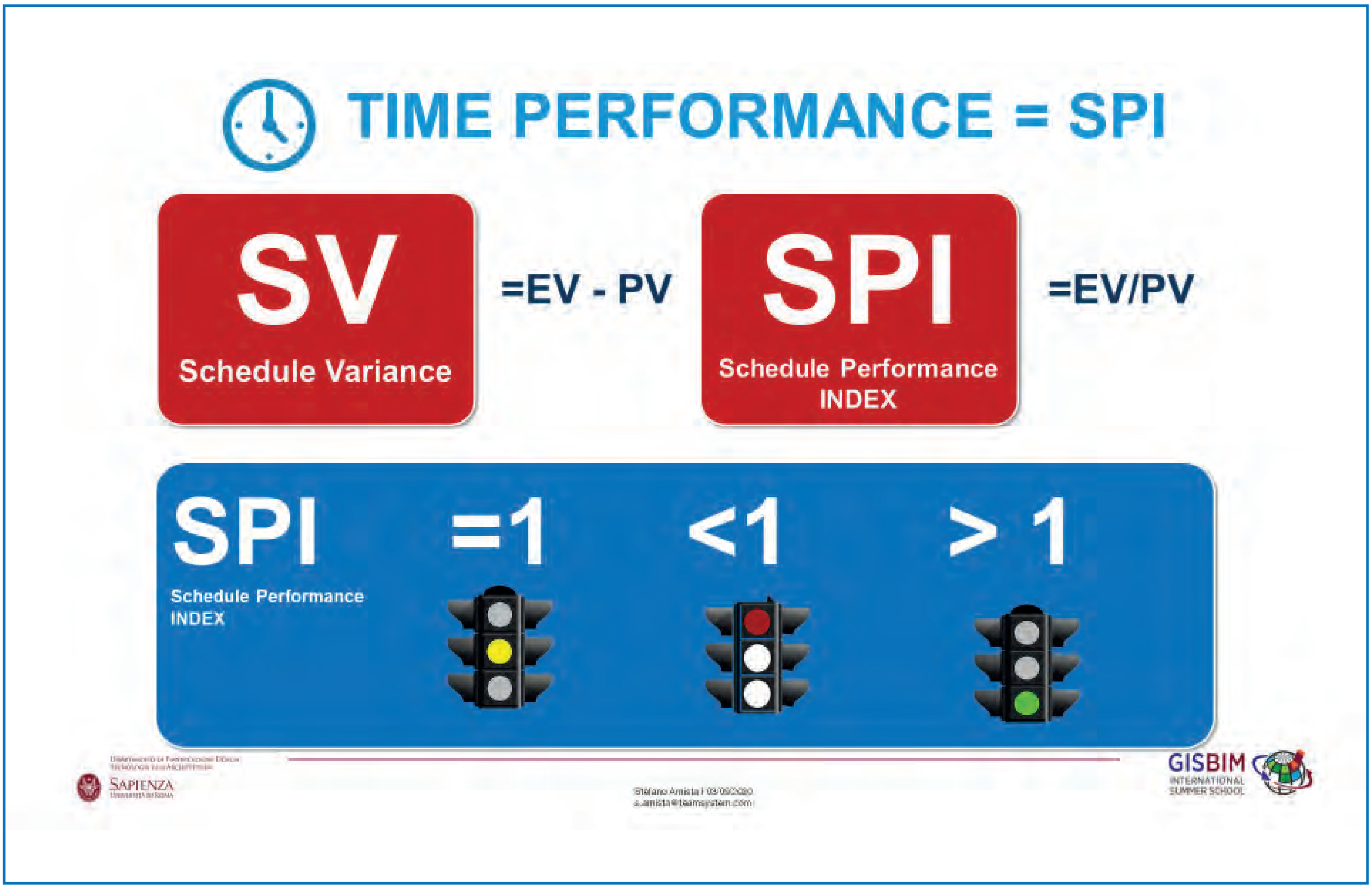
TIME PERFORMANCE = SPI
SV
Schedule Variance
=EV - PV
SPI
Schedule Performance INDEX
=EV/PV
SPI
Schedule Performance INDEX
=1
<1
> 1
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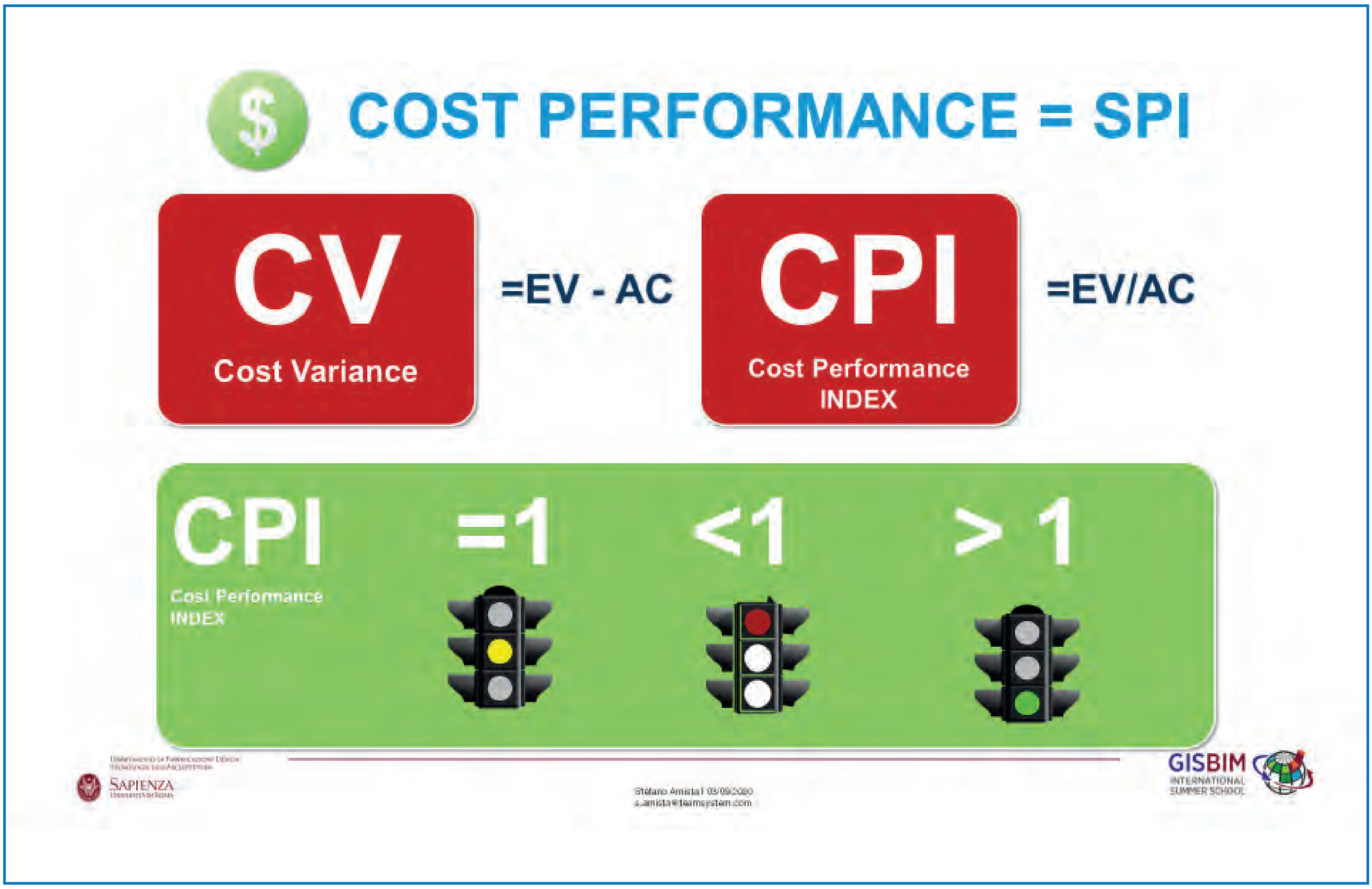
COST PERFORMANCE = SPI
CV
Cost Variance
=EV - AC
CPI
Cost Performance INDEX
=EV/AC
CPI
Cost Performance INDEX
=1
<1
> 1
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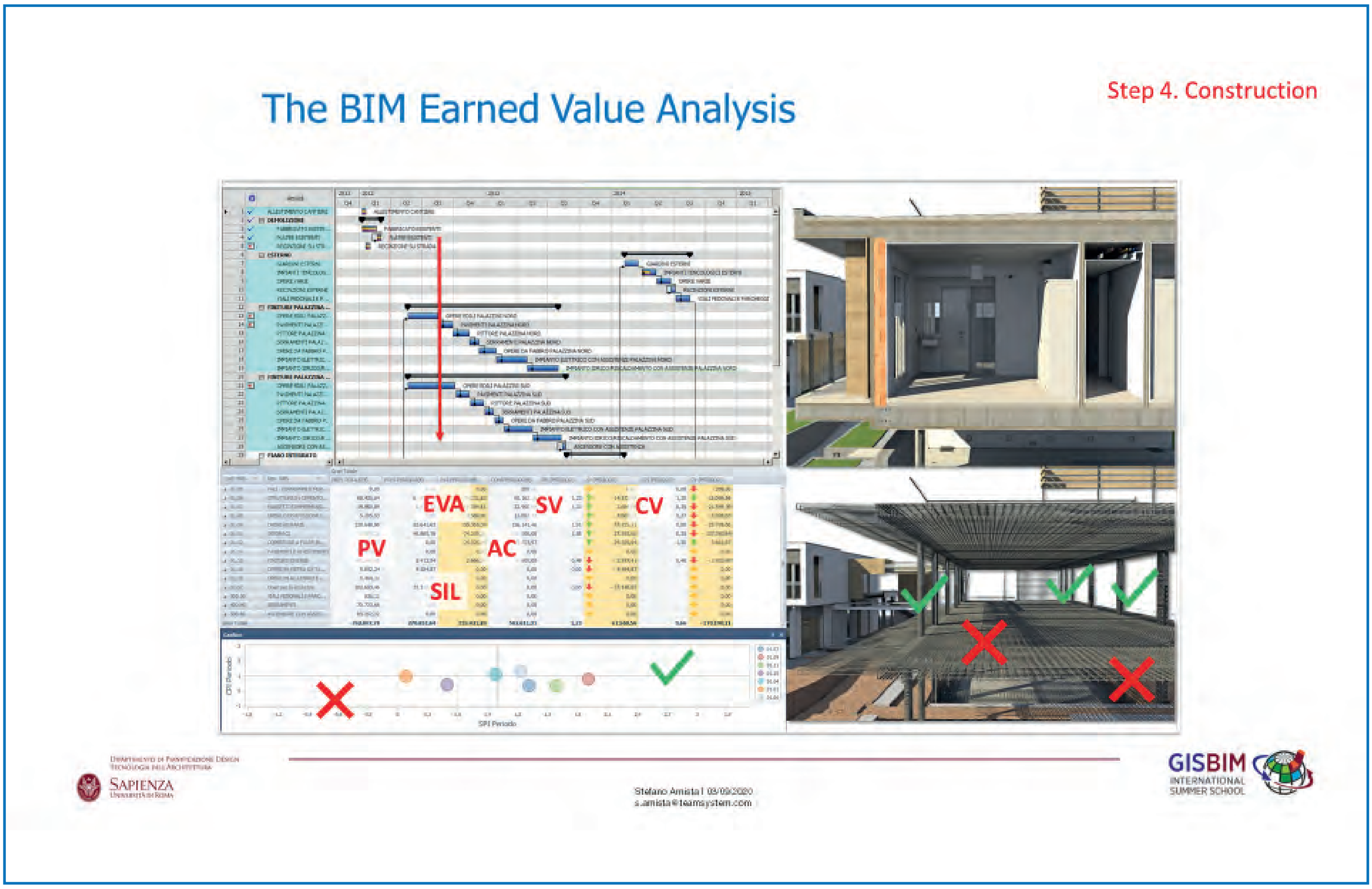
The BIM Earned Value Analysis
Step 4. Construction
EVA
SV
CV
PV
AC
SIL
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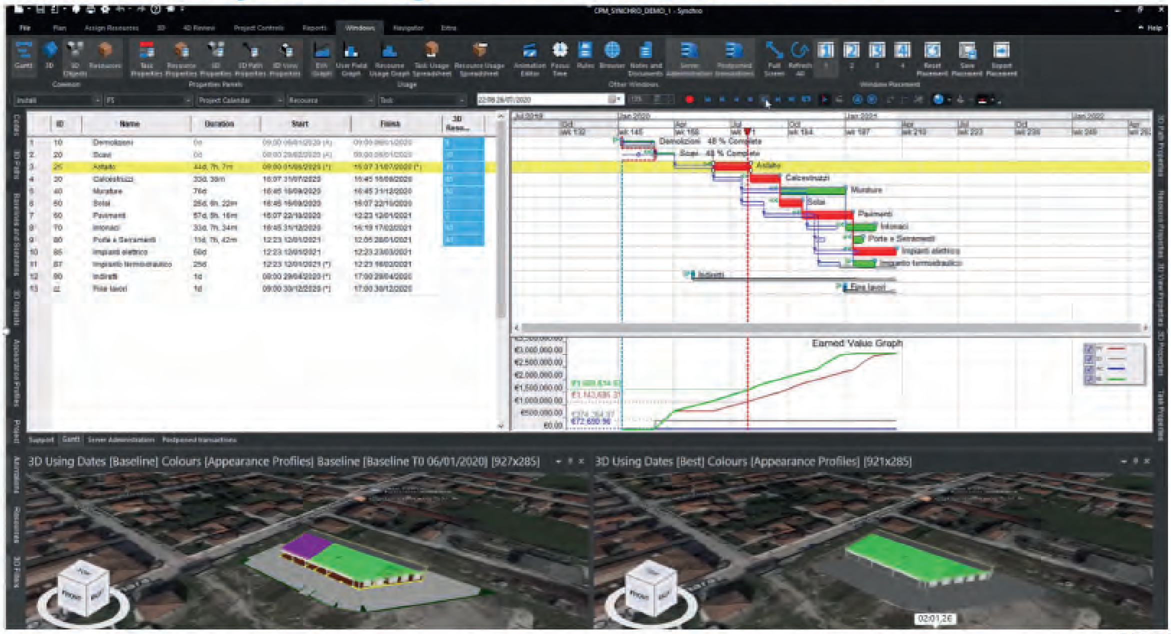
The BIM Project Management – Baseline vs Update Scheduling

Step 4. Construction



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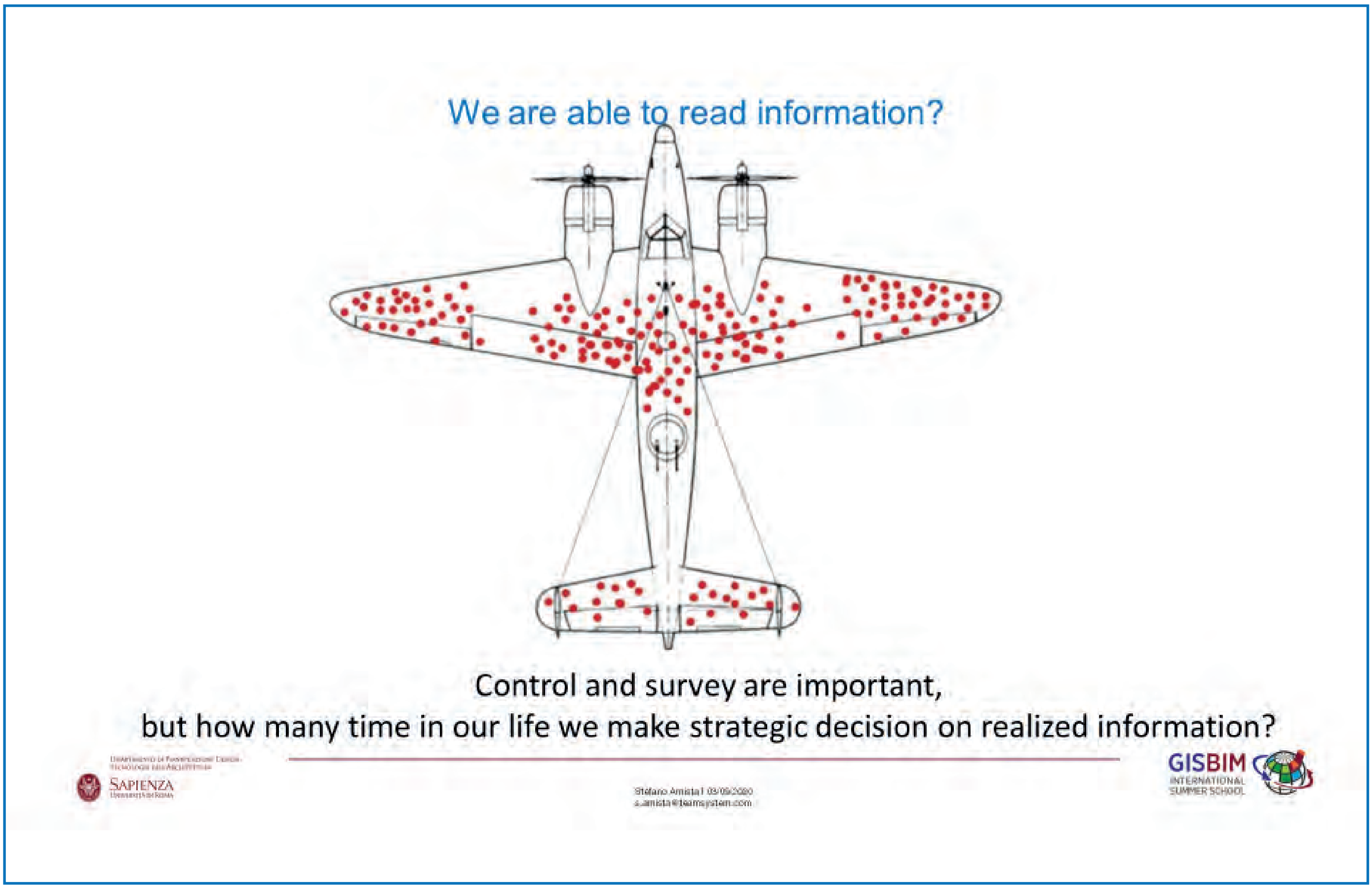
CONCLUSION


We are able to read information?
Control and survey are important,
but how many time in our life we make strategic decision on realized information?
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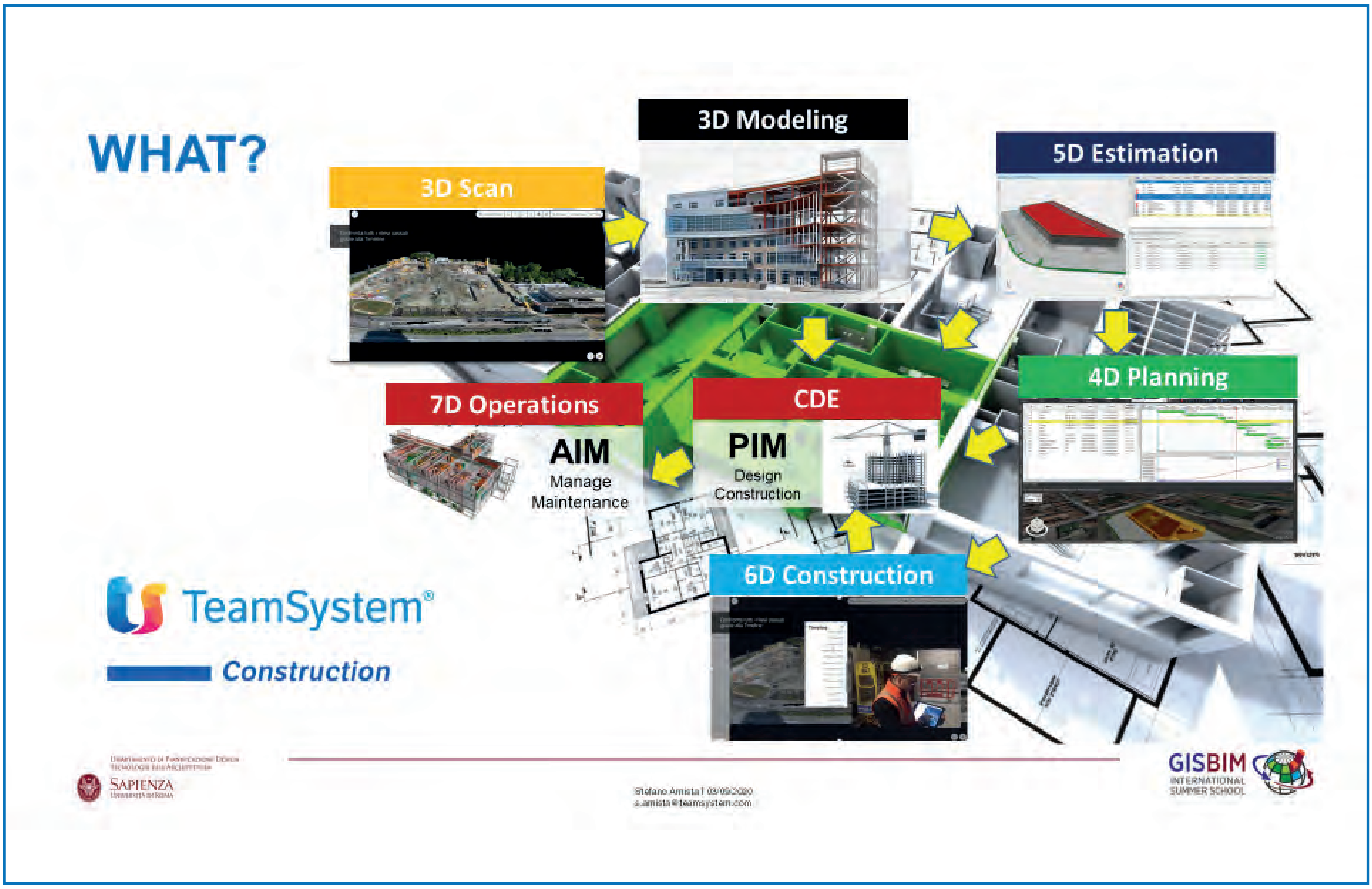
WHAT?
3D Modeling
5D Estimation
3D Scan
4D Planning
7D Operations
CDE
AIM
Manage
Maintenance
PIM
Design
Construction
6D Construction
TeamSystem®
Construction
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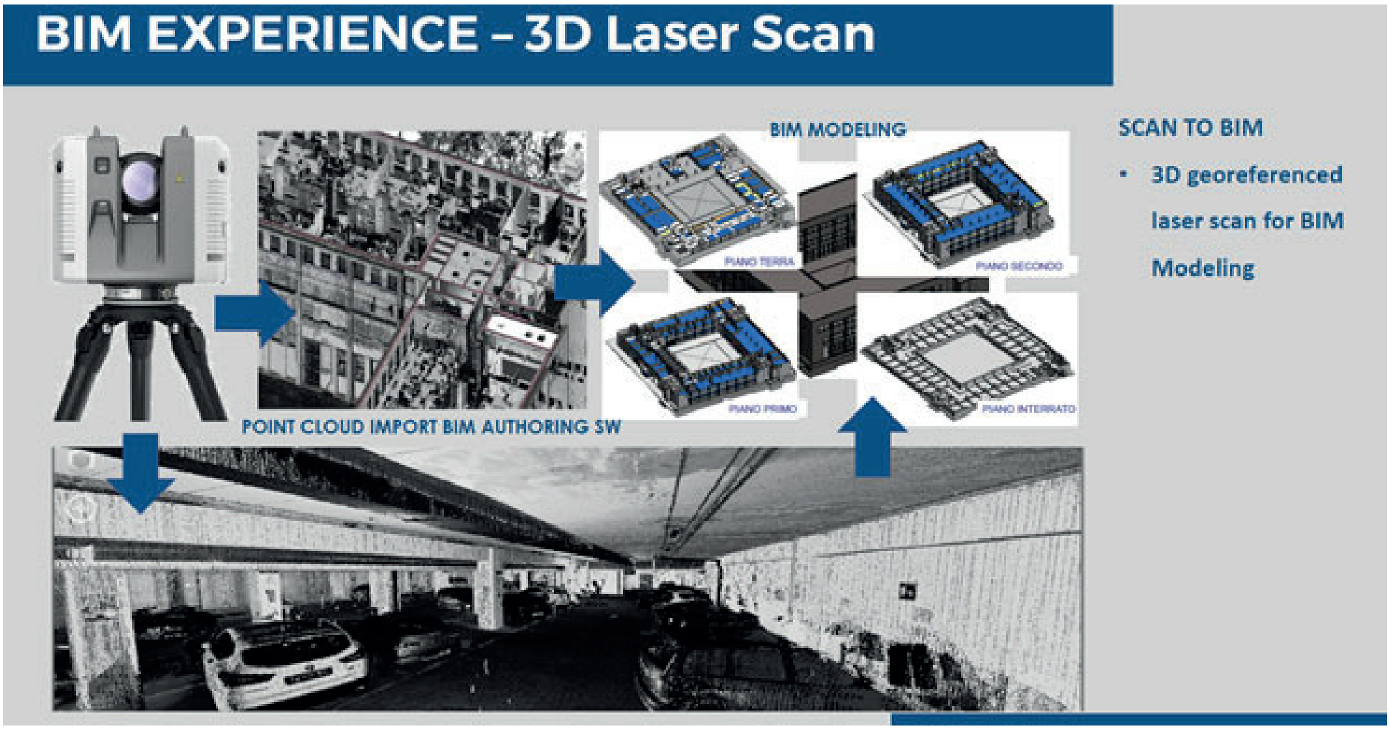
4D/5D modeling & management workflows at Cortina's Fis Alpine World Ski championships' new downhill race track

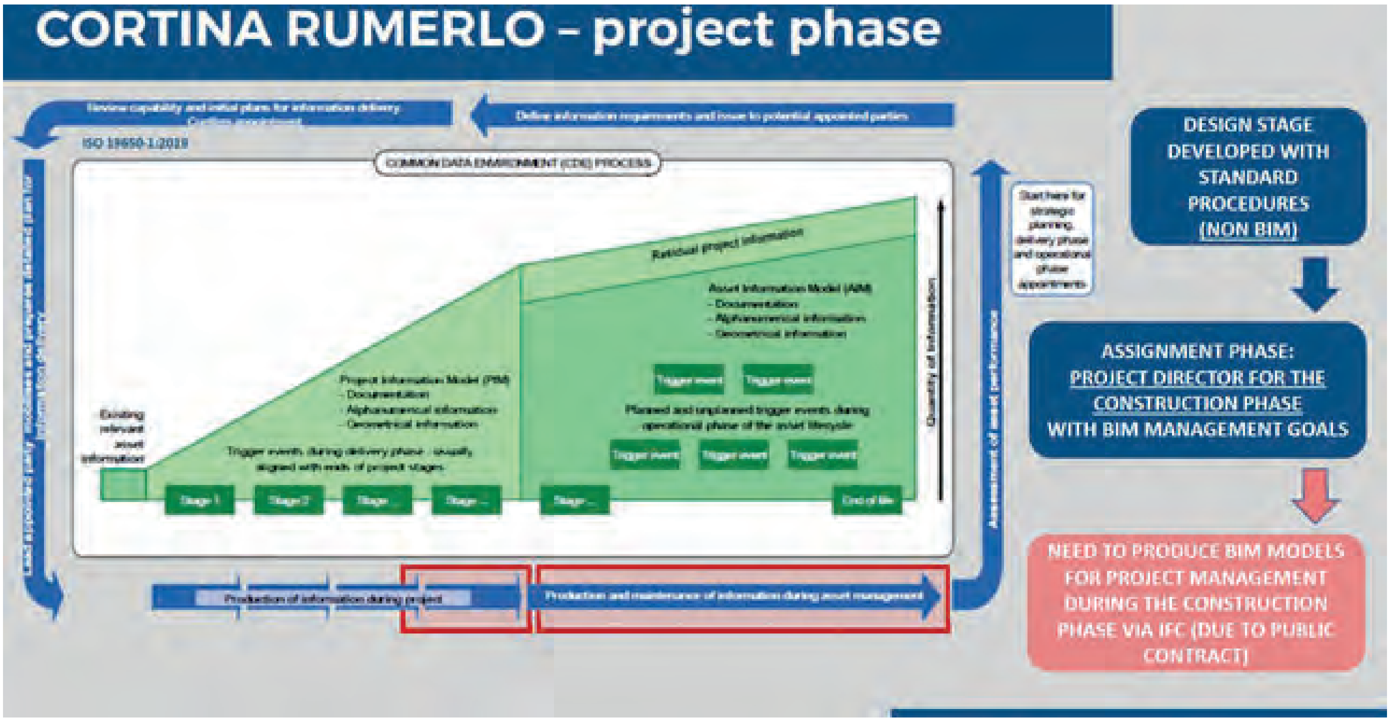
Dr. Simone Di Biase
Architect BIM Manager, DBA PRO S.p.A.

"BIM dimension" is one of the most important aspects of implementing BIM/GIS processes, from the design phase to the project management phase. In the case study illustrated at the "GIS BIM International Summer School" Cortina 2021 - Rumerlo have been analyzed the BIM workflows relative to the 5D (cost estimation for the construction phase) and 4D (time scheduling simulation for the construction phase) using BIM models set up with the target to optimize the processes of planning and execution of the work, exploiting the open BIM format IFC 2x3. The project has been developed by DBA PRO., a company with 30 years of experience operating in Italy and abroad in the field of architecture and engineering and in the management of the whole building life cycle, which for the specific project has been entrusted with the supervision of the works and coordination of safety during the construction phase.

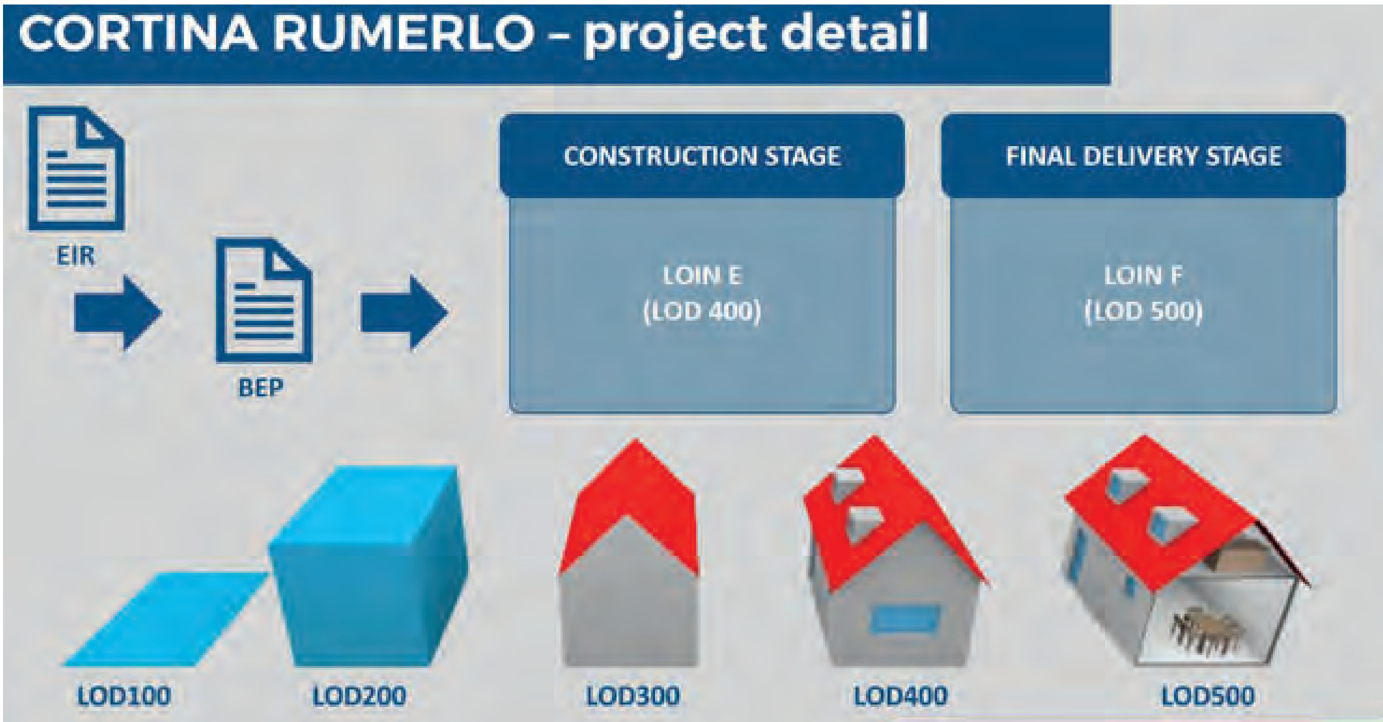
The Cortina Rumerlo project was developed in the context of a public contract which, according to current Italian legislation, does not require the use of the BIM methodology.



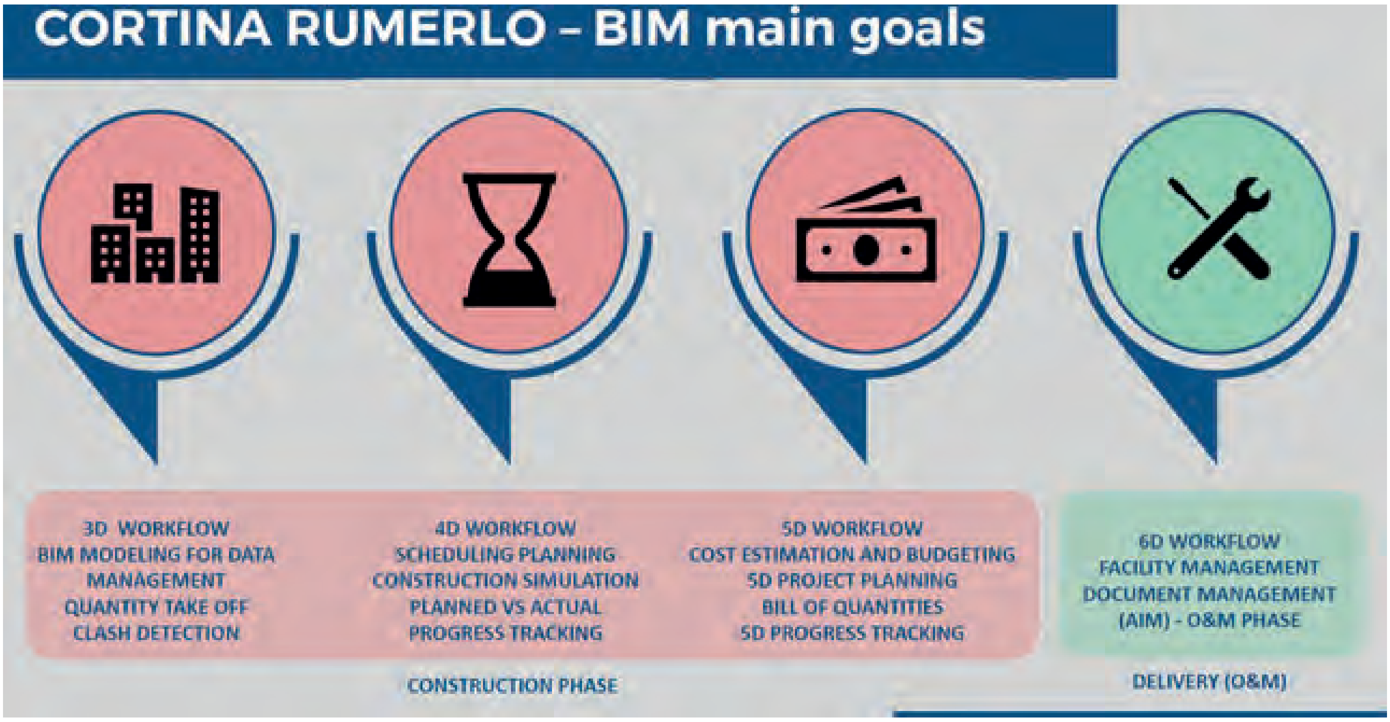
In the specific case, however, the Client specifically requested that time and cost management must be developed using BIM models. For this reason the BIM models were set up at the start of the construction phase with the support of the Constructor, using the tender design stage documents . For the construction phase a LOD 400 or LOD E was requested according to the Italian scale with reference to the UNI 11337 standard.



The main objectives are therefore 3D modeling, including BIM data management, modeling and setting of 4D and 5D workflows for the management of construction time scheduling and cost.



Regarding the BIM Uses of the project, the BIMe Initiative scheme was taken as a reference, identifying the main ones to be included in the BEP (BIM Execution Plan).



Therefore the main objective set by the Client was the setting of a BIM model that could be configured as a digital twin of the work to be carried out to control time scheduling and costs in the construction phase, and the verification of the progress of works. In Italy, public procurement is subject to the obligation to use open BIM formats. Therefore all the information exchanges used the IFC 2x3 format exported directly from the BIM native models.

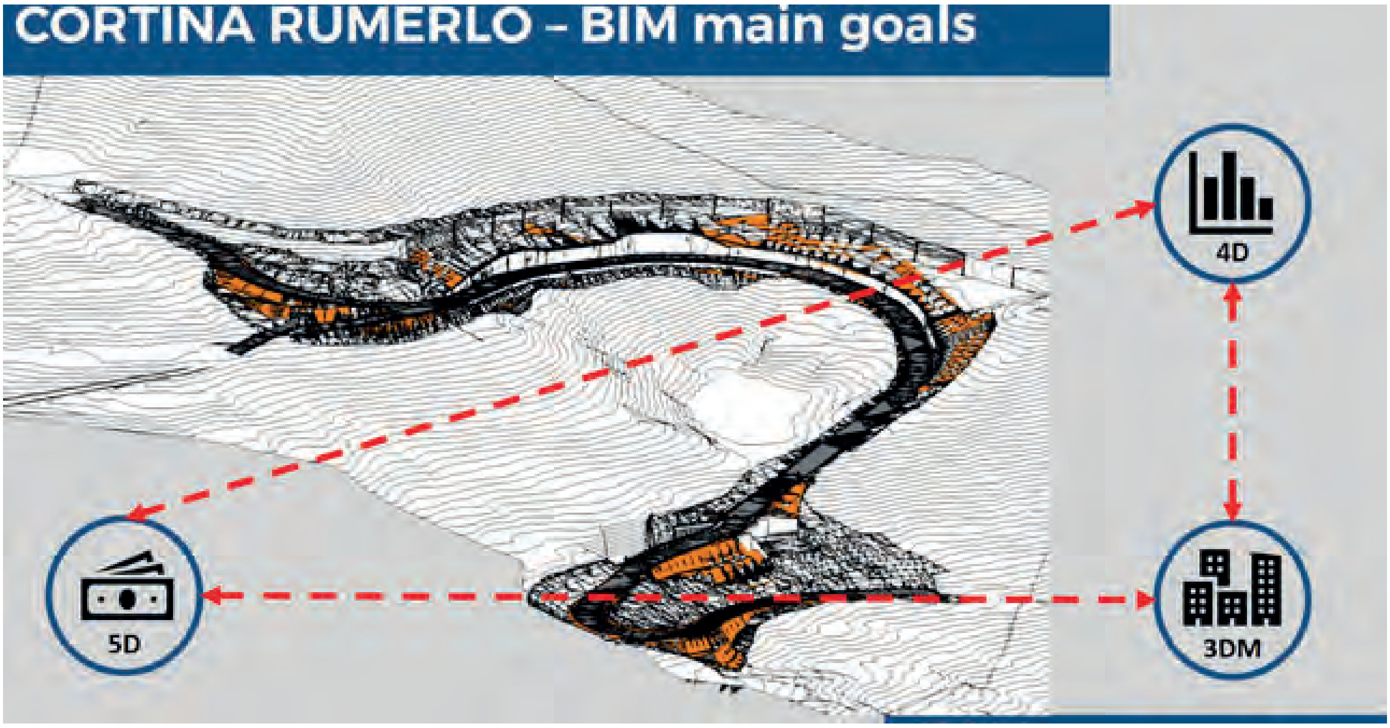
CORTINA RUMERLO – BIM USES

BIMe INITIATIVE

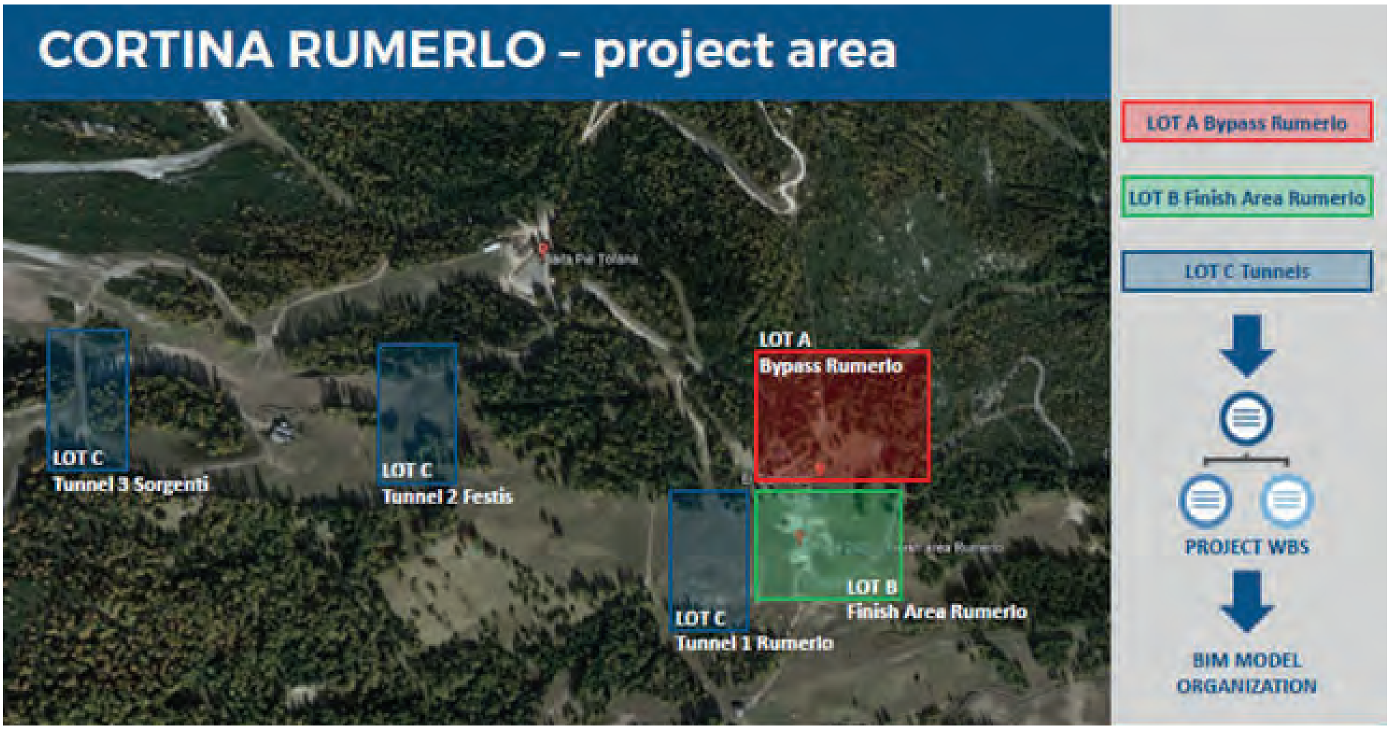
BIM MODEL USE LIST

CODE	Model Use Series	Model Use	Notes
2010	Capturing and Representing	2D Documentation	Sheets extracted from BIM models
2090		Visual Communication	Rendering and simulations
3020	Planning and Design	Construction Planning	4D planning
3040		Design Authoring	3D BIM modeling
4040		Clash Detection	BIM Coordination
4050		Code Checking and validation	Code check
4070		Cost Estimation	5D cost estimation documents
4130		Quantity Take Off	QTO for cost estimation
4210		Structural Analysis	-

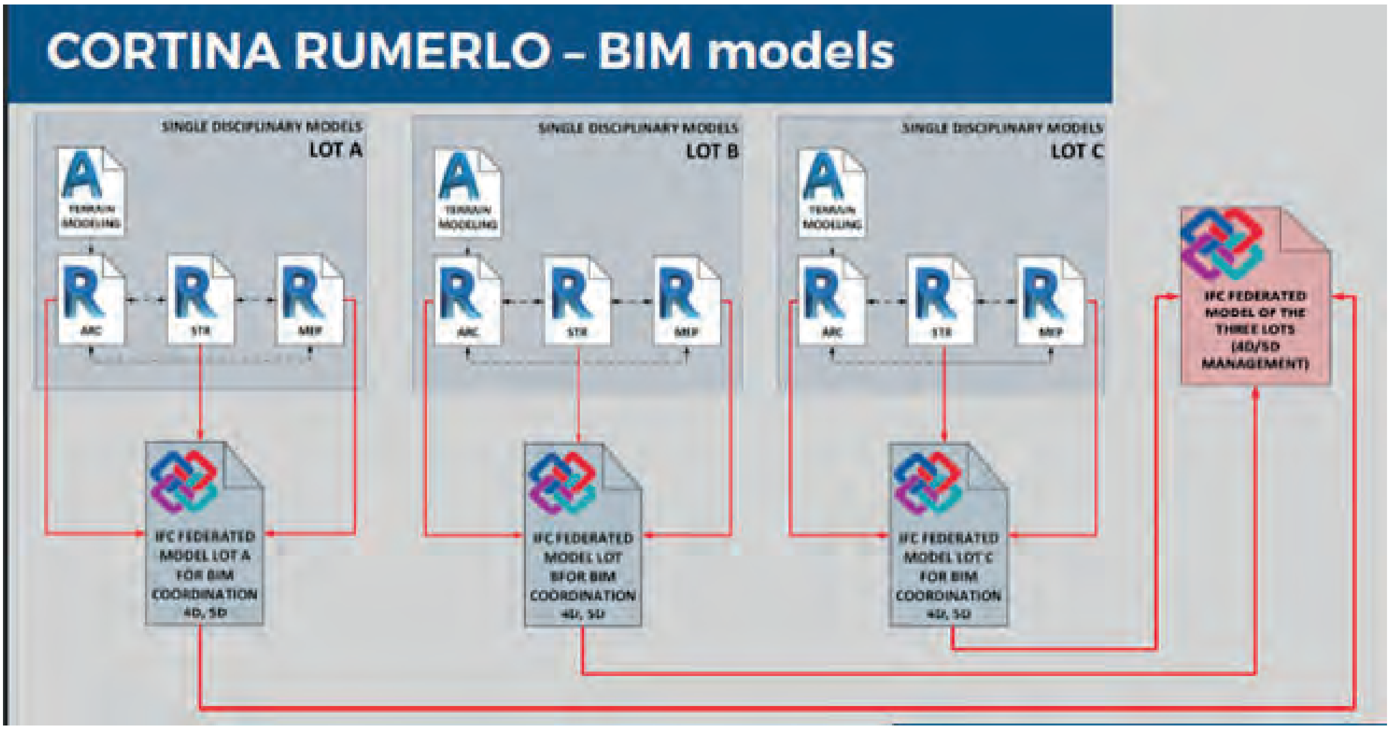
There were different software used for 3D, 4D and 5D workflows. Revit for 3D modeling and setting all data and parameters related to objects. MS Project for setting the project Gantt and STR Vision CPM for setting 4D simulations. STR Vision CPM for setting the quantity take off and cost estimation documents.



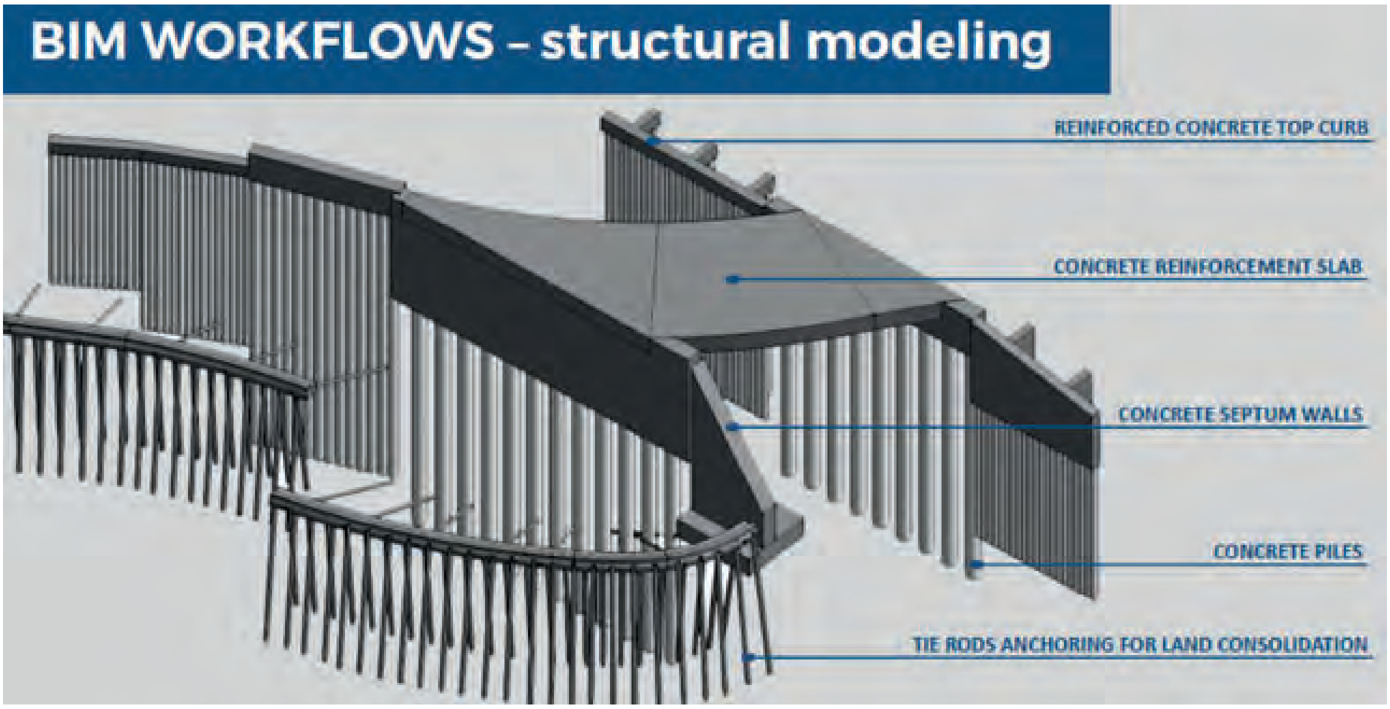
Obviously, as this is a complex infrastructural project divided into different areas of intervention, the information modeling has been divided into construction lots for which disciplinary BIM models have been set up for each discipline such as architectural, structural and plant works. For each disciplinary model has been exported the IFC model and in general different federated models were set up for project coordination in IFC format.

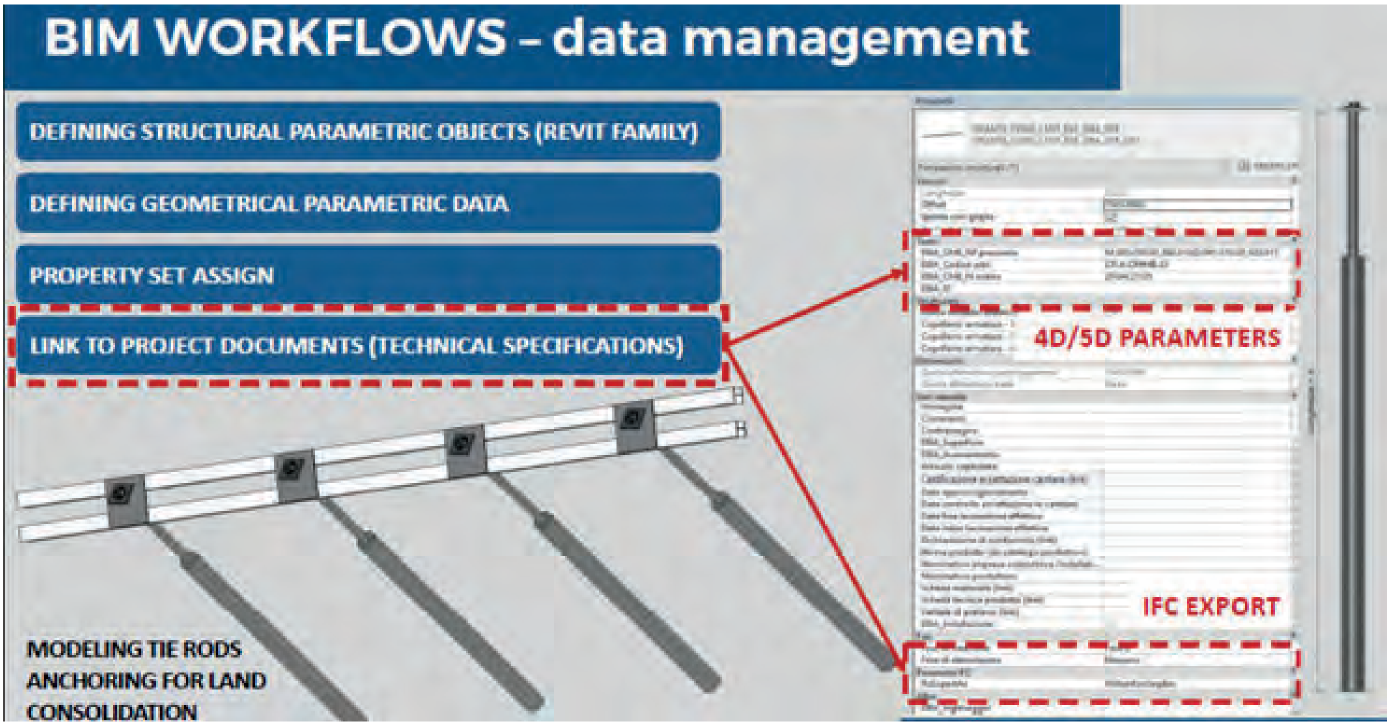


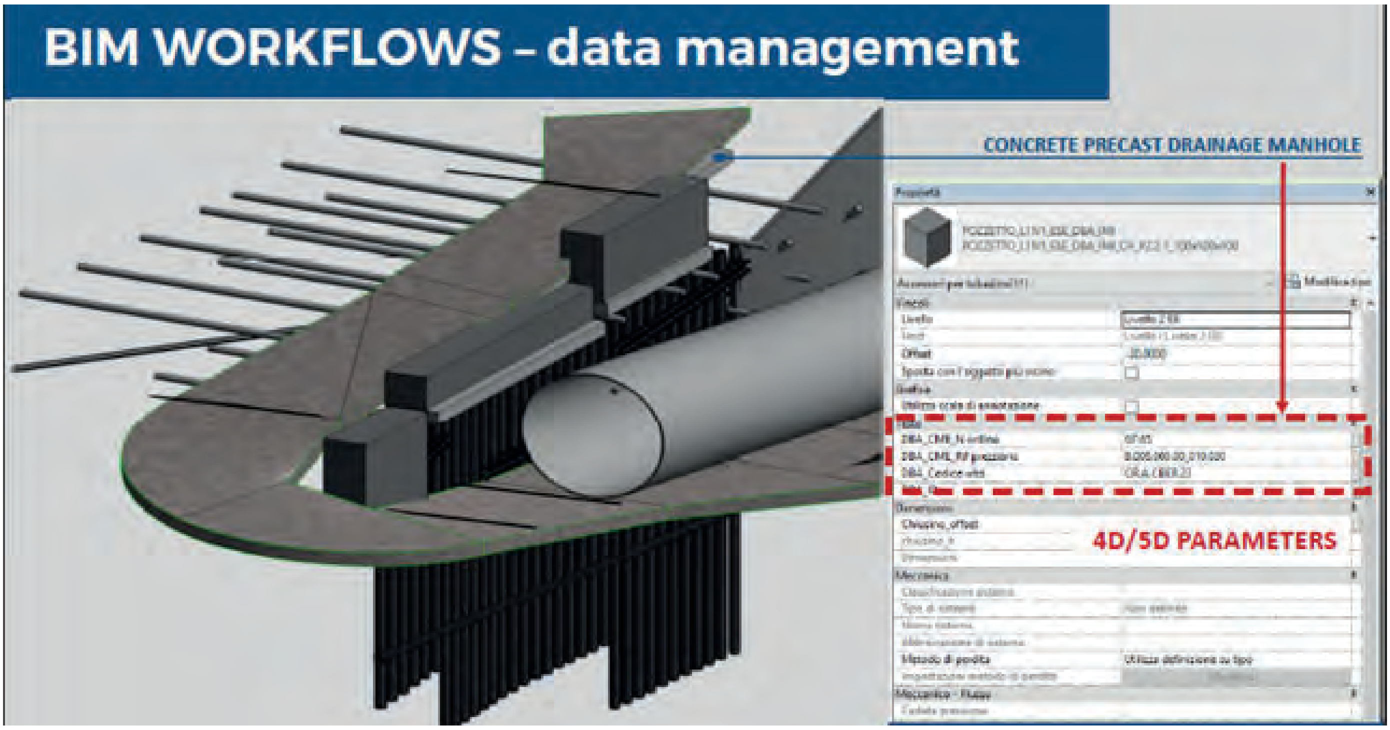
To set up 4D and 5D workflows, we started with the modeling of the terrain using Civil3D, following all the architectural, structural and plant elements have been modeled in Revit. To each element has been assigned parameter and information relating to the project WBS which was agreed with the Client. Through this information exported to the IFC models it was then possible to set the 4D simulations and 5D workflows outside the BIM authoring software.



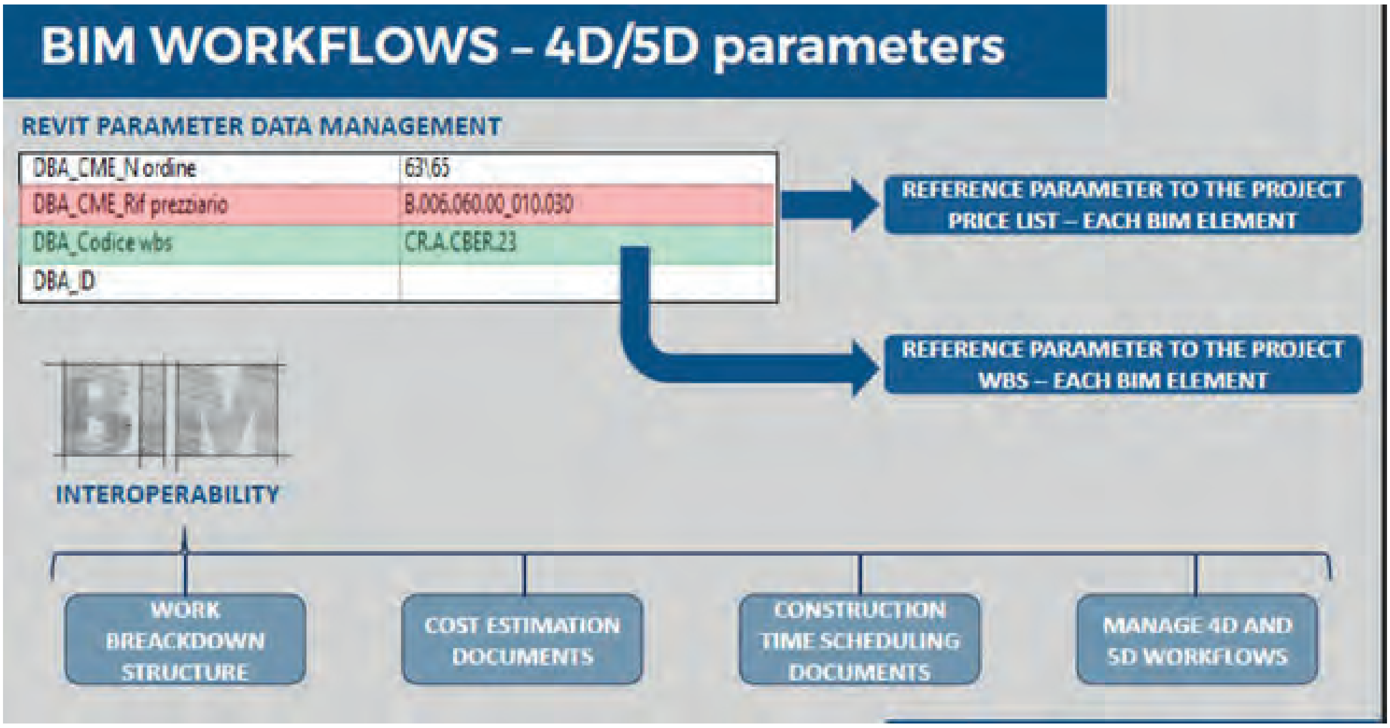
This was possible by entering information regarding the 4D and 5D workflows associated to each element (slide 24), from the very first stages of BIM modelling. All information are always referable to the structure of the project WBS which is the most important “information vehicle” in this kind of project.

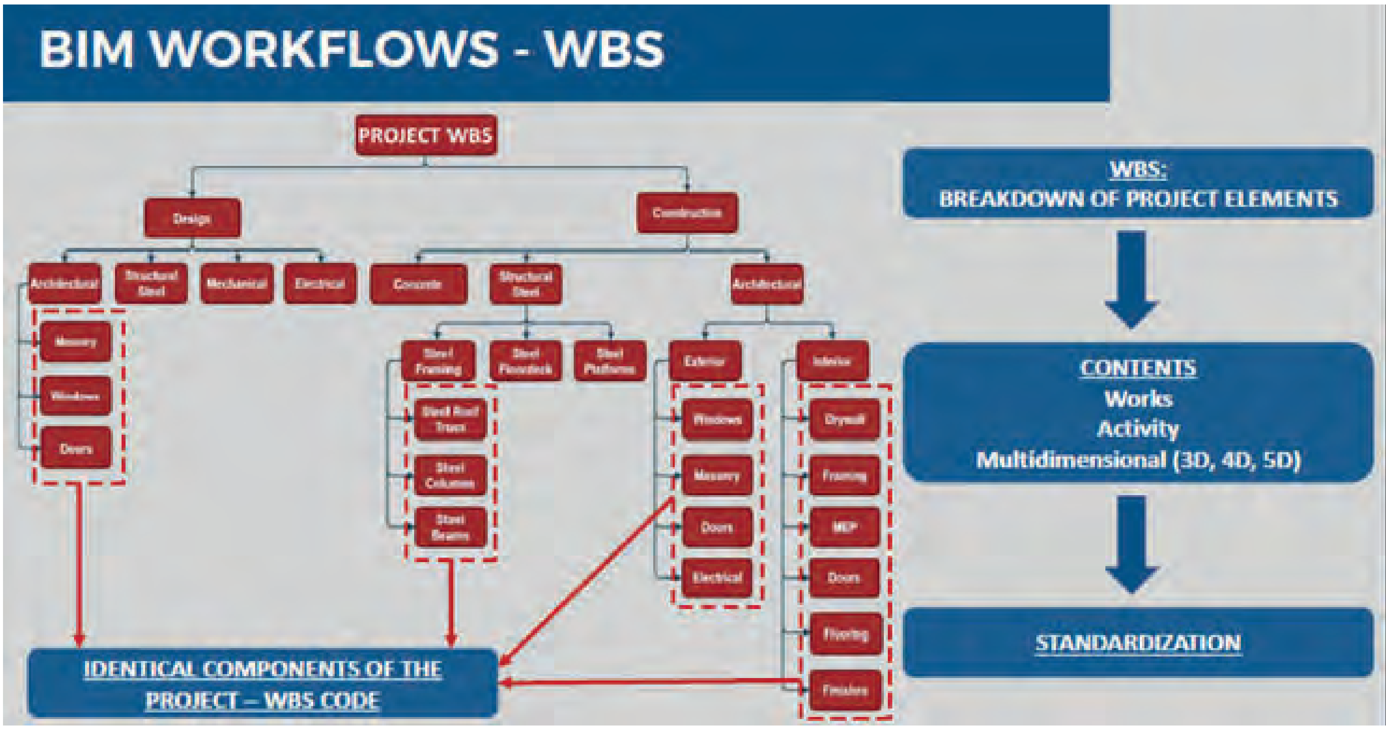




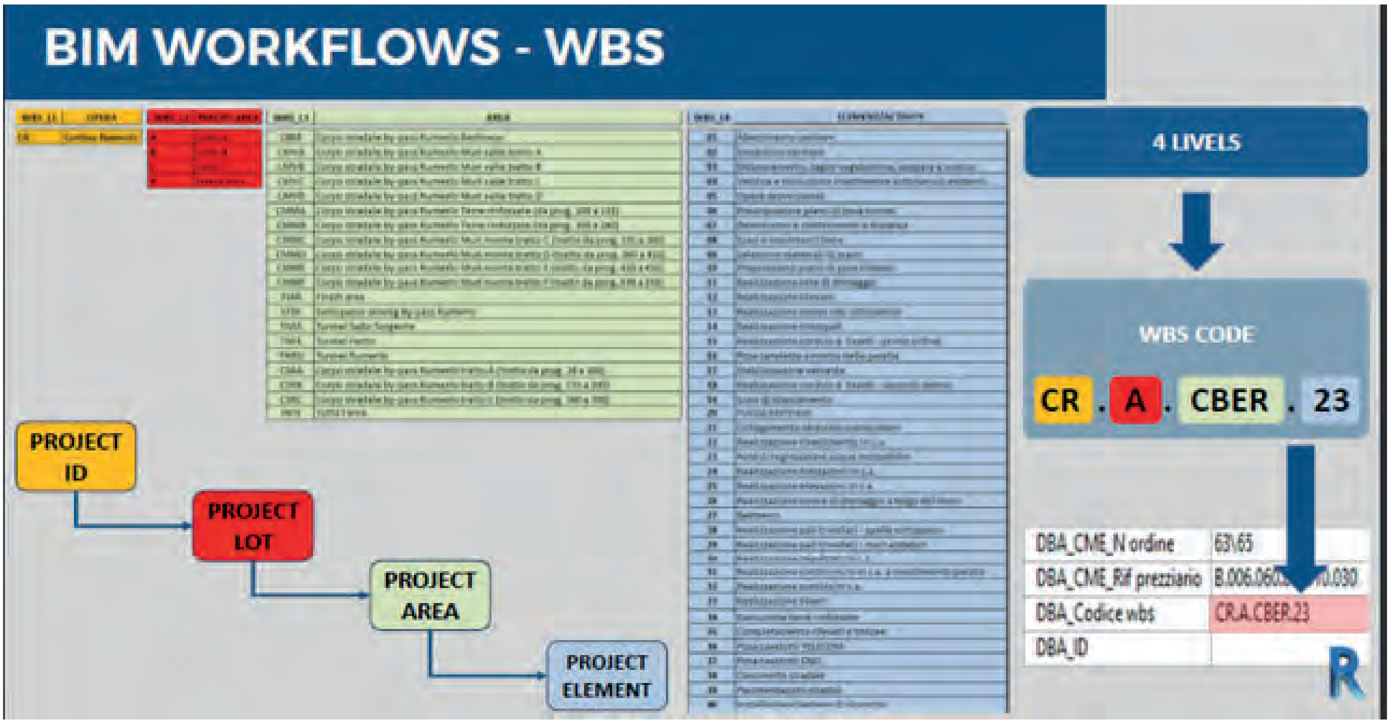


It is the project WBS that allows us in a BIM process to identify all the objects by tracing them to a standard coding that becomes of fundamental importance in order to standardize all the design phases. In the case of Cortina Rumerlo we started with the subdivision by lots (areas) up to the identification of the single object with a 4-field alphanumeric code.

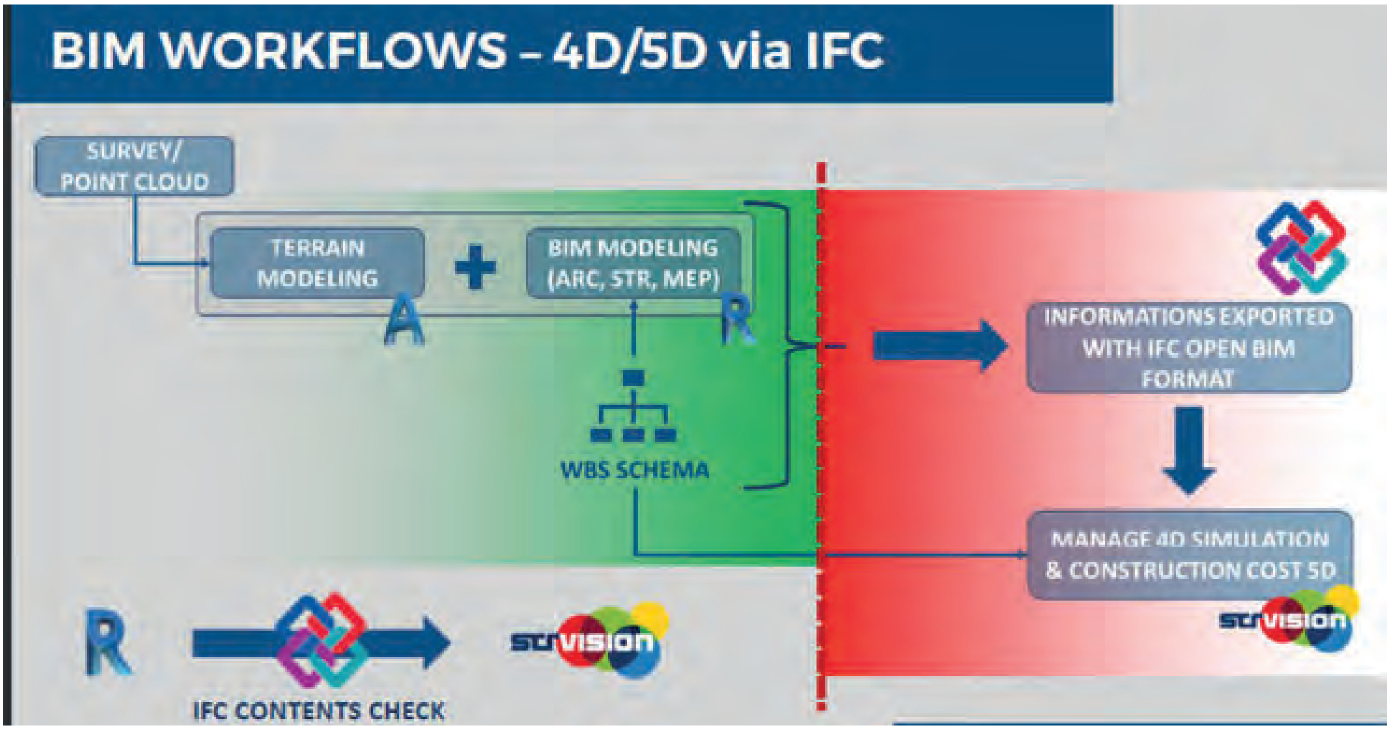


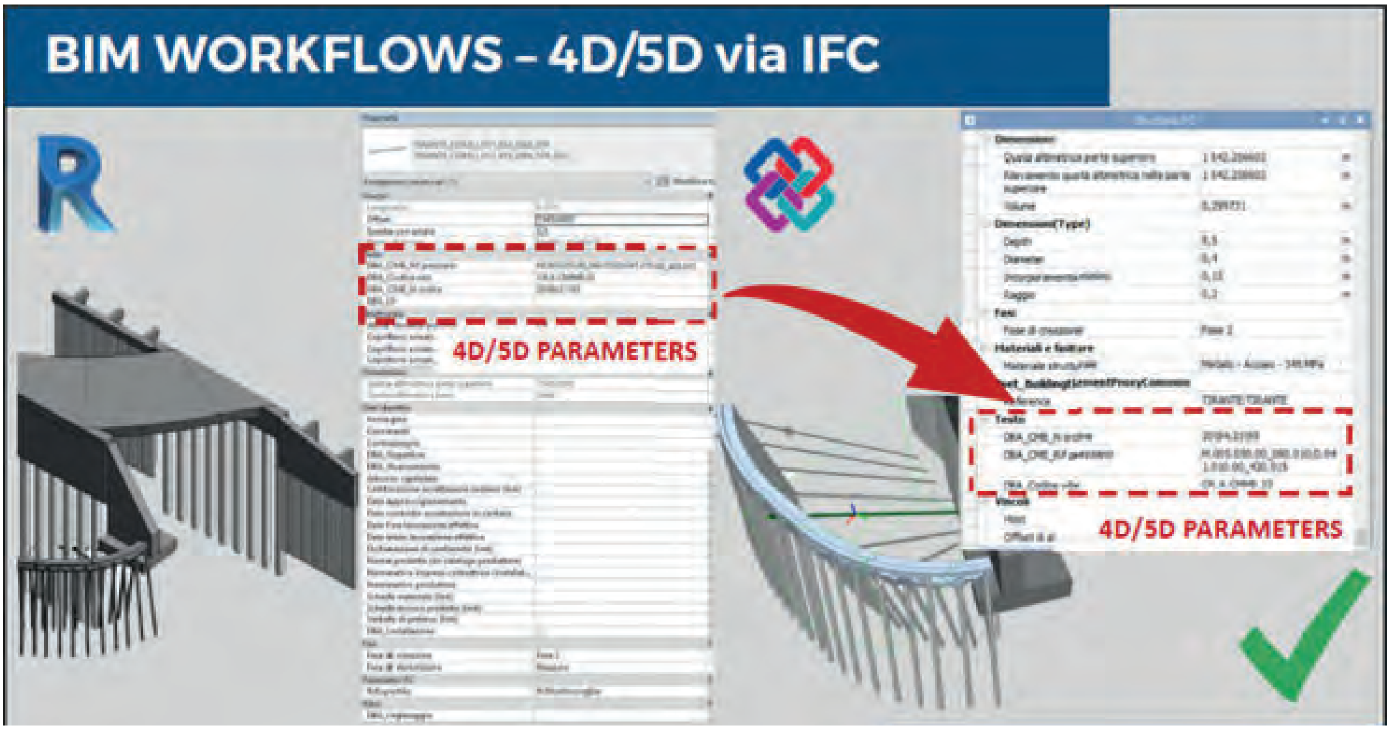


At this point in the process, with all the parameter and information associated with the objects within the BIM authoring software, the 3D modeling phase is completed and the export to the IFC 2x3 open format is completed. The next step after the export is the verification and validation of the IFC model contents, i.e. the verification that all the information entered in the BIM native models were contained in the IFC files, without any loss on information.

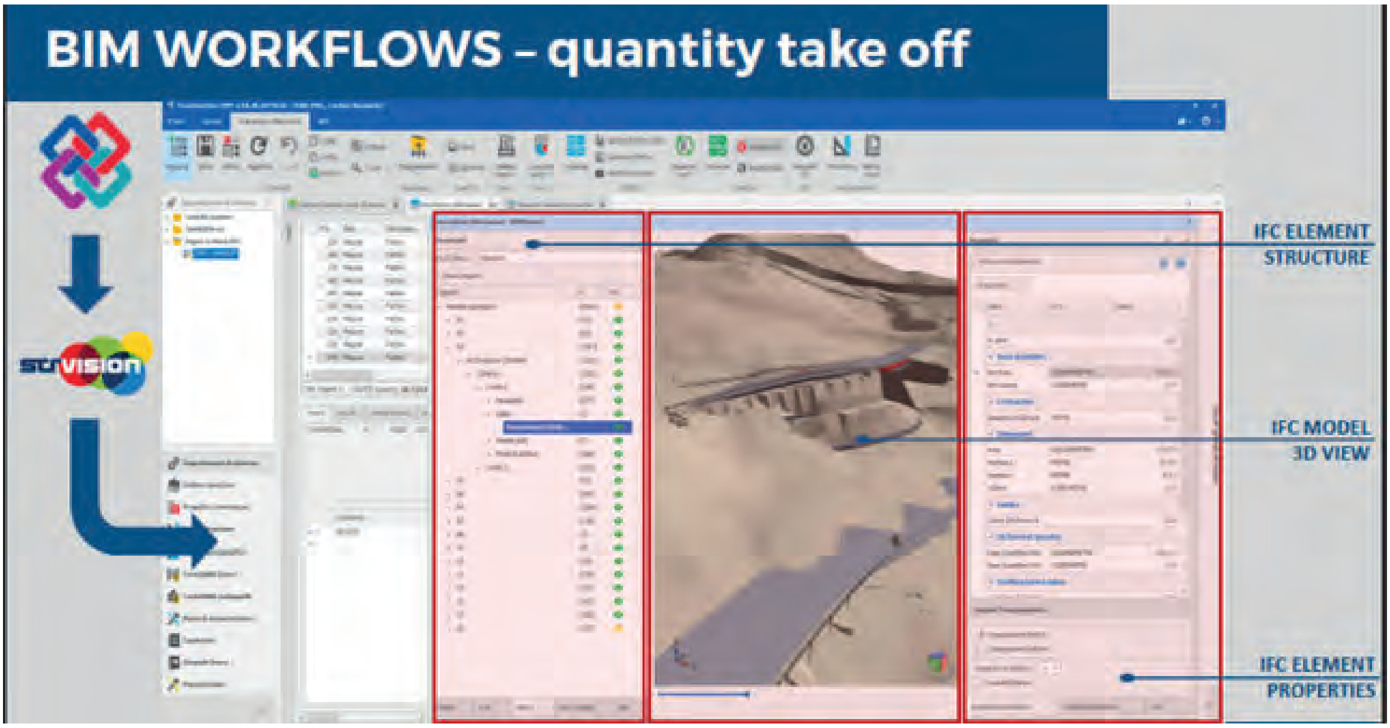


The validated IFC models were imported into an IFC compliant software that allows the setting of 4D and 5D workflows starting from the BIM models. This offers multiple benefits. First of all, the possibility to operate outside BIM authoring software in complete interoperability. It also offers the possibility of extracting all the quantities of objects for cost estimation starting from an information model that can be controlled and that can be updated over time in the event of variations both in the design and construction phases.

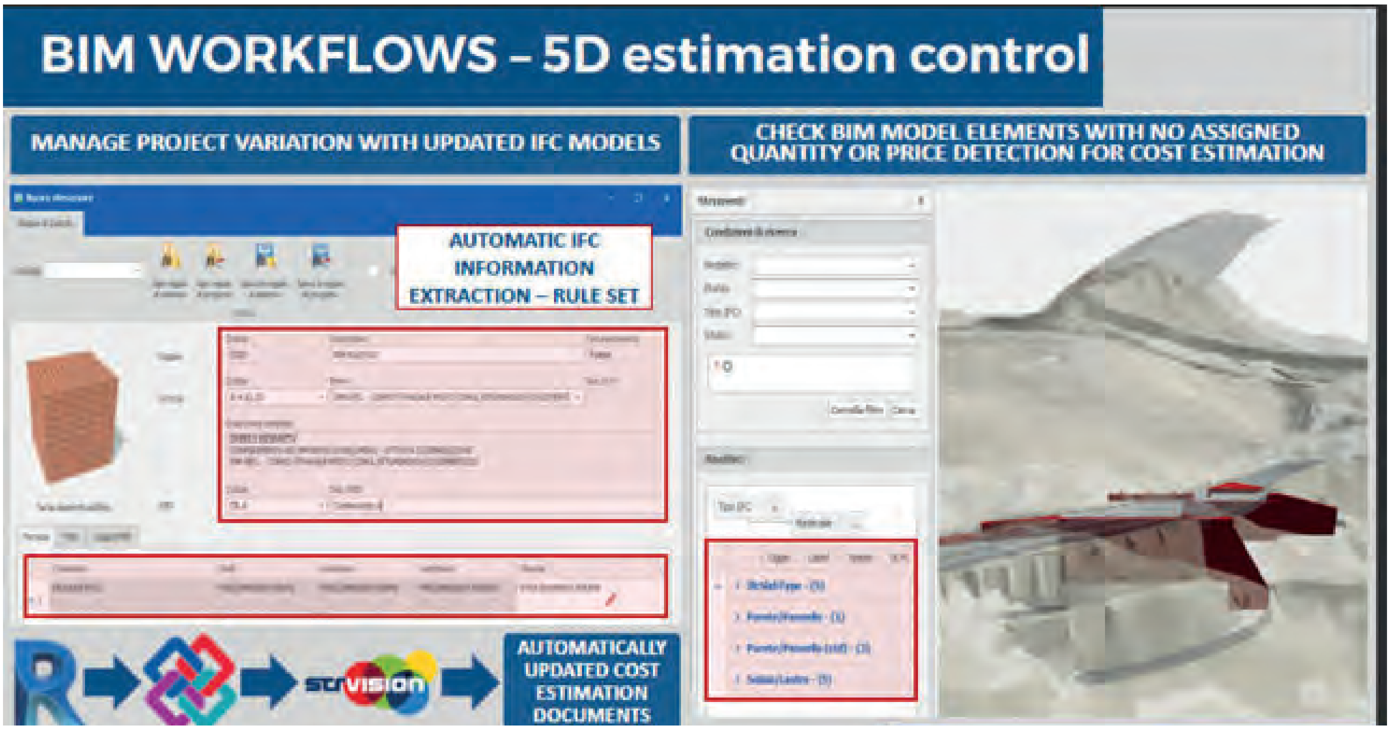




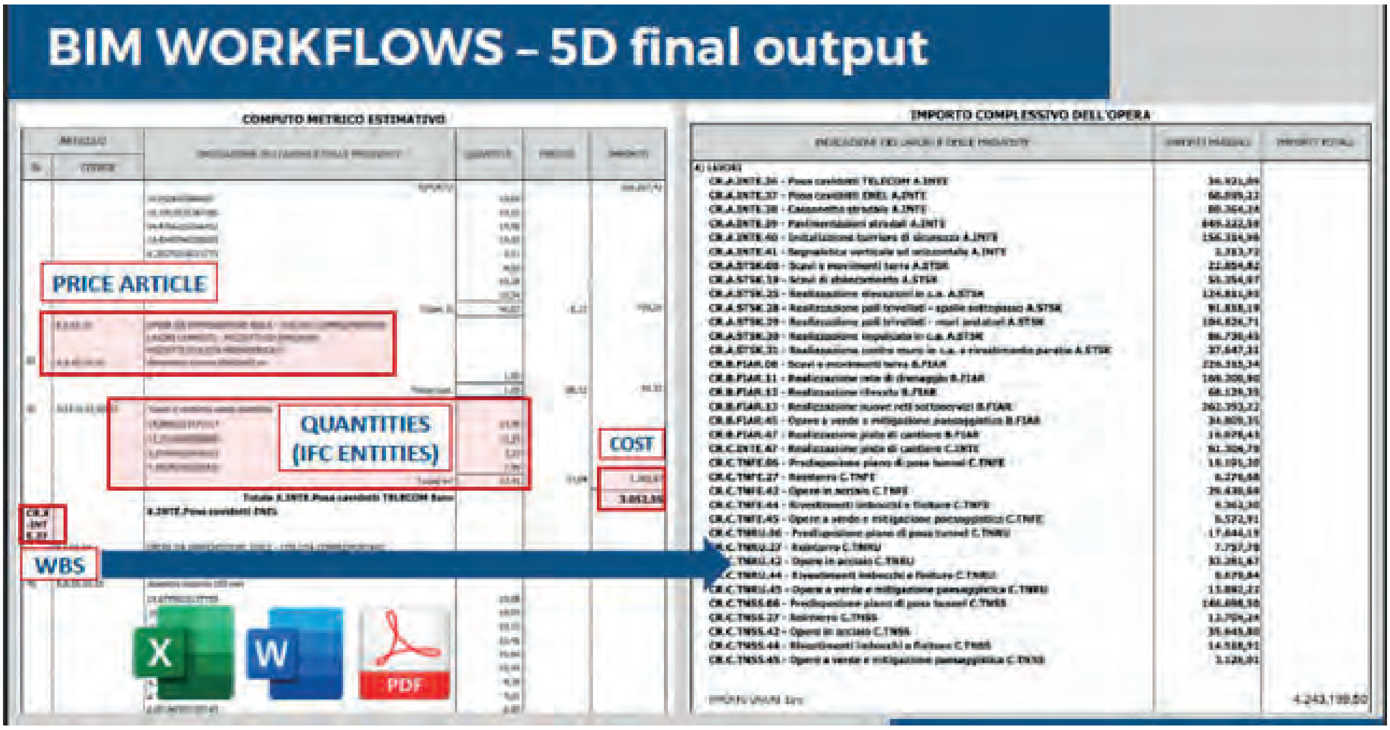
The software used is STR Vision CPM which allows to analyze IFC model contents and to extract all the contained information. It is also possible to detect information relating to the project WBS and insert price list items according to the Customer's specifications. Once the quantities of the objects have been extracted (from the quantitative and qualitative properties - slide 32) it is possible to associate the reference price to each quantity take off (slide 32) and automatically the software sets the individual computation lines for the preparation of project cost estimation documents.

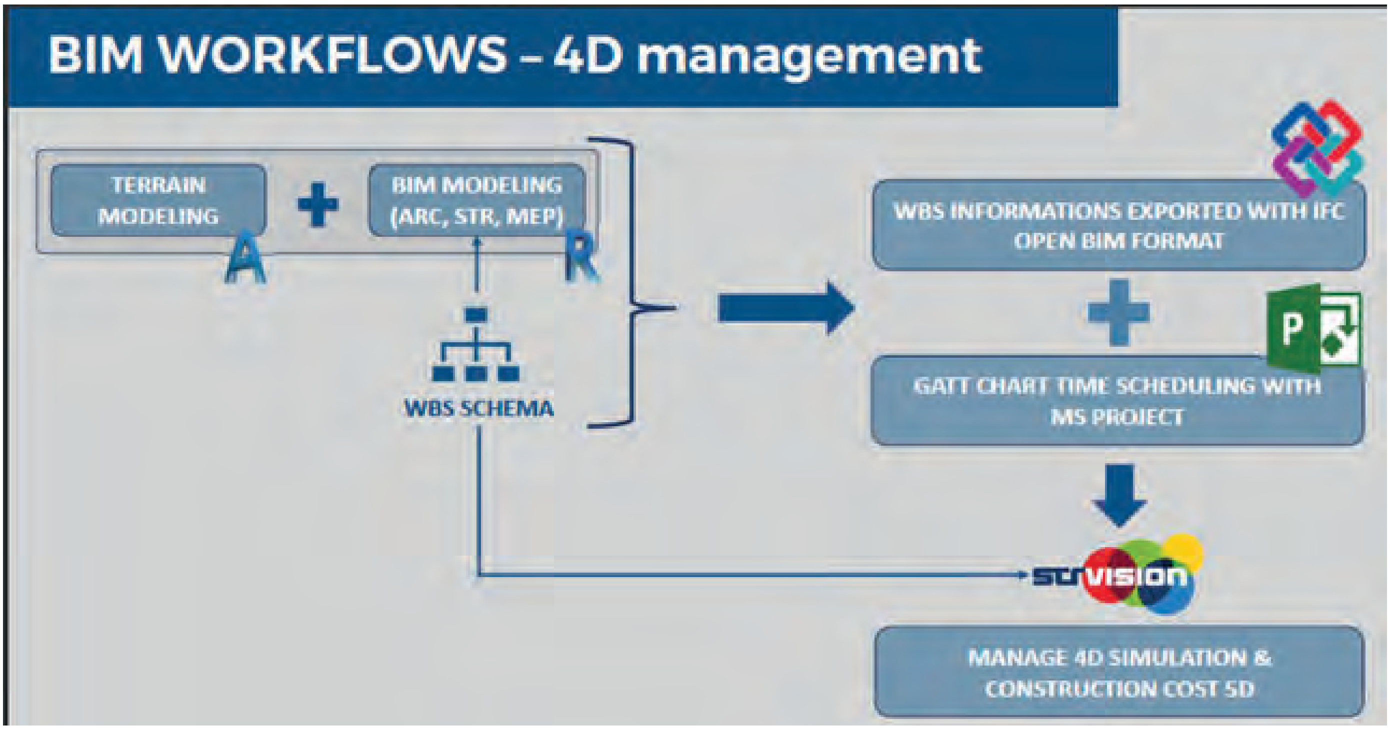


It is also possible to set automatic rules for the IFC detections that automatically update costs in the event of project variations with updated IFC models in both design and construction phases. This aspect is another of the added values using a BIM process (slide 36). The final report is a cost estimation document that can be exported in different formats (pdf, excel etc.) where we can find information about IFC object quantity take off.

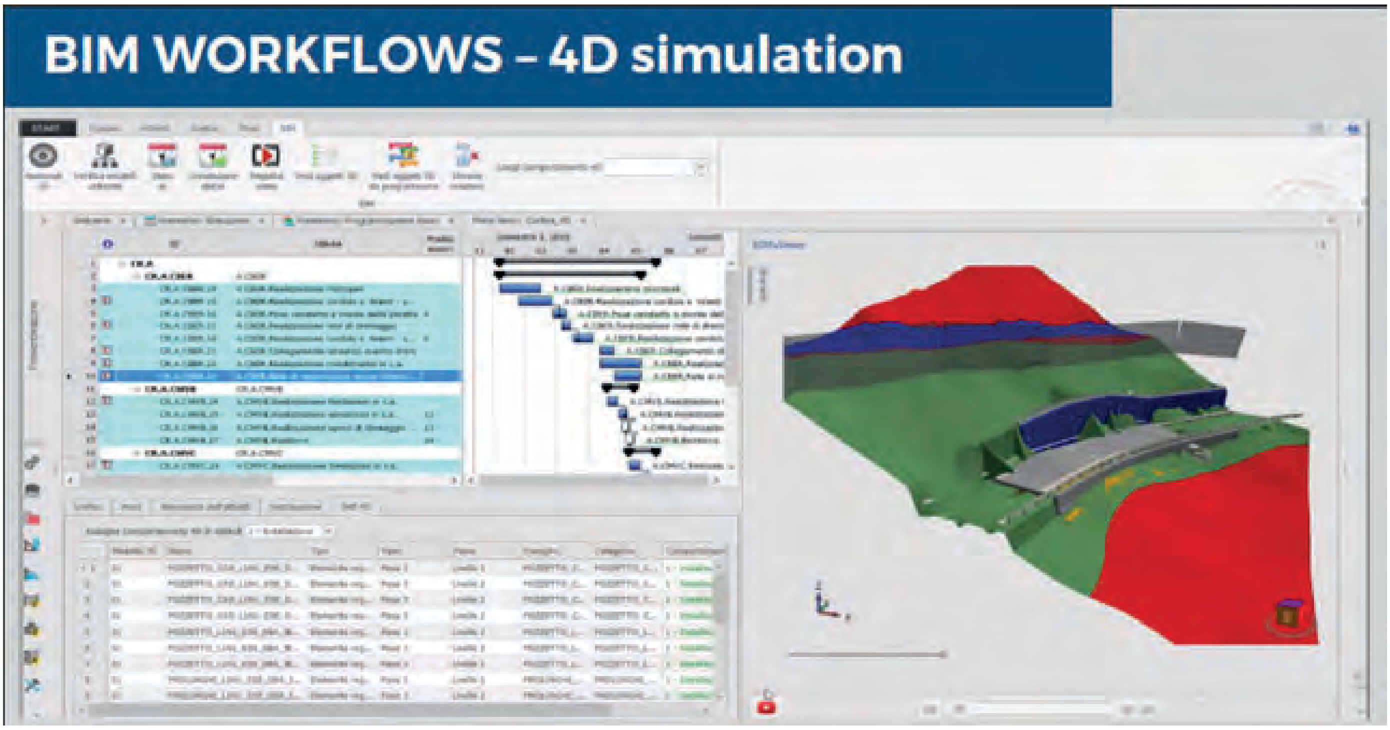


For the 4D workflow the process is similar. In this case, the project gantt drawn up with MS Project with which the software is compliant is imported into STR Vision CPM. The gantt must be set with the same structure as the project WBS. With semi-automated functions, the software recognizes all the objects with the related WBS codes and links them to the Gantt according to the same logic, associating in this case not the cost but the construction time scheduling of every task to every object.





The added value is that associating both cost and time scheduling in the same simulation environment it is possible to have an added control on the project, increasing its quality, and it is possible to carry out evaluations on the construction costs in a certain construction phase.



Basic theories of performance and optimization design of green buildings and cities

Xing Shi

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Zhichao Tian

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Going green is the current trend in the building industry and the response to the challenges of energy shortage and environmental problems. Although green buildings are defined differently in various standards and books, they all share one common theme, i.e., to maximize the performance of buildings while minimizing their negative impacts on the environment. Green building evaluation systems, standards, and codes are issued and implemented in many countries, examples being LEED (Leadership in Energy and Environmental Design) of the U.S., BREEAM (Building Research Establishment Environmental Assessment Method) of the U.K., GBL (Green Building Label) of China, CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) of Japan, DGNB (abbreviation in German) of Germany, etc. All these green building systems emphasize on the performance of green buildings. The important performance aspects can be loosely grouped into two categories, namely physical environment and energy. The category of physical environment includes heat, air, moisture, lighting, acoustics, solar, visual connection, etc.

To quantify the performance of green buildings, simulation is a commonly used technique. Simulation refers to a model of a set of problems or events that can be used to teach someone how to do something, or the process of making such a model environment. A typical simulation process includes steps of geometric model creation, parameters setup, simulation run, results analysis, and design feedback. It is critical to understand that simulation itself is never the purpose. The true purpose is to use simulation to assist design. Therefore, the steps of results analysis and design feedback are utterly important.

In green building design practice, performance optimization is both common and valuable. The general definition of the term “optimization” is “an act, process, or methodology of making something (such as a design, system, or decision) as fully perfect, functional, or effective as possible”. Green building performance design optimization often relies on algorithms to search for the optimal solution and drive the optimization process. Common optimization objectives include minimizing energy consumption, minimizing carbon emission, maximizing environmental qualities such as lighting, solar and acoustics, maximizing occupant comfort, and minimizing cost. Common design parameters are space and form, materials and construction, equipment, control strategies, etc.

Algorithms are the driving engine of the design optimization process. An algorithm is a procedure for solving a mathematical problem in a finite number of steps that frequently involves repetition of an operation. Optimization algorithms are a set of algorithms that are specialized in finding the optimal solution of a problem. Direct search algorithms and intelligent algorithms such as GA (genetic algorithm) are often used in green building performance optimization design.

Building performance simulation (BPS) programs are not only important tools to conduct various green building performance analysis, but also great resources to deepen the understanding of basic theories of building physics. When learning a BPS tool, one can check the theories hidden behind the interfaces, read case studies, and try to build models to solve design problems.

Building energy modeling is one of the most important and sophisticated simulations. Understanding the basic theories and operation of building energy simulation helps us master other simulations. OpenStudio is a free, open-source energy simulation program developed on EnergyPlus. Most energy simulation tasks can be conducted in OpenStudio. Ladybug tools are recommended for conducting various green building performance simulation tasks. They can be integrated with EnergyPlus, OpenStudio, and Radiance. Developed by architects, Ladybug is user-friendly and offers an intuitive work flow.

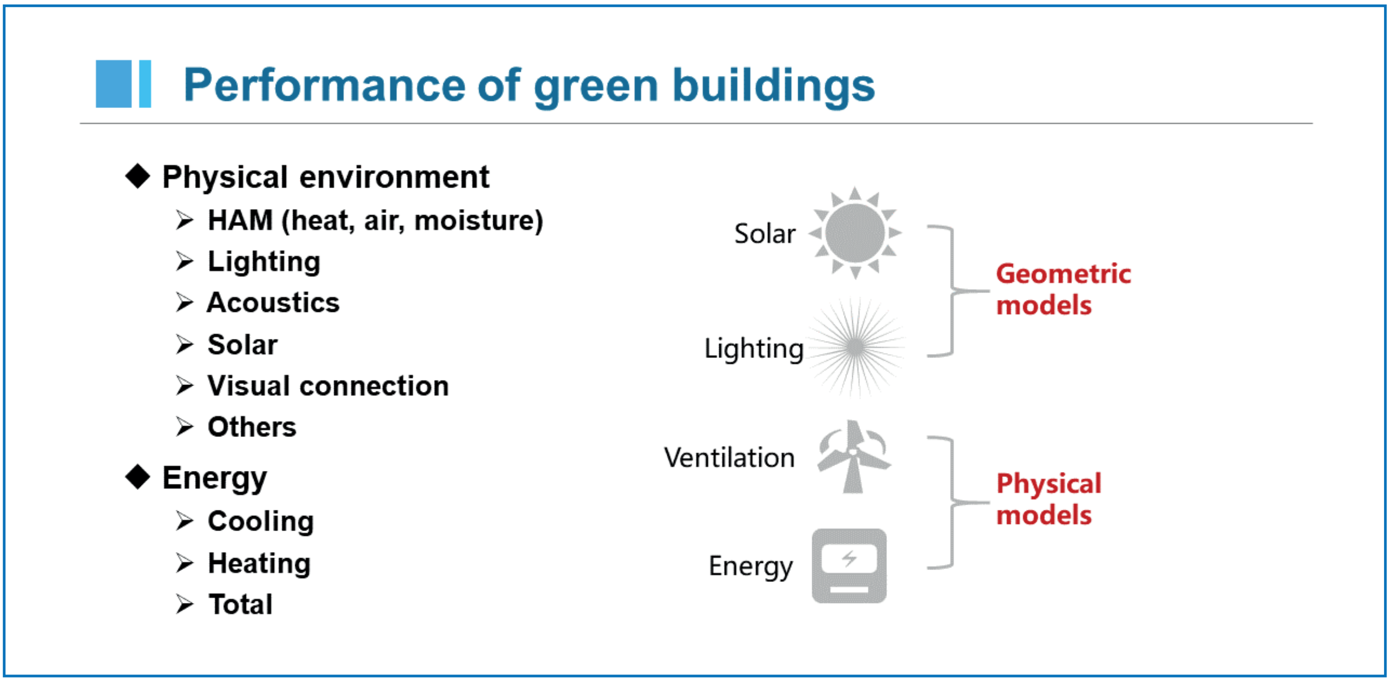
From the perspective of performance-driven design, BIM information network offers three advantages. First, component-centered data network is in line with the needs and working habits of architects and other professionals in the field of architecture. Secondly, multi-level data network exhibits a clear structure and logic. Thirdly, nD data network is extendable. The performance data in Autodesk Revit can be divided into project data, space data, HVAC zone data, component data, material data and external data. Revit platform supports various performance analysis functions. Main functions include local fast heating and cooling loads analysis, heating and cooling loads using cloud EnergyPlus engine, multiple light analysis in the cloud and solar analysis on model surfaces.

Rhino.Inside and Dynamo are two digital platforms supporting the performance-driven design in Revit. Rhino.Inside brings Rhino WIP and Grasshopper to Autodesk Revit. It can support various digital performance analysis functions, including Energy Consumption Simulation, Daylight Environment Assessment, Wind Environment Assessment etc. Most analytical processes in Rhino.Inside are based on Ladybug Tools. The performance evaluation based on the digital design platform is more complex than the performance evaluation in Revit. Dynamo is an open source graphical programming for design in Revit. It is more integrated than Grasshopper thus offers more access to various underlying parameters of Revit.

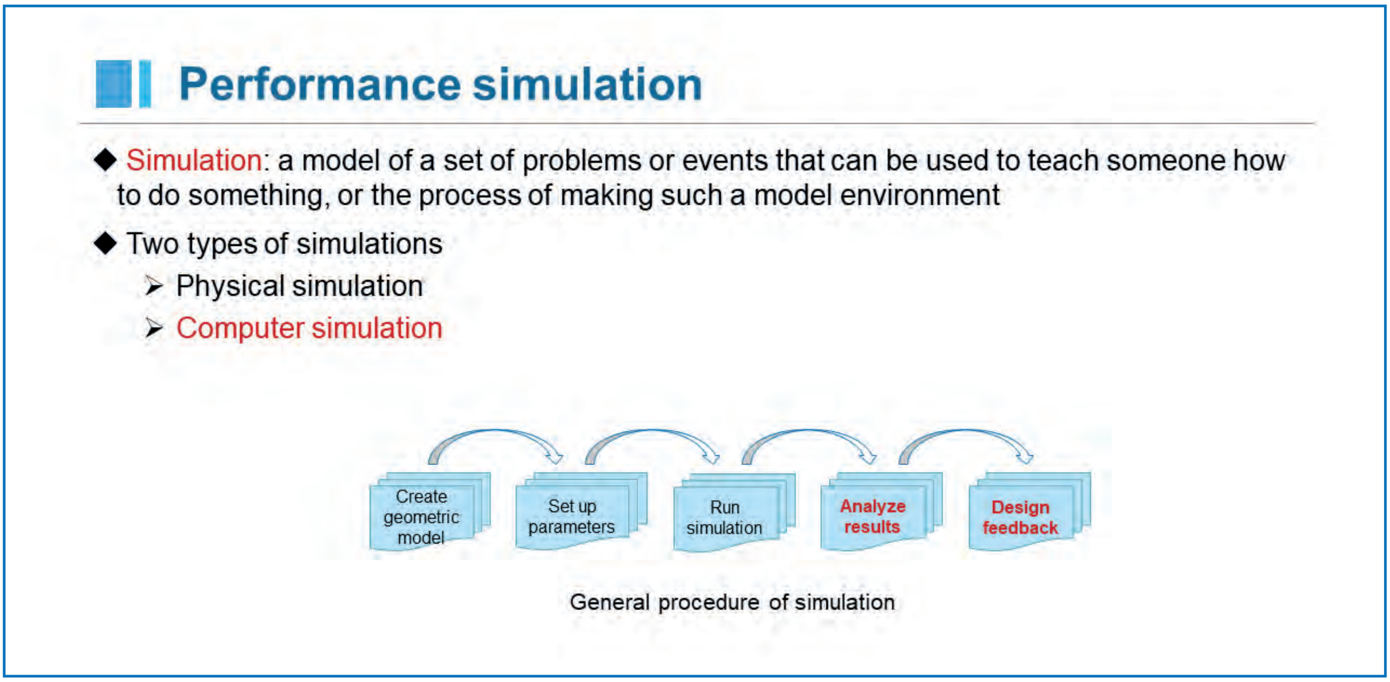
At present, genetic algorithms are widely used in architectural design. Genetic algorithms can be implemented in the digital design platform previously mentioned. The genetic algorithm engine in Dynamo is called Optimo. The tools in Rhino.Inside contain a single-objective optimization engine called Galapagos, and a multi-objective optimization engine called Octopus.

Slide 3: Going green is the current trend in the building industry and the response to the challenges of energy shortage and environmental problems. Although green buildings are defined differently in various standards and books, they all share one common theme, i.e., to maximize the performance of buildings while minimizing their negative impacts on the environment.

Slide 4: Green building evaluation systems, standards, and codes are issued and implemented in many countries, examples being LEED (Leadership in Energy and Environmental Design) of the U.S., BREEAM (Building Research Establishment Environmental Assessment Method) of the U.K., GBL (Green Building Label) of China, CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) of Japan, DGNB (abbreviation in German) of Germany, etc.



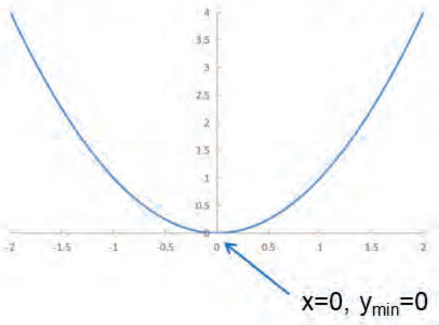
Slike 5: All these green building systems emphasize on the performance of green buildings. The important performance aspects can be loosely grouped into two categories, namely physical environment and energy. The category of physical environment includes heat, air, moisture, lighting, acoustics, solar, visual connection, etc.



Slide 6: To quantify the performance of green buildings, simulation is a commonly used technique. Simulation refers to a model of a set of problems or events that can be used to teach someone how to do something, or the process of making such a model environment. A typical simulation process includes steps of geometric model creation, parameters setup, simulation run, results analysis, and design feedback. It is critical to understand that simulation itself is never the purpose. The true purpose is to use simulation to assist design. Therefore, the steps of results analysis and design feedback are utterly important.

Optimization - basic concept

- What is optimization
  - General definition: an act, process, or methodology of making something (such as a design, system, or decision) as fully perfect, functional, or effective as possible
  - More specifically: the mathematical procedures (such as finding the maximum of a function) involved in this
- 3 components to form a complete optimization problem
  - Objective function, design parameter, constraint, objective

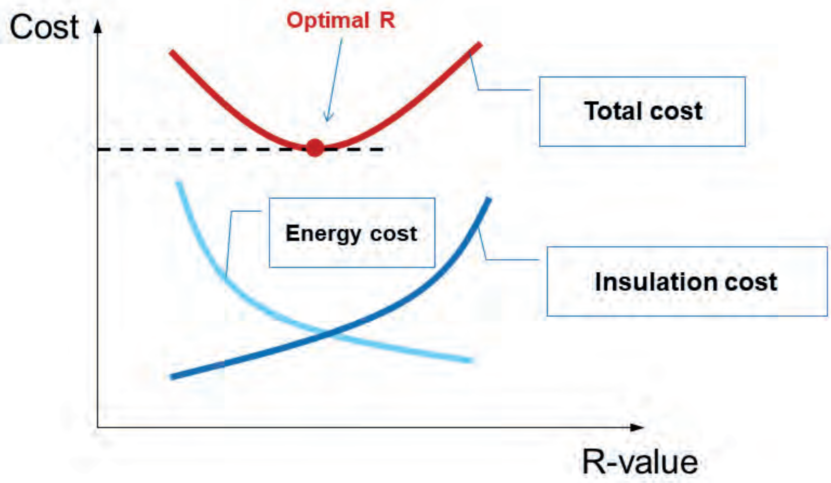


$y=x^2$, $-1 \le x \le 1$, find x to minimize y

objective function · constraint · design parameter · objective

An optimization design problem in green buildings

- Design the thickness of the wall insulation to minimize the total cost.



Slide 7-8: In green building design practice, performance optimization is both common and valuable. The general definition of the term "optimization" is "an act, process, or methodology of making something (such as a design, system, or decision) as fully perfect, functional, or effective as possible". Green building performance design optimization often relies on algorithms to search for the optimal solution and drive the optimization process.

Performance optimization design in green buildings

- Common optimization design objectives
  - Minimize energy consumption (cooling, heating, total)
  - Minimize carbon emission
  - Maximize environmental performance (lighting, solar, acoustics, etc.)
  - Maximize occupant comfort
  - Minimize cost (life cycle cost)
- Design parameters
  - Space and form (geometric parameters)
  - Material properties (thermal conductance or resistance of insulation, U-value of the window, etc.)
  - Equipment (HVAC, lighting, etc.)
  - Control strategies (temperature setpoint)


Renewable and Sustainable Energy Reviews

A review on building energy efficient design optimization rom the perspective of architects

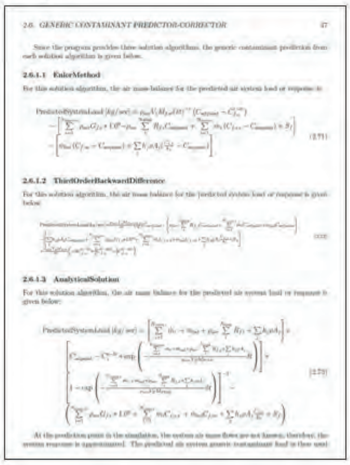
Xing Shi, Zhichao Tian, Wenqiang Chen, Binghui Si, Xing Jin

Renewable and Sustainable Energy Reviews, 2016
A review on building energy efficient design optimization from the perspective of architects

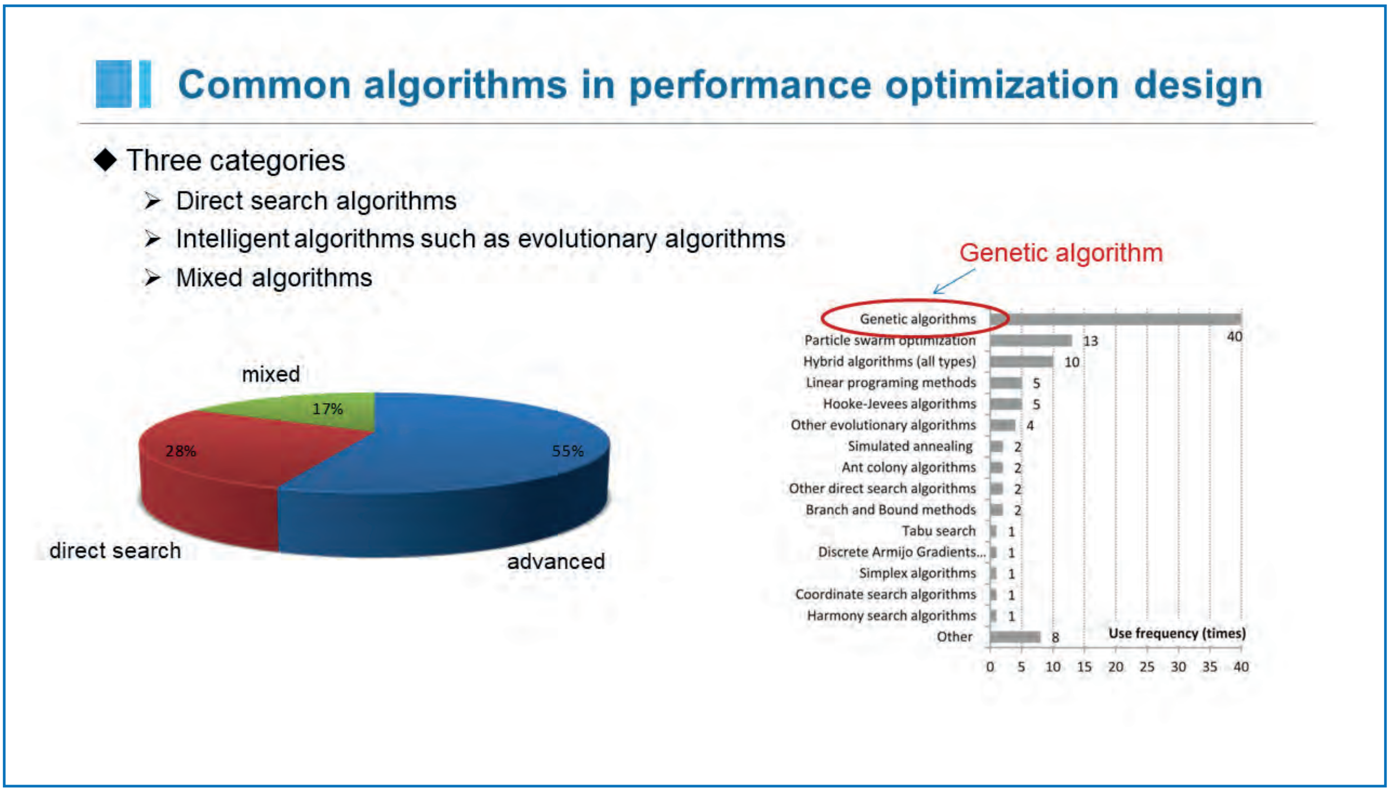
Slide 9: Common optimization objectives include minimizing energy consumption, minimizing carbon emission, maximizing environmental qualities such as lighting, solar and acoustics, maximizing occupant comfort, and minimizing cost. Common design parameters are space and form, materials and construction, equipment, control strategies, etc.

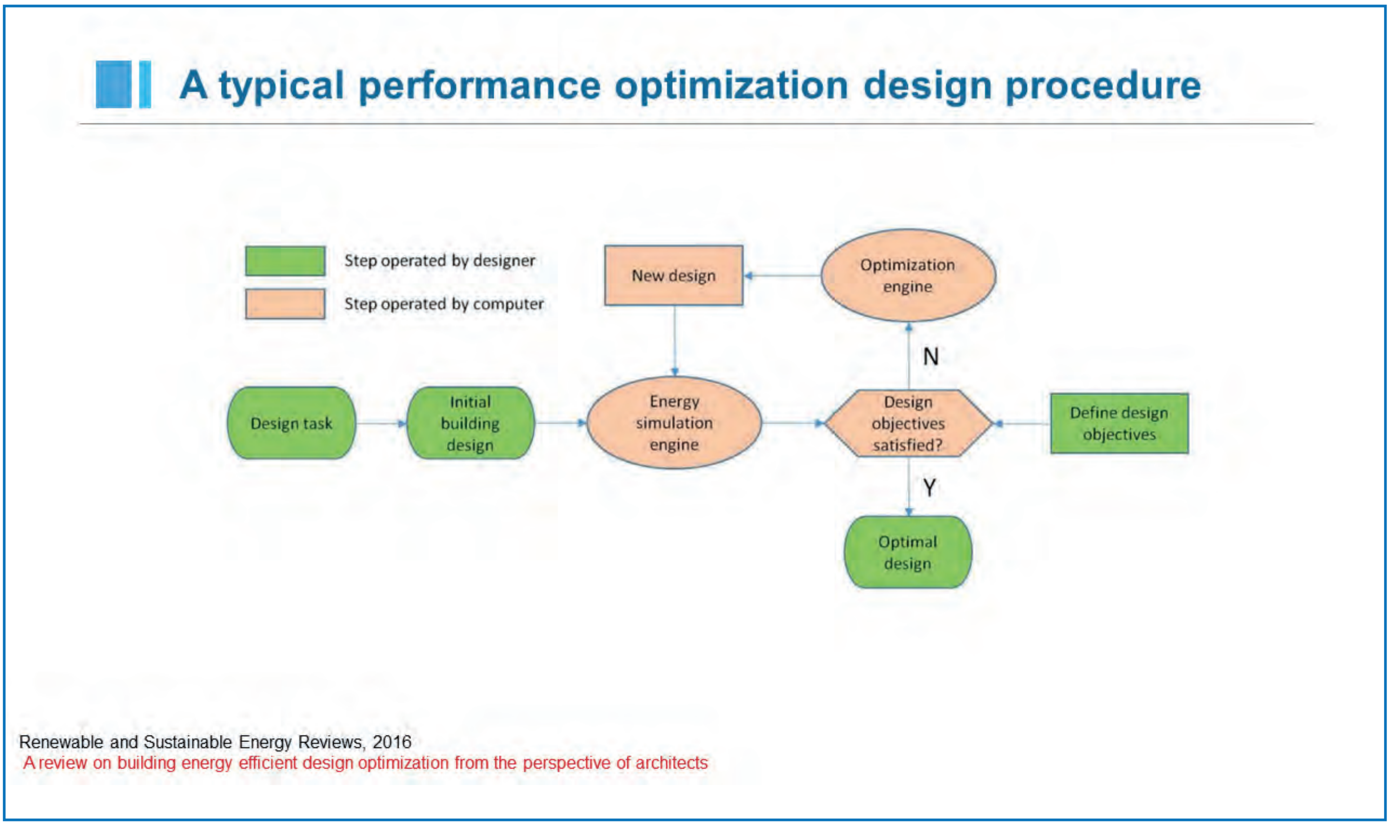
Algorithms

- What is an algorithm?
  - a procedure for solving a mathematical problem (as of finding the greatest common divisor) in a finite number of steps that frequently involves repetition of an operation
  - broadly: a step-by-step procedure for solving a problem or accomplishing some end
- Why need algorithms in green building performance optimization design?
  - Objective functions are complex
  - Performance simulation is needed
  - Optimization problems are very difficult and even impossible to solve manually



Engineering Reference of EnergyPlus
a total of **1748 pages!!!**





Slide 10-12: Algorithms are the driving engine of the design optimization process. An algorithm is a procedure for solving a mathematical problem in a finite number of steps that frequently involves repetition of an operation. Optimization algorithms are a set of algorithms that are specialized in finding the optimal solution of a problem. Direct search algorithms and intelligent algorithms such as GA (genetic algorithm) are often used in green building performance optimization design.

What's building performance simulation (BPS)?

- Building performance simulation assumes dynamic (and continuous in time) boundary conditions, and is normally based on numerical methods that aim to provide an approximate solution of a realistic model of complexity in the real world. (HENSEN and LAMBERTS, 2012)
- BPS is the replication of aspects of building performance using a computer-based, mathematical model created on the basis of fundamental physical principles and sound engineering practice. (Wikipedia,2020)
- Provides a virtual environment to test the performances of competing design solutions (e.g. different HVAC systems, constructions).

Slide 14: Building performance simulation (BPS) programs are not only important tools to conduct various green building performance analysis, but also great resources to deepen the understanding of basic theories of building physics. When learning a BPS tool, one can check the theories hidden behind the interfaces, read case studies, and try to build models to solve design problems.

Commonly used BPS Tools

- EnergyPlus (USA), DesignBuilder (UK), IES VE (USA), ESP-r (UK), TRNSYS (USA), eQuest (USA), OpenStudio (USA) and DeST (China) for energy simulation.
- EnergyPlus is a major energy simulation engine, Radiance is a widely used daylight simulation engine.
- Ladybug and Honeybee can glue various free building environment simulation tools into a unique platform.

EnergyPlus

Main components of an energy model

- Climate: dry-bulb temperature, relative humidity, and solar radiation etc.
- Geometry: building shape, space, and zone geometry.
- Envelope: materials, constructions, windows and shadings, and ventilation.
- Internal gains: people, lights, and equipment.
- Schedules: human behavior, controls, and operations.
- Thermal zone: thermostats, dividing rooms into zones.
- HVAC system: plants, air system, terminals.
- Controls: for windows, shadings, thermostats, plant components,

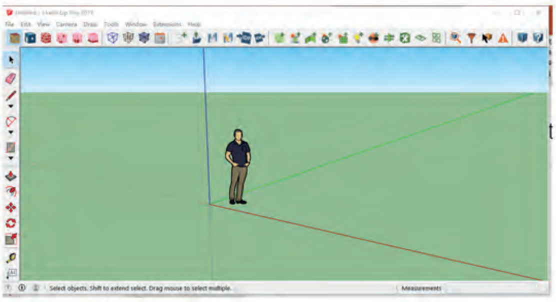
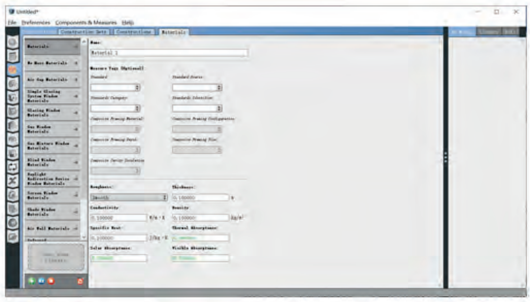
EPW —— EnergyPlus Weather Format

- EPWs are Typical Meteorological Years (TMY) data.
- TMY represents the annual average weather of multiple years.
- Aware of the difference between Actual Meteorological Year VS TMY
- Download epw files at www.climate.onebuilding.org/
- Design day is designed for load calculation and HVAC system sizing and selection.
- Two types of design day: summer design day and winter design day.

Slide 15-17: Building energy modeling is one of the most important and sophisticated simulations. Understanding the basic theories and operation of building energy simulation helps us master other simulations.

What's OpenStudio?

- A whole building energy simulation software with excellent user-interfaces;
- Uses EnergyPlus and Radiance for energy and daylight simulation;
- mainly consists of two programs, i.e. OpenStudio SketchUp Plugin (3D geometry) and OpenStudio Application (other parameters);

Steps of building energy models with OS

- Build 3D geometry with OpenStudio SU plugin
  - Simplified the original architecture drawings;
  - Build 3D geometry;
  - Set space type and thermal zone;
- Set other parameters with OpenStudio Application
  - Set site info (weather file)
  - Constructions;
  - Schedules;
  - Space types;
  - Thermal Zone (heating/cooling setpoint);
  - HVAC systems.
- Run simulation and check outputs

Slide 18-19: OpenStudio is a free, open-source energy simulation program developed on EnergyPlus. Most energy simulation tasks can be conducted in OpenStudio.

What's Ladybug tools?

- Ladybug performs detailed climate analysis emphasizing visualizations.
- Honeybee Run energy simulation with OpenStudio; daylight simulation with Radiance, and envelop heat flow using THERM;

Analyses can be fulfilled with Ladybug   Analyses can be fulfilled with Honeybee

Learning materials

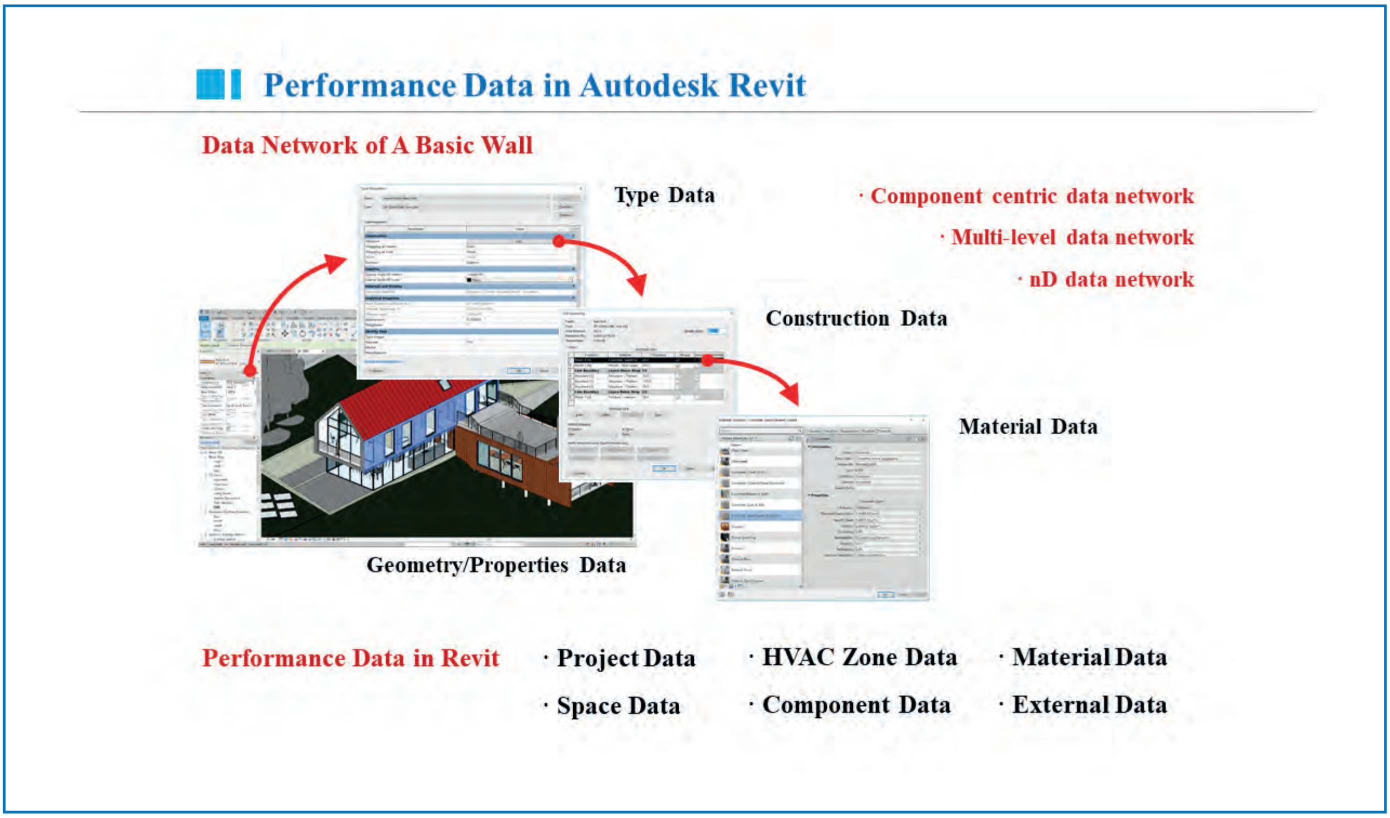
- OpenStudio:
  - Official website: www.openstudio.net
  - Brackney et al. *Building Energy Modeling with OpenStudio*. Springer. 2018
  - Videos: https://www.youtube.com/user/NRELOpenStudio/videos
- Ladybug and Honeybee
  - Official website: www.ladybug.tools;
  - Search online tutorials on Youtube;
  - Resources at www.grasshopper3d.com/group/ladybug

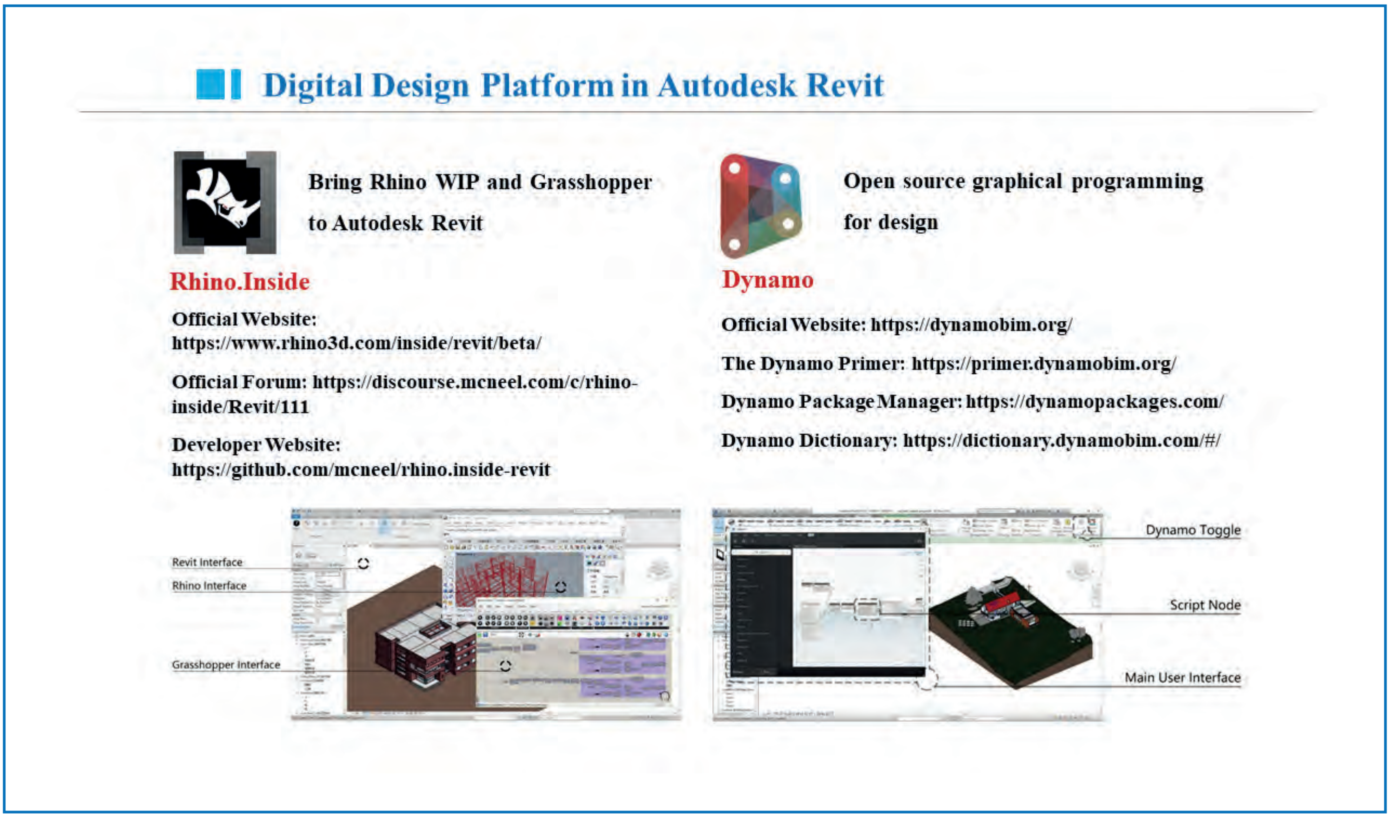
Slide 20-21: Ladybug tools are recommended for conducting various green building performance simulation tasks. They can be integrated with EnergyPlus, OpenStudio, and Radiance. Developed by architects, Ladybug is user-friendly and offers an intuitive work flow.

Limitations and future research directions

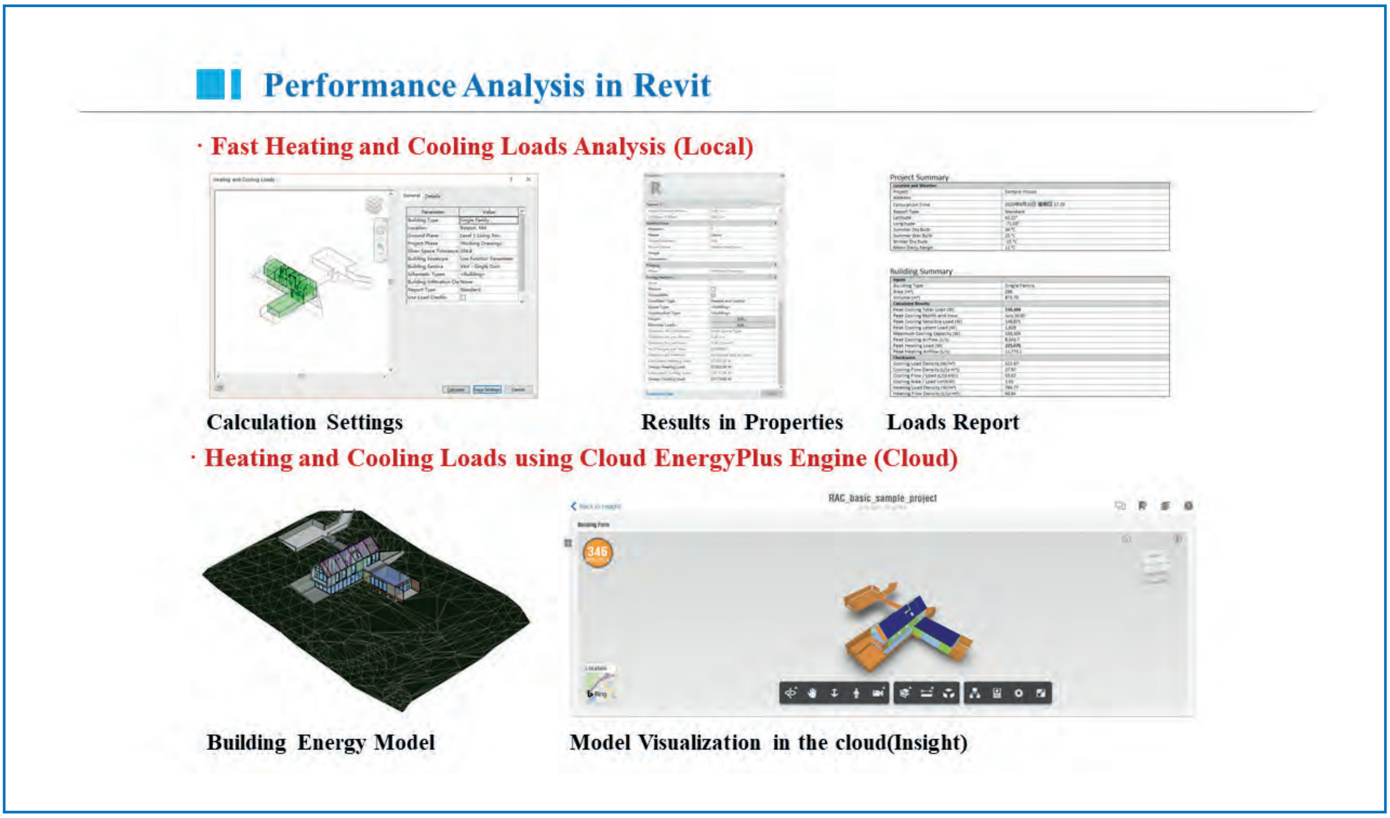
- The difference between actual and calculated energy is called the 'energy performance gap' (Brom, et al, 2018).
- It is hard to model human behavior in existing BPS software due to its stochastic nature.
- Data-driven building performance analysis is a research field with potential.

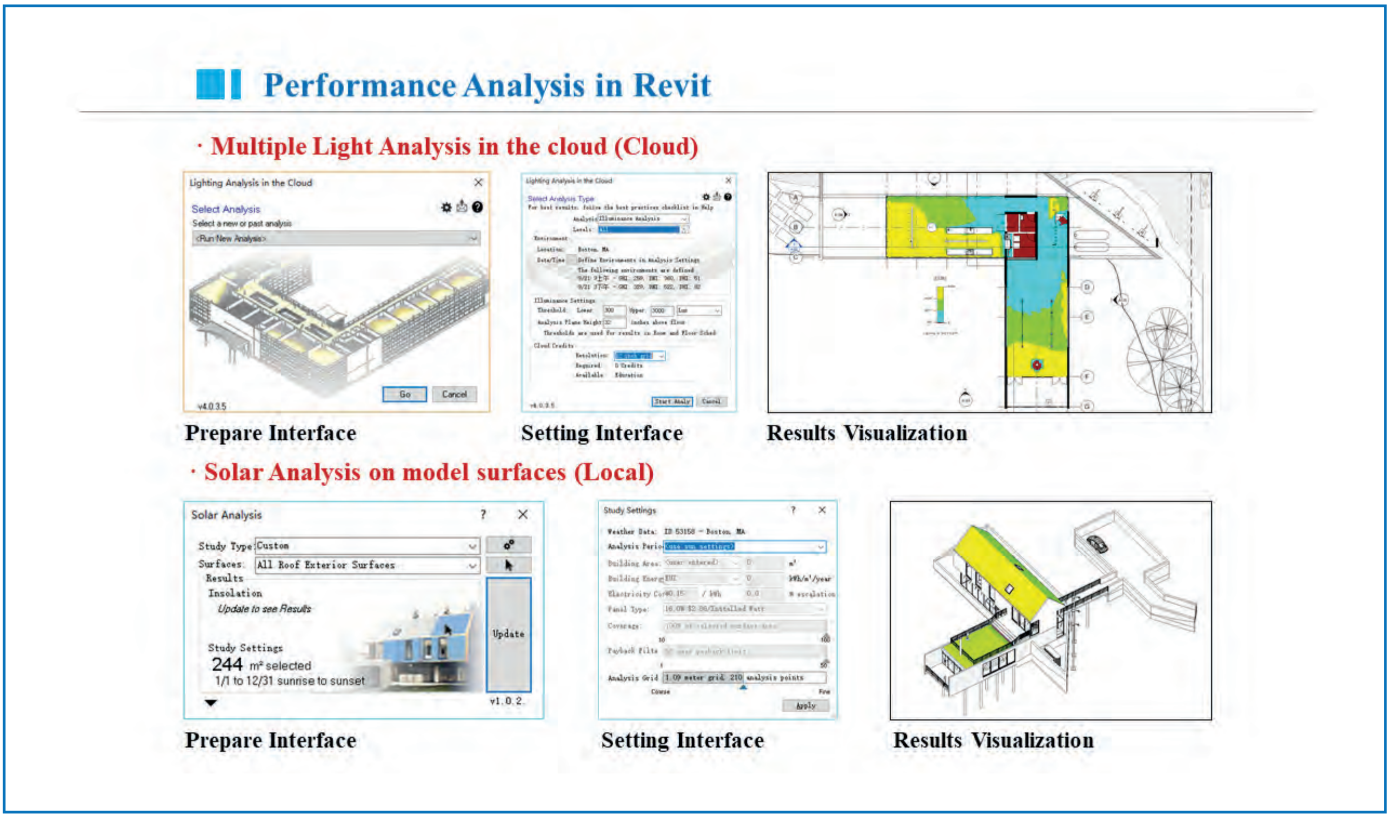
Slide 22: Building performance simulation is an active research field.





Slide 24-25: From the perspective of performance-driven design, BIM information network offers three advantages. First, component-centered data network is in line with the needs and working habits of architects and other professionals in the field of architecture. Secondly, multi-level data network exhibits a clear structure and logic. Thirdly, nD data network is extendable.





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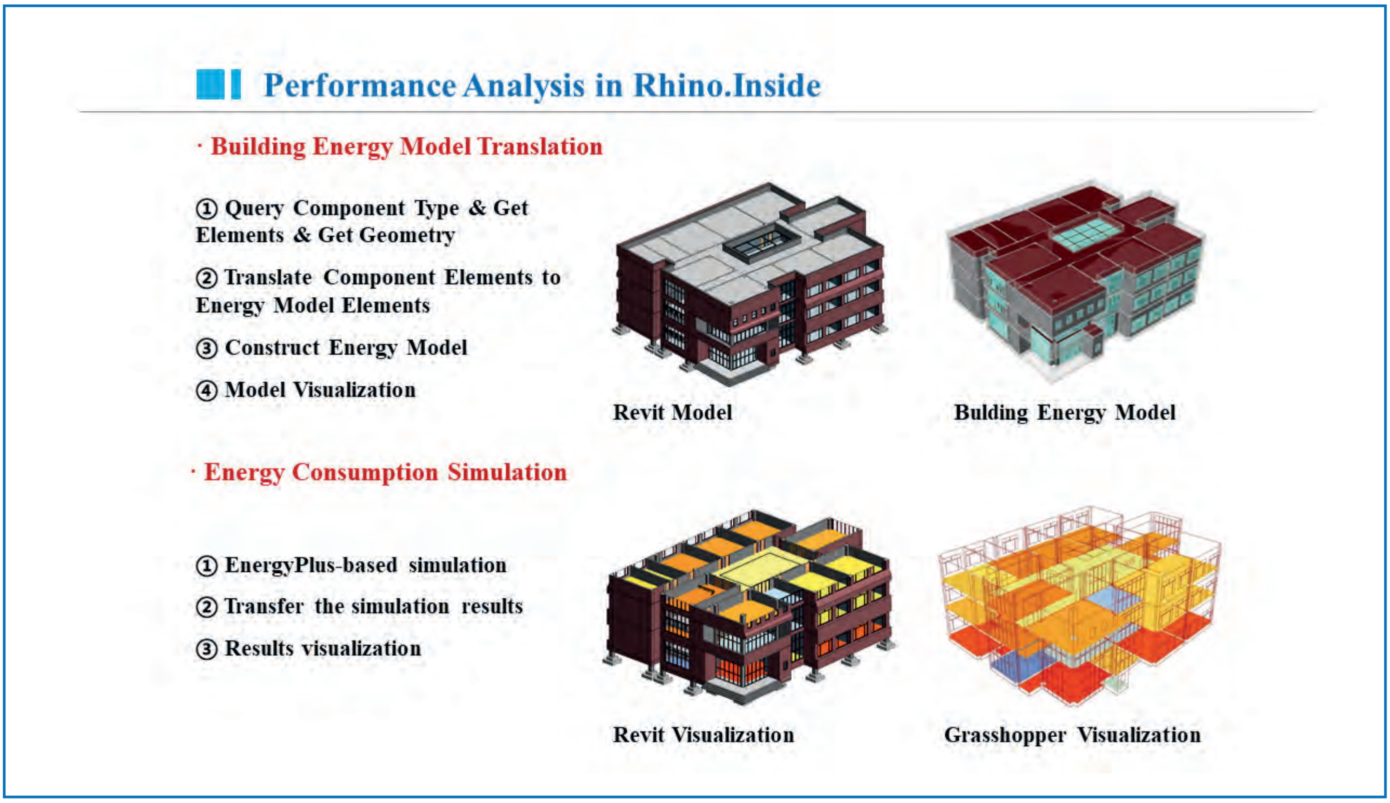
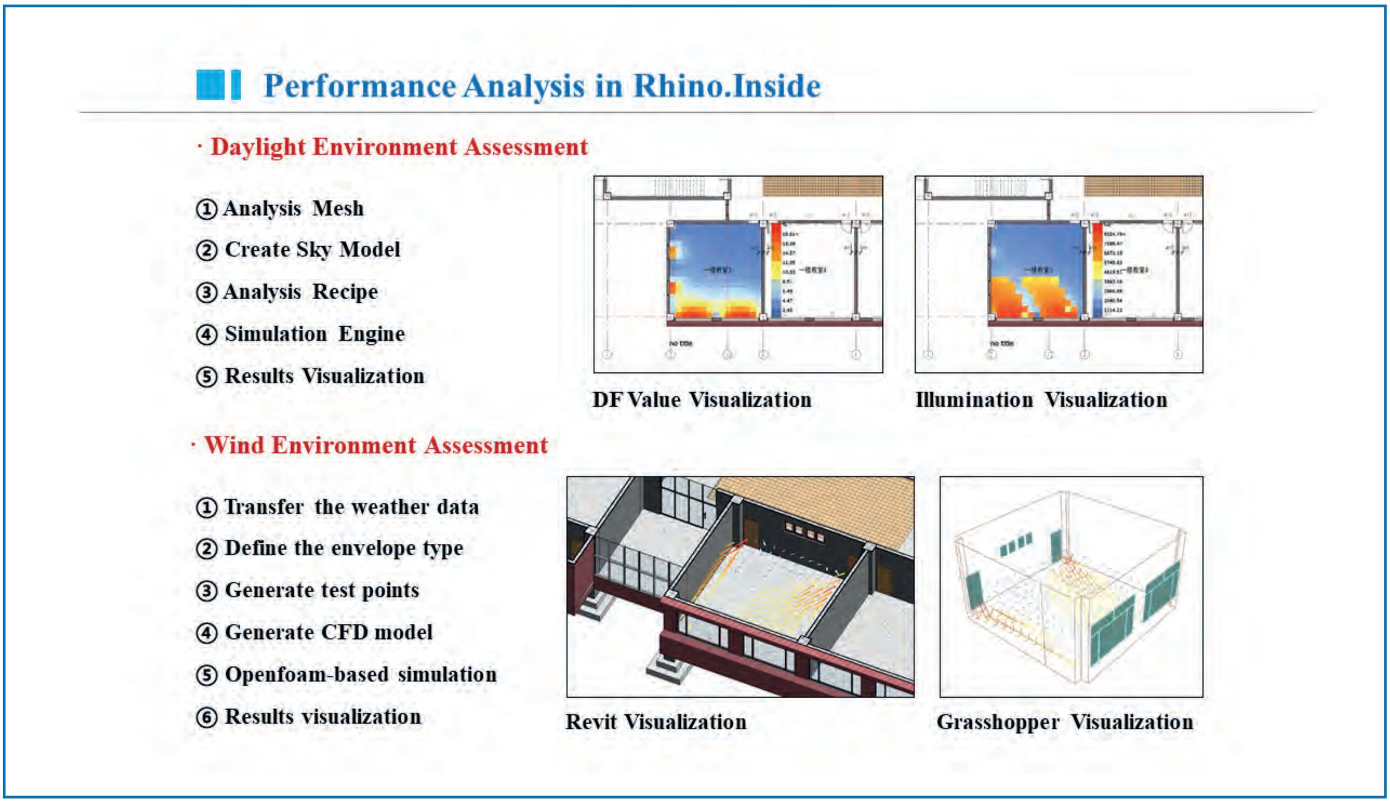
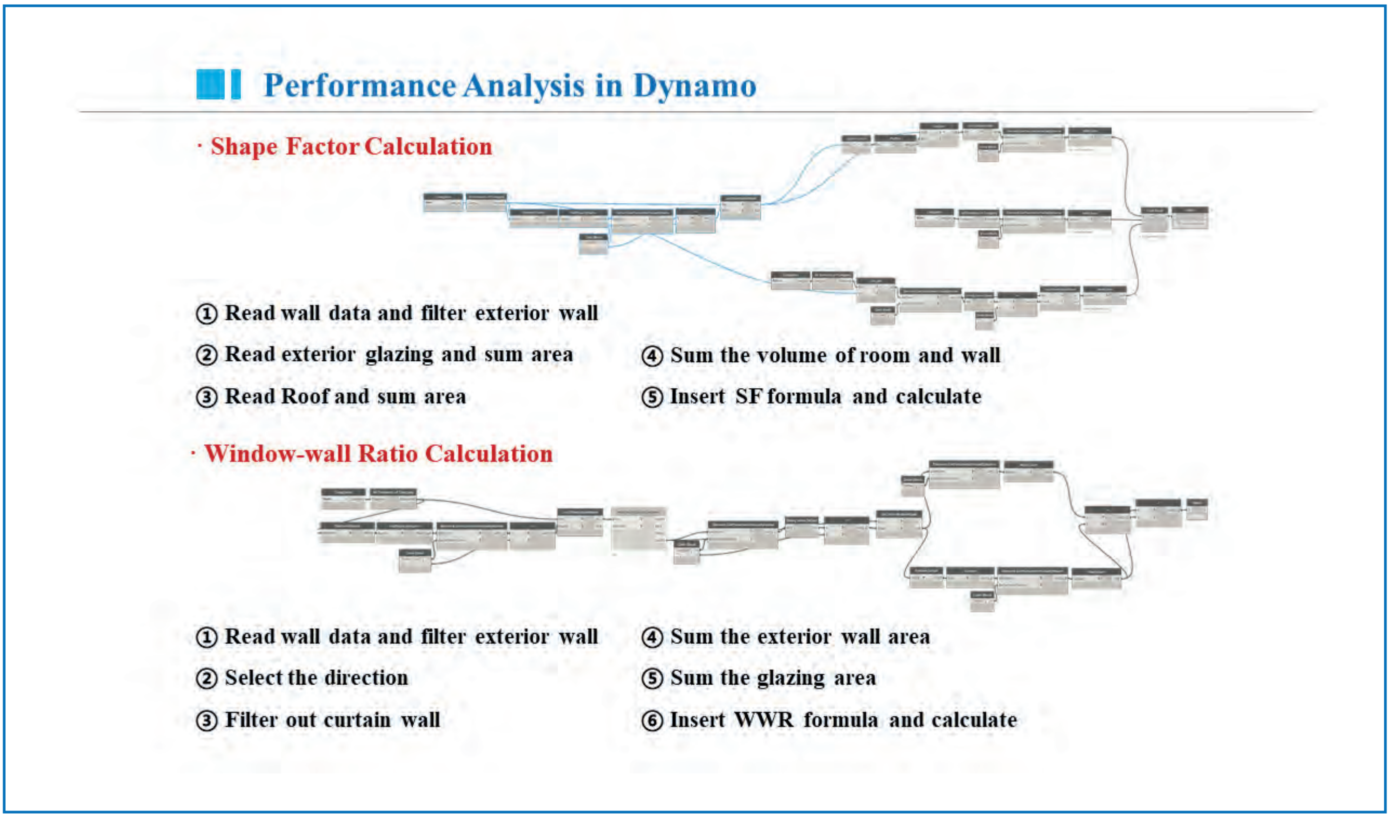
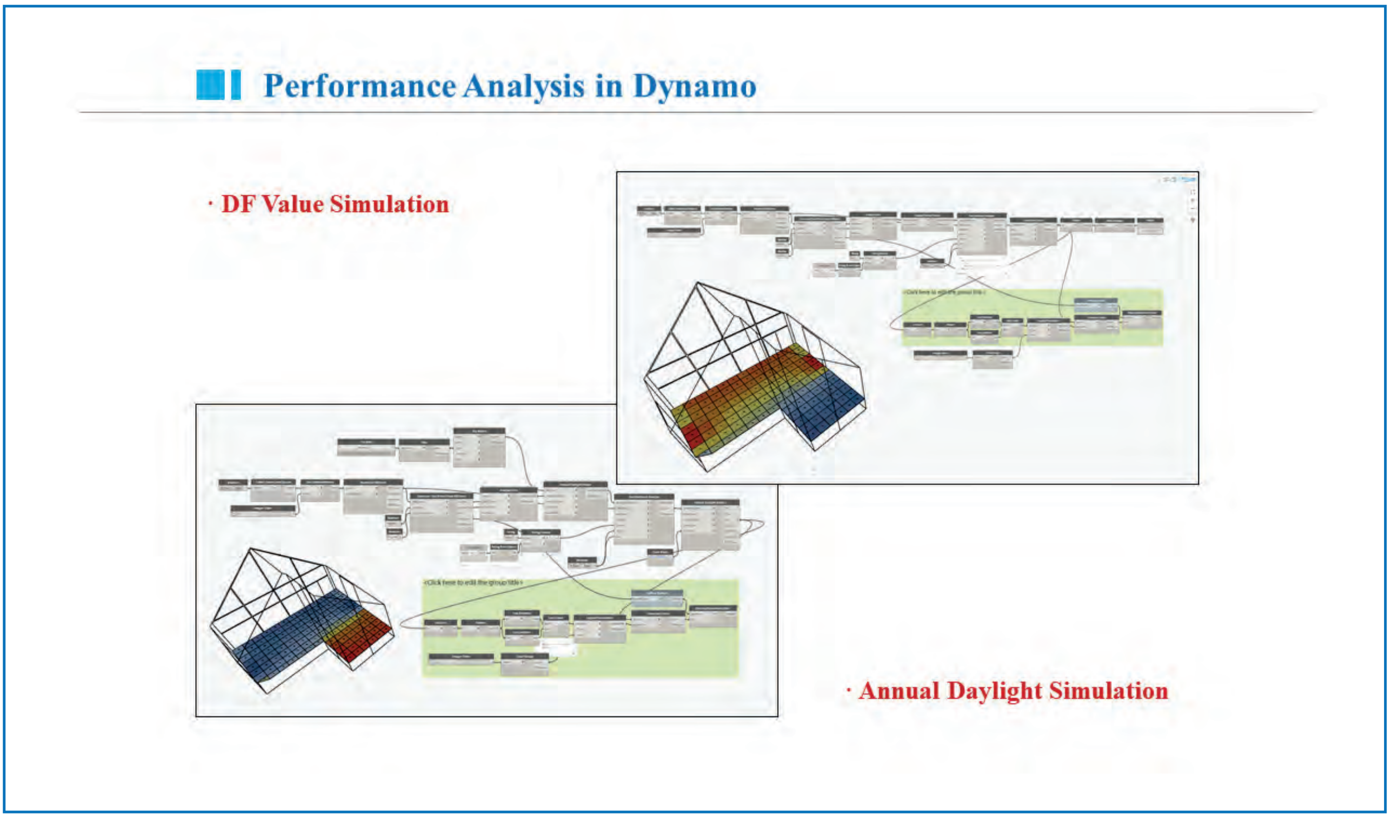




Slide 28-29: Rhino.Inside and Dynamo are two digital platforms supporting the performance-driven design in Revit. Rhino.Inside brings Rhino WIP and Grasshopper to Autodesk Revit. It can support various digital performance analysis functions, including Energy Consumption Simulation, Daylight Environment Assessment, Wind Environment Assessment etc. Most analytical processes in Rhino.Inside are based on Ladybug Tools. The performance evaluation based on the digital design platform is more complex than the performance evaluation in Revit.





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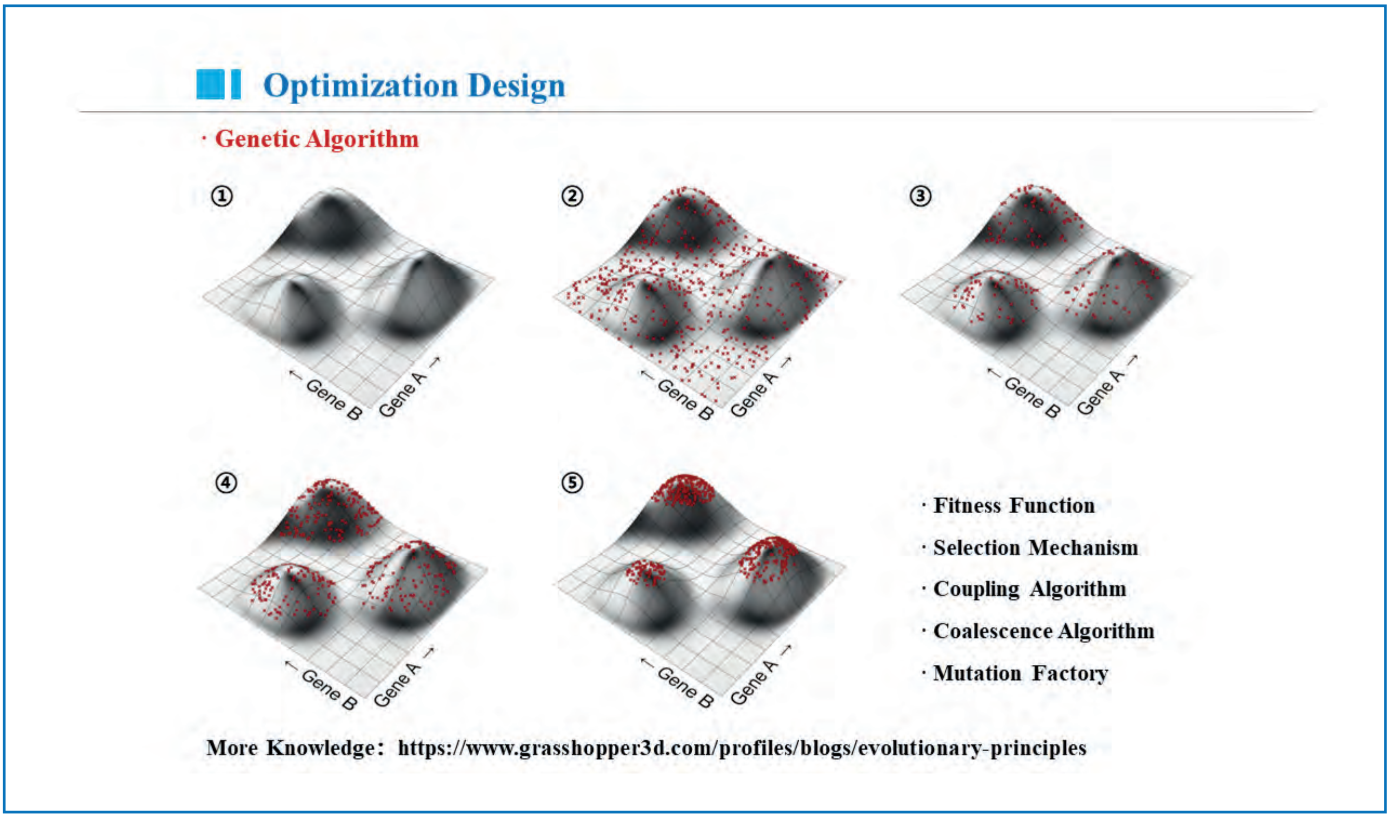

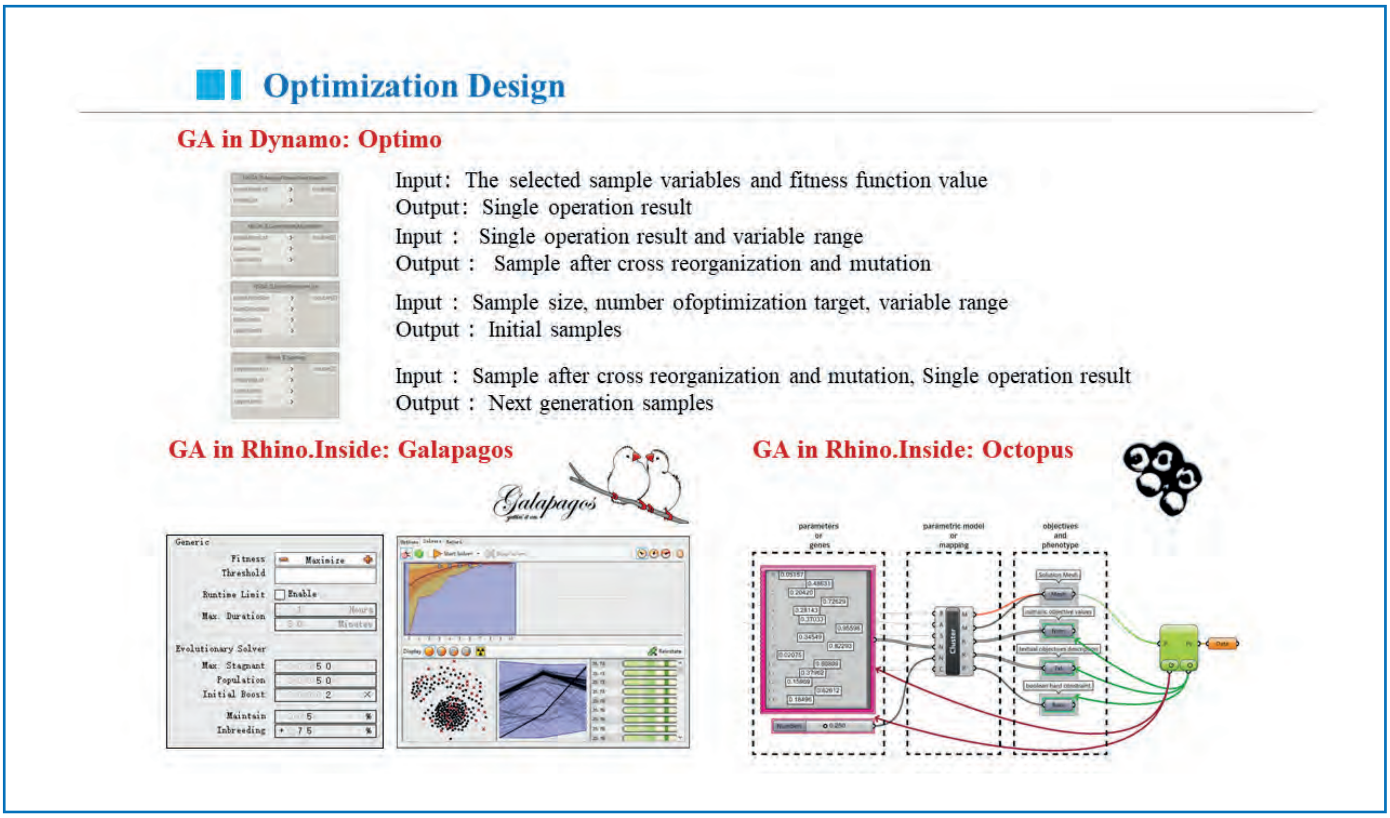

Slide 32-33: At present, genetic algorithms are widely used in architectural design. Genetic algorithms can be implemented in the digital design platform previously mentioned. The genetic algorithm engine in Dynamo is called Optimo. The tools in Rhino.Inside contain a single-objective optimization engine called Galapagos, and a multi-objective optimization engine called Octopus.

Geographic Information Systems and their integration with BIM

Patrick Maurelli

Coordinator of *Next City Lab for GIS BIM and Digital Twin*

CITERA - Interdepartmental Research Centre for Territory, Architecture, Heritage and Environment
Sapienza University of Rome

Why to integrate GIS with the BIM methodologies, tools and procedures? Going beyond the 3D modelling and simple representation purposes, we should approach geography and GIS multi-thematic environments looking for effective and useful additional dimensions of BIM data.

Before addressing the issue of operational integration between these two representation and modelling systems it is necessary to investigate the scopes in terms of opportunities and conceptual models.

The fundamental question therefore arises: why it is interesting and useful to integrate these different logics and methodologies?

There is a growing demand of City Information Models (CIM) to build and manage the scenarios of the Smart City; We need Digital Twins and Big Data for cities and territories where the scale of analysis is highly variable and represents indeed a continuum.

We can easily imagine some useful GIS-BIM applications: large complex asset management; design and maintenance process for linear land infrastructures; tri-dimensional cadastre; deepening and improving the land coverage representation (dealing with the rigidity limits of Corine Land Cover methodology); integrating land use and land coverage in the urban milieu, maybe introducing dynamicity. Other interesting applications will be suggested in the lesson's slides.

The short course is aimed to students or professionals who already have a fair degree of knowledge in GIS and BIM applications, that manage concepts as relational DBMS, Georeferenced Data, Data classification, Topology, Components and instances, parametric and data driven design.

To understand where and when GIS and BIM can meet, we need to reflect on the relations among the concepts of Resolution, Scale, Informative details and domains, levels of Detail (LOD) and investigate on the logics of data aggregation and disaggregation. The risks behind the corner are the loss of information and the trivialization.

How can we adapt and use Attributes and GIS classifications from thematic overlay to change or to enrich BIM categories?

We could further develop some operations in a GIS-BIM integrated environment:

- BIM feeding GIS Data through aggregation and summarize;
- GIS feeding BIM for new buildings context aware data.

The integration between software is going to improve models for GIS and BIM interoperability: 3D modelling in GIS environment and Cartographic models in BIM environment. This current technological challenge need to be supported by solid big data management models. There are other smart solutions that do not need the conception of a unique complex software.

Tools can dialog, maintaining their own skills and capabilities, if we focus on the standardization of data structures and interchange formats, on sharing and integrated management of spatial data through the Common Data Environment (CDE).

GIS manages Big Data at large scale and for wide thematic detail on several domains; BIM manages Big Data at fine scale and for high LOD and Granularity. The problem of multiplying vertical Big Data with horizontal Big Data could be badly set. Large datasets should be connected just on demand in case.

More and more often we talk about Digital twin but it should be noted that we will have different scenarios, and rules to deal with, in relation to different levels of scale and granularity. As always, tools are chosen according to operational objectives.

The ideal scale range for GIS and those for BIM they differ but have an overlap area between LOD100 and LOD200. When we deal with Digital Twin in in the urban context both GIS and BIM scale ranges have to be considered. Objects from BIM can appear into a GIS and elements from GIS can impact on BIM processes, and it's not just a question of software.

The focus must then move on to the relationship between the data that the two systems are managing. It is not really a matter of interoperability (of course we adore it) and not even of transferability of the geo-data from GIS to BIM or the BIM dataset into the GIS, the success key of the integration is in the adaptation and meaningful management of the different scale, resolution and granularity of the data. Once this is solved the relationships could be established eventually using a CDE (Common Data Environment) keeping GIS and BIM within their domains.

The Urban Digital Twin and the City Information Modelling are the perfect evolutionary domains for the GIS BIM integration.

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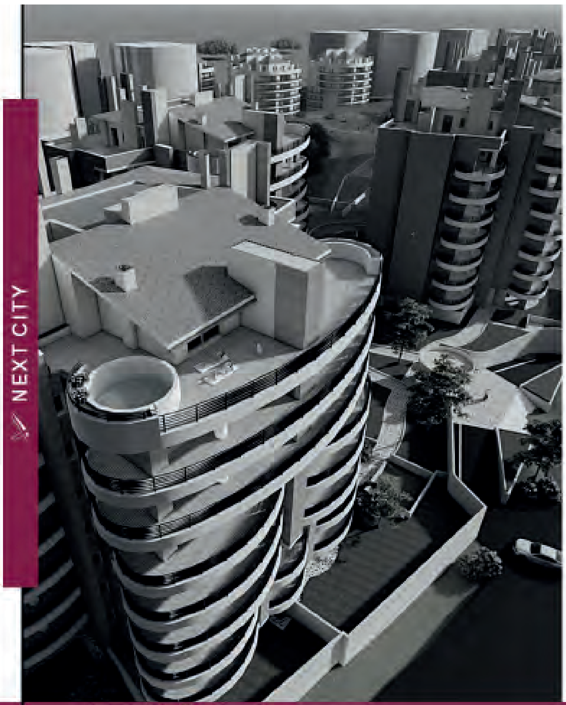


INTERNATIONAL SUMMER SCHOOL

BIM & GIS for integrated design

SAPIENZA UNIVERSITY OF ROME
FACULTY OF ARCHITECTURE

Rome, August 31st – September 11th 2020

PROF. PATRICK MAURELLI

MODULE 3 - Geographic Information Systems and its integration with BIM

09/09/2020 – 10/09/2020

SAPIENZA Università di Roma

GISBIM INTERNATIONAL SUMMER SCHOOL

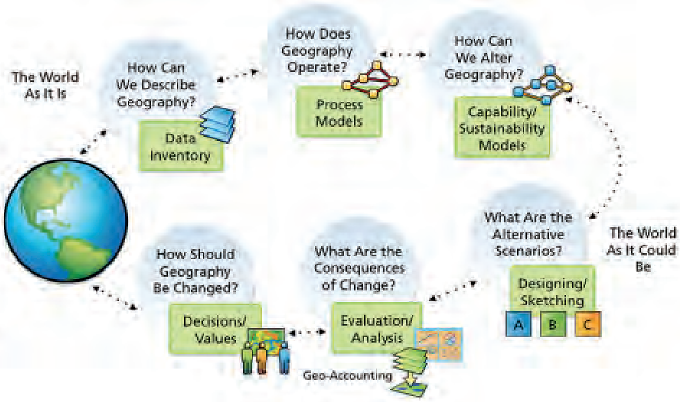
01 What is GIS I Geographic Information System

A geographic information system (GIS) is a **framework** for gathering, managing, and analyzing data. **Rooted in the science of geography, GIS integrates many types of data**. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes.

With this unique capability, **GIS reveals deeper insights into data, such as patterns, relationships, and situations—helping users make smarter decisions**.

Why we use GIS ?
To help decision making.

GIS is a DSS
Decision Support System



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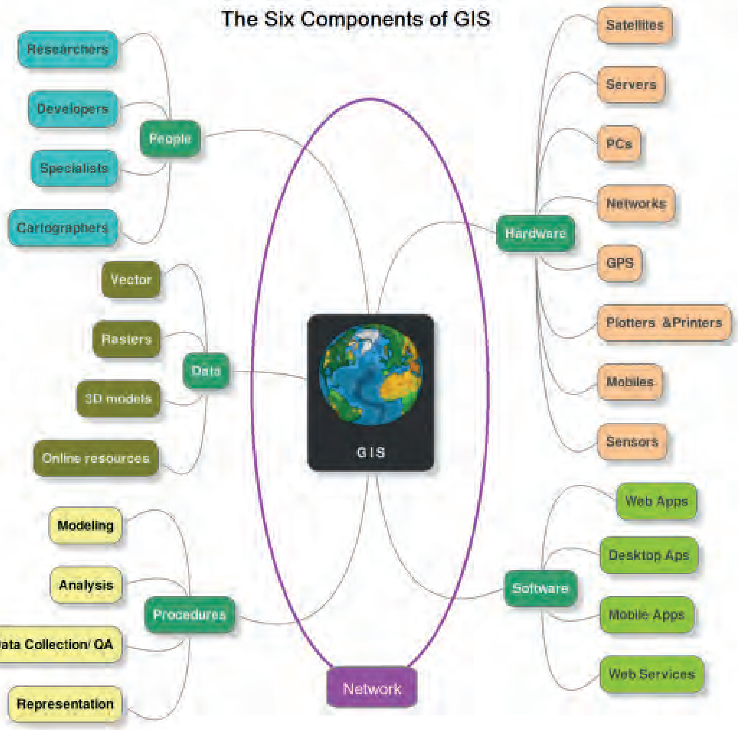
02

What is GIS I

A geographic information system (GIS) is **more than just software**. People and methods are combined with geospatial software and tools, to enable spatial analysis, manage large datasets, and display information in a map/graphical form.

The six **components** of a GIS are: **hardware**, **software**, **data**, **methods**, **people**, and **network**.



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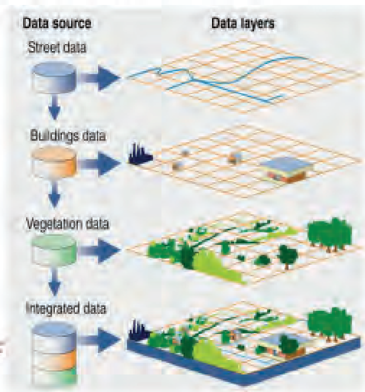
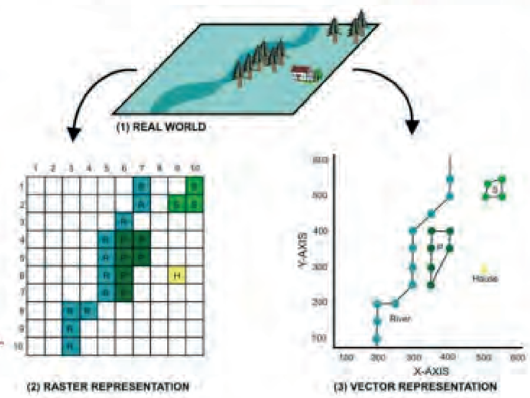
03

What is GIS I Geographic Information System

A geographic information system (GIS) is a **system** designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. The key word to this technology is **Geography** – this means that **some portion of the data is spatial**, in some way **referenced to locations on the earth (geospatial data)**. Within (geo)data we have **tabular data** known as **attribute data**, that can be generally **defined as additional information about each of the spatial features**.

Data in GIS are Mainly (Geo)Spatial Data





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04 What is GIS I Geographic Information System

GeoSpatial data, is a term used to describe any **data** related to or containing information about a **specific location on the Earth's surface**

A geographic information system (GIS) is a System to manage Geospatial Data.
Geospatial Data can be analyzed to determine :

(1) the location of features and relationships to other features, → Position and relation
(2) where the most and/or least of some feature exists, → Spatial frequency
(3) the density of features in a given space, → Density
(4) what is happening inside an area of interest (AOI), → Focus Analysis
(5) what is happening nearby some feature or phenomenon, → Proximity analysis
(6) and how a specific area has changed over time (and in what way). → Evolution

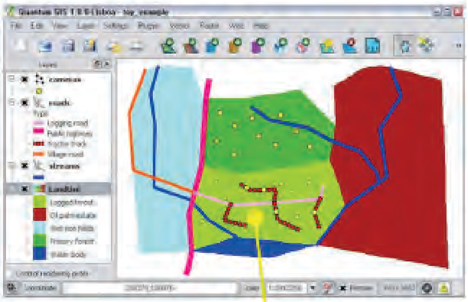
SCALE, Thematic Detail and **LoD** (Level of Detail) are correlated concepts

Different representation of the same building in GIS and in BIM

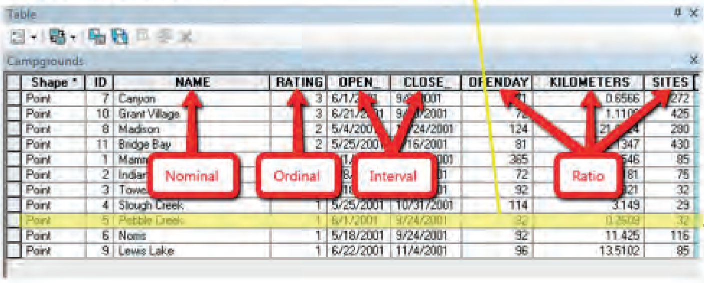
05 What is GIS I (Geo)Data Model

VECTOR LAYERS Or FEATURES LAYERS

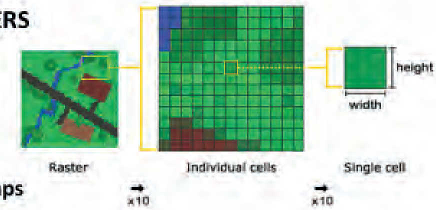
- **Points**
- **Lines**
- **Polygons**



+ ATTRIBUTES DATA

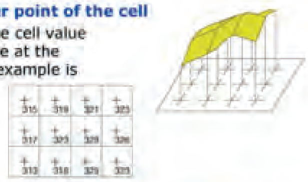


RASTER LAYERS

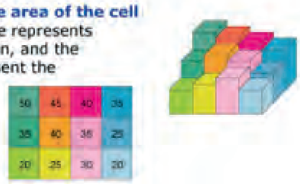


- **Imagery**
- **Scanned Maps**
- **Numerical Grids**

Value applies to the center point of the cell
For certain types of data, the cell value represents a measured value at the center point of the cell. An example is a raster of elevation



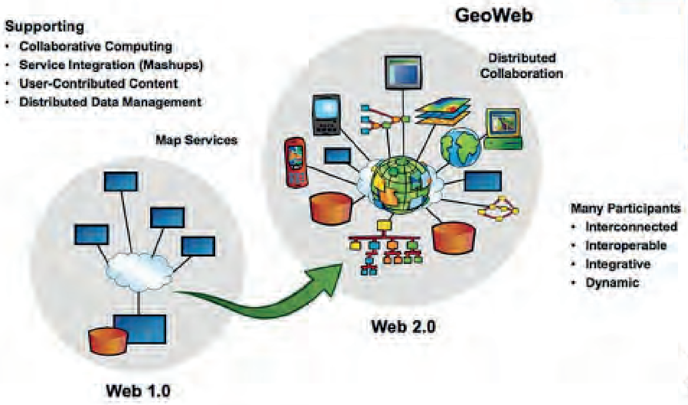
Value applies to the whole area of the cell
For most data, the cell value represents a sampling of a phenomenon, and the value is presumed to represent the whole cell square.



06 What is GIS I Geographic Information System

GIS published and managed on Web is
WEBGIS

GIS connecting to the Web is
GEOWEB



WMS – Web Map Services

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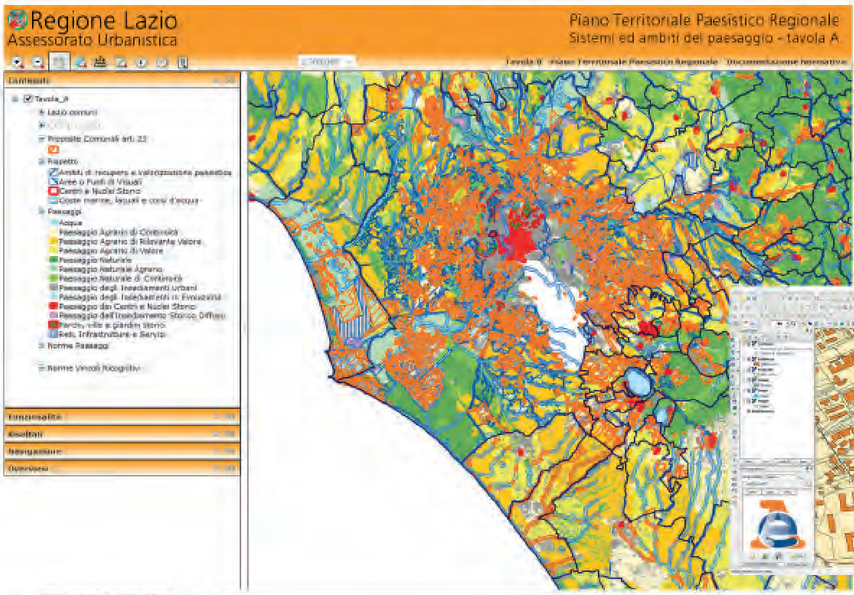
07 What is GIS I WebGIS Services



Generally is for consulting, querying, downloading, retrieving (WMS, WFS)

Some WebGIS application admit also editing vector data and attribute data

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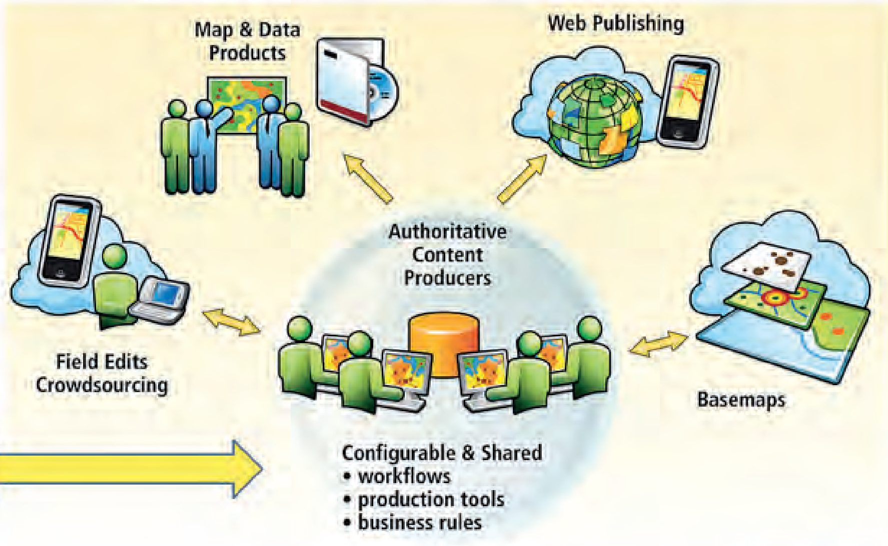
08

What is GIS | GeoWeb

GEoWeb 2.0

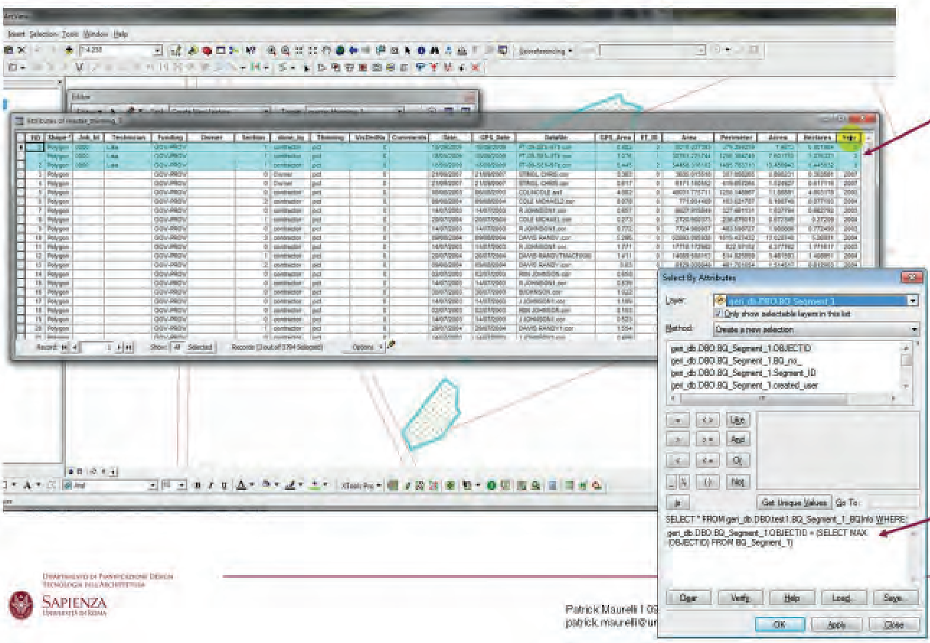
client devices interact by reading and providing data

- **Field Editing**
- **GPS Tracking**
- **IOT devices**



09

GIS Operations | Select Features



Features can be **SELECTED**

By attributes

Or

From the map

Or

By Spatial Query

A selection can be the result of a **COMPLEX QUERY**

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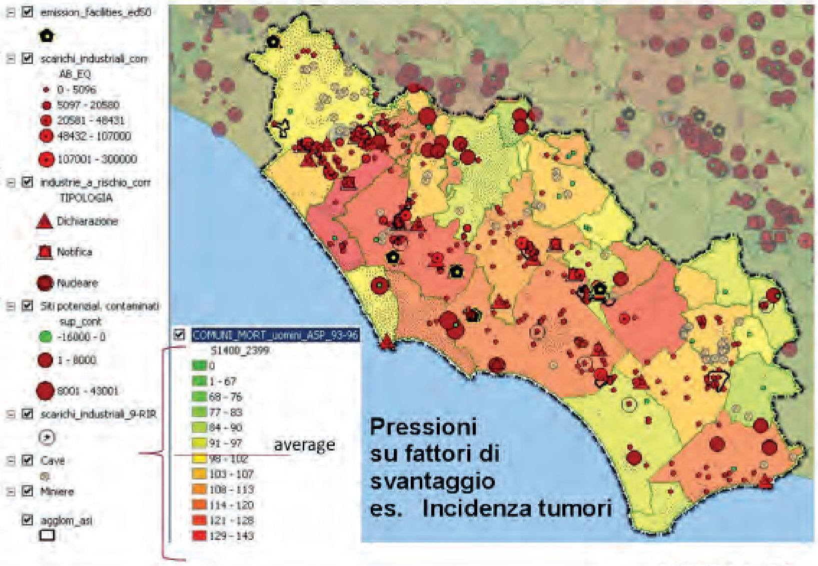
10 GIS Mapping | Classifications and Legends

Attributes Data of LAYER "industrial dumps"
→ Data Field "Equivalent inhabitants"
→ Classification by quantities
For Graduated Symbology
→ selected classification method "Quantile"

Attributes Data of LAYER "Dangerous Industr."
→ Data Field "Typology of Danger"
→ Classification by unique values
For Category Symbology
→ classification method "unique values"

Attributes Data of LAYER "Municipalities"
→ Data Field "Cancer Mortality - Men"
→ Classification by quantities
For Graduated Color (2 colours gradient)
→ selected classification method "Quantile"



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11 GIS | Classifications & Legends

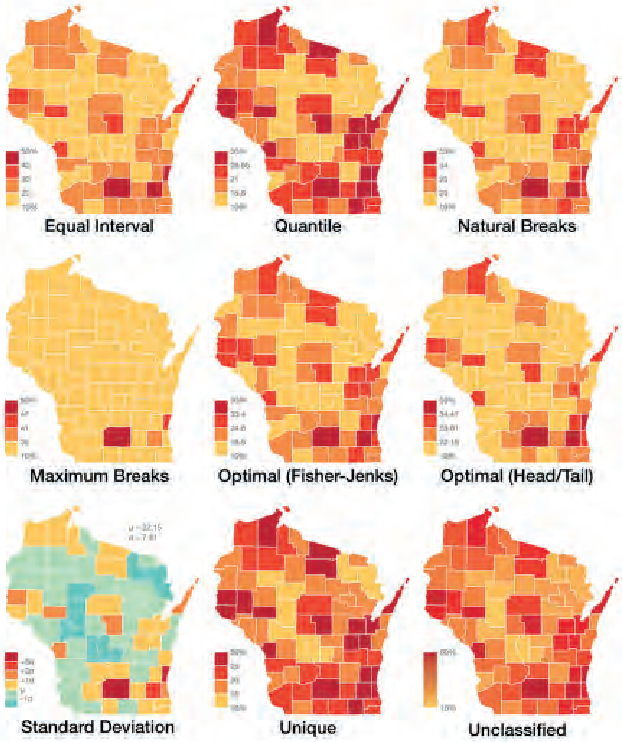
Classification methods are used for **classifying numerical fields for graduated symbology.**

When you classify your data, you can use one of many standard classification methods provided by GIS software, or you can manually define your own custom class ranges.

Manual interval
Use manual interval to define your own classes, to manually add class breaks and to set class ranges that are appropriate for the data.

Edit the Legend
.... to make it easy to understand the **THEME**

→ THEMATIC MAPS **i.e. Sealed Surface %**



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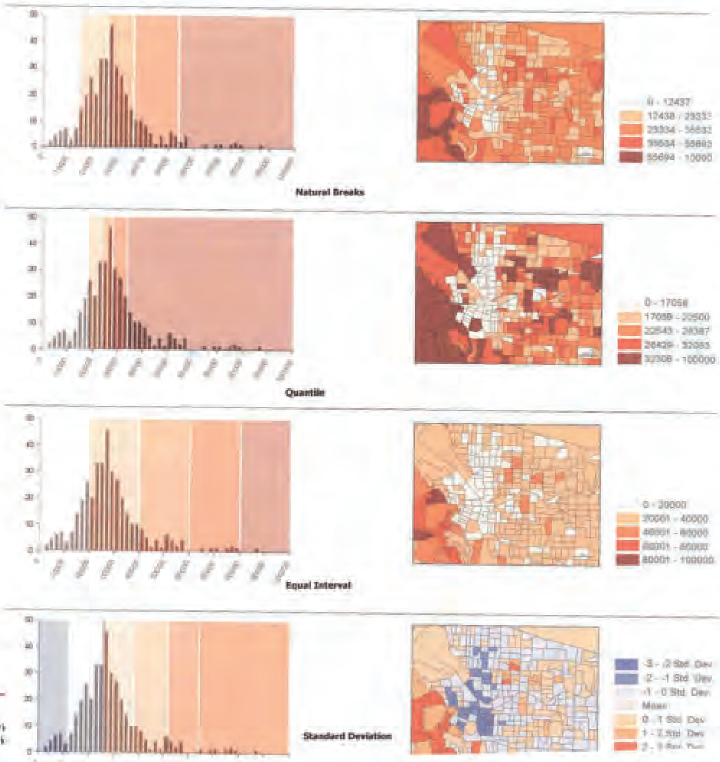
12 GIS I Classifications & Legends

Natural breaks (Jenks)
With natural breaks classification (Jenks) classes are based on natural groupings inherent in the data. Class breaks are created in a way that best groups similar values together and maximizes the differences between classes

Quantile classification divides classes so that the total number of features in each class are approximately the same.

Equal Interval
divides the range of attribute values into equal-sized subranges. This allows you to specify the number of intervals, and the class breaks based on the value range are automatically determined.

Standard Deviation
shows you how much a feature's attribute value varies from the mean. The mean and standard deviation are calculated automatically. Class breaks are created with equal value ranges that are a proportion of the standard deviation



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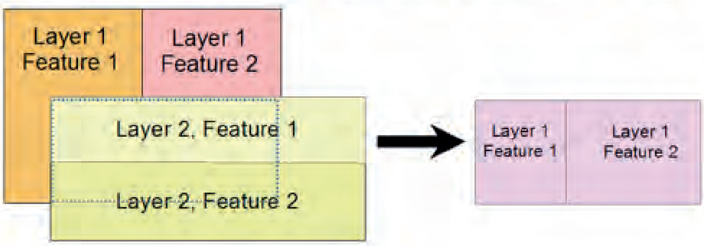
13 GIS Operations I Managing geometry, topology and data

A summary of the main basic GIS operations in pictures:
http://gsp.humboldt.edu/olm/Lessons/GIS/06%20Vector%20Analysis%20Attributes/Images/

CLIP POLYGONS →



TABLES JOIN →

Table A

Parcel-ID	Acres
2	2
5	1.5
6	6
1	3
8	1.6

\+

Table B

Parcel-ID	Owner
2	John Smith
5	Bruce Martin
6	Anne Davis
1	Steve Arnold
8	Rick James

=

Parcel-ID	Acres	Owner
2	2	John Smith
5	1.5	Bruce Martin
6	6	Anne Davis
1	3	Steve Arnold
8	1.6	Rick James

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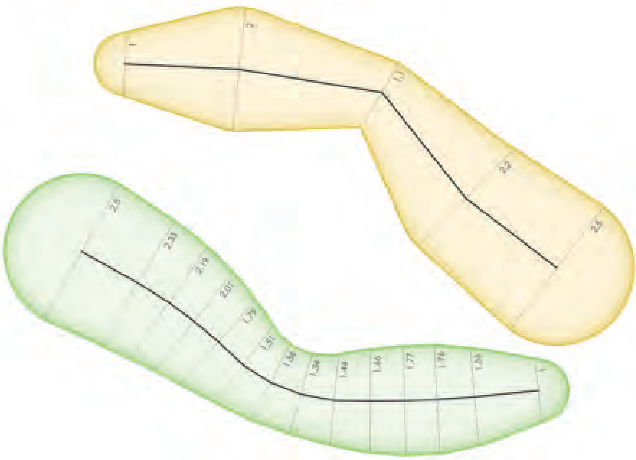
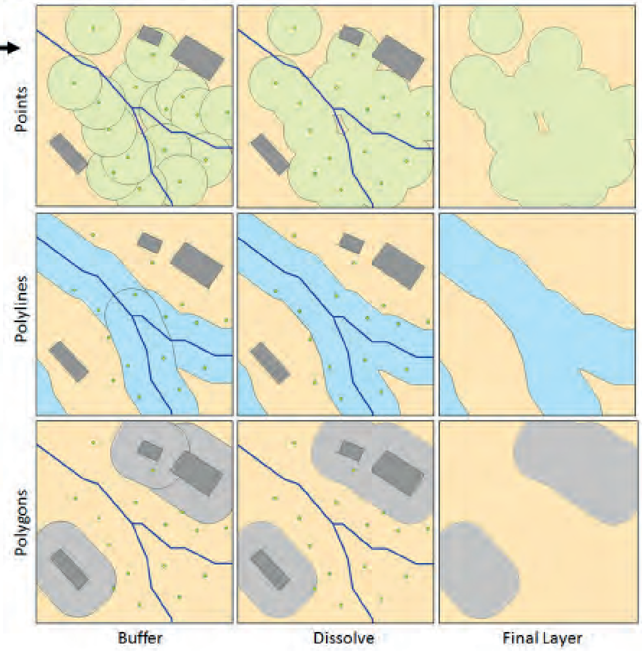
GIS Operations I Managing geometry, topology and data

BUFFER & DISOLVE

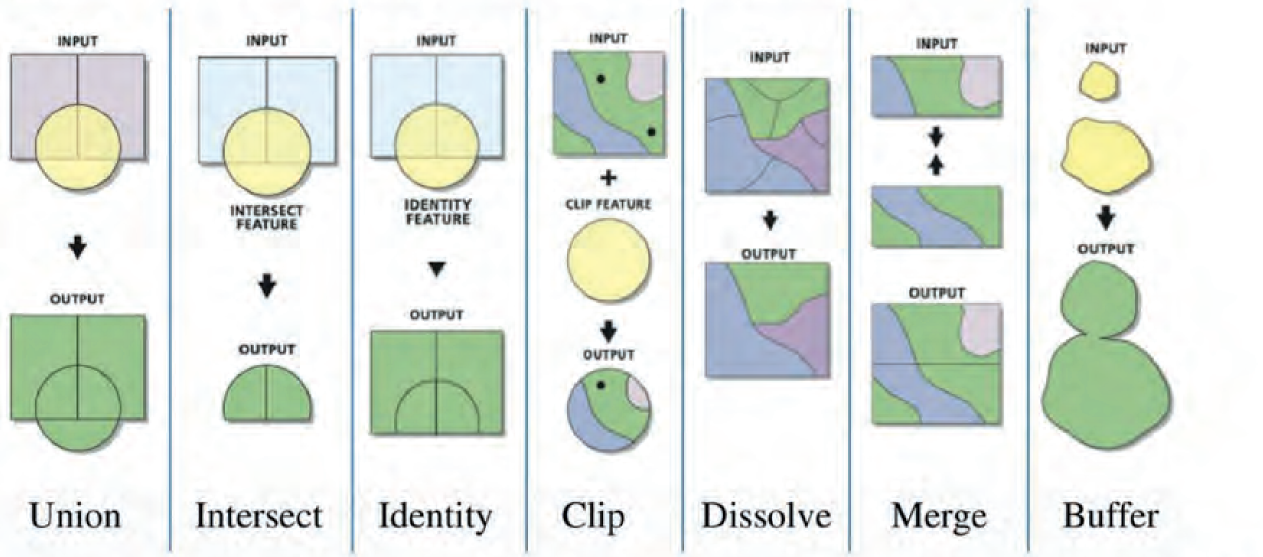
VARIABLE DISTANCE BUFFER

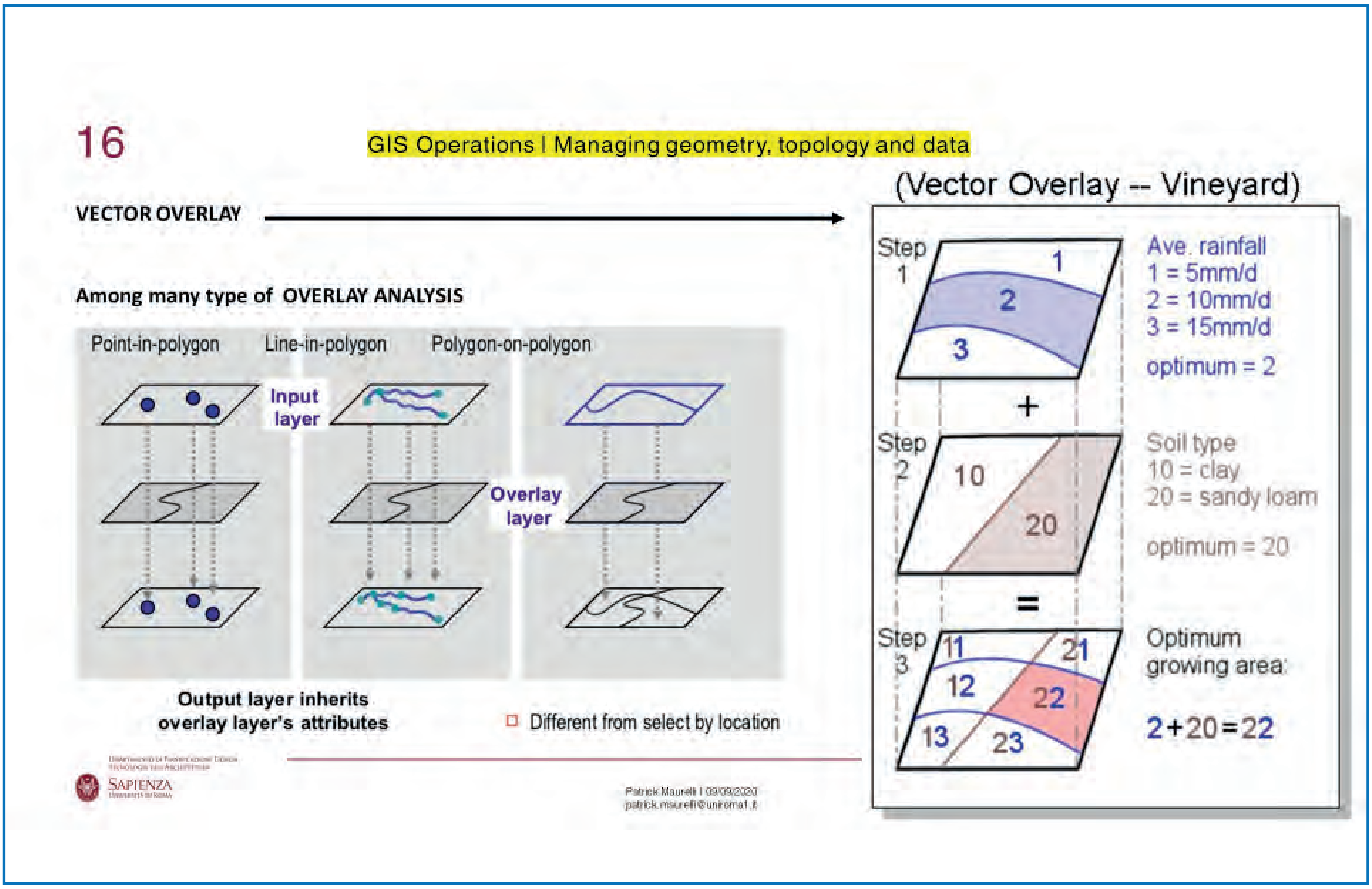




15

GIS Operations I GEOPROCESSING SUMMARY




16
GIS Operations I Managing geometry, topology and data
VECTOR OVERLAY
Among many type of OVERLAY ANALYSIS
Point-in-polygon
Line-in-polygon
Polygon-on-polygon
Input layer
Overlay layer
Output layer inherits overlay layer's attributes
Different from select by location
(Vector Overlay -- Vineyard)
Step 1
Ave. rainfall
1 = 5mm/d
2 = 10mm/d
3 = 15mm/d
optimum = 2
Step 2
Soil type
10 = clay
20 = sandy loam
optimum = 20
Step 3
Optimum growing area:
2+20=22
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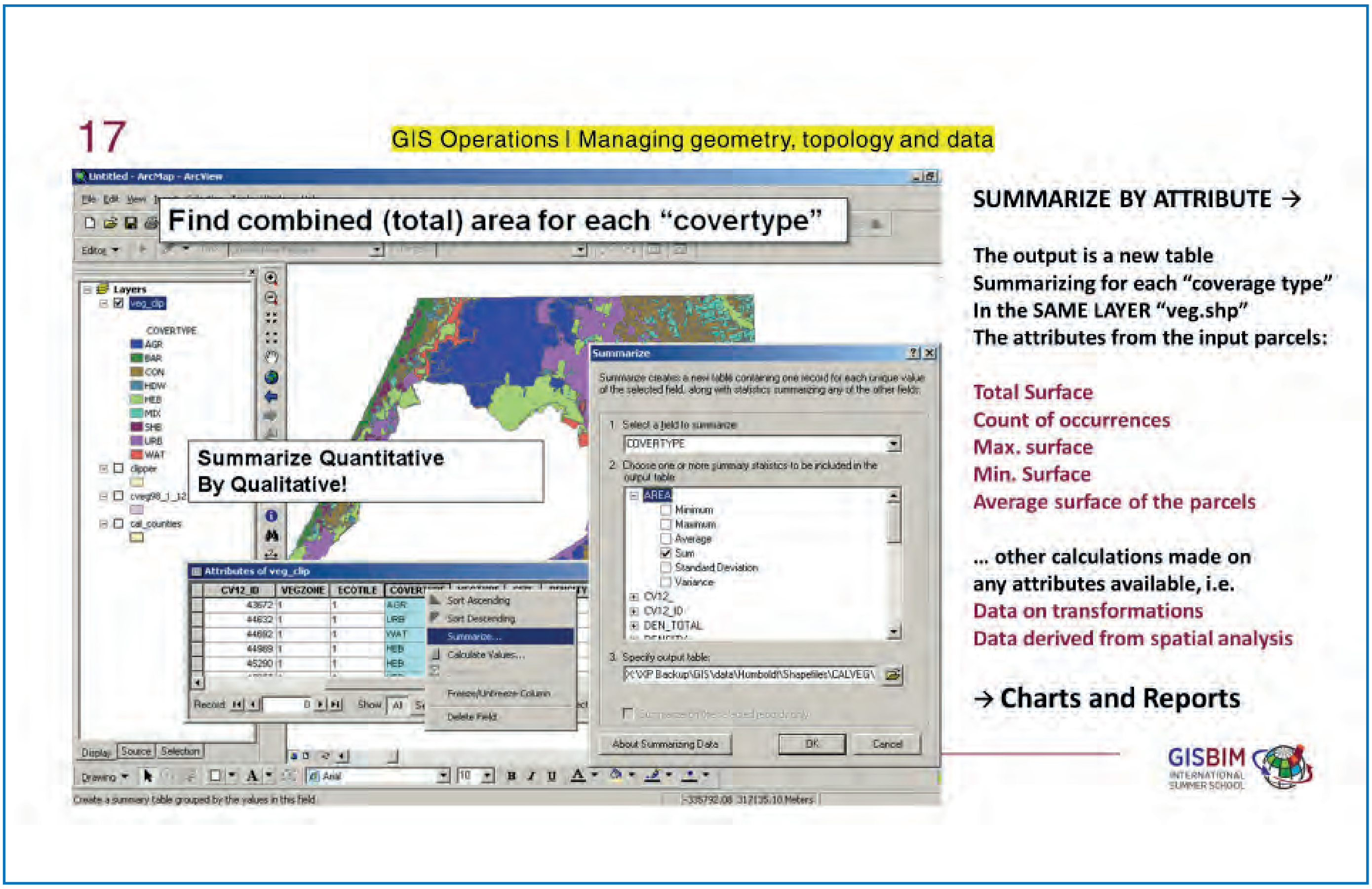
17
GIS Operations I Managing geometry, topology and data
Find combined (total) area for each "covertype"
Summarize Quantitative By Qualitative!
Summarize
COVERTYPE
Attributes of veg_clip
SUMMARIZE BY ATTRIBUTE →
The output is a new table
Summarizing for each "coverage type"
In the SAME LAYER "veg.shp"
The attributes from the input parcels:
Total Surface
Count of occurrences
Max. surface
Min. Surface
Average surface of the parcels
... other calculations made on any attributes available, i.e.
Data on transformations
Data derived from spatial analysis
→ Charts and Reports
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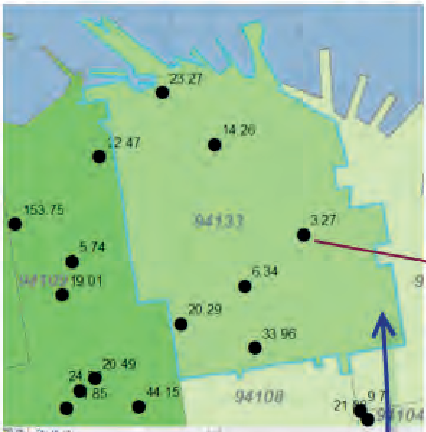
18

GIS Operations I Managing geometry, topology and data



FID	Shape *	ID	NAME	SALES	POINTCOUNT
1	Polygon	94116	San Francisco	1001.989998	12
2	Polygon	94124	San Francisco	879.640005	10
5	Polygon	94122	San Francisco	677.860006	13
15	Polygon	94103	San Francisco	462.239993	11
16	Polygon	94107	San Francisco	277.990001	7
4	Polygon	94133	San Francisco	101.390001	8
12	Polygon	94104	San Francisco	31.579999	2
8	Polygon	94117	San Francisco	10.69	1
9	Polygon	94108	San Francisco	8.91	1
3	Polygon	94130	San Francisco	0	0

SUMMARIZE BY ATTRIBUTE →

Each Point within the polygon contributes to the Summarize operation with the Record from the Attribute Data of the POINT coverage

WHAT IF EACH POINT REPRESENTS A BUILDING ?

WHAT IF EACH BUILDING IS DIGITALIZED IN A BIM ?

IS IT POSSIBLE TO COLLECT THE INFORMATION FROM EACH BIM (EACH BUILDING COULD SUMMARIZE SOME ATTRIBUTES i.e. Energy Consumptions, Number of Rooms, Surface of Windows, …) AND PASS THESE DATA TO THE GIS POINT COVERAGE ?

THE GIS OPERATIONS THAT CAN BE USED ARE:

RELATE ATTRIBUTES → ONE TO MANY RECORDS
JOIN TABLES → ONE TO ONE RECORD

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19

GIS Operations I Managing geometry, topology and data

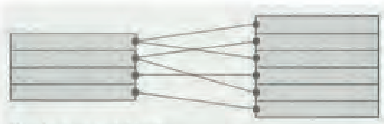
JOINS AND RELATES → these operations are often used to bring into GIS external Databases

Two ways of linking an external table **THAT COULD COME FROM A BIM DATASET** to a shapefile or geodatabase

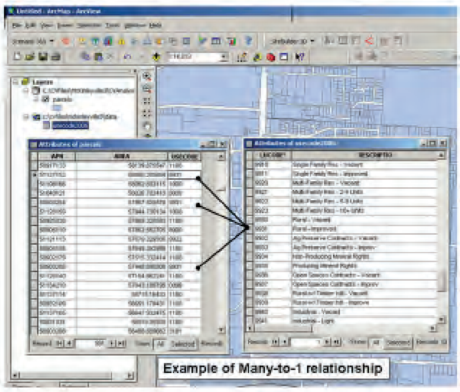
One-to-One relationship
is created using the JOIN operation
external table is appended to your shapefile/geodatabase attribute table

One-to-one relationship

One-to-Many relationship
is created using the RELATE operation
external table is physically separate from the attribute table



One-to-many relationship



Example of Many-to-1 relationship

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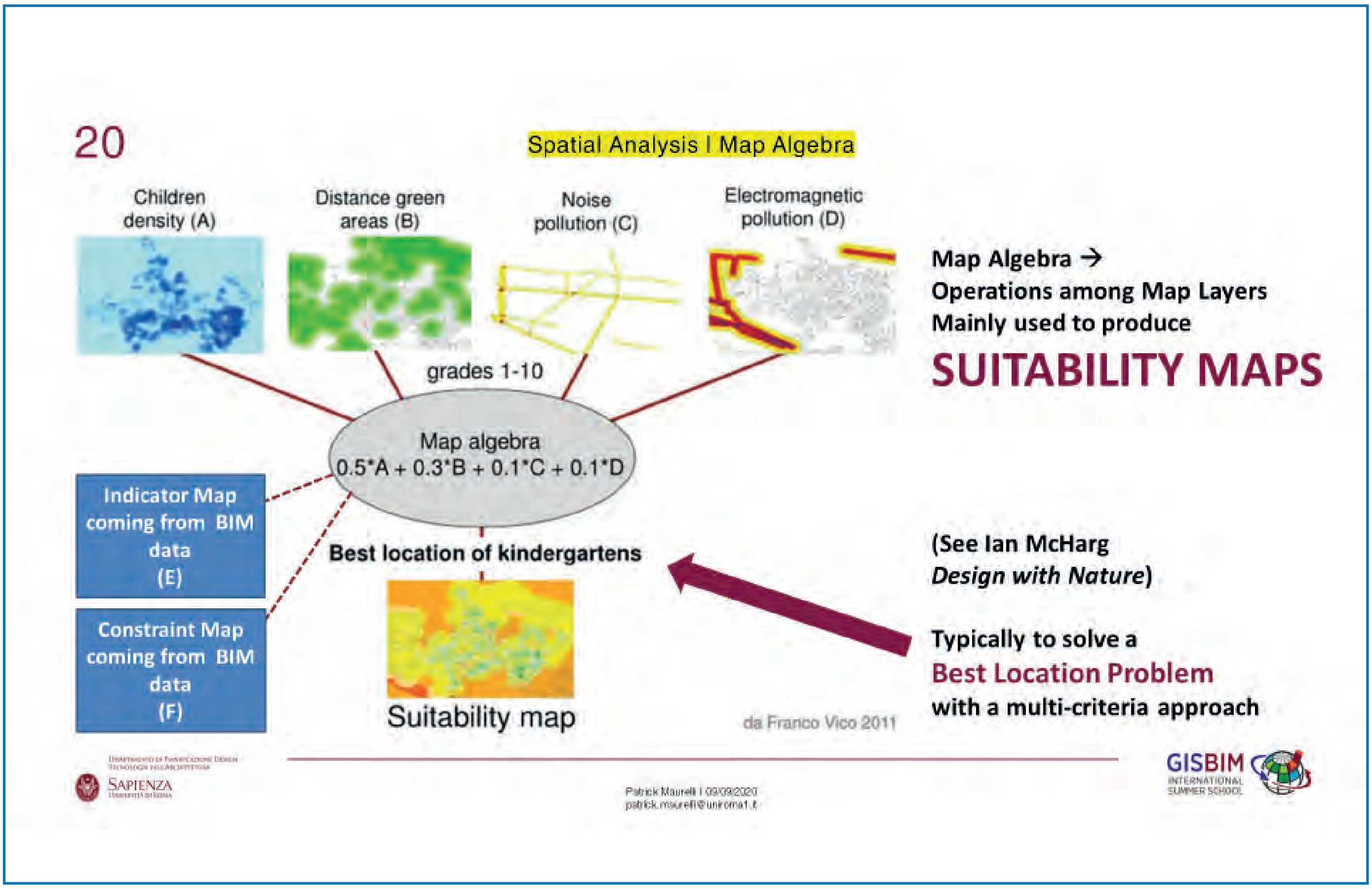
20
Spatial Analysis I Map Algebra
Children density (A)
Distance green areas (B)
Noise pollution (C)
Electromagnetic pollution (D)
grades 1-10
Map algebra
0.5*A + 0.3*B + 0.1*C + 0.1*D
Indicator Map coming from BIM data (E)
Constraint Map coming from BIM data (F)
Best location of kindergartens
Suitability map
da Franco Vico 2011
Map Algebra →
Operations among Map Layers
Mainly used to produce
SUITABILITY MAPS
(See Ian McHarg
Design with Nature)
Typically to solve a
Best Location Problem
with a multi-criteria approach
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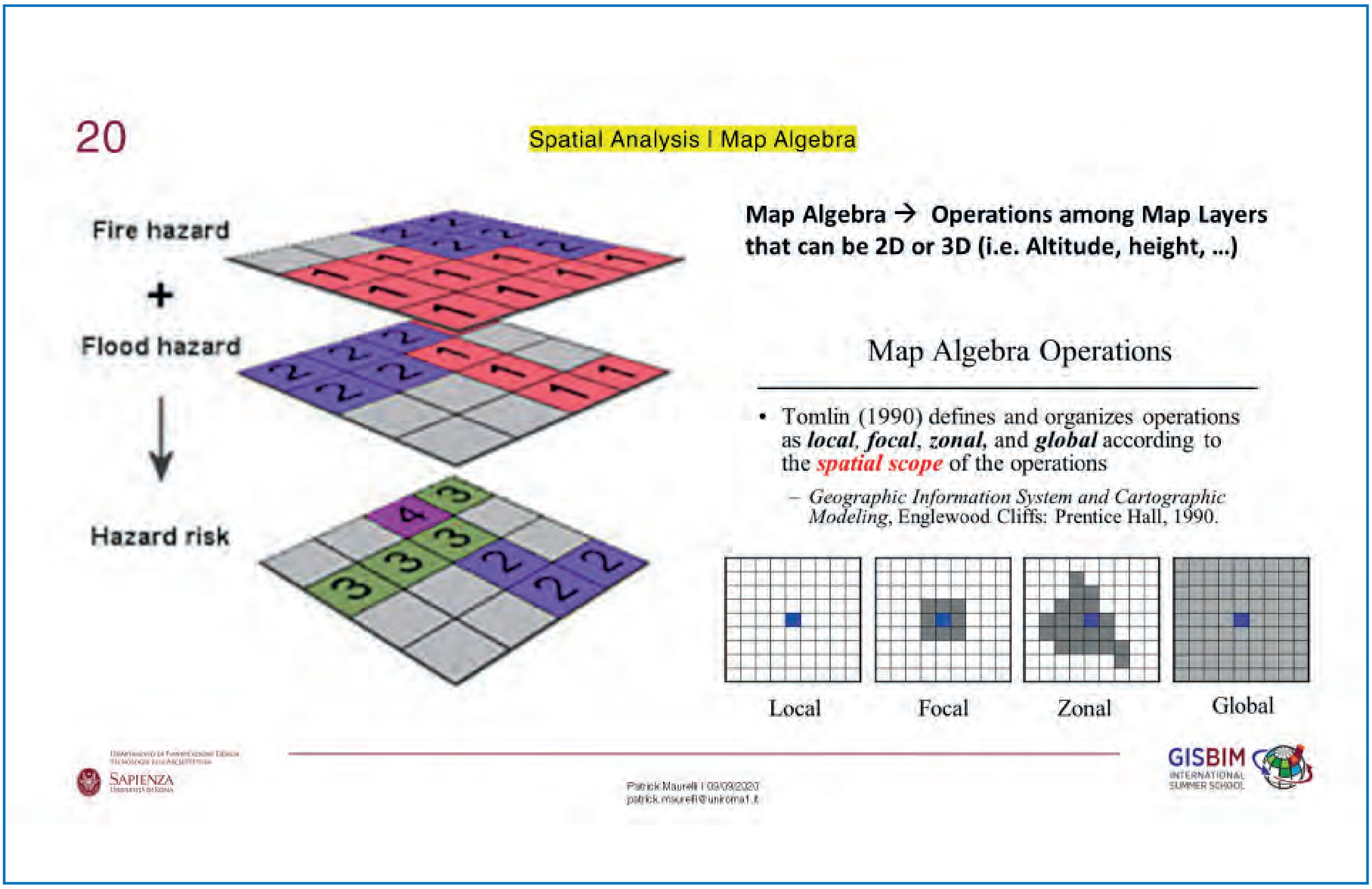
20
Spatial Analysis I Map Algebra
Fire hazard
+
Flood hazard
Hazard risk
Map Algebra → Operations among Map Layers
that can be 2D or 3D (i.e. Altitude, height, ...)
Map Algebra Operations
• Tomlin (1990) defines and organizes operations as local, focal, zonal, and global according to the spatial scope of the operations
– Geographic Information System and Cartographic Modeling, Englewood Cliffs: Prentice Hall, 1990.
Local
Focal
Zonal
Global
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21

Spatial Analysis I Map Algebra

To illustrate the neighborhood processing for Focal Statistics calculating a Sum statistic, consider the processing cell with a value of 5 in the following diagram. A rectangular 3 by 3 cell neighborhood shape is specified. The sum of the values of the neighboring cells (3 + 2 + 3 + 4 + 2 + 1 + 4 = 19) plus the value of the processing cell (5) equals 24 (19 + 5 = 24). So a value of 24 is given to the cell in the output raster in the same location as the processing cell in the input raster.

Input processing raster = Output raster

The above diagram demonstrates how the calculations are performed on a single cell in the input raster. In the following diagram, the results for all the input cells are shown. The cells highlighted in yellow identify the same processing cell and neighborhood as in the example above.

Input processing raster = Output raster

The shape of a neighborhood can be an annulus (a donut), circle, rectangle, or wedge. The possible statistics that can be calculated within a neighborhood are mean, majority, maximum, median, minimum, minority, range, standard deviation, sum, and variety.

The Focal Statistics tool gives control over the neighborhood type and statistic to be calculated.

Map Algebra →

Focal Spatial Operations

For example:

Geomarketing – How many households around a Store

Services Analysis – How many services around a Household

Urban Green – which total green area is around each residential location

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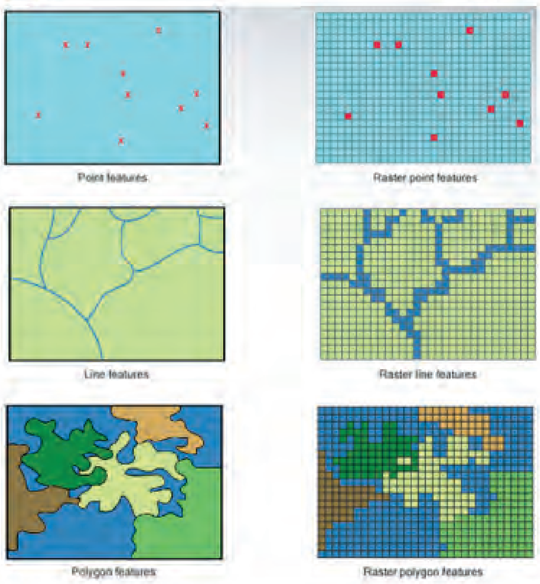
22

Spatial Analysis I Map Algebra



To proceed with Spatial Analysis and Map Algebra
Usually we need to convert Vector Data into Raster grids.

TIPS

Creating raster datasets in a geodatabase (ArcGis)

1. Right-click a geodatabase and click New > **Raster** Dataset.
2. Type the name of the new **raster** dataset. ...
3. Set the **Cell Size** of the geodatabase **raster** dataset.

THIS IS VERY IMPORTANT, CAN CHANGE THE SCALE OF THE ANALYSIS AND THEN THE RESULTS

4. Set the Pixel Type for the geodatabase **raster** dataset.
5. Click the Spatial Reference for **Raster** button. ...
6. Type the Number of Bands that the **raster** dataset will contain.

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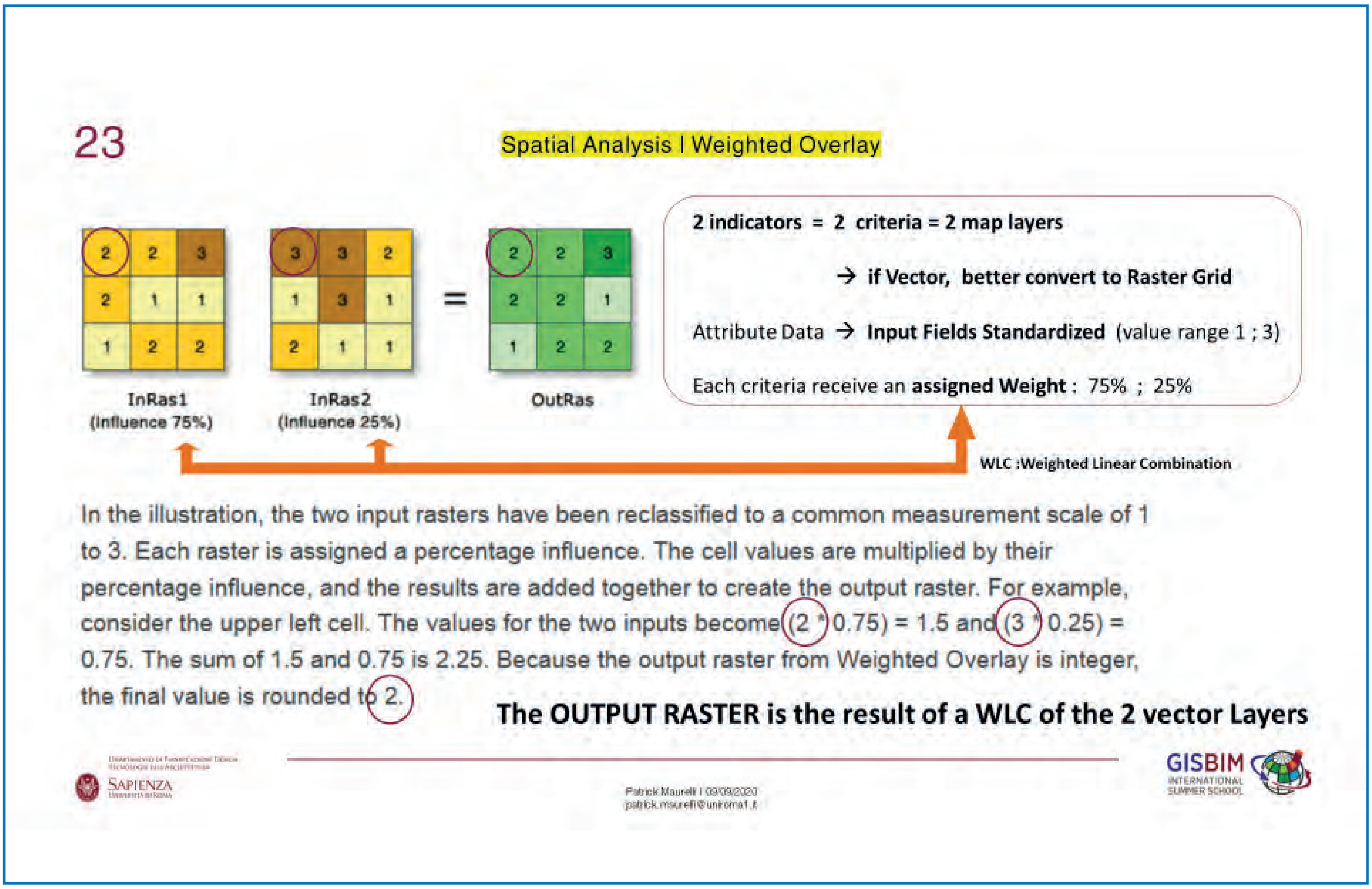
23
Spatial Analysis I Weighted Overlay
InRas1
(Influence 75%)
InRas2
(Influence 25%)
OutRas
2 indicators = 2 criteria = 2 map layers
→ if Vector, better convert to Raster Grid
Attribute Data → Input Fields Standardized (value range 1 ; 3)
Each criteria receive an assigned Weight : 75% ; 25%
WLC :Weighted Linear Combination
In the illustration, the two input rasters have been reclassified to a common measurement scale of 1 to 3. Each raster is assigned a percentage influence. The cell values are multiplied by their percentage influence, and the results are added together to create the output raster. For example, consider the upper left cell. The values for the two inputs become (2 * 0.75) = 1.5 and (3 * 0.25) = 0.75. The sum of 1.5 and 0.75 is 2.25. Because the output raster from Weighted Overlay is integer, the final value is rounded to 2.
The OUTPUT RASTER is the result of a WLC of the 2 vector Layers
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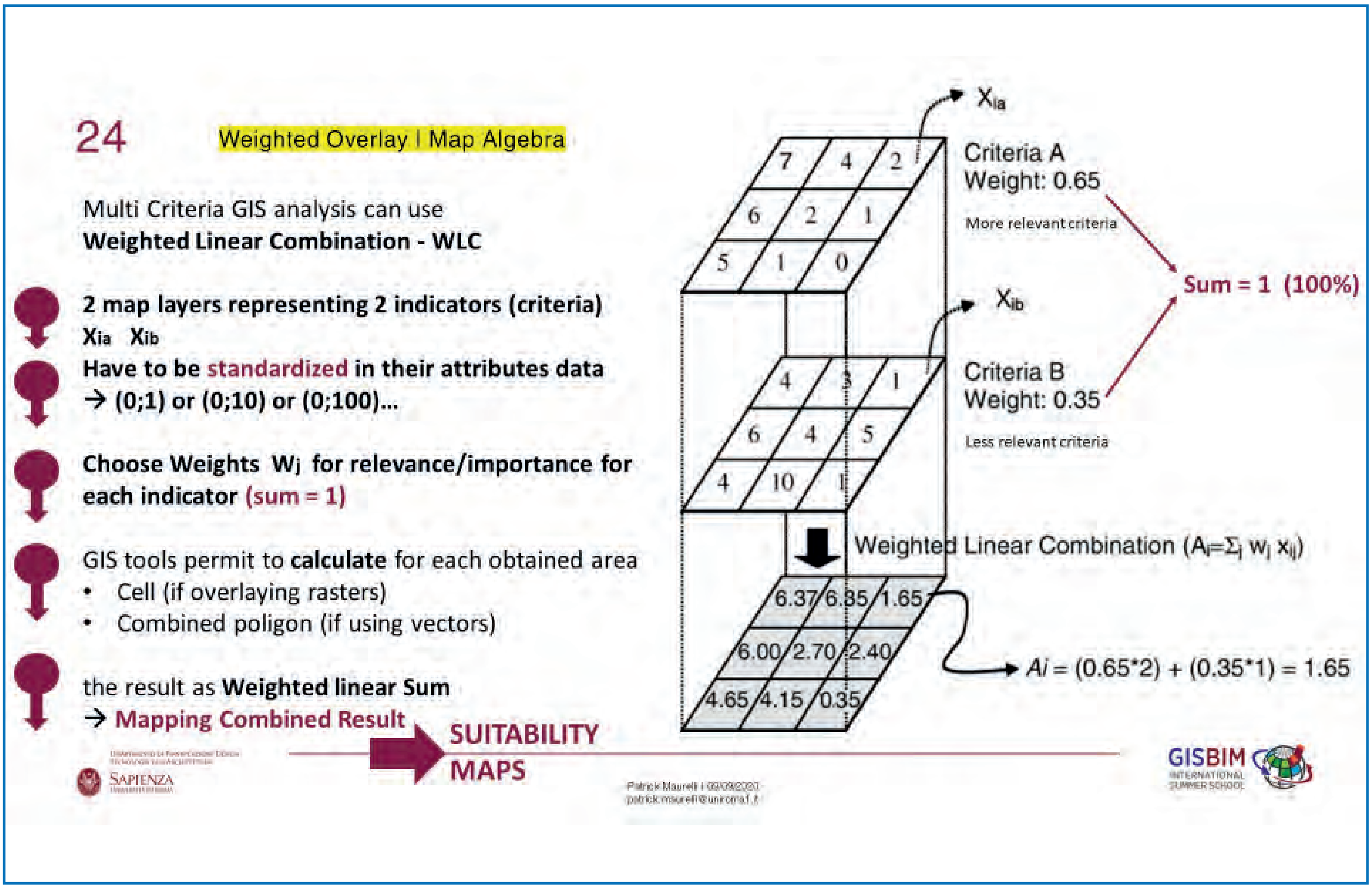
24
Weighted Overlay I Map Algebra
Multi Criteria GIS analysis can use
Weighted Linear Combination - WLC
2 map layers representing 2 indicators (criteria)
Xia Xib
Have to be standardized in their attributes data
→ (0;1) or (0;10) or (0;100)…
Choose Weights Wj for relevance/importance for each indicator (sum = 1)
GIS tools permit to calculate for each obtained area
• Cell (if overlaying rasters)
• Combined poligon (if using vectors)
the result as Weighted linear Sum
→ Mapping Combined Result
SUITABILITY
MAPS
Xia
Criteria A
Weight: 0.65
More relevant criteria
Sum = 1 (100%)
Xib
Criteria B
Weight: 0.35
Less relevant criteria
Weighted Linear Combination (Ai=Σj wj xij)
Ai = (0.65*2) + (0.35*1) = 1.65
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25 Overlay | Map Algebra

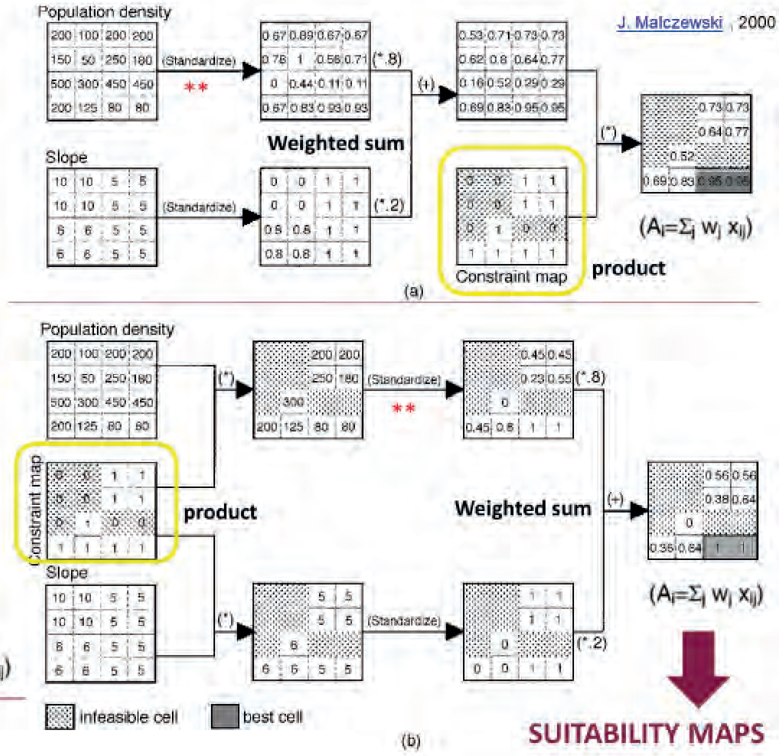
2 methods of WLC with attribute standardization (** 0;1) where:
(a) standardization is performed on all cells in attribute map layers;
(b) standardization is performed on the set of feasible cells or areas.

Feasibility = out of Constraints and Restrictions Areas
Feasibility = **BINARY CONSTRAINT MAP** (0 or 1)

Standardization **:
Population → lower Pop. = 1 ; higher pop. = 0
Slope → lower slope = 1 ; higher slope = 0

Weight assigned for the 2 map layers (indicators) representing the relevance for the 2 criteria
Population = 0,8 (80%) → lower Pop. = 1 x 0,8 = 0,8
Slope = 0,2 (20%) → lowe slope = 1 x 0,2 = 0,2

For each area GIS will calculate WLC values $(A_i=\Sigma_j w_j x_{ij})$



26 Suitability Map | Solar PV Farm Suitability

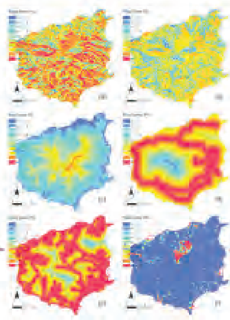
An island-based use case : Ulleungisland, Korea.
J. Suh, J.R.S.Brownson, 2016

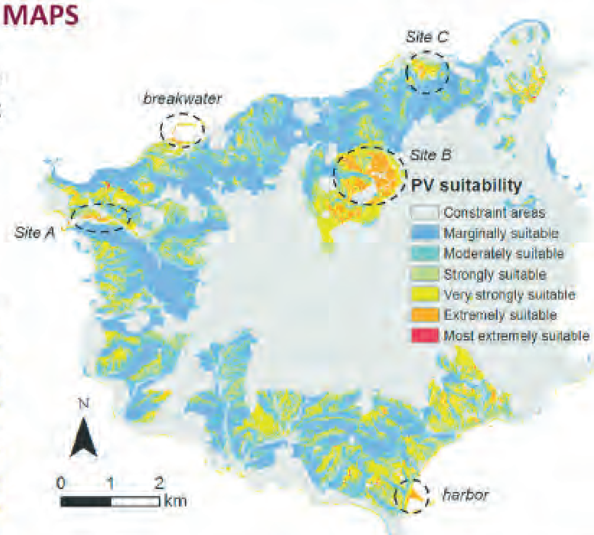
Multi-criteria evaluation (MCE) process → **SUITABILITY MAPS**

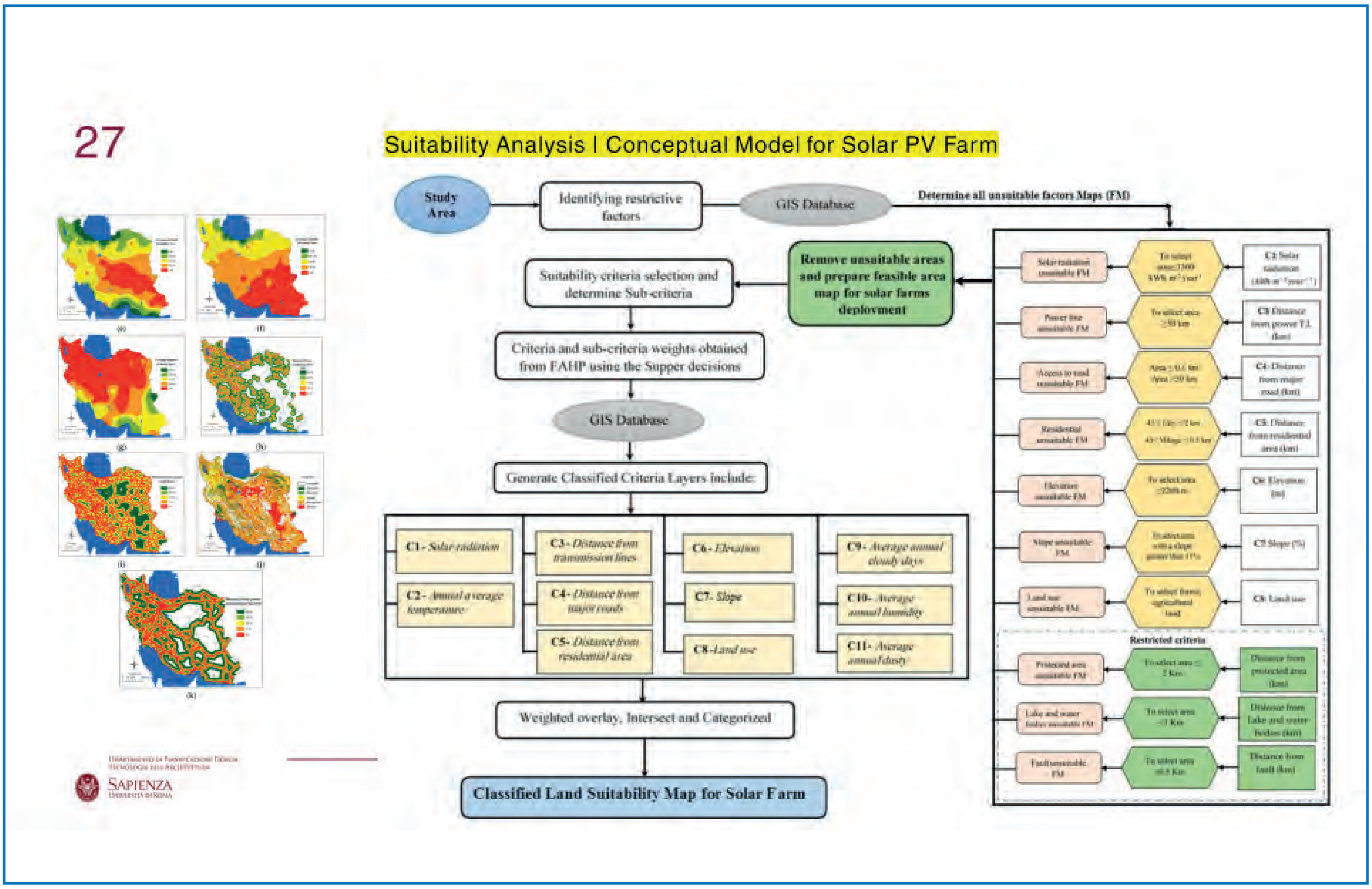
Constraint variables that identified areas forbidden to PV farm development were consolidated into a **single binary constraint layer** (environmental regulation, ecological protection, future land use, ...).

Six factor variables were selected as influential to seek out increased annual average power performance and reduced potential investment costs, forming new criteria layers for site suitability:

1. **solar irradiation**
2. **sunshine hours**
3. **average temperature in summer**
4. **proximity to transmission line**
5. **proximity to roads**
6. **slope**






27
Suitability Analysis I Conceptual Model for Solar PV Farm
Study Area
Identifying restrictive factors
GIS Database
Determine all unsuitable factors Maps (FM)
Remove unsuitable areas and prepare feasible area map for solar farms deployment
Suitability criteria selection and determine Sub-criteria
Criteria and sub-criteria weights obtained from FAHP using the Supper decisions
GIS Database
Generate Classified Criteria Layers include:
C1- Solar radiation
C2- Annual average temperature
C3- Distance from transmission lines
C4- Distance from major roads
C5- Distance from residential area
C6- Elevation
C7- Slope
C8- Land use
C9- Average annual cloudy days
C10- Average annual humidity
C11- Average annual dusty
Weighted overlay, Intersect and Categorized
Classified Land Suitability Map for Solar Farm
Restricted criteria
Distance from protected area (km)
Distance from lake and water bodies (km)
Distance from fault (km)
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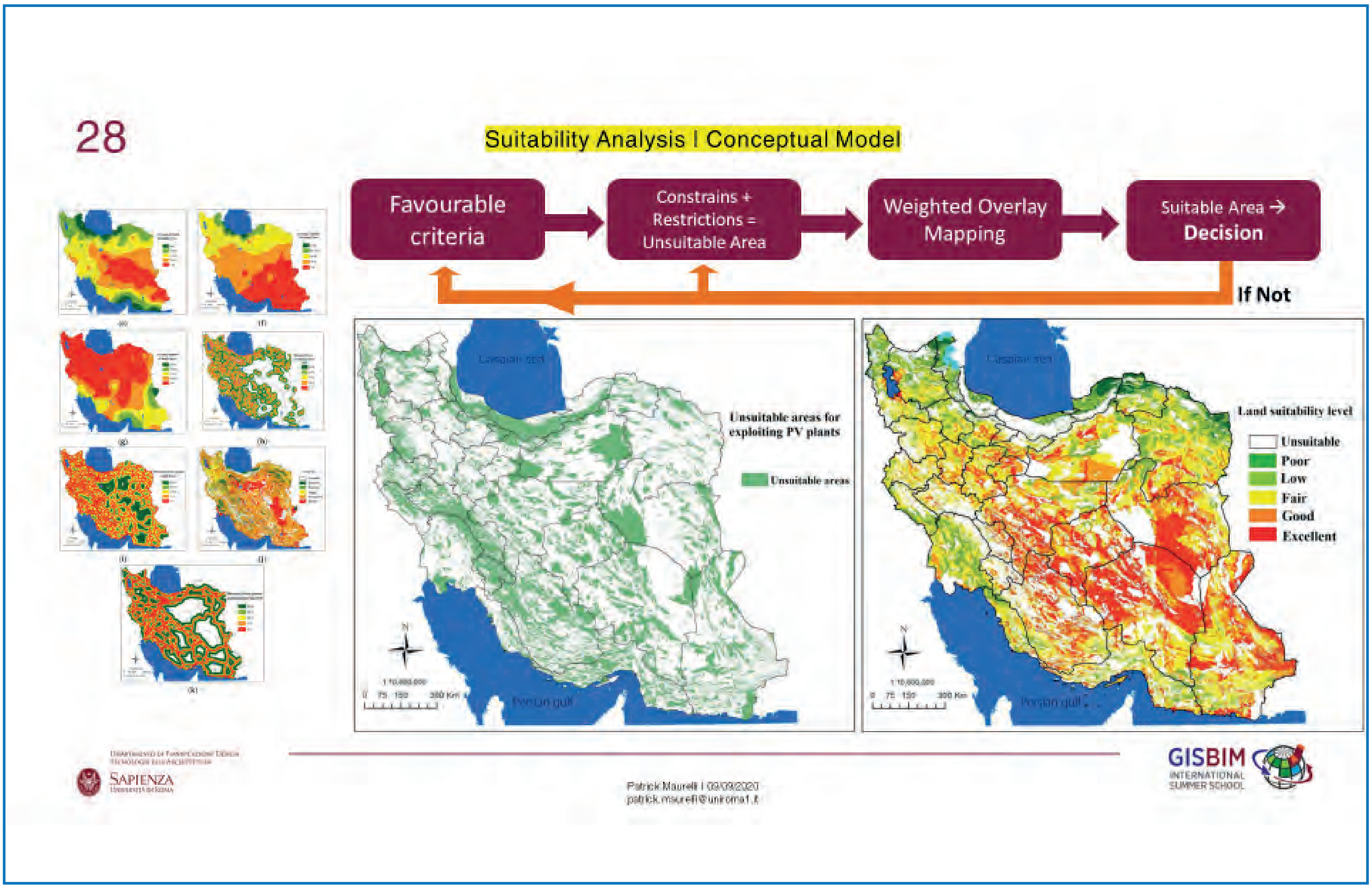
28
Suitability Analysis I Conceptual Model
Favourable criteria
Constrains + Restrictions = Unsuitable Area
Weighted Overlay Mapping
Suitable Area → Decision
If Not
Caspian sea
Unsuitable areas for exploiting PV plants
Unsuitable areas
Persian gulf
Land suitability level
Unsuitable
Poor
Low
Fair
Good
Excellent
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Suitability Analysis I An Application from CITERA

The overlay analysis was made to identify suitable roof surfaces, based on buildings parameters, in two different urban locations, of

- **PV Systems**
- **Solar Thermal Systems**

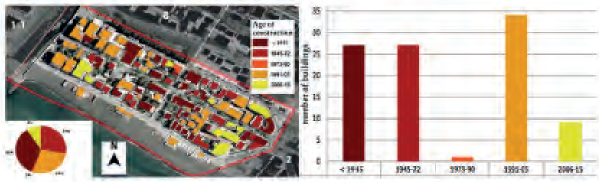

Fig. 4. Buildings age of construction of UC1.

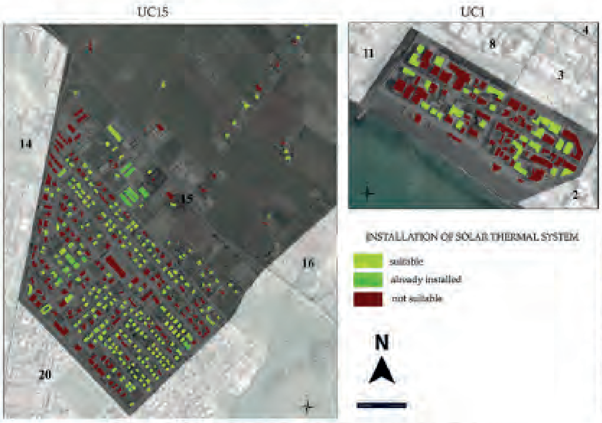

Fig. 6. Building suitability to an integrated installation of ST systems in UC1 and UC15.

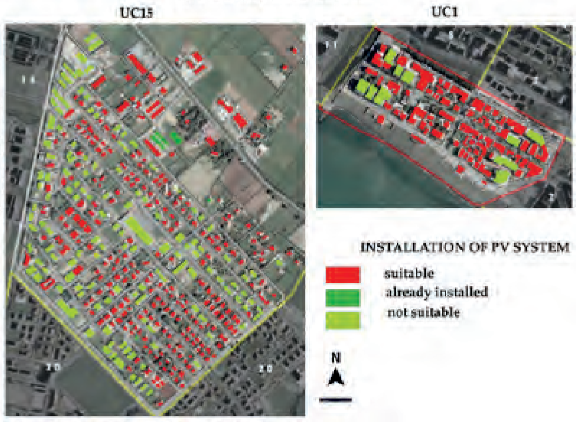

Fig. 13. Building suitability to an integrated installation of PV in UC1 and UC15.

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Suitability Map I exercise

Using the conceptual model in GIS to create a suitability map

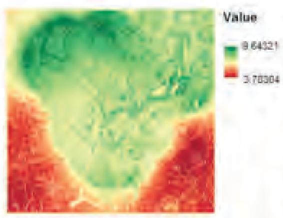
Your problem is to find the best location for siting a new school.

You will need to produce two maps.
The first will identify the suitability of each location relative to one another, known as the suitability map.
The final suitability surface ranks the attributes at each location relative to the **land-use type, slope, distance from recreation sites, and distance from schools.**

The second, which is derived from the suitability map, will identify the actual location to build the school accounting for the functional needs of the school (size and desired shape).

Last survey and assessment among suitable areas to Finally choose LOCATION

To create these two maps you will produce a **weighted suitability model.**



Output suitability map

The final suitability map is produced by combining all the maps.
Weights can be assigned at the same time as combining the suitability maps.

Most suitable locations are in the darkest green color. The least suitable locations are in red shades.

Locating the most suitable area

The final step to this modeling process is to actually locate the school.
The best site for your school would be located on 100 contiguous acres of land, to accommodate the athletic fields. The configuration of the site should be relatively compact.

https://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/solving-problems/using-the-conceptual-model-to-create-suitability.htm

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Suitability Map | Positioning Ecological Villages

Positive Energy Districts (PED) based Eco-Villages → Suitable locations by region municipalities

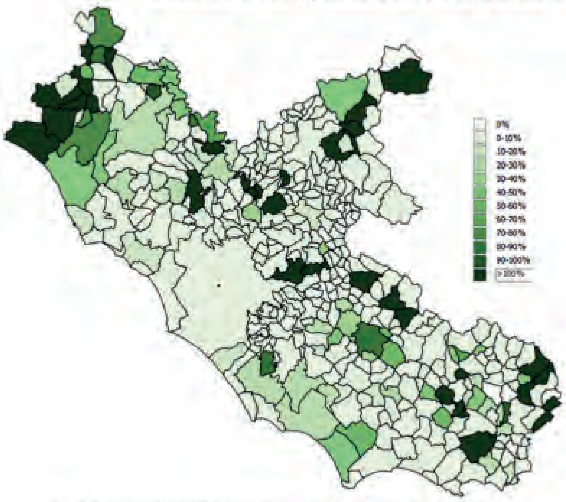

Fig. 11. Percentage of electricity consumptions covered from RES in each Lazio municipality.

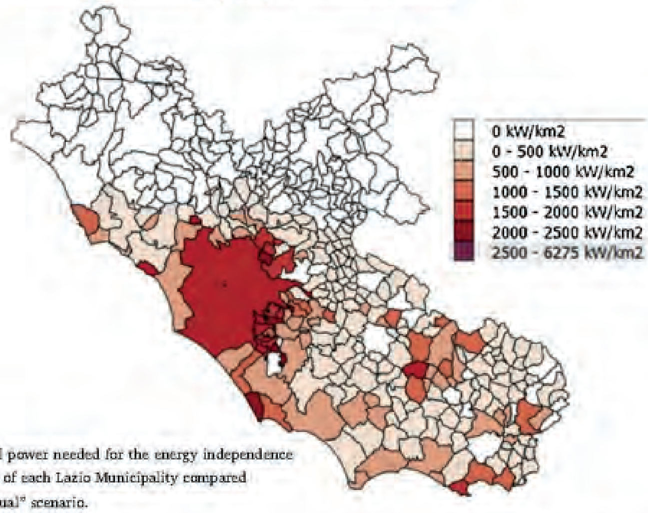

Fig. 19. Additional power needed for the energy independence per unit of surface of each Lazio Municipality compared to the 2030 "as usual" scenario.

toward zero-energy smart city districts
迈向零能源智慧城区

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Suitability Map | Positioning Ecological Villages

Positive Energy Districts (PED):
正能源地区

Energy Criteria:
Sectors Coupling
&
Positive Energy Buildings (PEB)

→ Electrification
→ V2G / V2B

Other criteria:
→ Circular (Economy) Districts
→ Low Carbon emission

toward zero-energy smart city districts → Eco-villages
迈向零能源智慧城区

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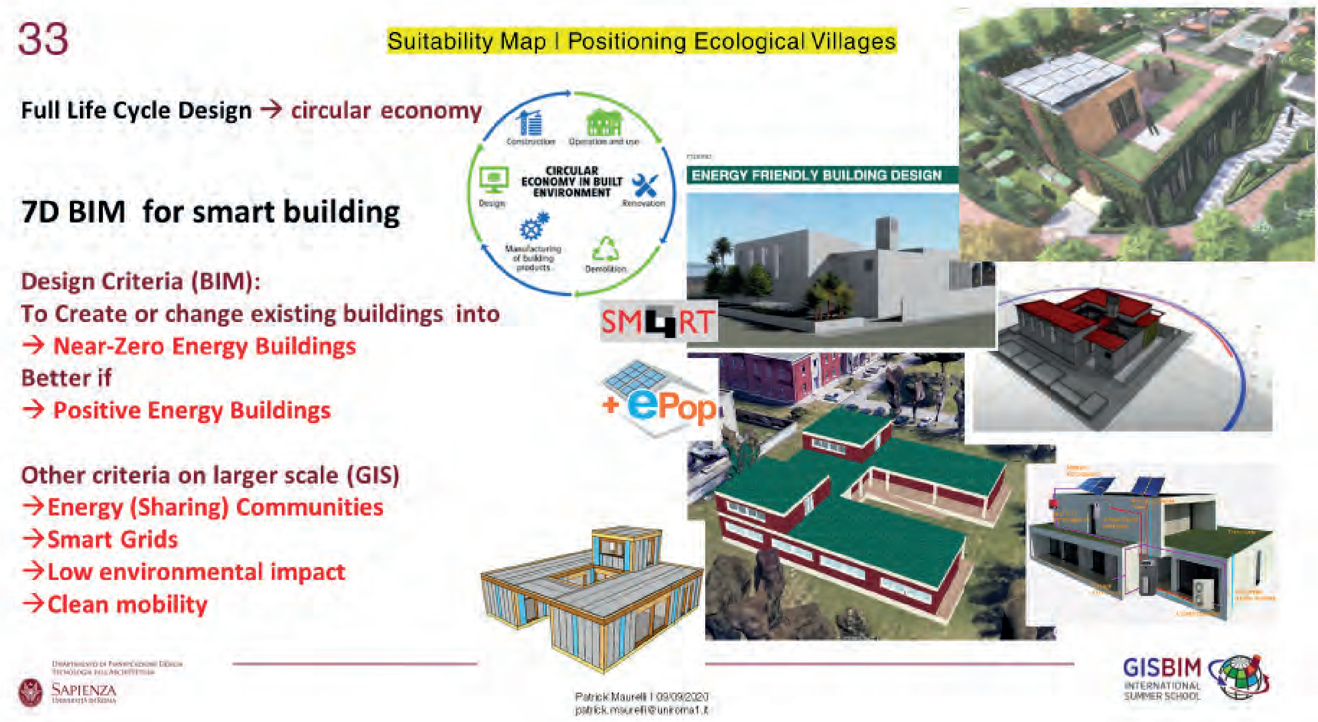
33
Suitability Map | Positioning Ecological Villages
Full Life Cycle Design → circular economy
7D BIM for smart building
Design Criteria (BIM):
To Create or change existing buildings into
→ Near-Zero Energy Buildings
Better if
→ Positive Energy Buildings
Other criteria on larger scale (GIS)
→Energy (Sharing) Communities
→Smart Grids
→Low environmental impact
→Clean mobility
CIRCULAR ECONOMY IN BUILT ENVIRONMENT
Construction
Operation and use
Design
Renovation
Manufacturing of building products
Demolition
ENERGY FRIENDLY BUILDING DESIGN
SM4RT
+ePop
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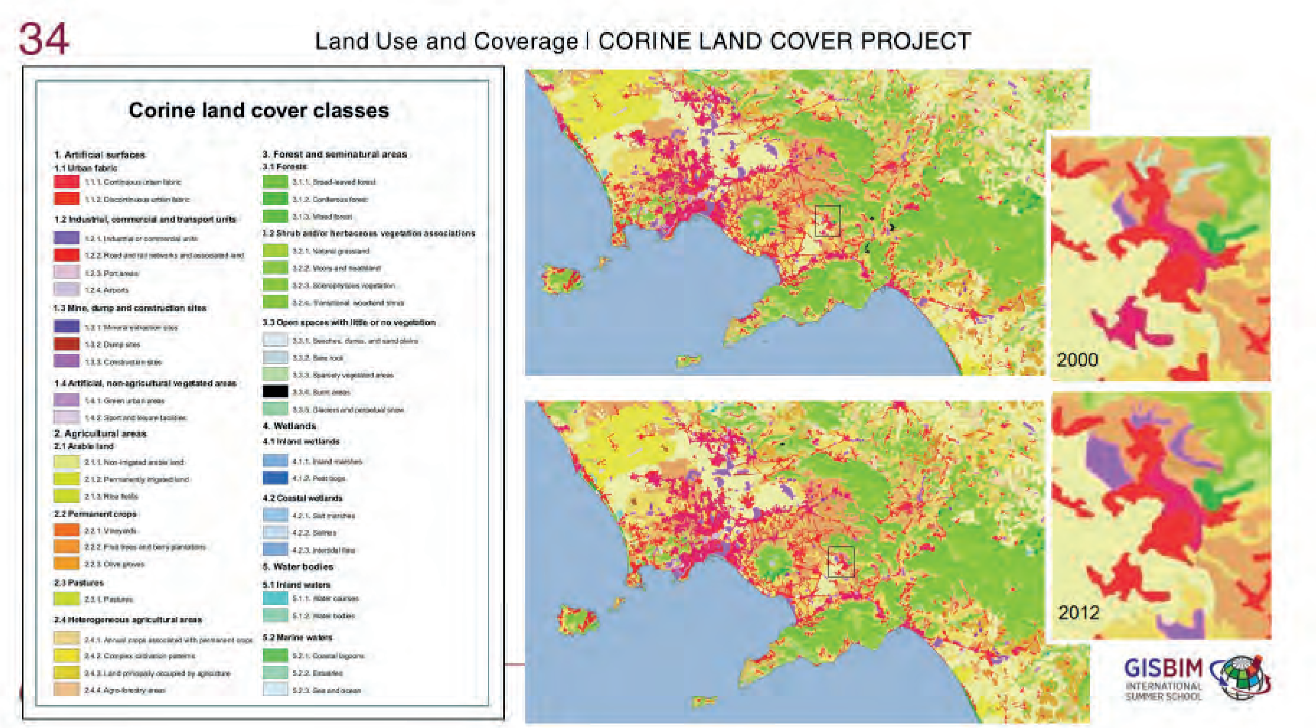
34
Land Use and Coverage | CORINE LAND COVER PROJECT
Corine land cover classes
1. Artificial surfaces
1.1 Urban fabric
1.2 Industrial, commercial and transport units
1.3 Mine, dump and construction sites
1.4 Artificial, non-agricultural vegetated areas
2. Agricultural areas
2.1 Arable land
2.2 Permanent crops
2.3 Pastures
2.4 Heterogeneous agricultural areas
3. Forest and seminatural areas
3.1 Forests
3.2 Shrub and/or herbaceous vegetation associations
3.3 Open spaces with little or no vegetation
4. Wetlands
4.1 Inland wetlands
4.2 Coastal wetlands
5. Water bodies
5.1 Inland waters
5.2 Marine waters
2000
2012
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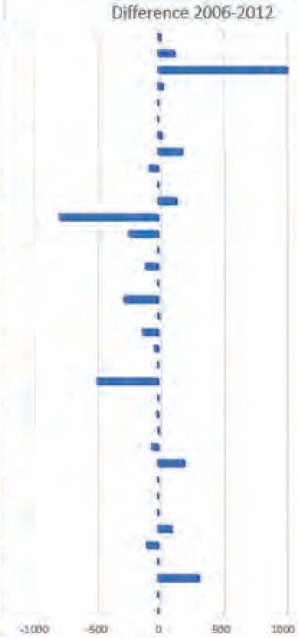
35 Land Use and Coverage | CORINE LAND COVER PROJECT

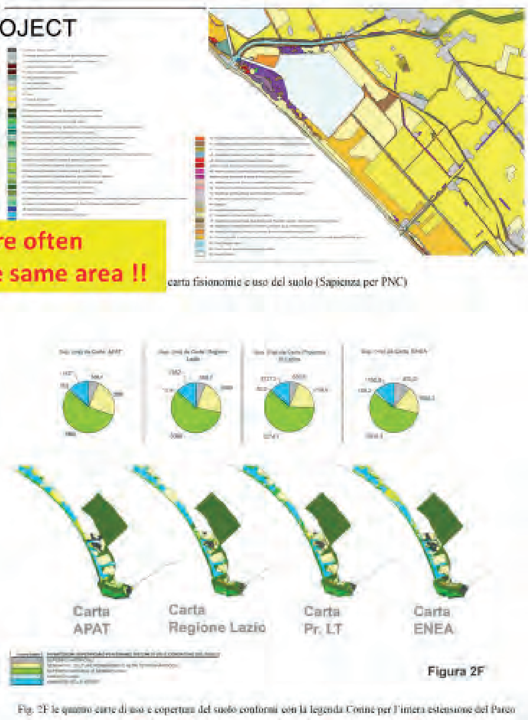
	Description CORINE LAND COVER 3rd Level Classes	CLC lev2	CLC Code	Surface 2000 (ha)	Surface 2006 (ha)	Surface 2012 (ha)	Difference 2000-2006	Difference 2000-2012	Difference 2006-2012	Difference 2006-2012
artificial surf	Continuous urban fabric	11	111	33.292	29.180	29.198	-4.112	-4.094	18	18
	Discontinuous urban fabric		112	43.687	51.940	52.068	8.253	8.381	128	128
	Industrial or commercial units	12	121	8.130	10.955	11.972	2.825	3.842	1.017	1017
	Road and rail networks and associated land		122	435	760	795	325	360	35	35
	Port areas		123	468	479	479	11	11	0	0
	Airports		124	554	554	554	0	0	0	0
	Mineral extraction sites	13	131	1.494	1.647	1.673	153	179	26	26
	Dump sites		132	27	174	365	147	338	191	191
	Construction sites		133	70	245	178	175	108	-67	-67
	Green urban areas	14	141	755	802	802	47	47	0	0
	Sport and leisure facilities		142	615	564	707	-51	92	143	143
agriculture	Non-irrigated arable land	21	211	296.763	281.659	280.883	-15.104	-15.880	-776	-776
	Permanently irrigated land		212	25.412	25.583	25.354	171	-58	-229	-229
	Vineyards	22	221	2.663	3.903	3.903	1.240	1.240	0	0
	Fruit trees and berry plantations		222	54.762	61.693	61.596	6.931	6.834	-97	-97
	Olive groves		223	60.468	65.776	65.775	5.308	5.307	-1	-1
	Pastures	23	231	14.192	13.403	13.136	-789	-1.056	-267	-267
	Annual crops associated with permanent crops		241	43.773	23.369	23.375	-20.404	-20.398	6	6
	Complex cultivation patterns	24	242	161.992	181.073	180.952	19.081	18.960	-121	-121
	Land occupied by agric., with significant areas of natural veget.		243	88.860	94.983	94.956	6.123	6.096	-27	-27
	Agro-forestry areas		244	418	141	141	-277	-277	0	0
forest & semi	Broad-leaved forest	31	311	367.183	363.464	362.985	-3.719	-4.198	-479	-479
	Coniferous forest		312	8.115	7.584	7.584	-531	-531	0	0
	Mixed forest		313	9.392	9.366	9.360	-26	-32	-6	-6
	Natural grasslands	32	321	53.053	48.152	48.159	-4.901	-4.894	7	7
	Sclerophyllous vegetation		323	18.432	16.976	16.928	-1.456	-1.504	-48	-48
	Transitional woodland-shrub		324	52.042	52.736	52.944	694	902	208	208
	Beaches, dunes, sands	33	331	1.842	1.825	1.825	-17	-17	0	0
	Bare rocks		332	1.000	974	974	-26	-26	0	0
	Sparsely vegetated areas		333	6.731	6.406	6.406	-325	-325	0	0
	Burnt areas		334	353	436	542	83	189	106	106
wetlands	Inland marshes	41	411	482	386	296	-96	-186	-90	-90
water	Water courses	51	511	793	746	746	-47	-47	0	0
	Water bodies		512	1.368	1.681	2.003	313	635	322	322
	Coastal lagoons	52	521	26	26	26	0	0	0	0
	Sea and ocean		523	294	291	291	-3	-3	0	0



36 Land Use and Coverage | CORINE LAND COVER PROJECT

CLC Level 1	CLC Level 2	CLC Level 3	Ecosystem types level 2
1. Artificial surfaces	1.1. Urban fabric	1.1.1. Continuous urban fabric	Urban
		1.1.2. Discontinuous urban fabric	
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units	
		1.2.2. Road and rail networks and associated land	
		1.2.3. Port areas	
		1.2.4. Airports	
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites	
		1.3.2. Dump sites	
		1.3.3. Construction sites	
	1.4. Artificial non-agricultural vegetated areas	1.4.1. Green urban areas	
		1.4.2. Sport and leisure facilities	
2. Agricultural areas	2.1.Arable land	2.1.1. Non-irrigated arable land	Cropland
		2.1.2. Permanently irrigated land	
		2.1.3. Rice fields	
	2.2. Permanent crops	2.2.1. Vineyards	
		2.2.2. Fruit trees and berry plantations	
		2.2.3. Olive groves	
	2.3. Pastures	2.3.1. Pastures	Grassland
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops	Cropland
		2.4.2. Complex cultivation patterns	
		2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation	
		2.4.4. Agro-forestry areas	
3. Forests and semi-natural areas	3.1. Forests	3.1.1. Broad-leaved forest	Woodland and forest
		3.1.2. Coniferous forest	
		3.1.3. Mixed forest	
	3.2. Shrub and/or herbaceous vegetation association	3.2.1. Natural grassland	Grassland
		3.2.2. Moors and heathland	Heathland and shrub
		3.2.3. Sclerophyllous vegetation	
		3.2.4. Transitional woodland shrub	Woodland and forest

1.X Coverages and Uses are often different and mixed in the same area !!



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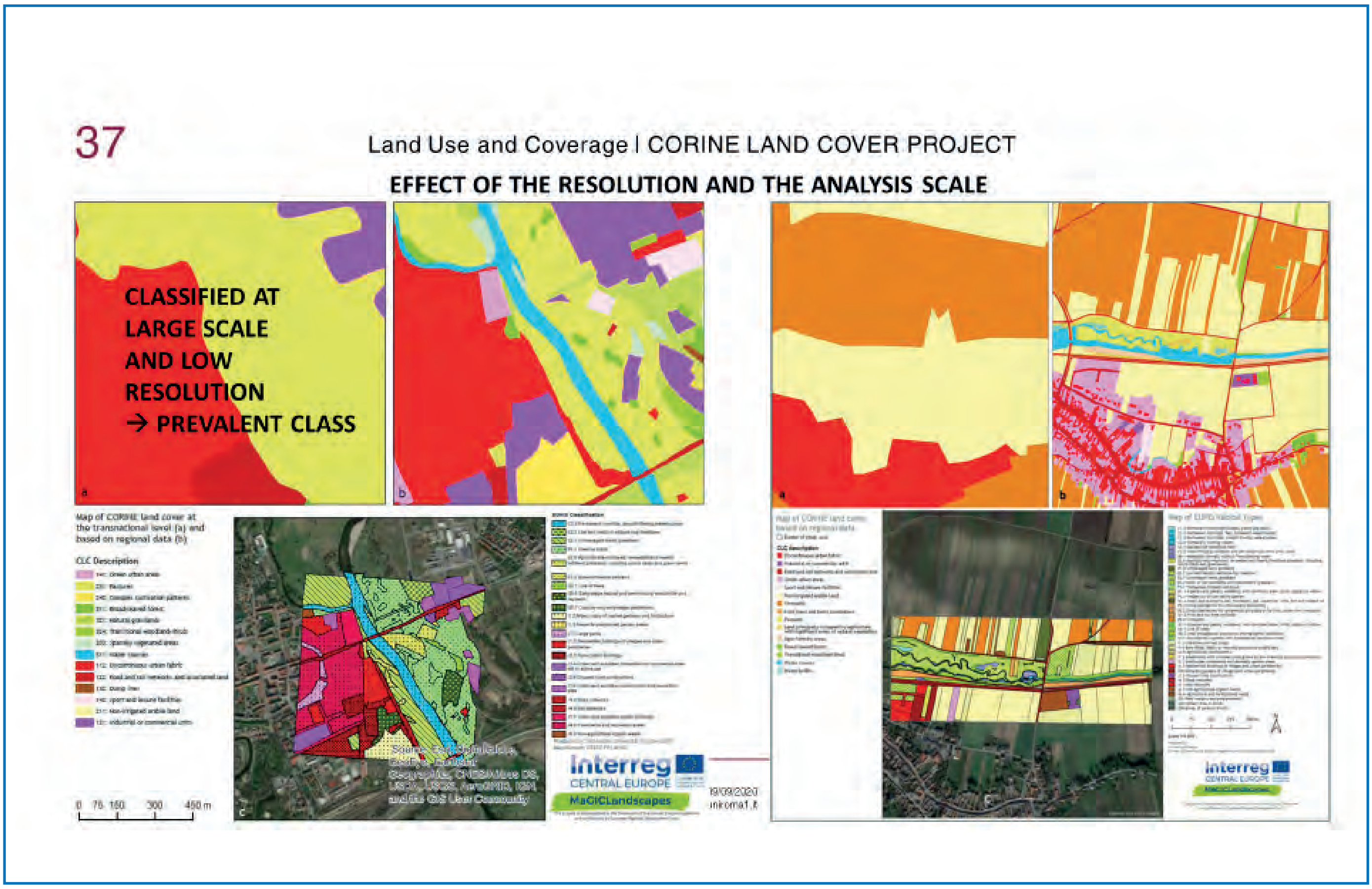
37
Land Use and Coverage I CORINE LAND COVER PROJECT
EFFECT OF THE RESOLUTION AND THE ANALYSIS SCALE
CLASSIFIED AT
LARGE SCALE
AND LOW
RESOLUTION
→ PREVALENT CLASS
Interreg
CENTRAL EUROPE
MaGICLandscapes
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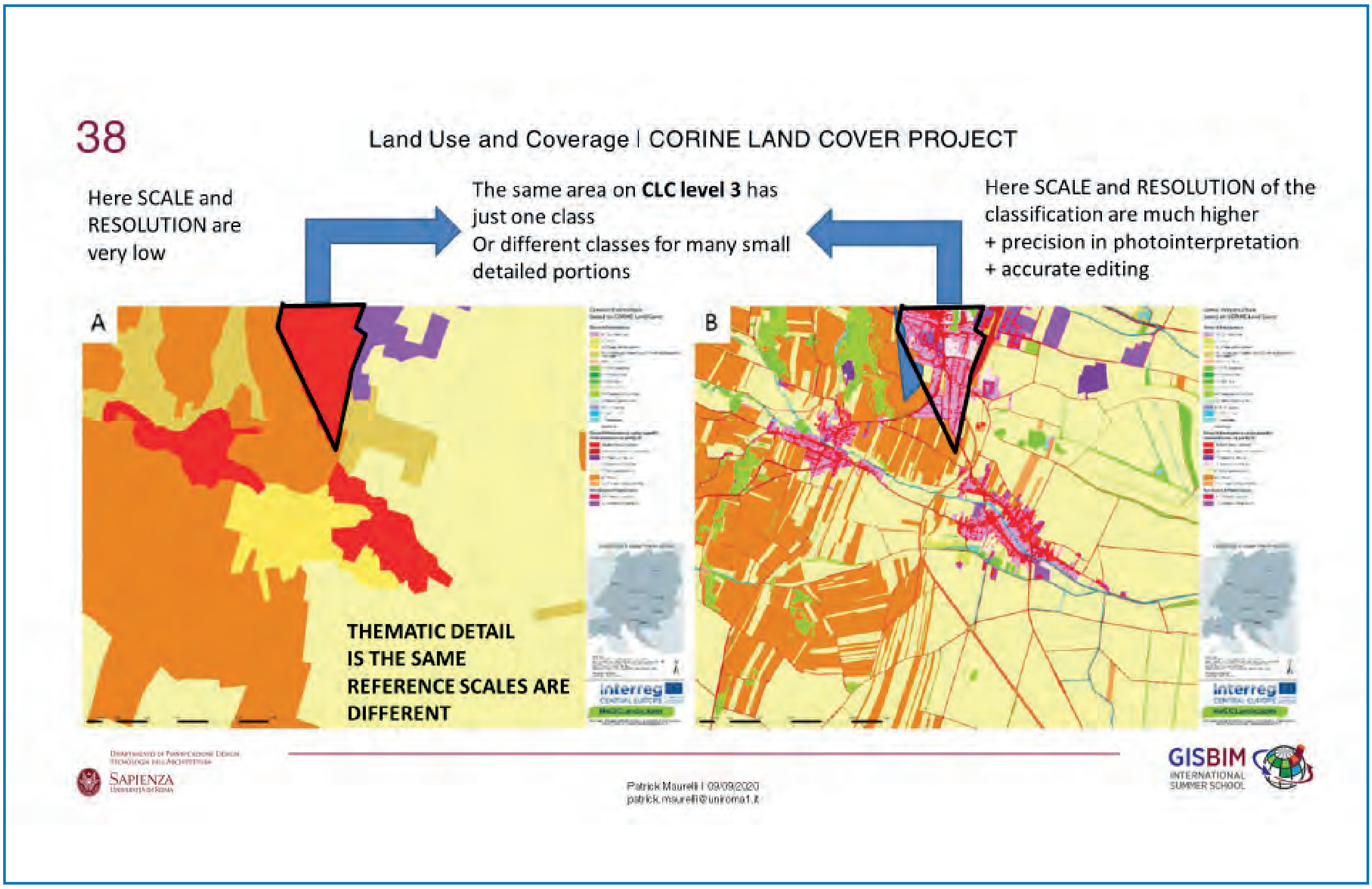
38
Land Use and Coverage I CORINE LAND COVER PROJECT
Here SCALE and
RESOLUTION are
very low
The same area on CLC level 3 has
just one class
Or different classes for many small
detailed portions
Here SCALE and RESOLUTION of the
classification are much higher
+ precision in photointerpretation
+ accurate editing
A
B
THEMATIC DETAIL
IS THE SAME
REFERENCE SCALES ARE
DIFFERENT
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GIS BIM INTEGRATION I LAND USE & COVERAGE

What if we raise GIS scale and level of Analysis ? → we can build new CLC sub-classes

Inside the smaller administrative/analysis zone we can deepen the details on Land Use Coverage using BIM

CORINE LAND COVER can raise the THEMATIC DETAIL → **raising classification levels (sub-categories 1.1.1.1.x)**
→ **raising the scale of analysis (photointerpretation)**

Example: Urban Fabric Continuous and Dense (1.1.1.1 Region Lazio)

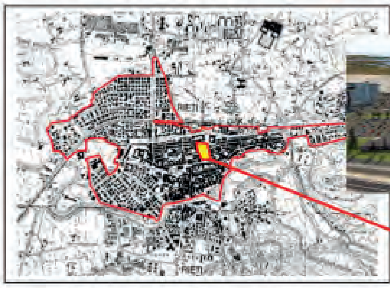
1.1.1.1 class can be splitted into other typologies using detailed informations coming from BIM

- **1.1.1.1.1**
- **1.1.1.1.2**
- **1.1.1.1.3**
- **1.1.1.1.4**

1.1.1.2

...

1.2.2.1 (Roads ...)
1.2.2.2
1.2.2.3 + 1.2.2.4



Parking Area 1.2.2.4

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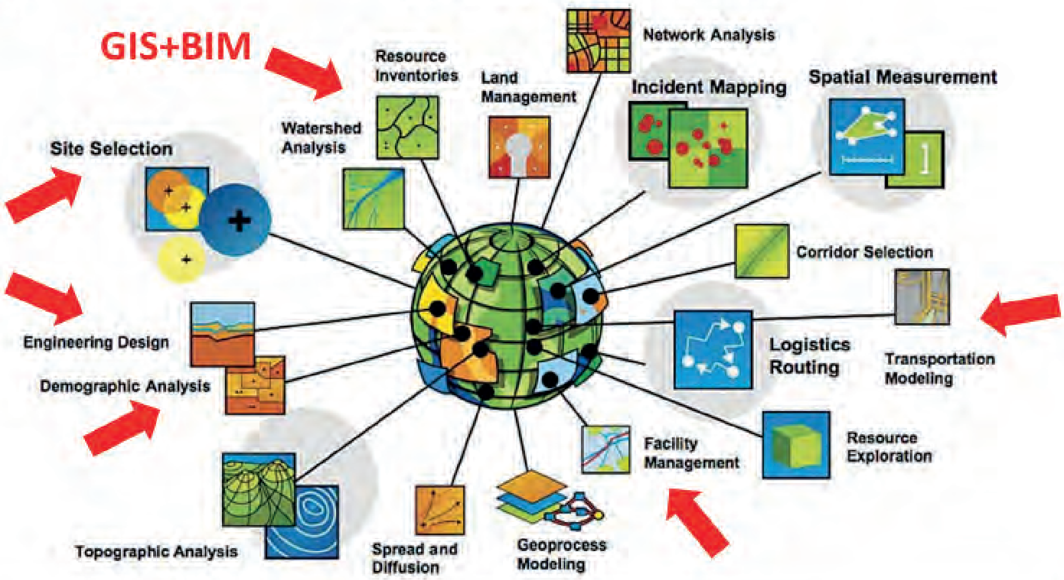
GIS APPLICATIONS I An Overview



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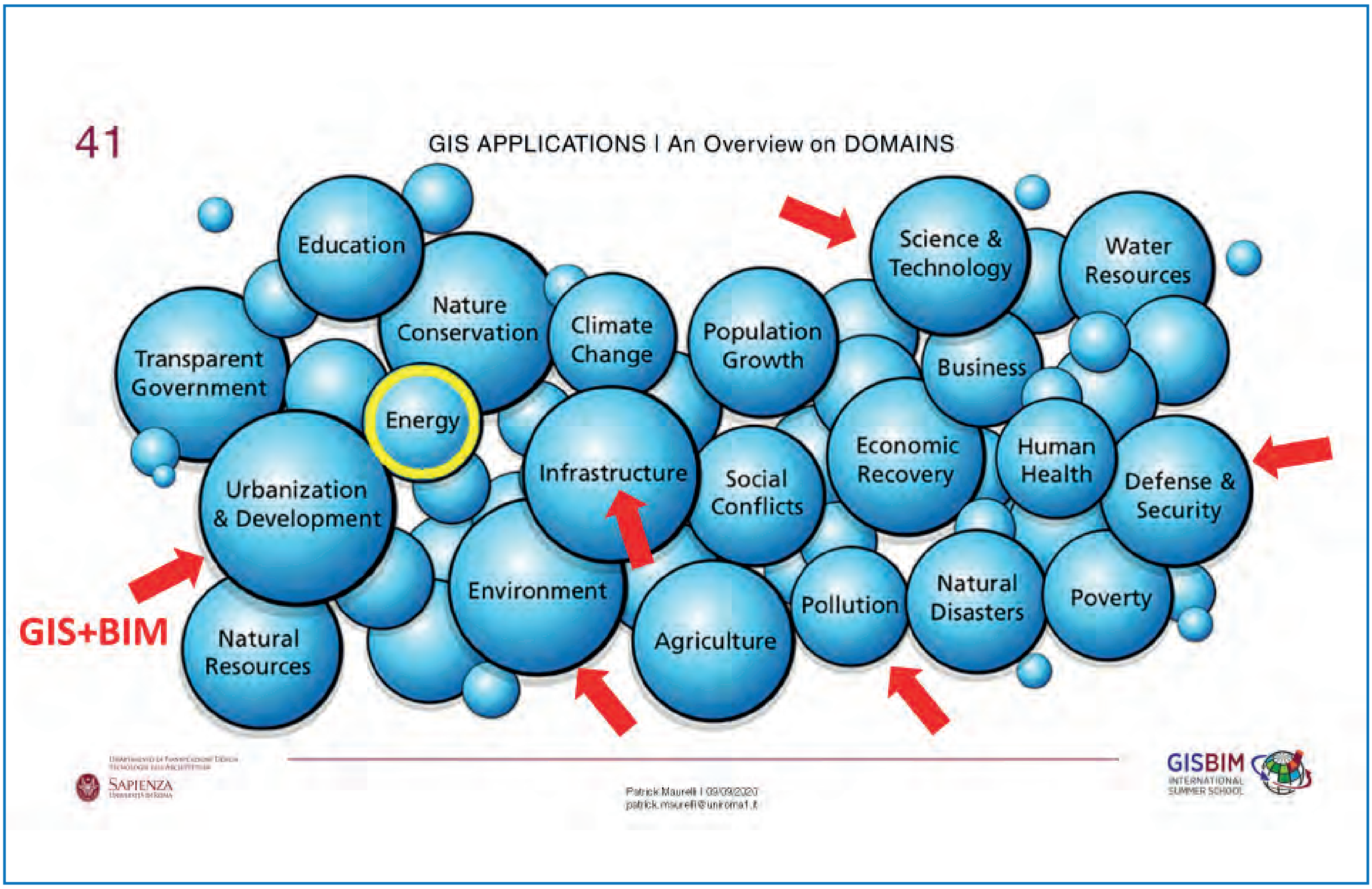
41
GIS APPLICATIONS I An Overview on DOMAINS
Education
Nature Conservation
Climate Change
Population Growth
Science & Technology
Water Resources
Transparent Government
Energy
Business
Urbanization & Development
Infrastructure
Social Conflicts
Economic Recovery
Human Health
Defense & Security
GIS+BIM
Natural Resources
Environment
Agriculture
Pollution
Natural Disasters
Poverty
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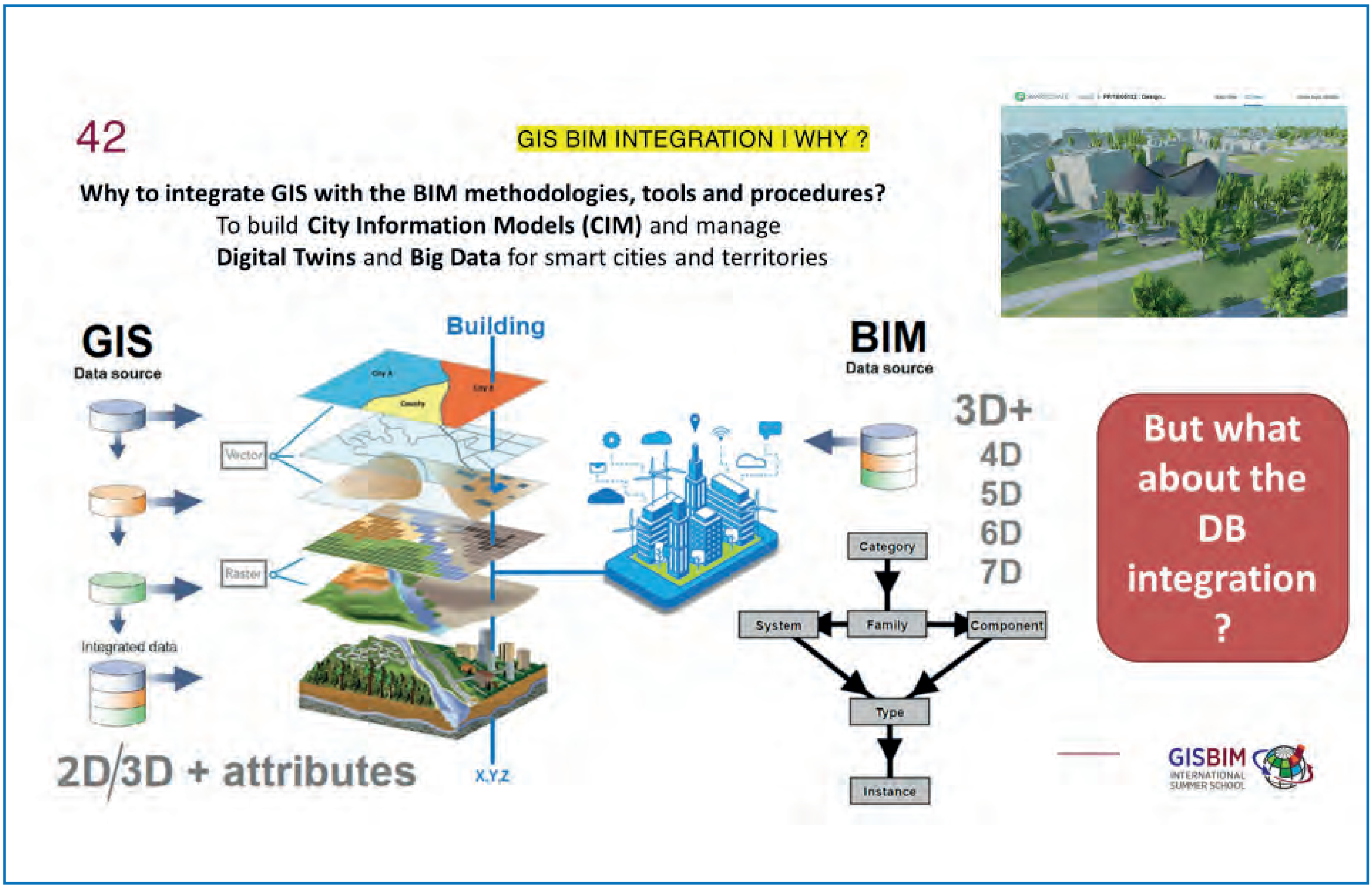
42
GIS BIM INTEGRATION I WHY ?
Why to integrate GIS with the BIM methodologies, tools and procedures?
To build City Information Models (CIM) and manage
Digital Twins and Big Data for smart cities and territories
GIS
Data source
Building
BIM
Data source
Vector
Raster
Integrated data
3D+
4D
5D
6D
7D
Category
System
Family
Component
Type
Instance
But what about the DB integration ?
2D/3D + attributes
X,Y,Z
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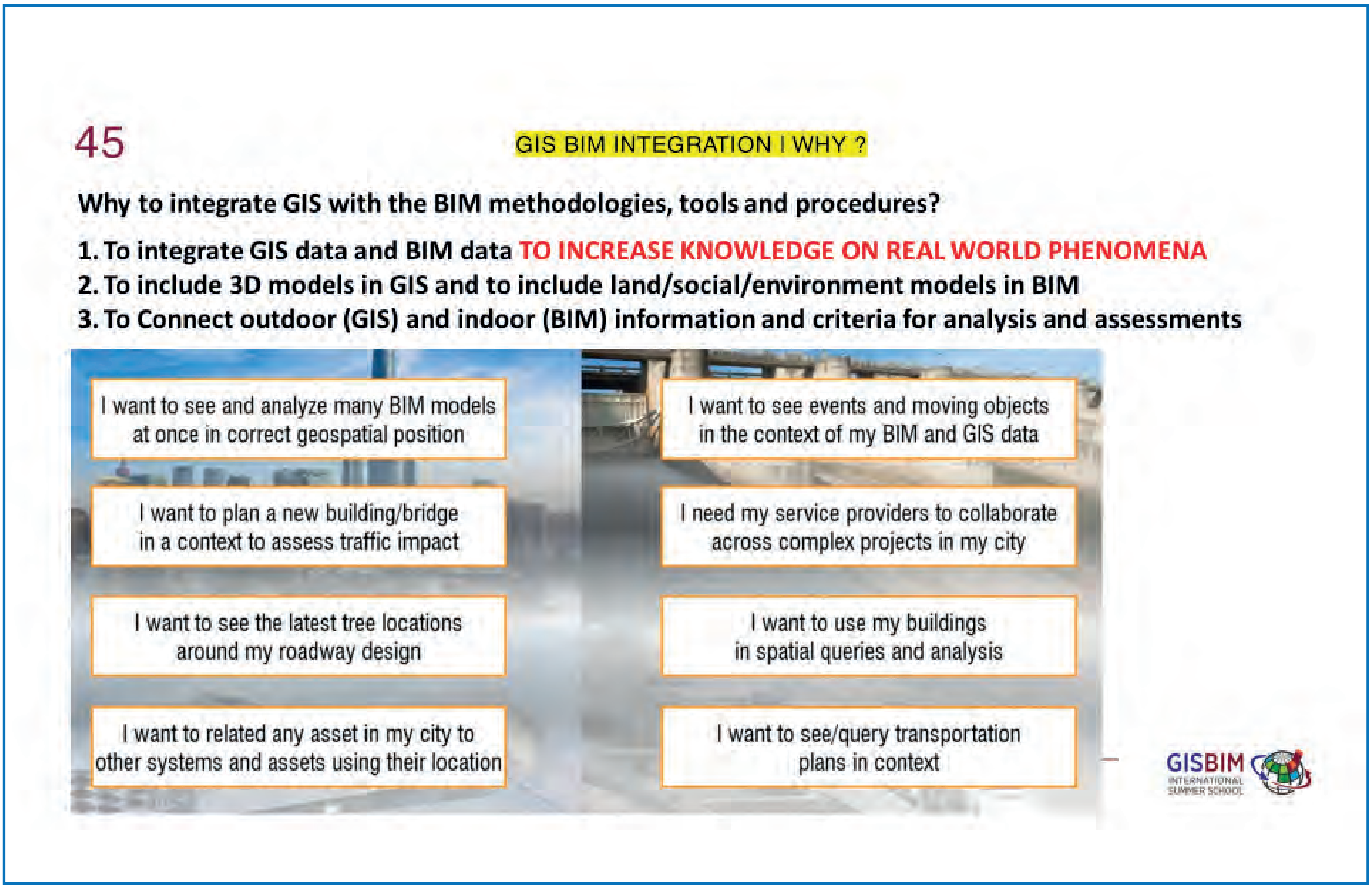
45
GIS BIM INTEGRATION I WHY ?
Why to integrate GIS with the BIM methodologies, tools and procedures?
1. To integrate GIS data and BIM data TO INCREASE KNOWLEDGE ON REAL WORLD PHENOMENA
2. To include 3D models in GIS and to include land/social/environment models in BIM
3. To Connect outdoor (GIS) and indoor (BIM) information and criteria for analysis and assessments
I want to see and analyze many BIM models at once in correct geospatial position
I want to see events and moving objects in the context of my BIM and GIS data
I want to plan a new building/bridge in a context to assess traffic impact
I need my service providers to collaborate across complex projects in my city
I want to see the latest tree locations around my roadway design
I want to use my buildings in spatial queries and analysis
I want to related any asset in my city to other systems and assets using their location
I want to see/query transportation plans in context
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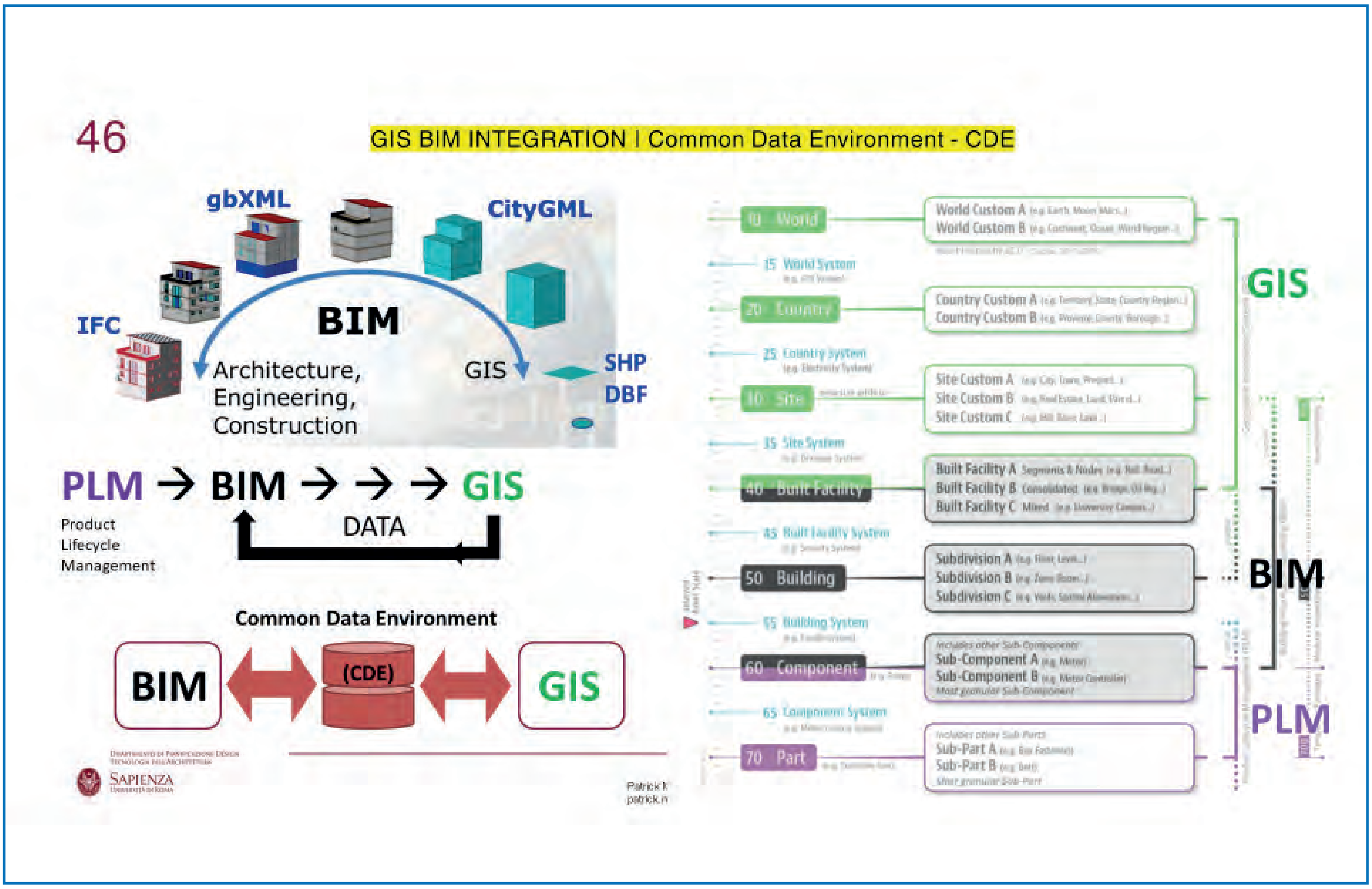
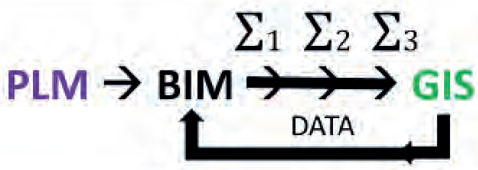

46
GIS BIM INTEGRATION I Common Data Environment - CDE
gbXML
CityGML
IFC
BIM
Architecture,
Engineering,
Construction
GIS
SHP
DBF
PLM → BIM → → → GIS
Product
Lifecycle
Management
DATA
Common Data Environment
BIM
(CDE)
GIS
SAPIENZA
10 World
World Custom A
World Custom B
15 World System
20 Country
Country Custom A
Country Custom B
25 Country System
30 Site
Site Custom A
Site Custom B
Site Custom C
35 Site System
40 Built Facility
Built Facility A
Built Facility B
Built Facility C
45 Built Facility System
50 Building
Subdivision A
Subdivision B
Subdivision C
55 Building System
60 Component
Sub-Component A
Sub-Component B
65 Component System
70 Part
Sub-Part A
Sub-Part B
GIS
BIM
PLM

47 GIS BIM INTEGRATION | MODELS & OPERATIONS

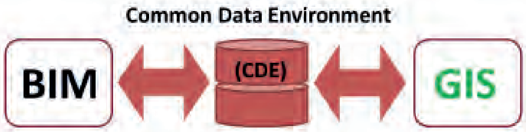
Which models for GIS and BIM interoperability ?
- 3D modelling in GIS environment
- Or Geographic / (Geo)spatial models in BIM environment ??

DATA FLOWS in GIS-BIM integrated environment:

- **BIM feeding GIS** Data through aggregation and summarize
- **GIS feeding BIM** with OUTDOOR context related data



Standardisation of data structures and interchange formats: sharing and integrated management of spatial data through the **Common Data Environment (CDE).**



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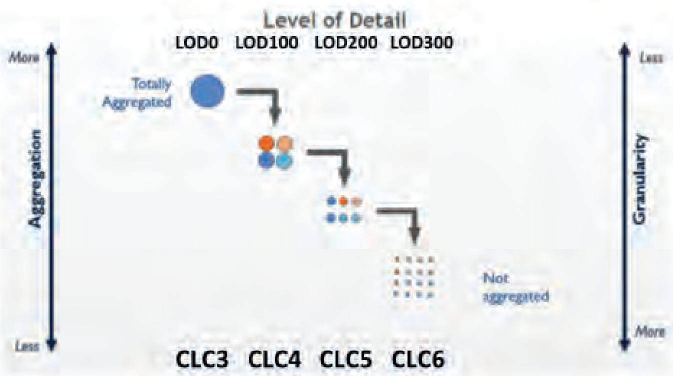
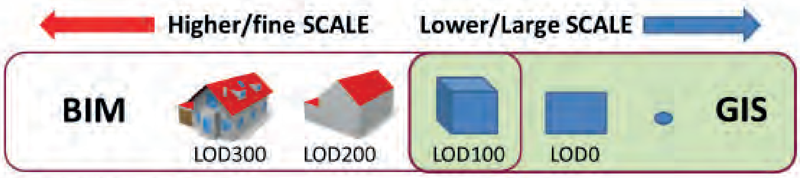
48 GIS BIM INTEGRATION | MODELS & OPERATIONS

Relations among concepts

in GIS
SCALE → **REFERENCE SCALE** of GeoSpatial Data
Informative details and domains → **THEMATIC DETAIL**

in BIM
LOD Level of Detail
GRANULARITY





LOD100 Is the Common level

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GIS BIM INTEGRATION I MODELS & OPERATIONS

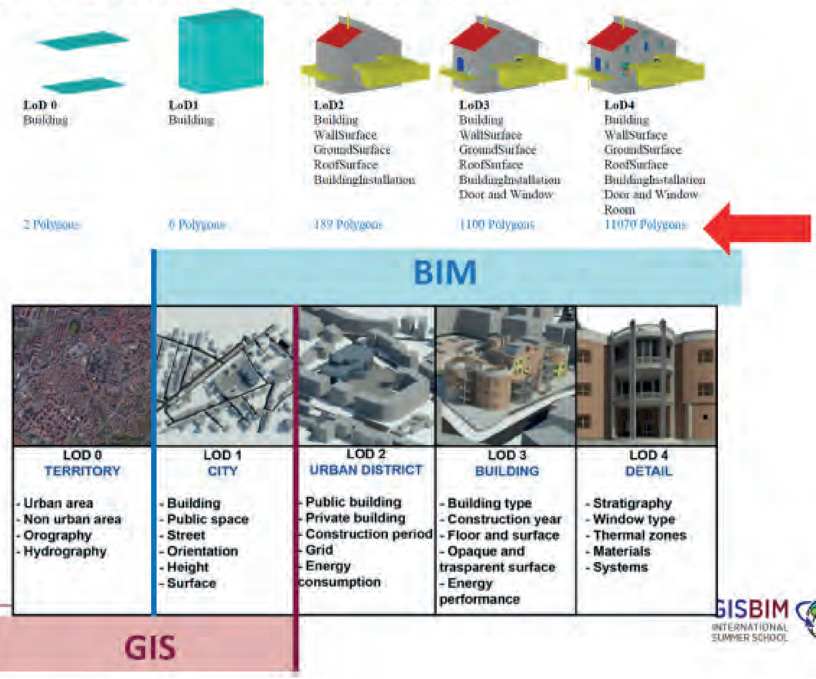
Relations among concepts

GIS REFERENCE SCALE
GIS THEMATIC DETAIL

BIM LOD
BIM GRANULARITY

GIS manages **BIG DATA** at large scale and for wide thematic detail and domains

BIM manages **BIG DATA** at fine scale and for high LOD and Granularity



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GIS BIM INTEGRATION I APPLICATIONS OVERVIEW

Some GIS-BIM applications to be further developed:

- **Complex Buildings Asset Management** (Design and/or Maintenance);
- **Design and Maintenance process for linear infrastructures;**
- **Environmental Impact Assessment of infrastructures or complex buildings**
- **Tri-dimensional Cadastre**
- Multi-scale **Urban Quality Assessment**
- **Real Estate Quality Assessment**
- **Energy analysis of Buildings Performances**
- PEB/PED Planning and Design (**Positive Energy Blocks/Districts)**
- **Smart Grids & Energy Communities** Design and Assessment
- Positioning Planning and Design of **Eco-Villages / Eco-Neighbourhoods**
- Increasing the detail of **Land Use & Coverage maps**
- Improving **Noise Pollution Mapping**
- **Age Friendly design and certification** for buildings and zones
- ....
- → improved **Suitability Analysis** in many domains

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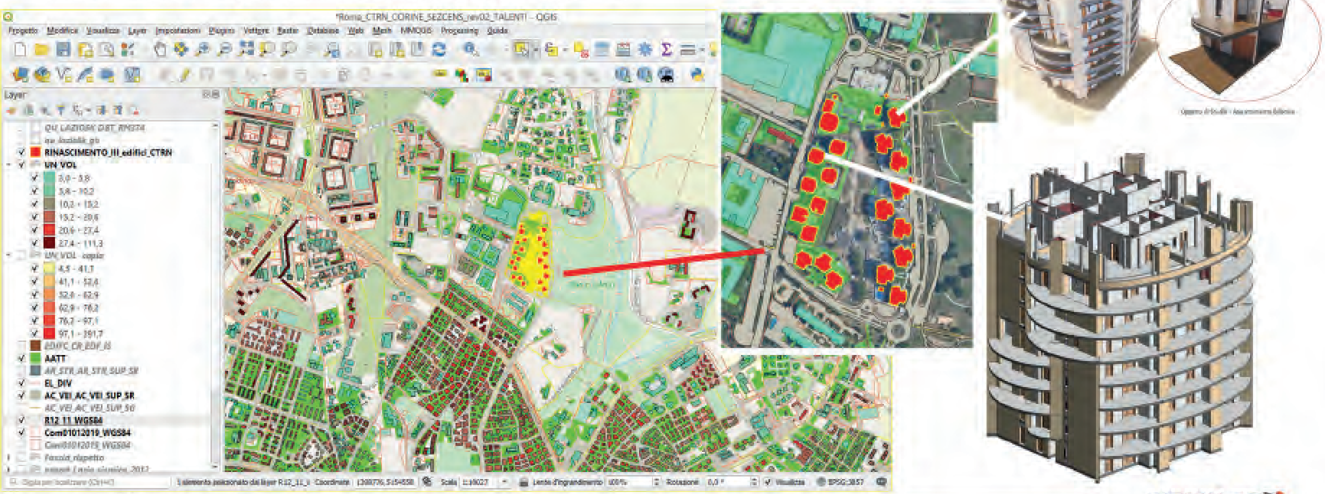
52 GIS BIM INTEGRATION I REAL ESTATE QUALITY ASSESSMENT

- Urban integrated planning & design 都市整合规划及设计
- Large Asset Management 大型资产管理
- Multi-scale Analysis & Assessment 多尺度分析与评估



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53 GIS BIM INTEGRATION I REAL ESTATE QUALITY ASSESSMENT

Real Estate Value Assessment

↓

GIS APPLICATION

+

Some BIM Analysis

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54 GIS BIM INTEGRATION I REAL ESTATE QUALITY ASSESSEMENT

Case study: the analysis of REAL ESTATE values , integrating indoor and outdoor values.
which informations from BIM scale can we add to GIS analysis?

GIS APPLICATION

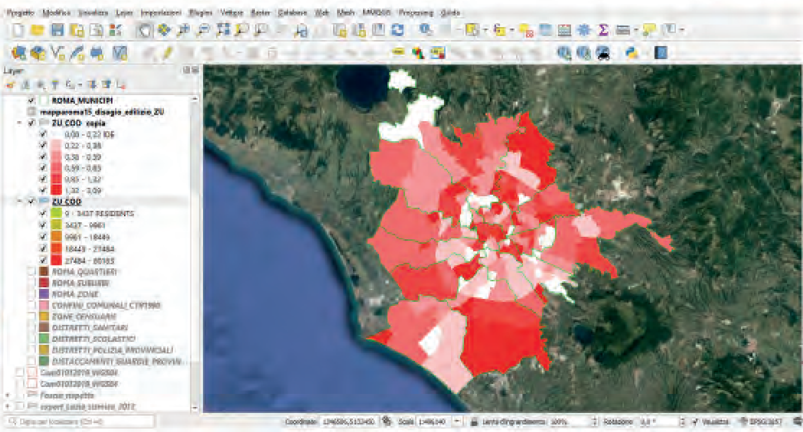
Residential	Impact factors	Descriptions	Analysis methods
Regional factors	Regional planning	Urban master planning & detailed planning etc.	Spatial query, spatial overlay
	Regional prosperity	Distance to multilevel business area	Spatial measurement, network analysis
	Transportation convenience	The number and distance of public transportation facilities (e.g. bus stop, subway stations, etc.) and road network service capabilities	Spatial measurement, network analysis, road network accessibility analysis, spatial statistics
	Landscape	The view of quality and distance to ocean, lake, mountain, green, forest park or golf course etc.	Visibility analysis, spatial measurement, spatial statistics
	Environmental condition	The air condition, noise, pollution, waste yard, incineration plant, power station, high-voltage power lines, etc. and the sunshine time	Spatial query, noise propagation analysis, pollutants diffusion analysis, visibility analysis, spatial statistics, BIM sunlight duration analysis, BIM community ventilation analysis **BIM**
	Fundamental infrastructure	The surrounded fundamental infrastructure, such as, water, electricity, gas, communications, cable, internet, wireless local area network, etc.	Spatial query, spatial statistics
	Public facility conditions	The distance to public facilities such as school, park, sport center, hospital, bank, ATM, supermarket, shopping mall, convenience store, theatre, etc.	Spatial query, spatial statistics

55 GIS BIM INTEGRATION I URBAN QUALITY ASSESSMENT

Case Study: For deepening the analysis of urban values , integrating indoor and outdoor values,
which informations from BIM scale can we add to GIS analysis?

We can Aggregate BIM informations to enrich
The ***building hardship index***, calculated for Rome urban areas, which compares the **state of conservation of the buildings** with the **deviation from national average value of the buildings**

Add BIM data :
....



Add BIM data :
....

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56 GIS BIM INTEGRATION I URBAN QUALITY ASSESSMENT

Case Study: For deepening the analysis of urban values , integrating indoor and outdoor values, which informations from BIM scale can we add to GIS analysis?

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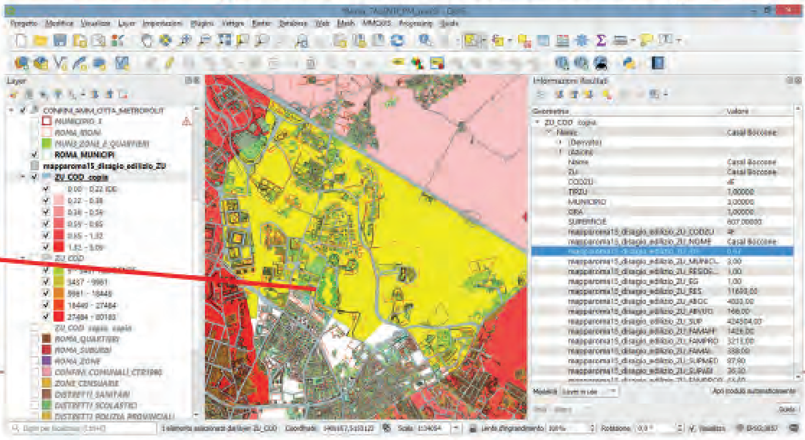
The ***Building Discomfort Index***, calculated for Rome urban areas, which compares the **state of conservation of the buildings** with the **deviation from national average value of the buildings**

Add BIM data :
....



Add BIM data :
....
CALCULATE VALUE OF THE BUILDING USING INDOOR QUALITIES

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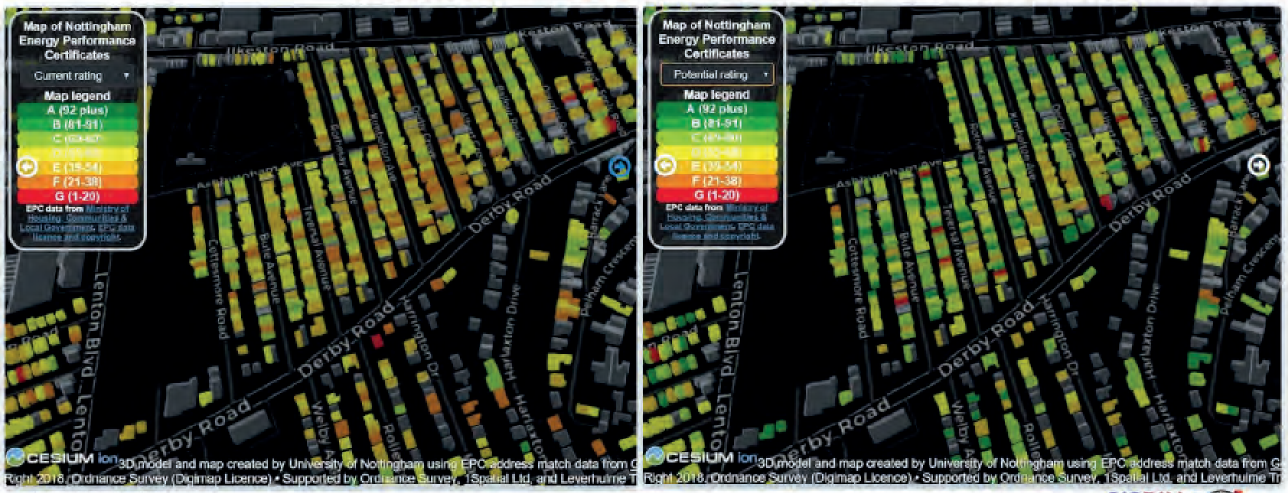
57 **District Scale Energy Analysis| EPC for BUILDINGS**

GIS analyses Distribution of Energy Performance Certificates (current & Potential) for single unit buildings, BUT WHAT IF we have Multiple Units Buildings with several EPCs for each one ?

→ **we need to summarize BIM data** to obtain an index for **Buildings Energy Performances**



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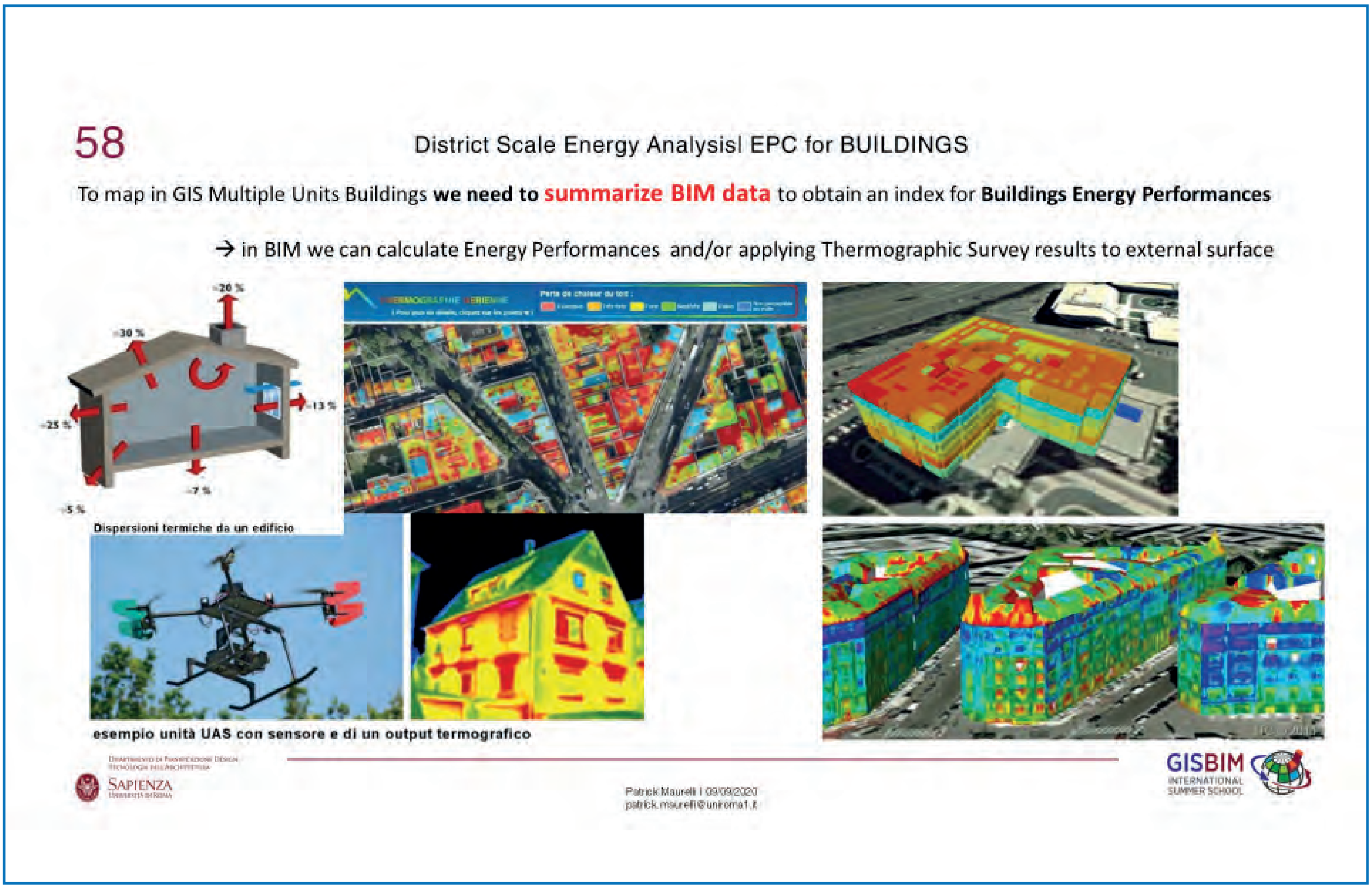
58
District Scale Energy AnalysisI EPC for BUILDINGS
To map in GIS Multiple Units Buildings we need to summarize BIM data to obtain an index for Buildings Energy Performances
→ in BIM we can calculate Energy Performances and/or applying Thermographic Survey results to external surface
-20 %
-30 %
-13 %
-25 %
-7 %
-5 %
Dispersioni termiche da un edificio
esempio unità UAS con sensore e di un output termografico
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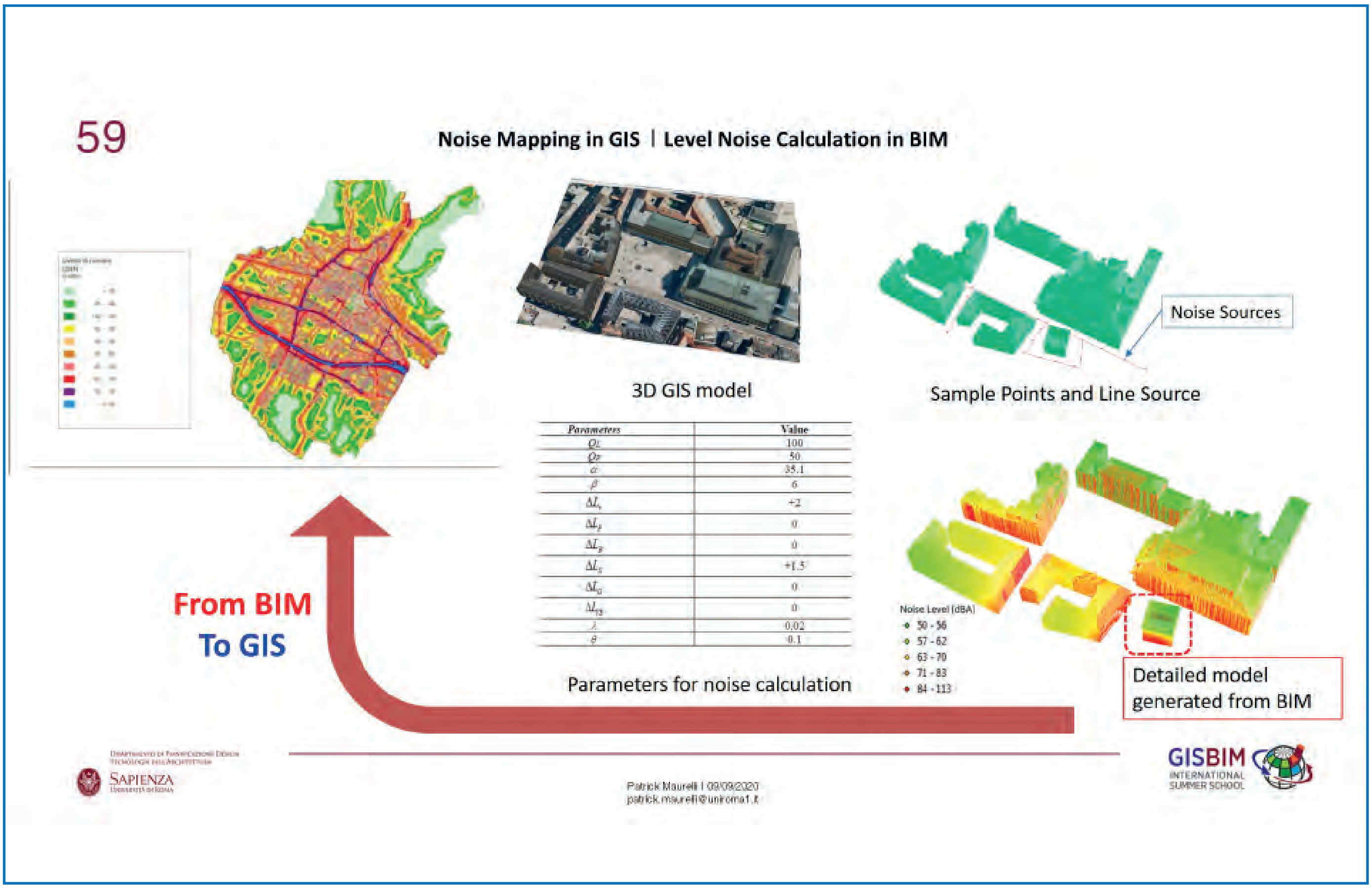
59
Noise Mapping in GIS I Level Noise Calculation in BIM
3D GIS model
Noise Sources
Sample Points and Line Source
Parameters Value
QL 100
50
α 35.1
β 6
ΔL +2
ΔL 0
ΔL 0
ΔL +1.5
ΔL 0
ΔL 0
λ 0.02
θ 0.1
Parameters for noise calculation
Noise Level (dBA)
50 - 56
57 - 62
63 - 70
71 - 83
84 - 113
Detailed model generated from BIM
From BIM
To GIS
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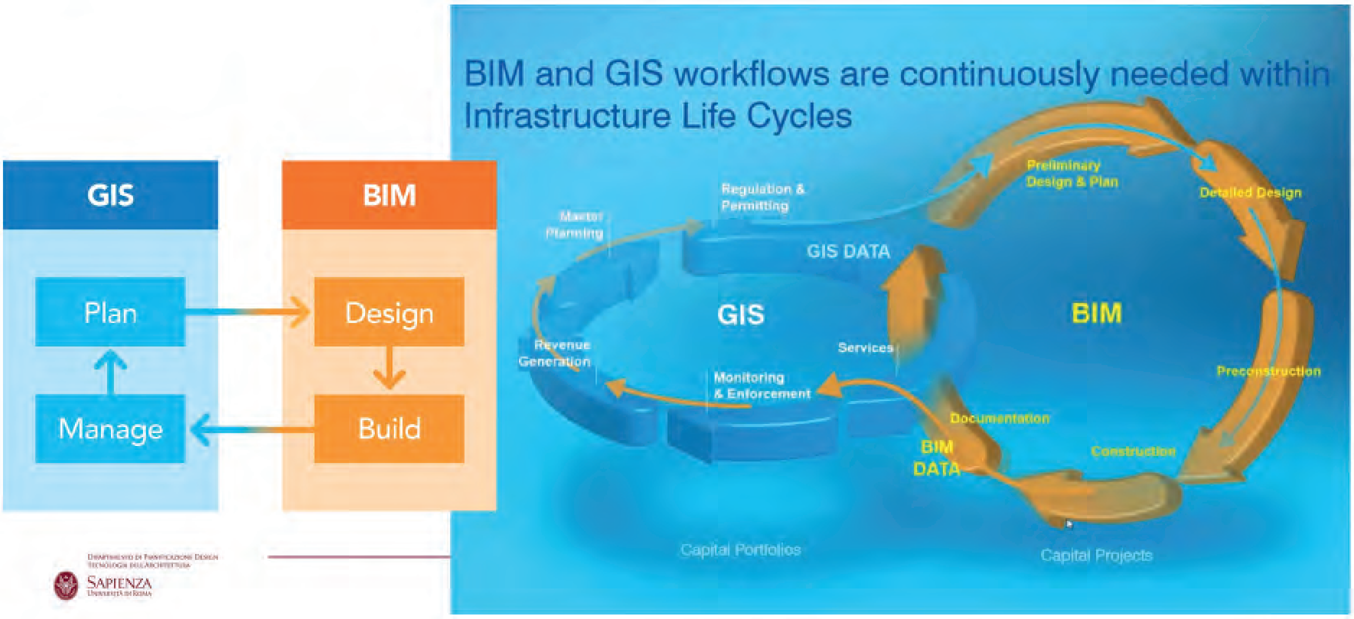
60 GIS BIM INTEGRATION | next future



61 GIS BIM INTEGRATION | next future


63
GIS BIM INTEGRATION I next future
Revit Workflows in ArcGIS Pro
Publishing to AGOL / Enterprise 10.7
Use Create Building Scene Layer Package tool (new in Pro 2.3)
BuildingSceneLayer with Slice widget
Revit and ArcGIS Pro
Revit is Autodesk's BIM application utilized by designers for vertical BIM
Revit models (.RVT) includes spatial data and related non-spatial information
ArcGIS Pro 2.3 supports Autodesk Revit 2015 through 2019 file formats (*.RVT)
Default Behavior
REVIT File
WALLS
ROOFS
WINDOWS
DOORS
FLOORS
<CATAGORIES>
Direct Read Map Layers
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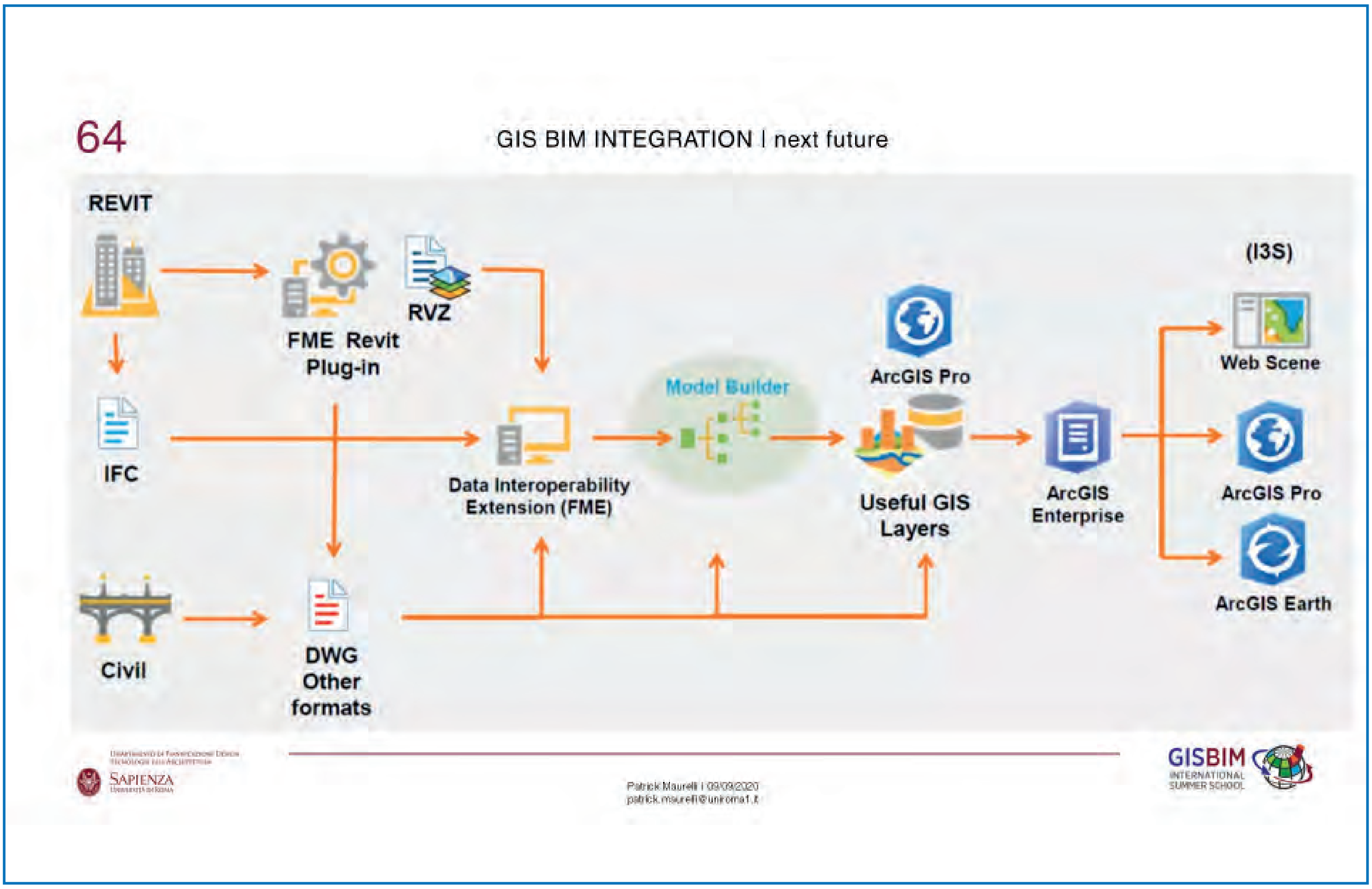
64
GIS BIM INTEGRATION I next future
REVIT
FME Revit Plug-in
RVZ
IFC
Data Interoperability Extension (FME)
Model Builder
ArcGIS Pro
Useful GIS Layers
ArcGIS Enterprise
(I3S)
Web Scene
ArcGIS Pro
ArcGIS Earth
Civil
DWG Other formats
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Digital methods and tools in the construction process for efficient project management workflows: case histories

Sofia Agostinelli
CITERA - Interdepartmental Research Centre for Territory, Architecture, Heritage and Environment
Sapienza University of Rome

Buildings are becoming far more than walls, roofs and masonry: thanks to Artificial Intelligence (AI), building systems are becoming able to autonomously integrate the proliferation of data from IoT devices and occupant behavior to apply learning, optimize performance and improve environmental efficiency. As AI is integrated with building systems and Internet of Things (IoT) devices, it has the potential to improve occupant experience, increase operational efficiency and optimize space and asset utilization.

A vast array of information from digital devices provides insights about the operations, use and condition of everything from the building's infrastructure, physical environment, climate, water and energy usage, to an occupant's experience and satisfaction, then IoT and platforms embedded with Artificial Intelligence and machine learning make it possible to develop innovative new services for engaging with building occupants. These systems have the potential to radically reduce costs through automation and optimization of operations.

By taking advantage of powerful analytics and Artificial Intelligence for example, building owners can significantly cut energy consumption and achieve ambitious cost-saving targets. After equipment performance information is collected through sensors and meters, a library of benchmark data is applied, analytics are performed and potential operational improvements are identified.

Analytics can also be used to prevent energy waste by isolating inefficient energy use. Sensor-controlled systems can monitor dispensing and water use. Cognitive maintenance systems can help preserve the health of critical building equipment and assets by anticipating asset failure and guiding timely interventions and so on.

A comprehensive building optimization system leverages all aspects of building and facility management. These types of systems allow for monitoring the use of space, water and the usage and allocation of energy. Taking this monitoring one step further, building equipment data collected from IoT sensors that is tagged by location or asset type and associated with business rules can trigger algorithms to not only detect but also predict and respond to anomalies. These optimized ecosystems of building technologies identify opportunities for efficiency controls through predictive maintenance. They identify possible root causes, so actions can be prioritized, assigned, monetized and prevented, as recommendations that appear on dashboards or adjustments can be routed directly to the IoT device for action.

AI is able to capture data from day-to-day building operations to enable new levels of automation, which enables buildings to "think," engage and learn. These buildings can autonomously monitor and predict their own maintenance needs. Data transmitted from connected assets, such as boilers, pumps, chillers and elevators, is analyzed and enriched to identify anomalies, such as equipment operating outside of normal parameters. Potential failure modes are identified from tolerance and business rules, and devices are automatically instructed to take corrective action. The building memorizes the result of the intervention so it can improve the accuracy of detection and resolution of future incidents.

The integration of cognitive analytics, sensors and existing building systems can also significantly improve occupant experience. Envision going to work in a building that works for you. While you're there, IoT sensors are constantly monitoring your movement and the temperature. It turns lights on and off for you, adjusts the flow of water in restrooms and listens for your voice commands. Even breaths are monitored for carbon dioxide concentration in case an airflow adjustment is needed. And when the building detects that people have left their assigned workspaces, it turns on the lights in the parking garage, places the building systems into rest mode and checks tomorrow's weather.

This kind of approach to problem solving is related to simulation modelling, which aims at reproducing in a virtual environment the behavior of a non-linear dynamic system. It serves as a digital testbed where one can assess ex-ante different strategies over a simulated time-horizon.

The development of the Digital Twin therefore begins with an integrated Information Model, in the case of buildings this is the so-called BIM (Building Information Model), able to contain data and information useful to simulate the process, which in communication with data from sensors becomes a Digital Twin with learning capabilities, able to process the information received. Artificial Intelligence algorithms then allow the Digital Twin to develop predictive capabilities and finally to make and implement autonomous decisions based on the analysis performed.

The project aims to investigate, build and test methods and approaches that respond to the challenges proposed by the increasingly necessary digitization of industrial processes, as a true digital management, which combined with the growing potential of Artificial Intelligence and machine learning, allows to manage, optimize and automate the phases of construction processes, with particular regard to the management phase of processes related to the life cycle of the built environment.

As already mentioned, the key word is management: in particular it is explored a case history about the Digital Twin-based management of a portion of city, in the specific case of a residential area located in Rome and composed of 16 buildings. The goal is to build a digital process and ecosystem based on three-dimensional information models that are able to replicate physical objects, such as buildings, and especially manage and monitor their interactions with reality.

The Digital Twin of a residential system can therefore be a key tool for the storage, visualization, analysis and creation of data useful for the management of urban life and, considering the absolute centrality of data in the realization of digital processes, an important development consists in the integrated use of GIS and BIM, aimed at the information management and processing of information both at the scale of the building and at the geographical and territorial scale. BIM and GIS, although they share the essential concept of description of the real world through the combination of visual representations and information, are conceived and developed as belonging to different domains, and therefore have differences also and especially in the level of detail. BIM can be used to create, manage and share life-cycle data for vertical structures, such as buildings, while GIS can store, manage and analyze data describing the urban environment, distributed horizontally.

Therefore, Digital Twins of buildings reproduce their geometric, but above all, informative characteristics, and they appear as 3D models but they have the particularity of being configured and structured as real time three-dimensional databases, where data are contained within objects equipped with specific parameters and attributes that describe the characteristics of the components themselves, thus enclosing useful information for the definition and simulation of processes. The Digital Twin gradually becomes able to improve and enrich its knowledge and improves data, receiving inputs and signals from sensors constantly monitoring the buildings, developing self-learning and above all predictivity capabilities, through the integration with Artificial Intelligence algorithms.


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BIM & GIS for digital integrated design
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FACULTY OF ARCHITECTURE
Rome, August 31st – September 11th 2020
PROF. SOFIA AGOSTINELLI
SMART CITIES AND INDUSTRY 4.0
THROUGH DIGITAL TWINS AND CYBER-PHYSICAL SYSTEMS
07/09/2020
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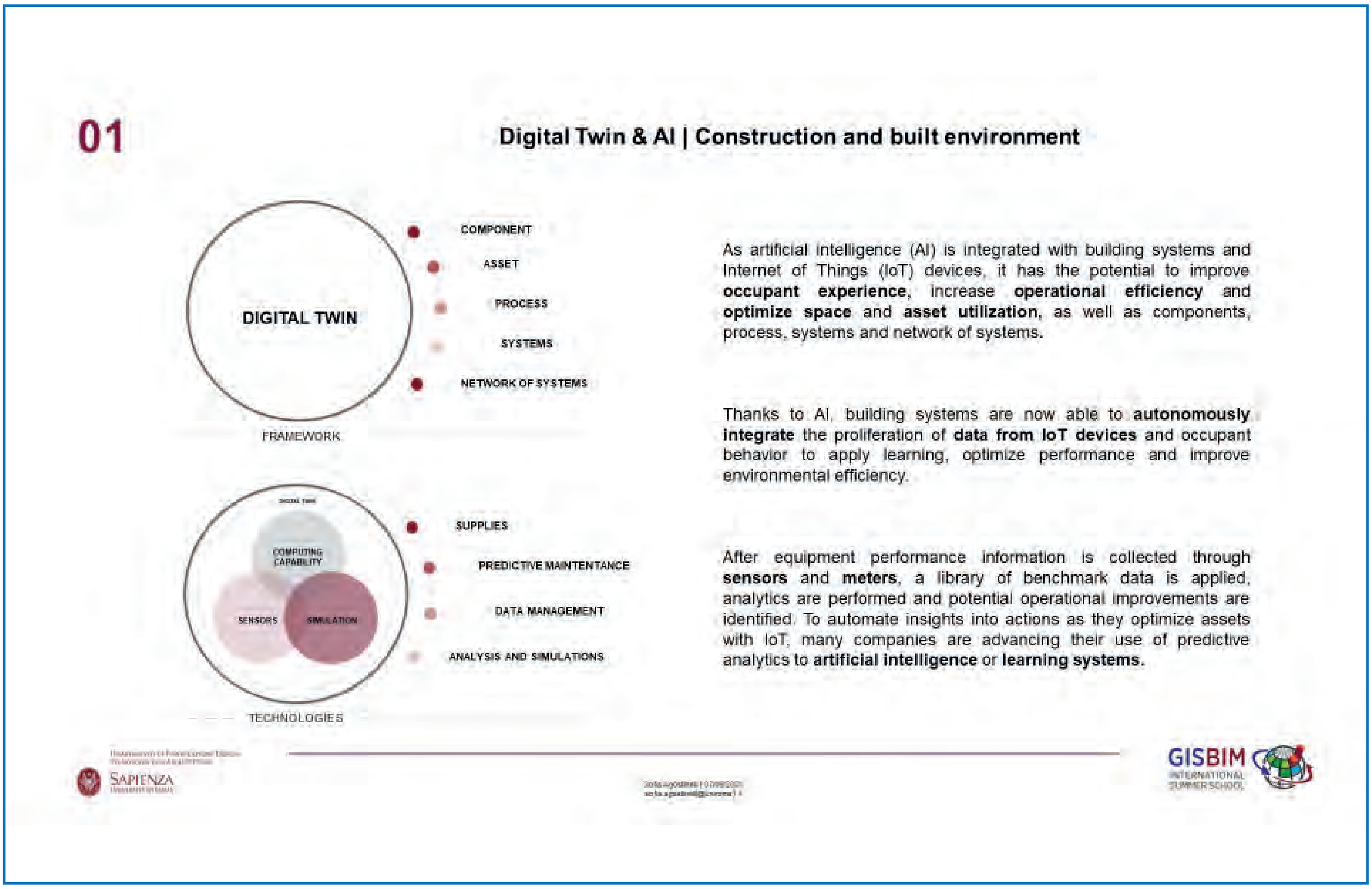
01
Digital Twin & AI | Construction and built environment
DIGITAL TWIN
COMPONENT
ASSET
PROCESS
SYSTEMS
NETWORK OF SYSTEMS
FRAMEWORK
COMPUTING CAPABILITY
SENSORS
SIMULATION
SUPPLIES
PREDICTIVE MAINTENTANCE
DATA MANAGEMENT
ANALYSIS AND SIMULATIONS
TECHNOLOGIES
As artificial intelligence (AI) is integrated with building systems and Internet of Things (IoT) devices, it has the potential to improve **occupant experience**, increase **operational efficiency** and **optimize space** and **asset utilization**, as well as components, process, systems and network of systems.
Thanks to AI, building systems are now able to **autonomously integrate** the proliferation of **data from IoT devices** and occupant behavior to apply learning, optimize performance and improve environmental efficiency.
After equipment performance information is collected through **sensors** and **meters**, a library of benchmark data is applied, analytics are performed and potential operational improvements are identified. To automate insights into actions as they optimize assets with IoT, many companies are advancing their use of predictive analytics to **artificial intelligence** or **learning systems**.
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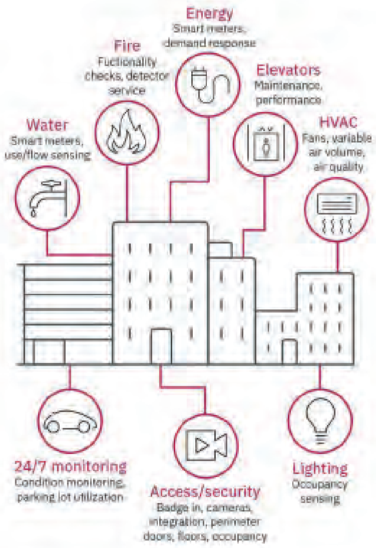
02 Digital Twin & AI | Framework and objectives



AI is able to capture **data from day-to-day building operations** to enable new levels of automation, which enables buildings to "**think," engage and learn**. These buildings can autonomously monitor and predict their own maintenance needs.

Building intelligence into buildings means:

Optimize building maintenance and improve responsiveness.
Use advanced algorithms to detect future operating faults before they occur. Expose faults with predictive analytics to determine case, impact and recommendation. Automate device responses.

What percentage of buildings operating costs is allocated to maintenance?

Integrate sensors, devices, data and external data sources.
Infuse weather data, micro-location forecasts and advanced analytics to make more informed energy decisions. Identify and reduce water waste, usage and costs by detecting leaks and other anomalies.

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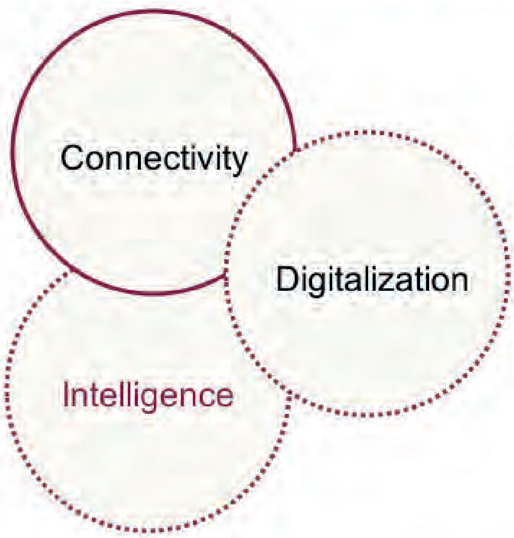
03 Big Data and Artificial Intelligence | Enabling technologies



Connectivity

Sensors

Sensors distributed throughout the processes and operations create signals that enable Digital Twin to capture operational and environmental data pertaining to the physical process in the real world.

Big data

Real-world operational and environmental data from the sensors are aggregated and combined with data from different sources.

IoT

sensors communicate the data to the digital world through integration technology (which includes edge, communication interfaces, and security) between the physical world and the digital world, and vice versa.

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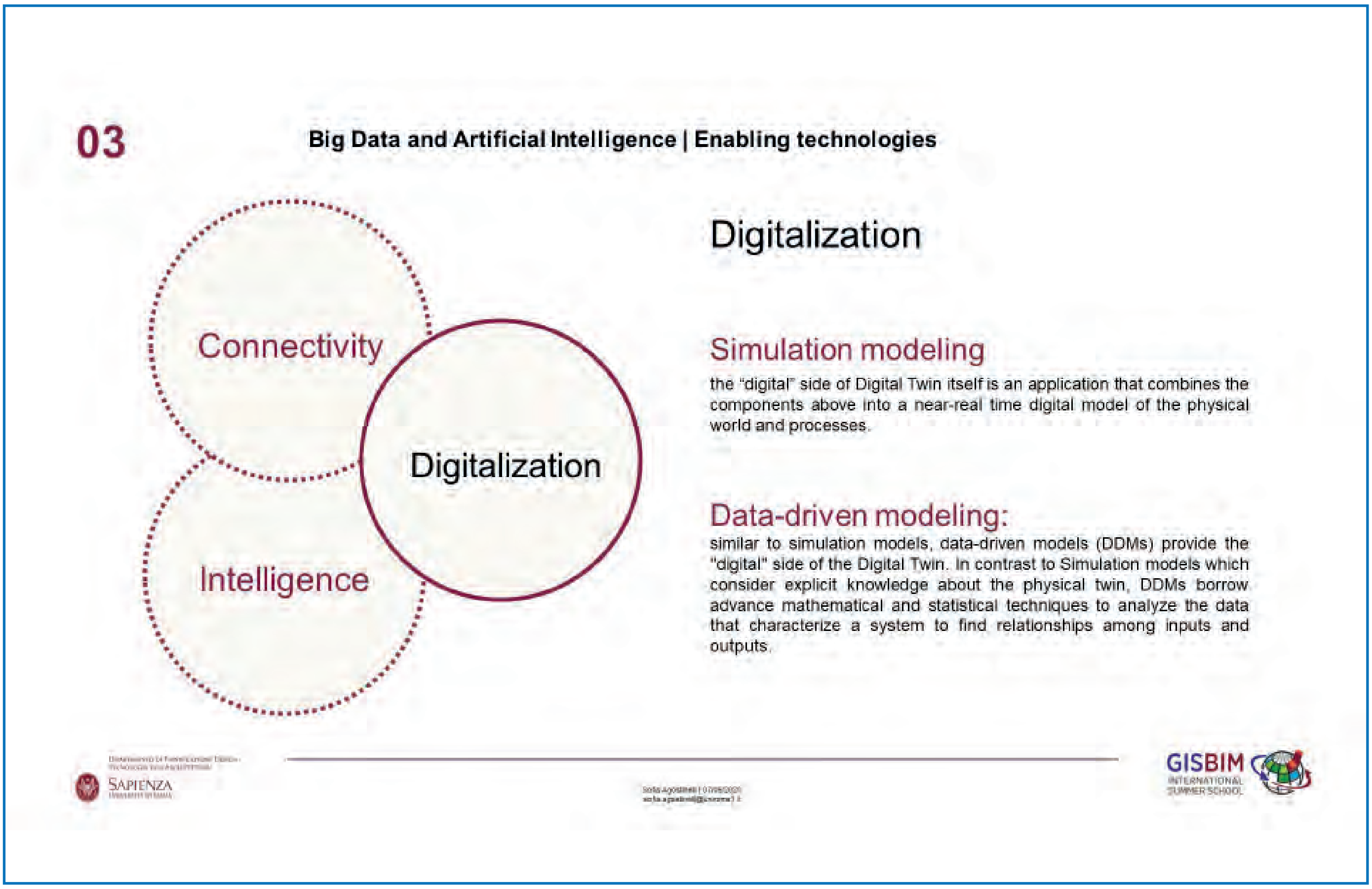
03
Big Data and Artificial Intelligence | Enabling technologies
Connectivity
Digitalization
Intelligence
Digitalization
Simulation modeling
the "digital" side of Digital Twin itself is an application that combines the components above into a near-real time digital model of the physical world and processes.
Data-driven modeling:
similar to simulation models, data-driven models (DDMs) provide the "digital" side of the Digital Twin. In contrast to Simulation models which consider explicit knowledge about the physical twin, DDMs borrow advance mathematical and statistical techniques to analyze the data that characterize a system to find relationships among inputs and outputs.
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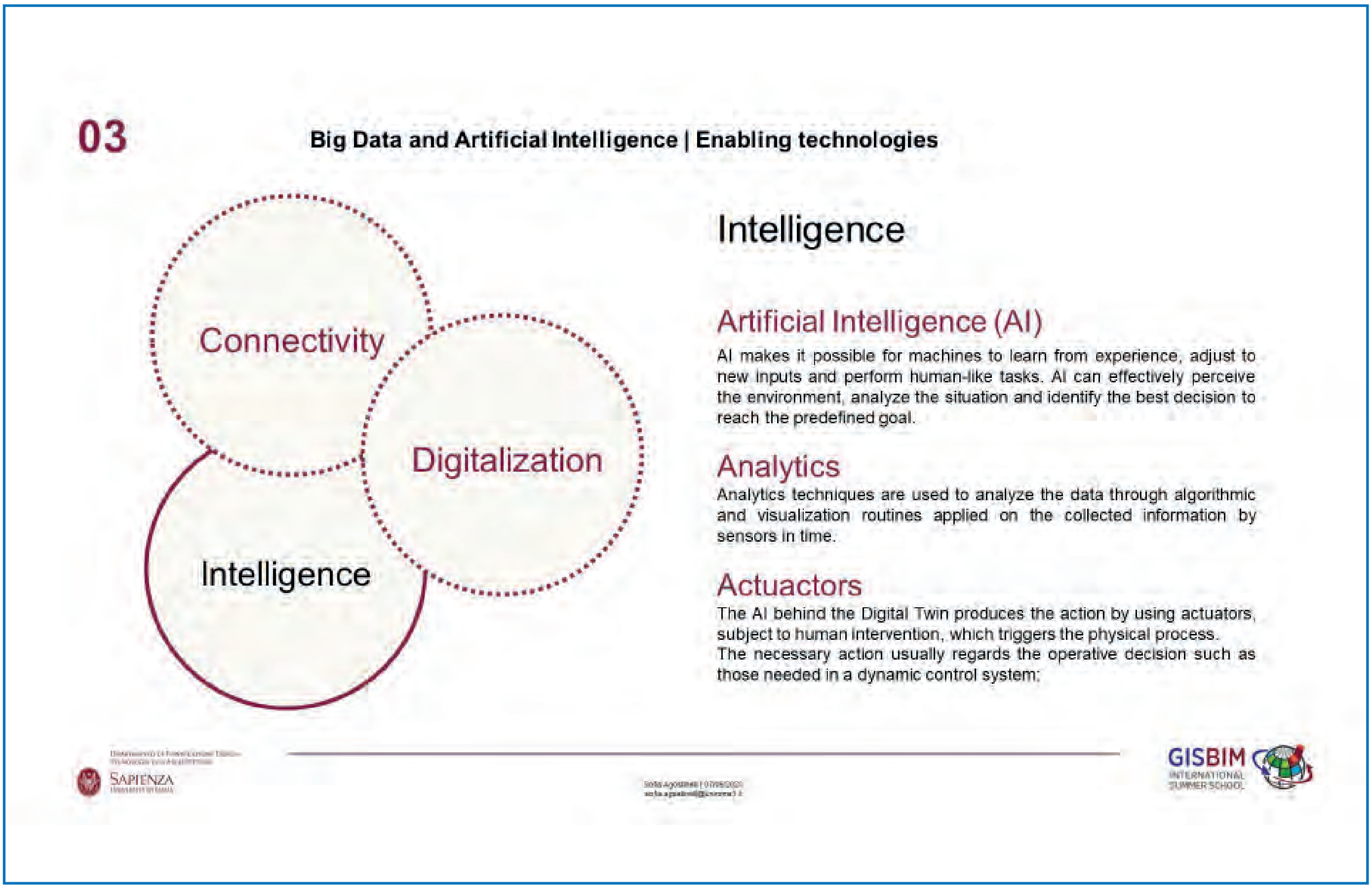
03
Big Data and Artificial Intelligence | Enabling technologies
Connectivity
Digitalization
Intelligence
Intelligence
Artificial Intelligence (AI)
AI makes it possible for machines to learn from experience, adjust to new inputs and perform human-like tasks. AI can effectively perceive the environment, analyze the situation and identify the best decision to reach the predefined goal.
Analytics
Analytics techniques are used to analyze the data through algorithmic and visualization routines applied on the collected information by sensors in time.
Actuactors
The AI behind the Digital Twin produces the action by using actuators, subject to human intervention, which triggers the physical process.
The necessary action usually regards the operative decision such as those needed in a dynamic control system;
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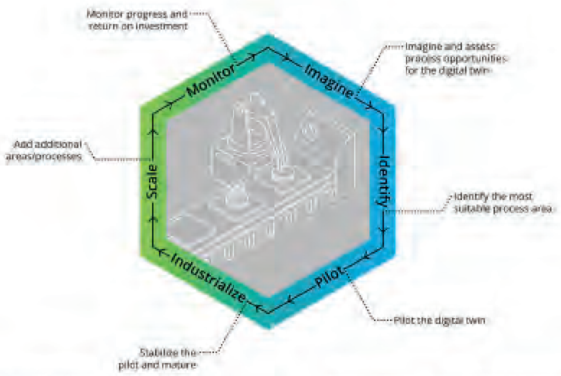

Source: Deloitte analysis. Deloitte University Press | dupress.deloitte.com

Applications

Manufacturing

Digital Twin is poised to change the current face of manufacturing sector. Digital Twins have a significant impact on the way products are designed manufactured and maintained.

Automobile

Digital Twins can be used in the automobile sector for creating the virtual model of a connected vehicle. It captures the behavioral and operational data of the vehicle and helps in analyzing the overall vehicle performance as well as the connected features.

Retail

Appealing customer experience is key in the retail sector. Digital Twin implementation can play a key role in augmenting the retail customer experience by creating virtual twins for customers and modeling fashions for them on it.

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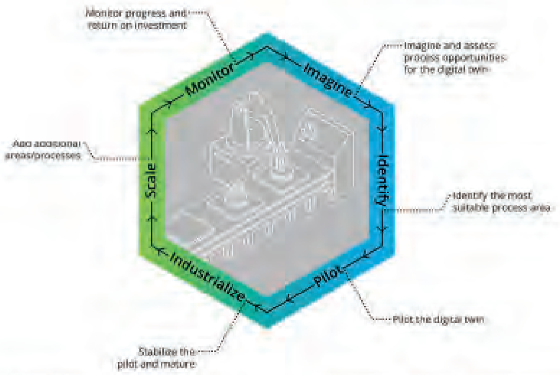
03 Big Data and Artificial Intelligence | Enabling technologies



Source: Deloitte analysis. Deloitte University Press | dupress.deloitte.com

Applications

Healthcare

Digital Twins along with data from IoT can play a key role in the health care sector from cost savings to patient monitoring, preventative intervention and providing personalized health care.

Smart Cities

The smart city planning and implementation with Digital Twins and IoT data helps enhancing economic development, efficient management of resources, reduction of ecological foot print and improving the overall quality of a citizen's life.

Industrial IoT

industrial firms with Digital Twin implementation can now monitor, track and control industrial systems digitally. Apart from the operational data, the Digital Twins capture environmental data such as location, configuration, financial models etc. which helps in predicting the future operations and anomalies.

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04 Between Simulation models and Digital Twins | Opposite approaches

MORE THAN A DIGITAL MODEL

SIMULATION MODEL	DIGITAL TWIN
To-be	As-is
One-time built	Continuous evolutions
Offline	Online
Analysis	Actions
Logic based	Data intensiveness
Stand-alone	Connectivity
Single focus	Multiple focus

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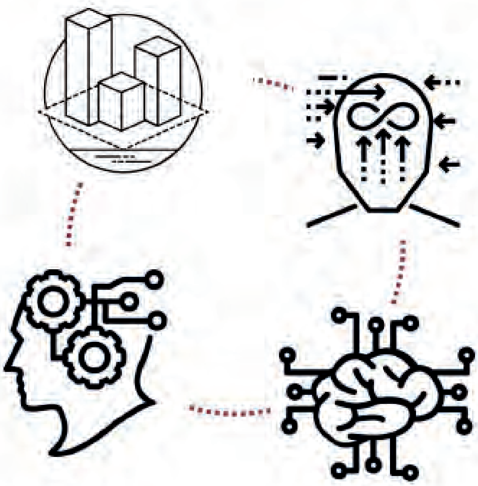
05 From information to automation | Construction workflow



Information model
3D federated information models

Learning
Digital models with learning capabilities, which process and transmit information detected by sensors

Intelligence
Integrated models with algorithms able to develop predictive analysis systems

Automation
models able to make autonomous decisions and implement the resulting actions

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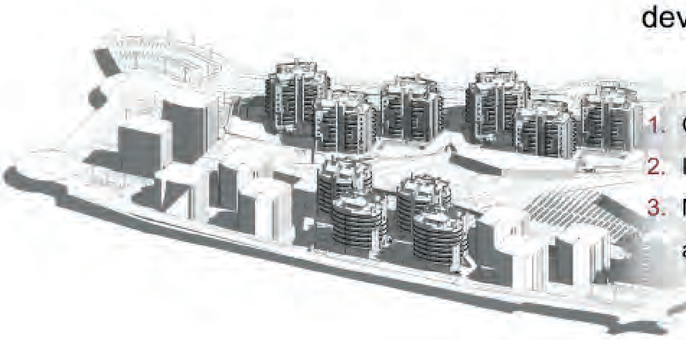
06

Between BIM and GIS | Towards interoperability



Building the buildings Intelligence:

developing model in the urban context

1. Optimize the supply chain
2. Implement predictive maintenance systems
3. Manage and monitor the entire life cycle of urban assets serving decision makers, users and citizens

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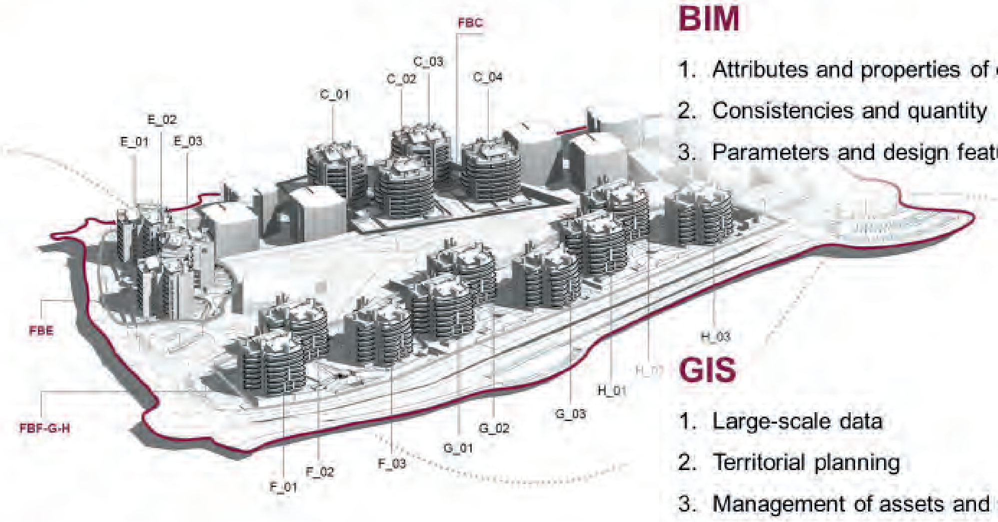
06

Between BIM and GIS | Towards interoperability



BIM

1. Attributes and properties of components
2. Consistencies and quantity
3. Parameters and design features

GIS

1. Large-scale data
2. Territorial planning
3. Management of assets and urban areas

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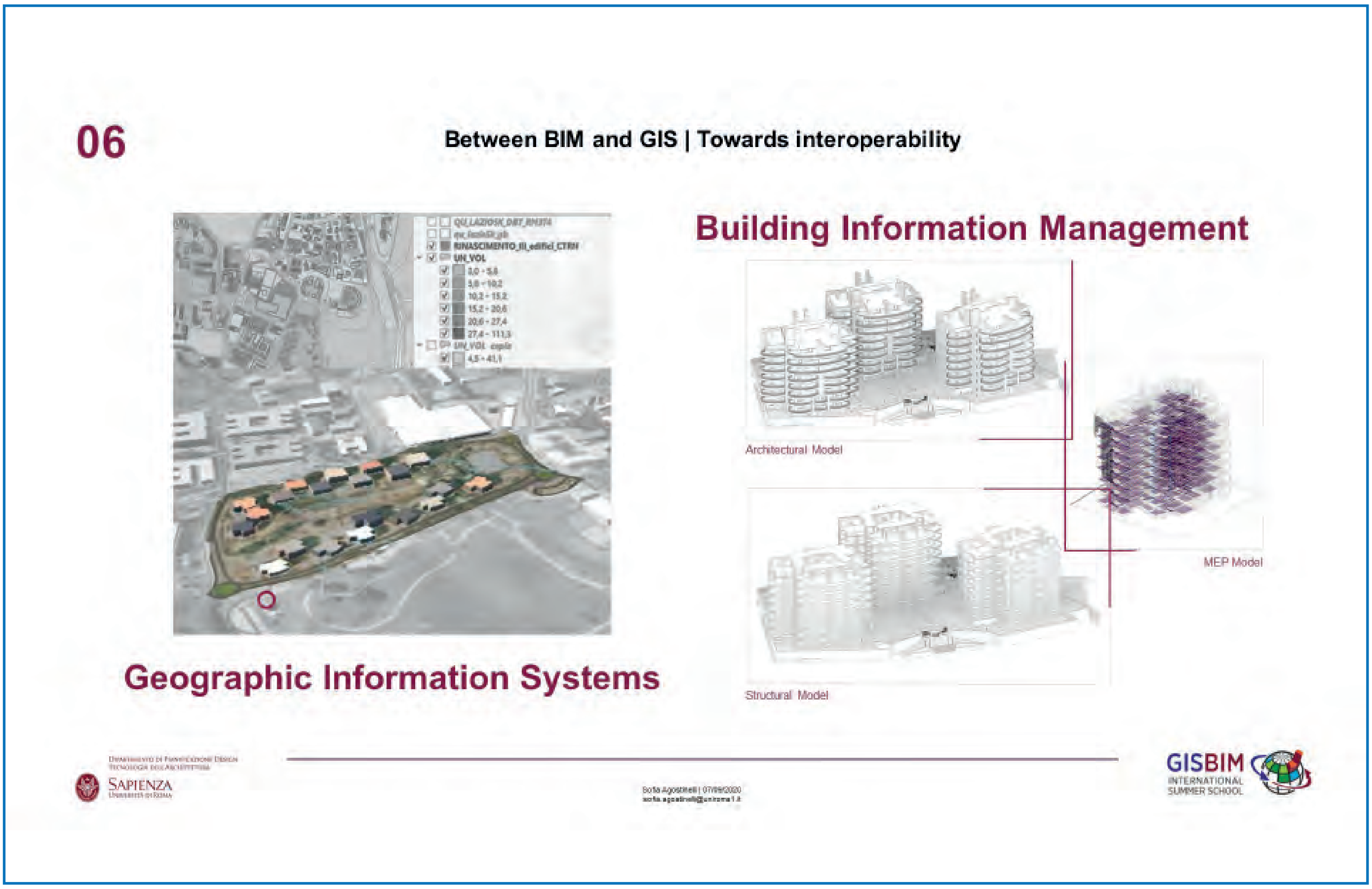
06
Between BIM and GIS | Towards interoperability
Building Information Management
Architectural Model
MEP Model
Structural Model
Geographic Information Systems
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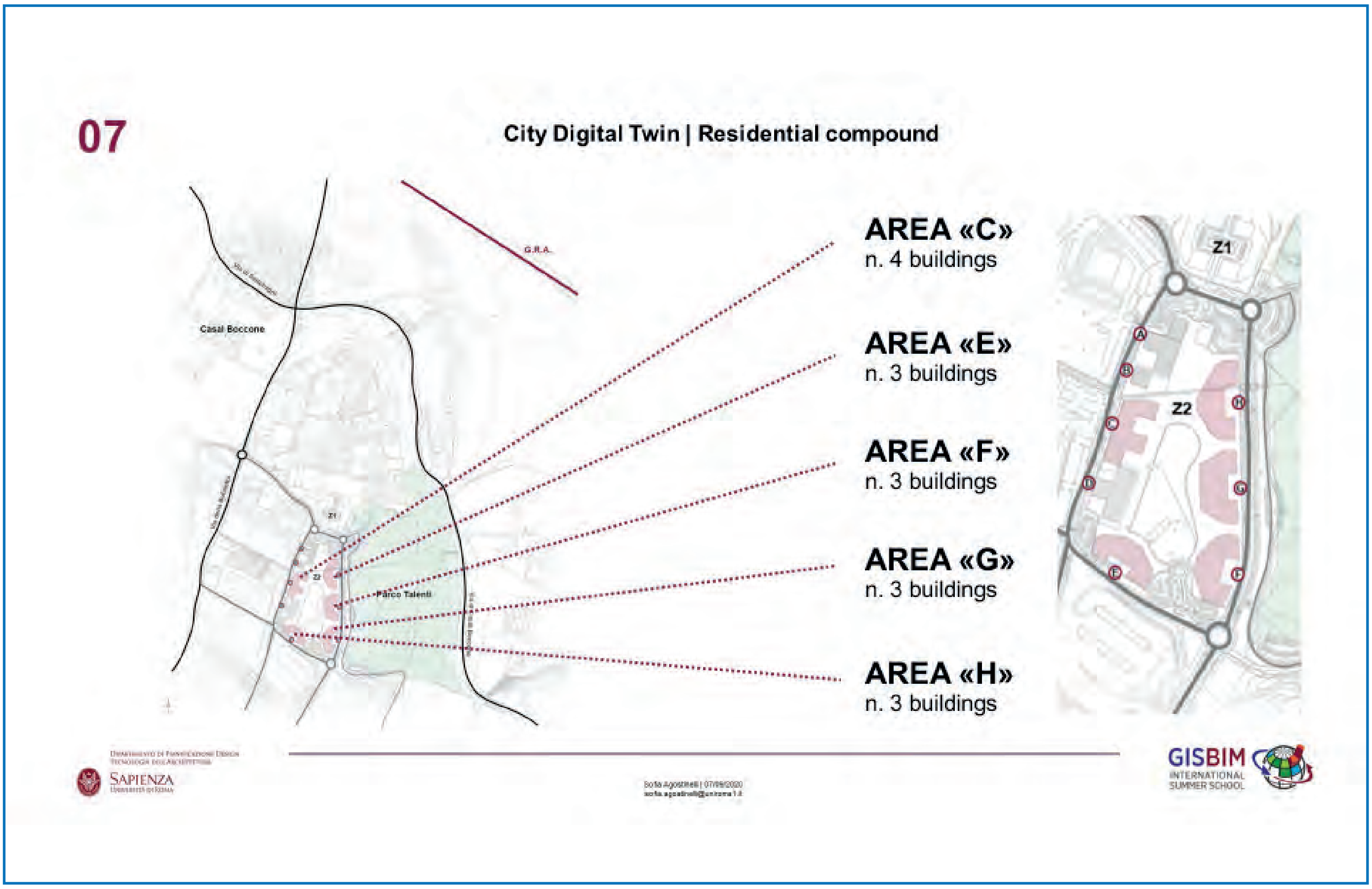
07
City Digital Twin | Residential compound
AREA «C»
n. 4 buildings
AREA «E»
n. 3 buildings
AREA «F»
n. 3 buildings
AREA «G»
n. 3 buildings
AREA «H»
n. 3 buildings
Casal Boccone
Parco Talenti
G.R.A.
Z1
Z2
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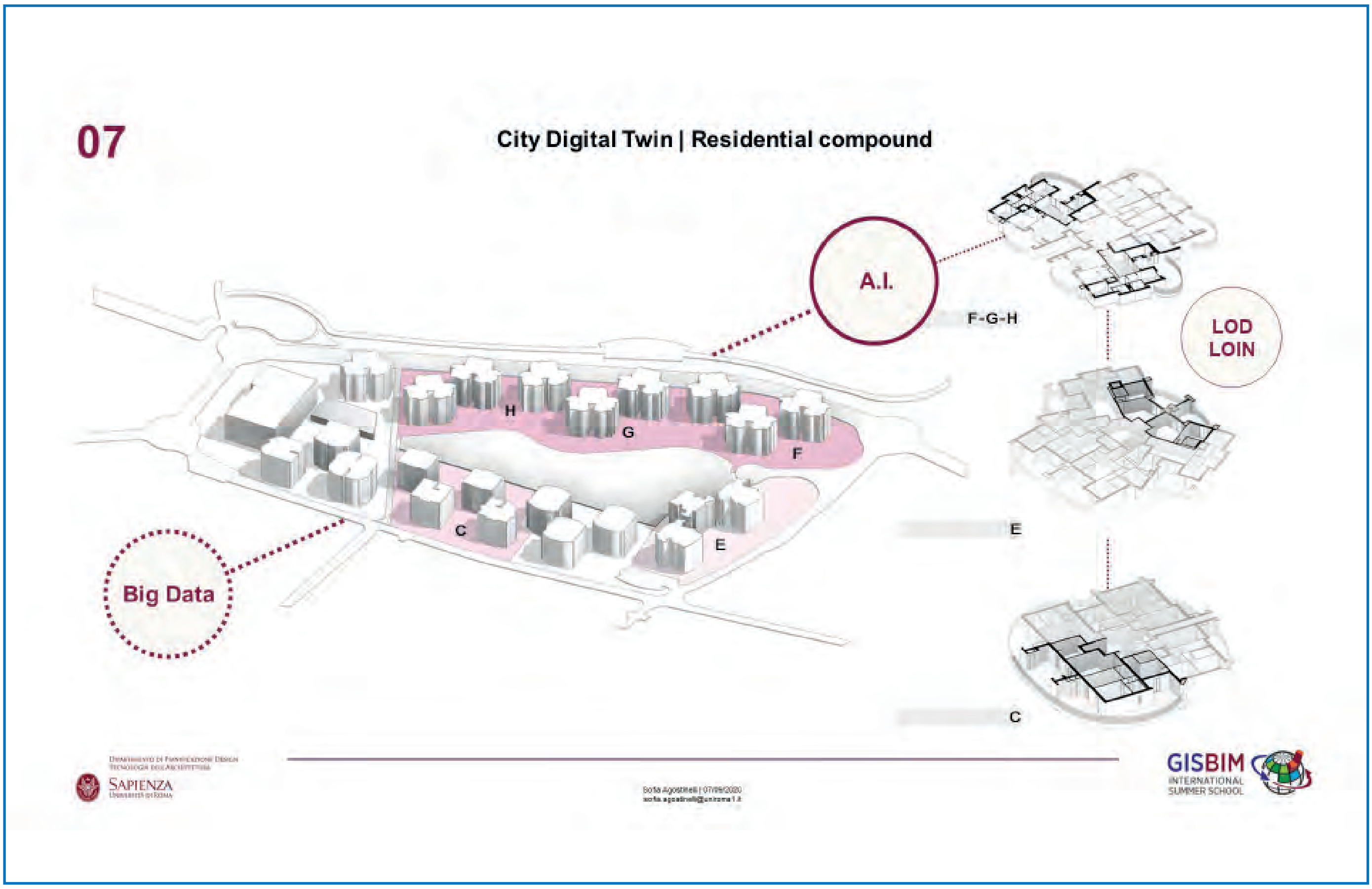
07
City Digital Twin | Residential compound
A.I.
F-G-H
LOD
LOIN
H
G
F
C
E
E
C
Big Data
Sapienza
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07
City Digital Twin | Residential compound
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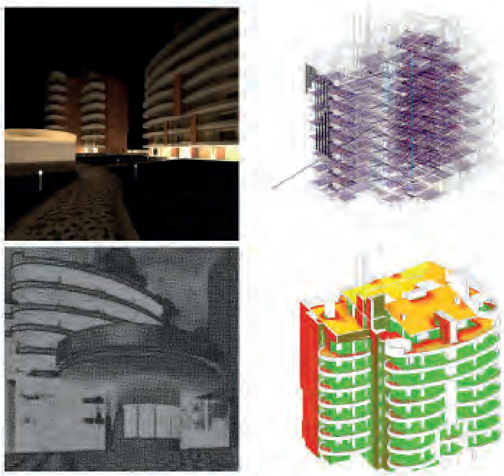
09

Predictive management systems | Objectives and further developments



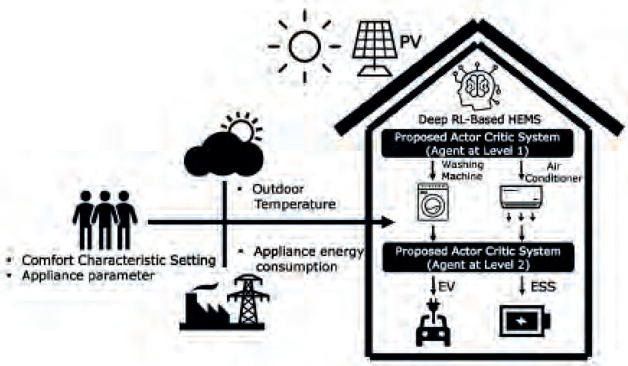
1. **Energy Management**
   self-managed oriented energy smart grid for consumption and production optimization

2. **Security Management**
   integrated digital system for unmanned security management (independent from human component)

3. **Facility Management**
   reduction of operating costs and malfunctions through predictive maintenance systems

09

Machine learning | Energy Management

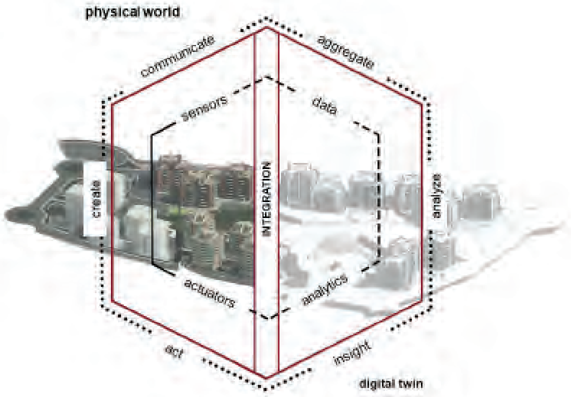


Dataset is passed to a machine learning algorithm that is literally "trained", making it possible to predict or accurately estimate the future energy consumption of devices or loads.

By processing energy consumption data, for example, the historical data of energy consumed by a building from 1996 to 2015, it is possible for a model to reveal **trends** and **patterns**, but also, to predict **future energy consumption patterns** with 3 major benefits:

- Economic: companies and individuals can translate energy into cost, and therefore estimate their energy bill, and make decisions based on this.
- Practical: By not only knowing how much energy we will consume, but understanding how and why we will, we can change our habits without affecting our productivity or the quality of our lives.
- Technical: Better managing energy data unlocks new possibilities in the collection and analysis of this data, as well as in generating more accurate predictions..

09 Machine learning | Energy Management



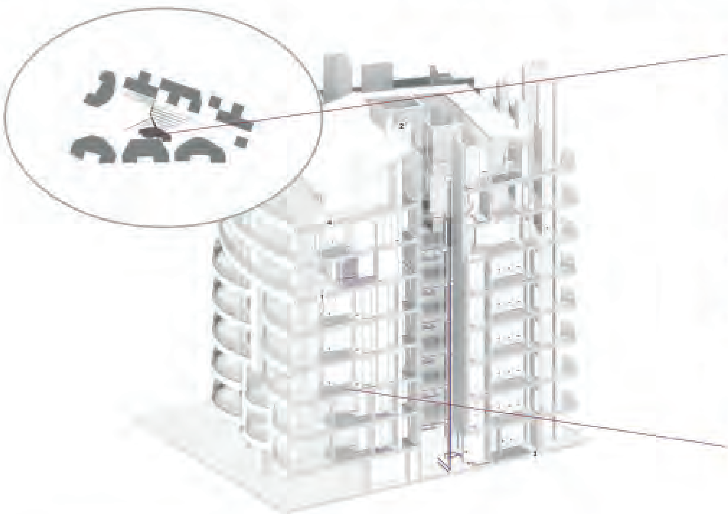
1. Time series

are among the most used for **energy consumption or producing prediction.** For instance, when it comes to forecasting the behaviour of wind: such as speed and direction. It is fundamental to input **the data at regular intervals of time**, so that the model can learn by the evolution of this data over time, which make it possible to predict the output of energy sources based on past observation.

2. Artificial neural networks

which comprise what is called **deep learning**, an advanced form of machine learning inspired by the way the brain of animals works.
Deep learning is highly valuable in the energy industry as the algorithms are suited for **large datasets**. In the case of historical energy consumption and generation, data sets tend to be massive, and require the right techniques so they can be processed and analysed efficiently.

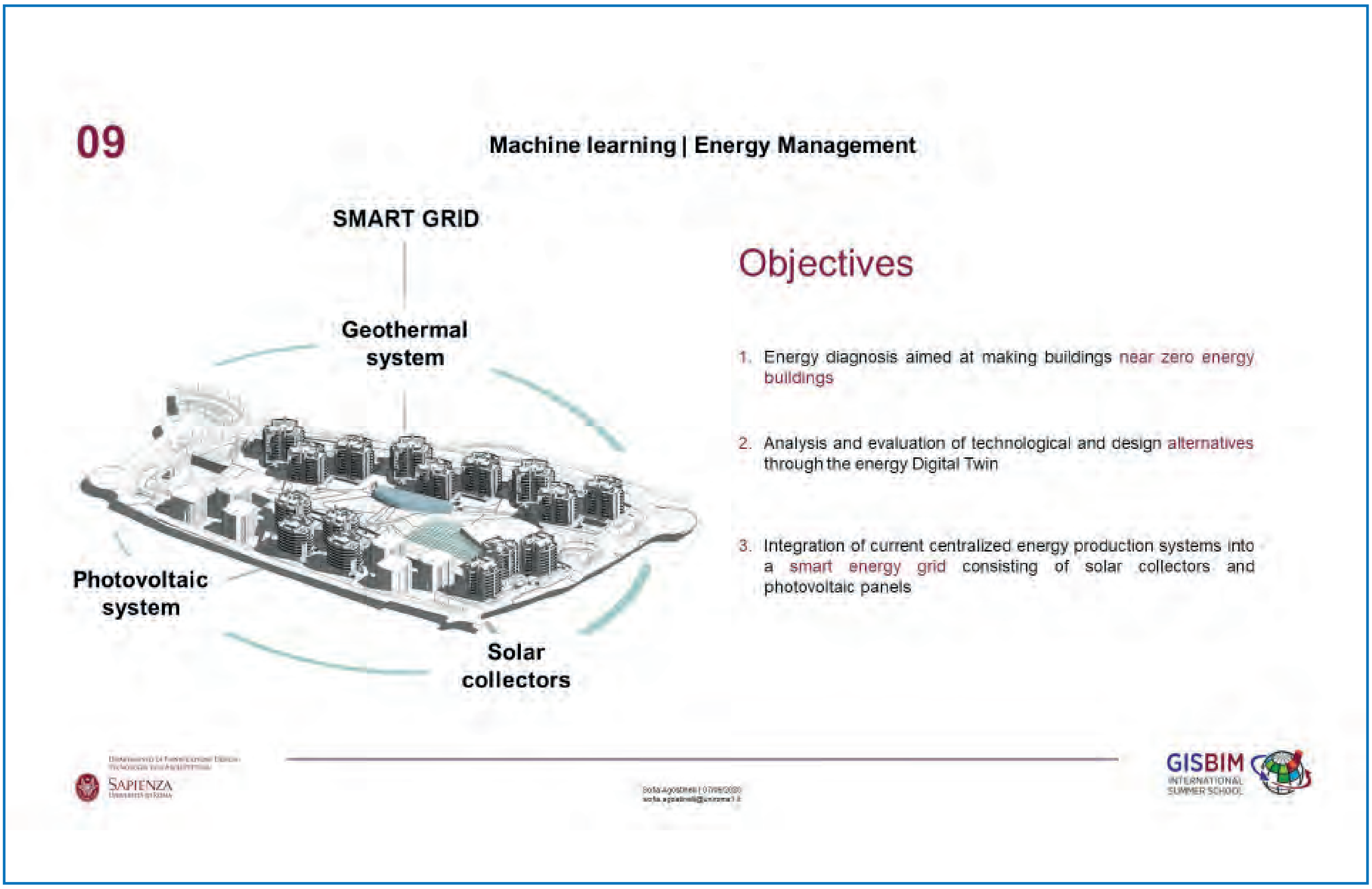
09 Machine learning | Energy Management



Geothermal power plant
200 geothermal probes and high-efficiency heat pumps

Traditional systems
air-cooled refrigeration units powered by mains electricity to produce chilled water and gas-fired cogenerators to produce heat and electricity

Distribution system with underfloor heating and cooling


09
Machine learning | Energy Management
SMART GRID
Geothermal system
Photovoltaic system
Solar collectors
Objectives
1. Energy diagnosis aimed at making buildings near zero energy buildings
2. Analysis and evaluation of technological and design alternatives through the energy Digital Twin
3. Integration of current centralized energy production systems into a smart energy grid consisting of solar collectors and photovoltaic panels
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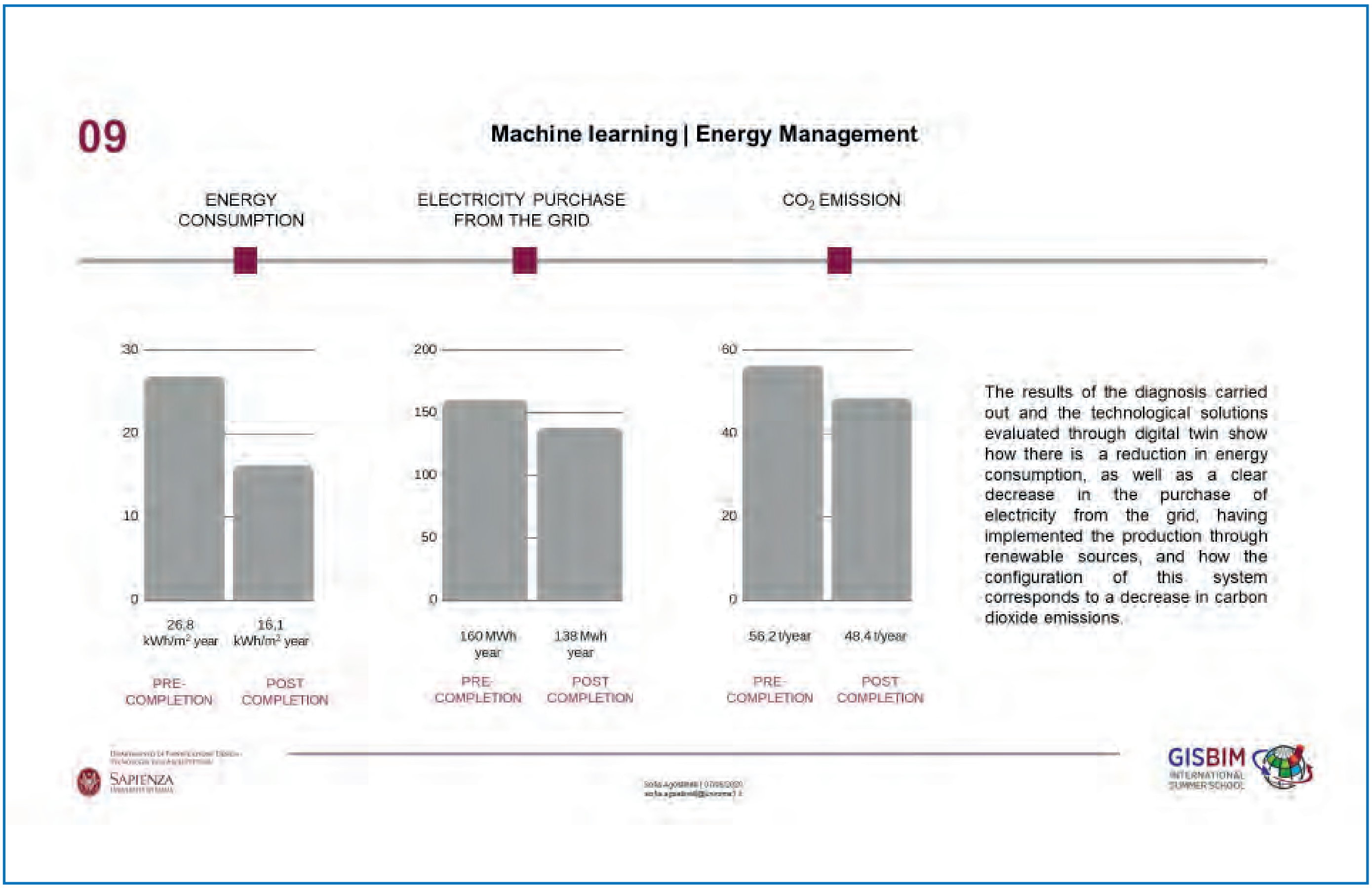
09
Machine learning | Energy Management
ENERGY CONSUMPTION
ELECTRICITY PURCHASE FROM THE GRID
CO_2 EMISSION
30
20
10
0
26,8 kWh/m² year
16,1 kWh/m² year
PRE-COMPLETION
POST COMPLETION
200
150
100
50
0
160 MWh year
138 Mwh year
PRE-COMPLETION
POST COMPLETION
60
40
20
0
56,2 t/year
48,4 t/year
PRE-COMPLETION
POST COMPLETION
The results of the diagnosis carried out and the technological solutions evaluated through digital twin show how there is a reduction in energy consumption, as well as a clear decrease in the purchase of electricity from the grid, having implemented the production through renewable sources, and how the configuration of this system corresponds to a decrease in carbon dioxide emissions.
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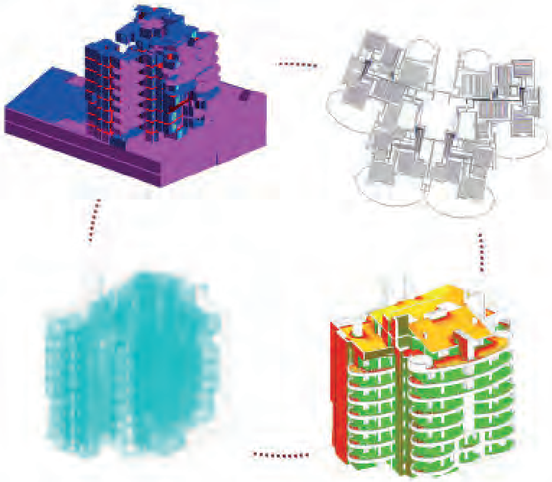
10 BEM & Energy Analysis | Case study



BEMs for energy audits

1. Definition of general data about buildings (location, climate etc.)
2. Identification of materials, structures, windows and doors
3. Definition of exposures
4. Definition of buildings units and zones
5. Inclusion of thermal bridges
6. Winter Dispersion Calculation
7. Calculation of Thermal Loads

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11 Smart grid management through AI | Case study

Objectives

1. Use the potential of machine learning to create a virtuous automated system for the management of both the **production** and **consumption** of electricity and heat in the whole compound.

2. Algorithms for calculating the maximum energy that can be produced by the three systems (geothermal, solar thermal and solar photovoltaic), which predict the consumption of buildings based on historical data transmitted by sensors and integrated with the daily calculation of thermal loads made by digital twin

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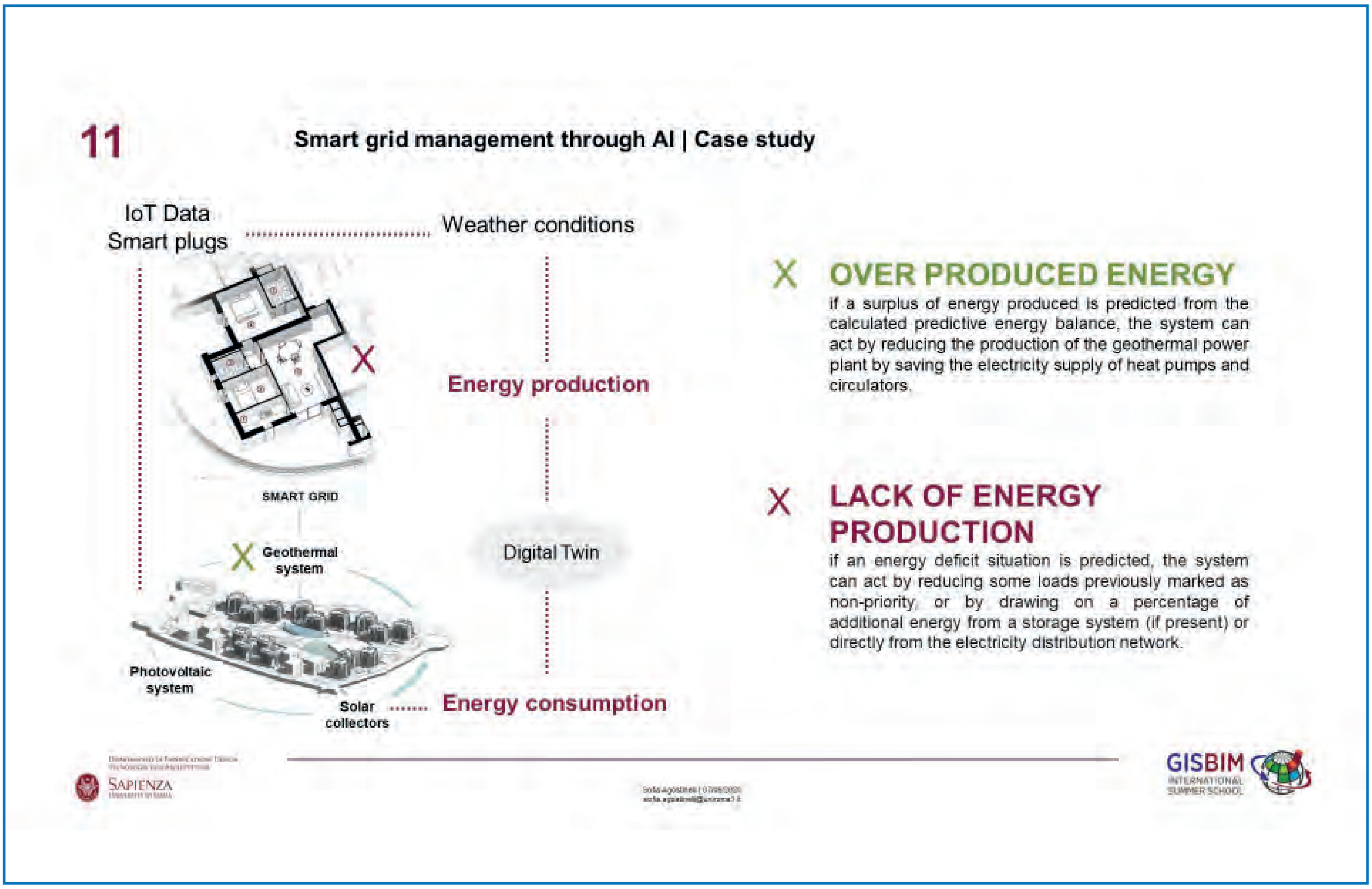
11
Smart grid management through AI | Case study
IoT Data
Smart plugs
Weather conditions
Energy production
SMART GRID
Geothermal system
Digital Twin
Photovoltaic system
Solar collectors
Energy consumption
OVER PRODUCED ENERGY
if a surplus of energy produced is predicted from the calculated predictive energy balance, the system can act by reducing the production of the geothermal power plant by saving the electricity supply of heat pumps and circulators.
LACK OF ENERGY PRODUCTION
if an energy deficit situation is predicted, the system can act by reducing some loads previously marked as non-priority, or by drawing on a percentage of additional energy from a storage system (if present) or directly from the electricity distribution network.
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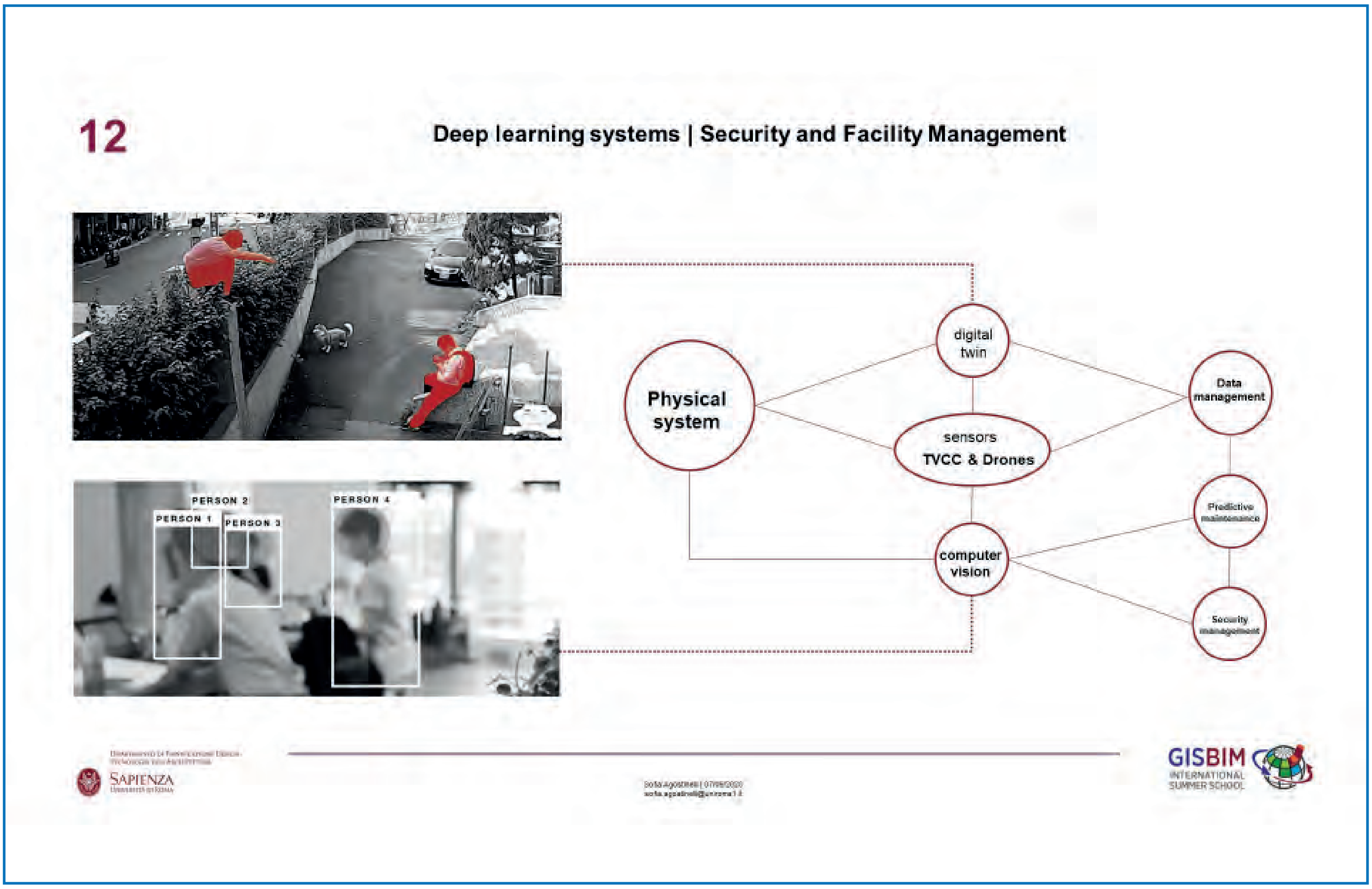
12
Deep learning systems | Security and Facility Management
PERSON 1
PERSON 2
PERSON 3
PERSON 4
Physical system
digital twin
sensors
TVCC & Drones
computer vision
Data management
Predictive maintenance
Security management
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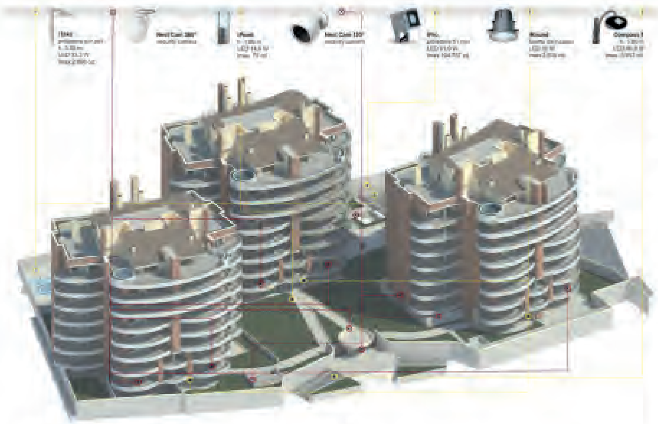
13

TVCC & lighting systems | Security and Facility Management



The era of **Big Data** and **computing power** has brought artificial intelligence closer to video security systems, creating intelligent detection algorithms based on Deep Learning to analyze hundreds of **real-world detection cases**. The result is the possibility to apply a filter in **VCA** (video content analysis) detections that allows to distinguish human beings and vehicles from other targets that can generate false alarms.

The ability of these devices consists in the detection in detail and in a fully automated way of suspicious attitudes or actions that can be postponed to theft or assault. The Artificial Intelligence systems are therefore able to activate themselves in an instantaneous and preventive way, reporting what is happening through alerts, activation of alarms, visual signals, call to the police, notification to the security manager etc. according to the type of scene identified.

The potentialities of such advanced security systems also reside in the possibility to create a profile of the protagonists of unclear actions, so that they can be identified at a later time, even if they wear different clothes or have their head covered.

This system needs to be implemented with a **TVCC network** with the integration of a **lighting system** that allow cameras to detect actions and recognize details.

TVCC system
Closed Circuit Television

Lighting system

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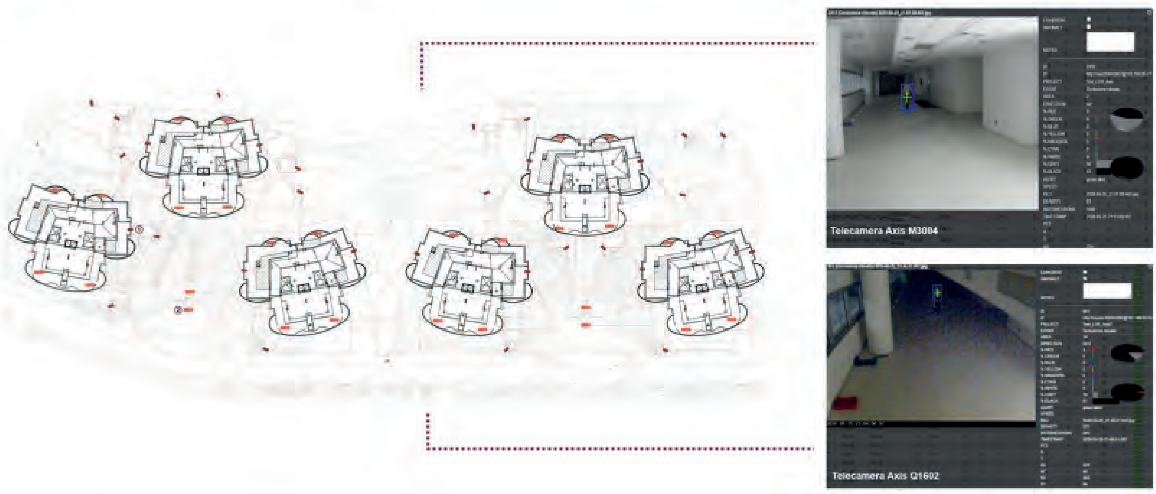
13

TVCC & lighting systems | Security and Facility Management



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14

Risk analysis | Security Management

The digital security management of the sector then goes through the careful phase of **risk modeling**, i.e. the configuration within the model of different categories of areas to be monitored and differentiated basing on possible intercepted emergencies.

Each area has therefore been assigned a set of possible risks connected and evaluated basing on the **structural nature** of the area (interior, perimeter, public areas, etc.) and the **lighting levels**.

The analysis of the risk factors identified leads to a summary picture that highlights the critical areas and identifies in detail the **monitoring parameters** of the individual areas that make up the residential compound.

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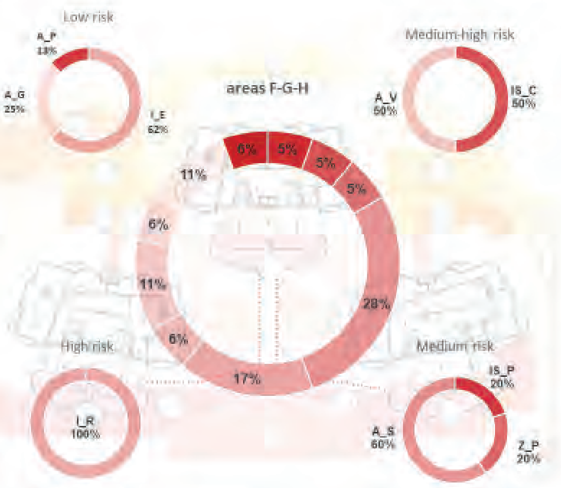
14

Risk analysis | Security Management



Through digital twin, therefore, a **risk database** is created within a **three-dimensional information model** that contains a volumetric recognition of the areas subjected to video surveillance.

Each area is analyzed and evaluated according to the hazard and the associated risks with reference to current security conditions, which can be implemented through **analysis** and **simulation** of **different design solutions**, evaluated through digital twin, up to define an **image recognition system** integrating cameras and related lighting system necessary to ensure high levels of security.

The result of the analysis of the risk database is therefore the definition of a **risk level** for each area, evaluated through a matrix that identifies the **nature of the area**, its current safety level in terms of **levels of lighting**, and assigns a rank useful for the **digital monitoring** of the entire area.

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15

Artificial Intelligence for O&M | Facility Management

Objectives

1. Reconfiguration of the maintenance approaches (currently limited to plant operation and fault intervention), by implementing intelligent systems for **predictive maintenance**, based on sensors and historical data.

2. Monitoring with digital systems for the reduction of maintenance interventions with the aim of ensuring overall **cost savings.**

3. Implementation of the information model with the technical data of the individual interventions (costs, duration, frequency) for the configuration and **digital management** of the maintenance program

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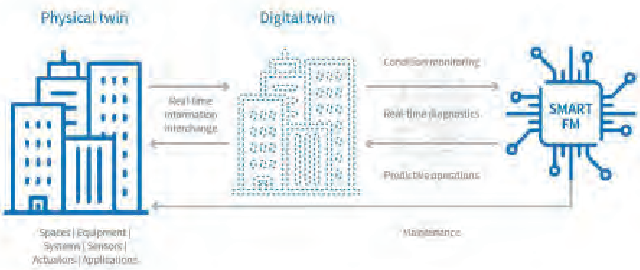
15

Artificial Intelligence for O&M | Facility Management



Objectives

1. Reconfiguration of the maintenance approaches (currently limited to plant operation and fault intervention), by implementing intelligent systems for predictive maintenance, based on sensors and historical data.

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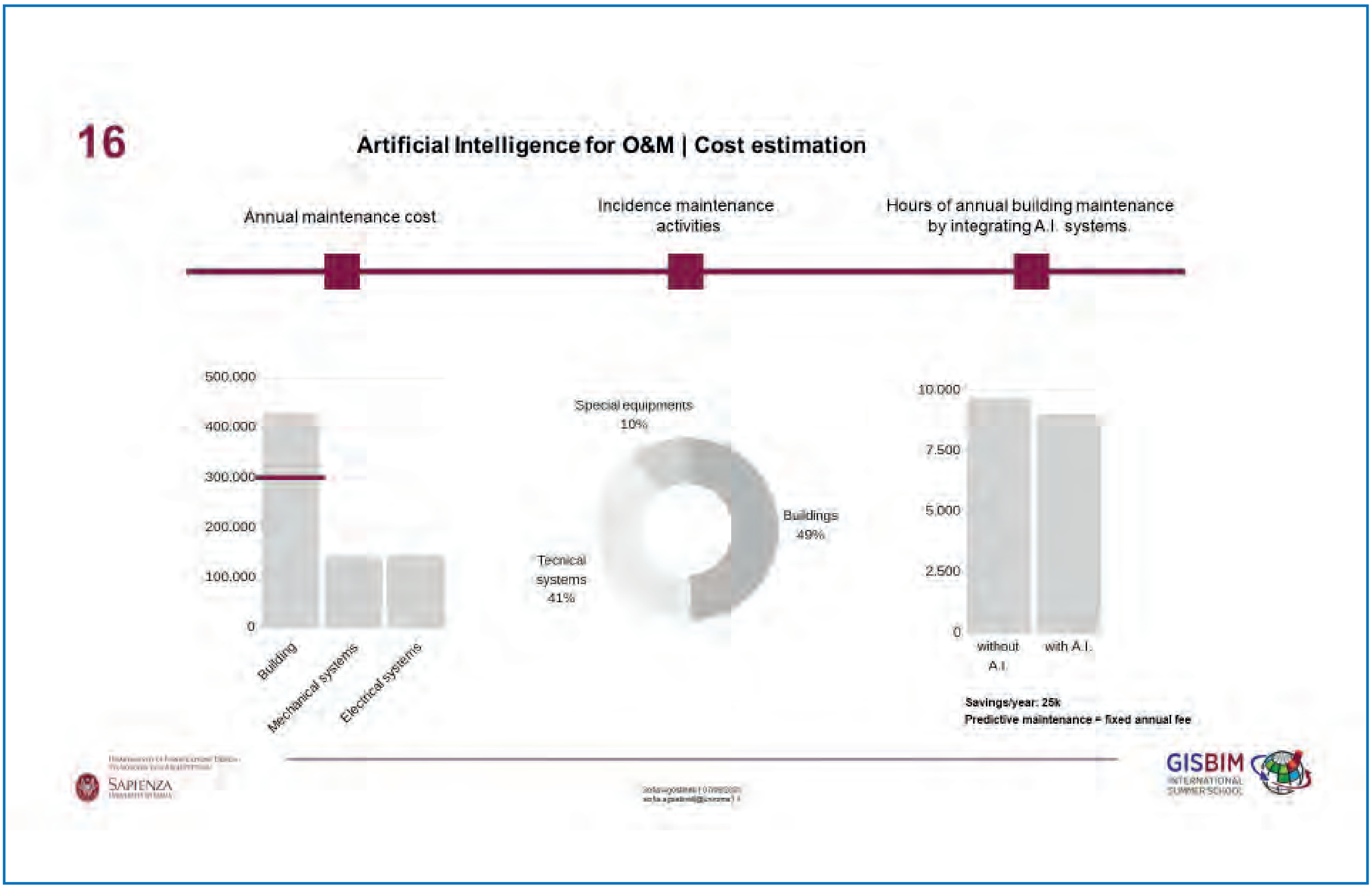
16
Artificial Intelligence for O&M | Cost estimation
Annual maintenance cost
Incidence maintenance activities
Hours of annual building maintenance by integrating A.I. systems
500.000
400.000
300.000
200.000
100.000
0
Building
Mechanical systems
Electrical systems
Special equipments 10%
Buildings 49%
Tecnical systems 41%
10.000
7.500
5.000
2.500
0
without A.I.
with A.I.
Savings/year: 25k
Predictive maintenance = fixed annual fee
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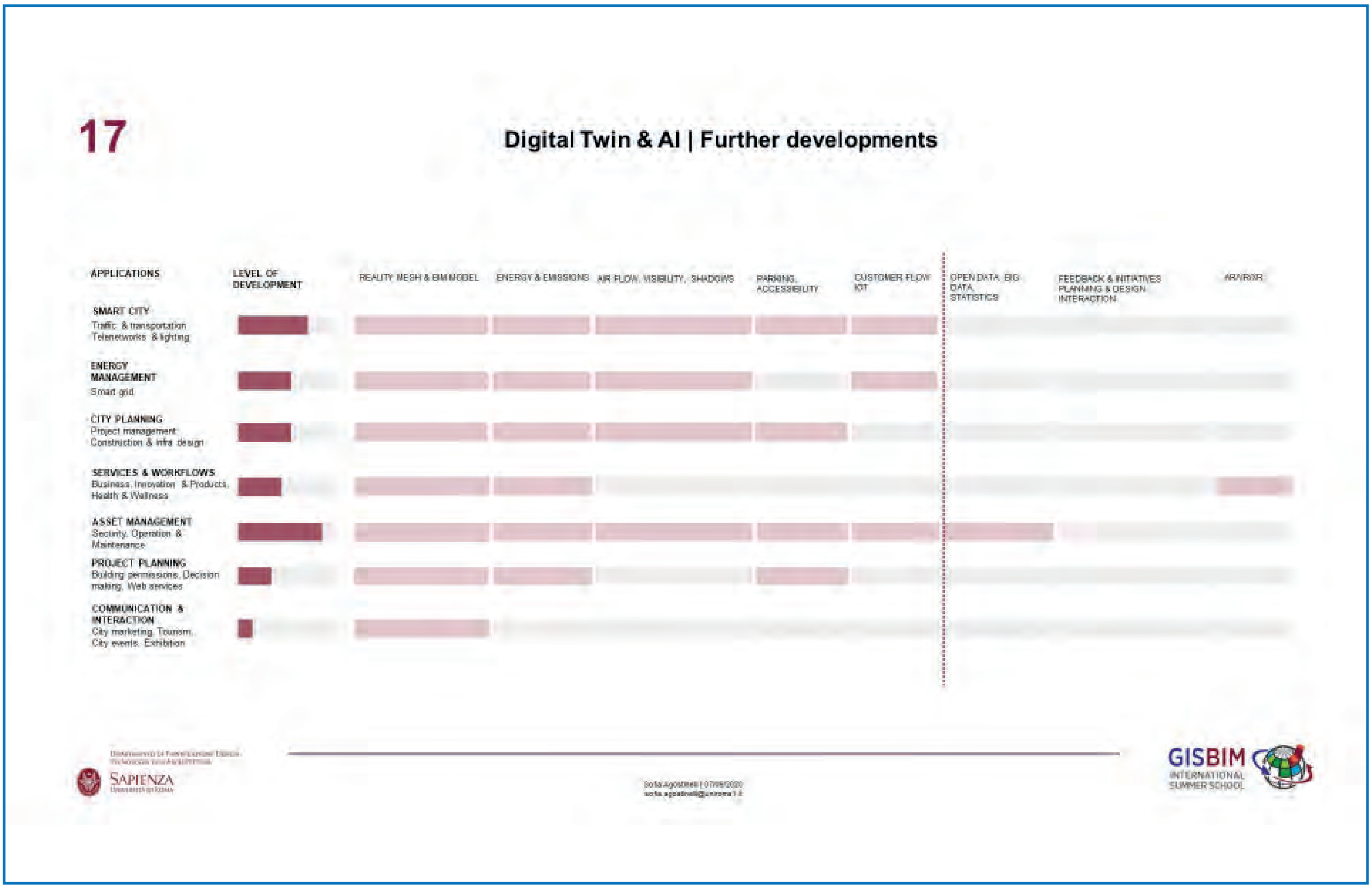
17
Digital Twin & AI | Further developments
APPLICATIONS
LEVEL OF DEVELOPMENT
REALITY MESH & BIM MODEL
ENERGY & EMISSIONS
AIR FLOW, VISIBILITY, SHADOWS
PARKING, ACCESSIBILITY
CUSTOMER FLOW IOT
OPEN DATA, BIG DATA, STATISTICS
FEEDBACK & INITIATIVES PLANNING & DESIGN INTERACTION
AR/VR/XR
SMART CITY
Traffic & transportation
Telenetworks & lighting
ENERGY MANAGEMENT
Smart grid
CITY PLANNING
Project management
Construction & infra design
SERVICES & WORKFLOWS
Business, Innovation & Products, Health & Wellness
ASSET MANAGEMENT
Security, Operation & Maintenance
PROJECT PLANNING
Building permissions, Decision making, Web services
COMMUNICATION & INTERACTION
City marketing, Tourism, City events, Exhibition
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Machine Learning: digital methods and tools

Prof. Claudio Tomazzoli

Adjunct Professor at the Department of Computer Science of the University of Verona

Machine learning

Machine learning is a form of Artificial Intelligence that enables a system to learn from data rather than through explicit programming.

Machine learning produce models where there are some kind of regularity in data.

Like human children learning process, it is driven by "experience".Models can be refined given a certain amount of data to train a "machine-learning algorithm".

The more and the better are the training data, the more accurate the model will be. After training, when you provide a model with an input, you will be given an output.

For example, a predictive algorithm will create a predictive model.

Machine learning techniques are divided in three categories: Supervised learning, Unsupervised learning and Reinforced learning (see slide n.02).

Supervised learning are machine learning techniques for creating a function from training data.

Training and test data are "labeled", so that they are pairs of input objects (typically vectors) and desired outputs, where the label is the desired output.

The output of the function can be a continuous value ("regression"), or a class label of the input object ("classification").

The task of the supervised learner is to predict the value of the function for any valid input object after having seen only a limited number of training examples.

Techniques which have proven to be effective are *Decision Trees, Support Vector Machine, Bayesian Classification*.

Decision tree learning is widely used because of its accuracy and computational cost.

The learned classification model is represented as a tree, called decision tree, in which there are decision nodes (internal) and leaf nodes. A decision node specifies some test, while on a single attribute, while a leaf node indicates a class. An example can be seen in slide n.03.

A *Support Vector Machine* (SVM) is a discriminative classifier formally defined by a separating hyperplane.In other words, given labeled training data (supervised learning), the algorithm outputs an optimal hyperplane which categorizes new examples.

In a space with two dimensions this hyperplane is a line dividing a plane in two parts where in each class lay in either side (see slide 04).

The *naive Bayesian classifier* is a probabilistic approach to classification.

Given an unclassified object X = (x1,...,xn) the classifier predicts that X belongs to the category having the highest posterior probability conditioned on X.

Specifically, this classifies object X into category Ci if and only if P(Ci|X) > P(Cj|X) for all j different from i.

In text classification, a famous approach based on bayesian classification is the Bag of Word approach:

A bag-of-words model (also known as a term-frequency counter) records the number of times that words appear in each document of a collection.The bag-of-words approach represents a document d by {tfwd } where tfwd is the number of times the word w appears in the document d. An example can be seen in slide 05.

Unsupervised learning refers to machine learning algorithms used to draw inferences from datasets consisting of input data without labeled responses.

Unsupervised learning conducts an iterative process, analyzing data without human intervention.

The most common unsupervised learning method are *cluster analysis* and *neural networks* (recently led to deep learning)

K-means is one of the simplest unsupervised learning algorithms that solve the well known clustering problem. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters (assume k clusters) fixed a priori.

The main idea is to define k centroids, one for each cluster. These centroids shoud be placed in a cunning way because of different location causes different result (see slide 06).

The next step is to take each point belonging to a given data set and associate it to the nearest centroid. When no point is pending, the first step is completed and an early groupage is done (slide 07).

Neural networks is a biologically-inspired programming paradigm to emulate how the human brain works, so computers can be trained to deal with poorly defined abstractions and problem.

The average five-year-old child can easily recognize the difference between his teacher's face and the face of the crossing guard. In contrast, the computer must do a lot of work to figure out who is who.Deep learning is a powerful set of techniques for machine learning using neural networks. Neural networks and deep learning currently provide the best solutions to many problems in image recognition, speech recognition, and natural language processing. They are described in slides 08 and 09.

Reinforcement learning is a behavioural learning model. The algorithm receives feedback from the data analysis, guiding the user to the best outcome. Reinforcement learning differs from other types of supervised learning, because the system isn't trained with the sample data set. Rather, the system learns through trial and error.

The workflow of a machine learning process is shown in slide n.10.

A "digital twin model" has been applied to the case study of a residential district, and organized as a three-dimensional data system able to participate to the intelligent optimization and automation of the energy management and efficiency of the building system (slide 11): it is named "Rione Rinascimento"(slide 12) and it's energy need have been studied extensively(slides 13, 14, 15 and 16). An artificial intelligence method has been devised (slides 17,18) which makes use of clustering (slides 19,20,21), association rule mining (slides 22, 23, 24) and a novel method which includes bag of word (slides 25,26,27,28,29,30) to ensure that the digital model sticks with the real word.


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SAPIENZA UNIVERSITY OF ROME
FACULTY OF ARCHITECTURE
Rome, August 31st – September 11th 2020
PROF: Claudio Tomazzoli
TITLE:Digital methods and tools
01/09/2020
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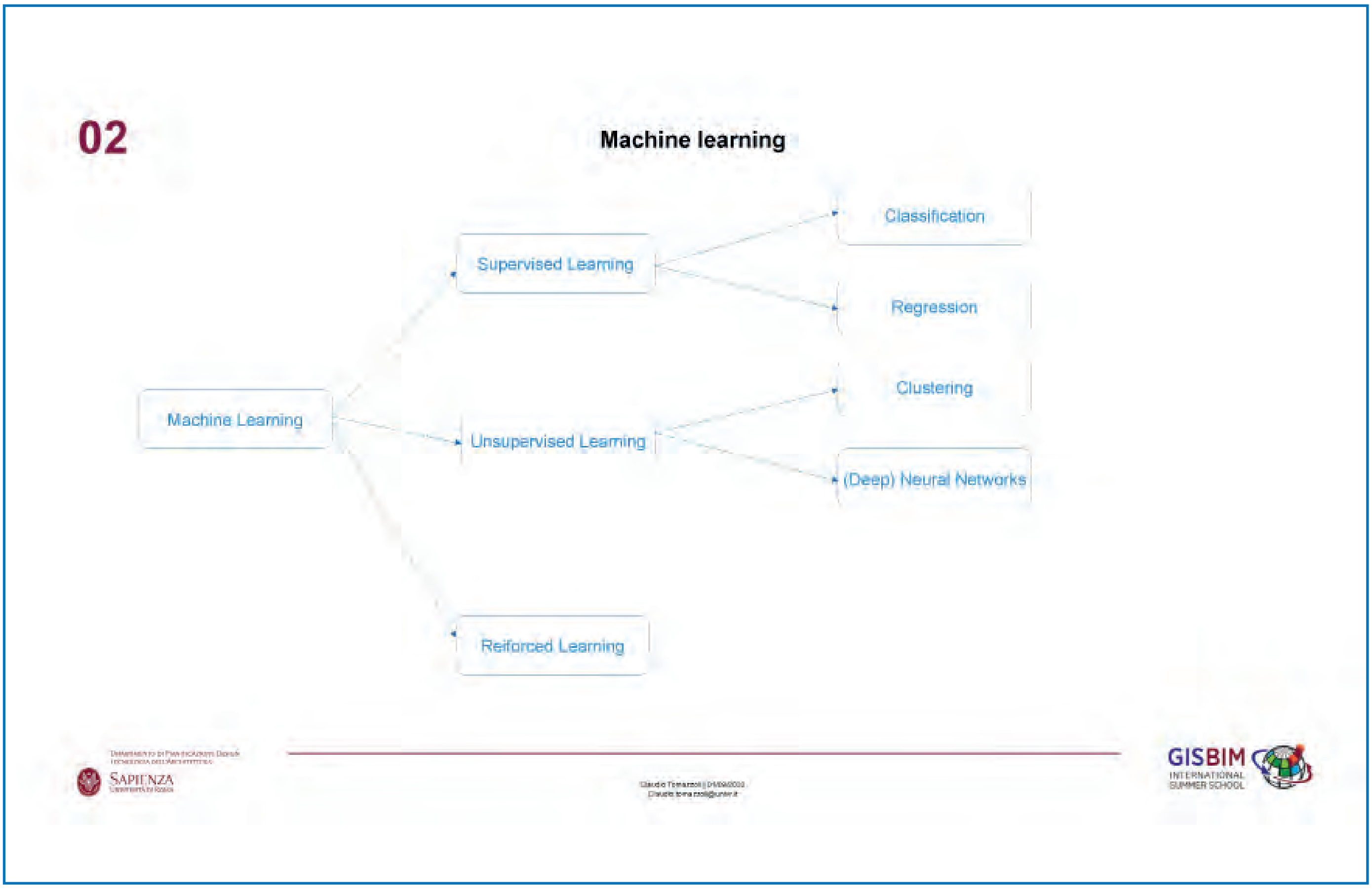
02
Machine learning
Machine Learning
Supervised Learning
Unsupervised Learning
Reiforced Learning
Classification
Regression
Clustering
(Deep) Neural Networks
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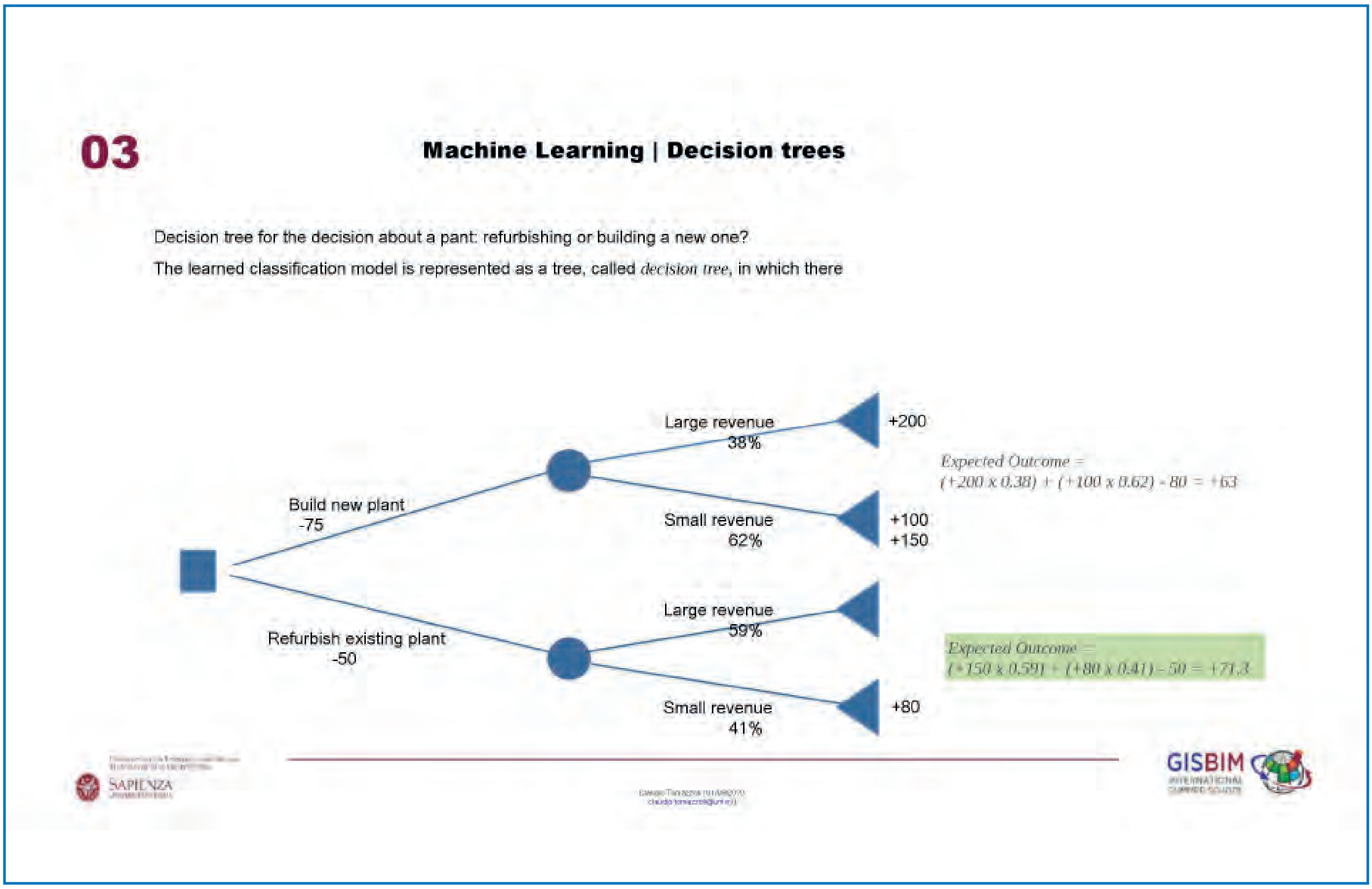
03
Machine Learning | Decision trees
Decision tree for the decision about a pant: refurbishing or building a new one?
The learned classification model is represented as a tree, called decision tree, in which there
Build new plant
-75
Refurbish existing plant
-50
Large revenue
38%
Small revenue
62%
Large revenue
59%
Small revenue
41%
+200
+100
+150
+80
Expected Outcome =
(+200 x 0.38) + (+100 x 0.62) - 80 = +63
Expected Outcome =
(+150 x 0.59) + (+80 x 0.41) - 50 = +71,3
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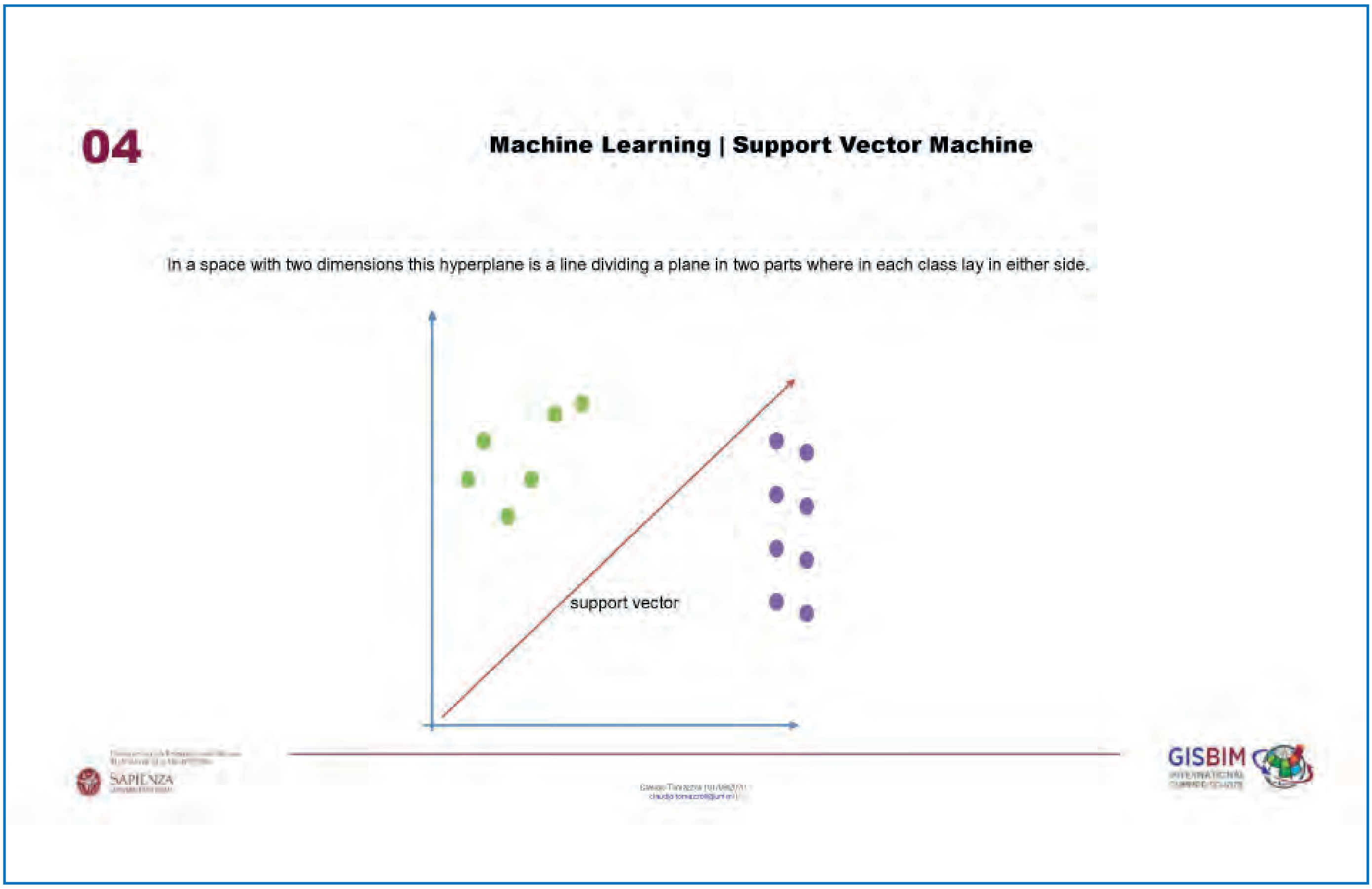
04
Machine Learning | Support Vector Machine
In a space with two dimensions this hyperplane is a line dividing a plane in two parts where in each class lay in either side.
support vector
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Machine Learning I Bayesian Classification, Bag of Word

Text 1: This movie is very scary and long

Text 2: This movie is not scary and is slow

Text 3: This movie is spooky and good

	This	movie	is	very	scary	and	long	not	slow	spooky	good
Text 1	1	1	1	1	1	1	1	0	0	0	0
Text 2	1	1	2	0	1	1	0	1	1	0	0
Text 3	1	1	1	0	0	1	0	0	0	1	1

Text 1: {1,1,1,1,1,1,1,0,0,0,0}

Text 2: {1,1,2,0,1,1,0,1,1,0,0}

Text 3: {1,1,1,0,0,1,0,0,0,1,1}

06

Machine Learning | Clustering

Clustering: K- Means algoritm

The better choice is to place them as much as possible far away from each other.

K = 3 (a priori)

07 Machine Learning | Clustering

Clustering: K- Means algoritm

Associate each point to the nearest centroid.

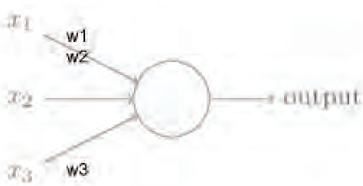
K = 3 (a priori)

08 Machine Learning | Neural Networks

Neural networks are based on a concept of an "artificial neuron".

The simplest artificial neuron is the Perceptron [1960], in which the output is determined by a weighted sum of the inputs:

the so called "activation function" is therefore defined as : "*If this weighted sum is above a certain threshold, then the output is 1, else it is 0*"

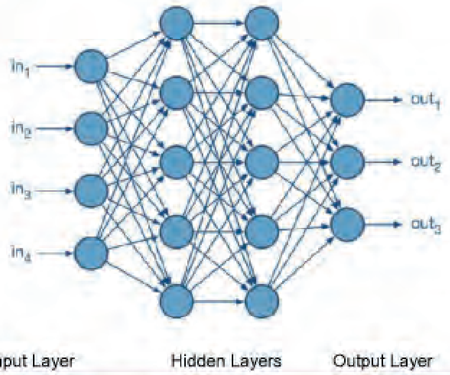


09

Machine Learning | Neural Networks

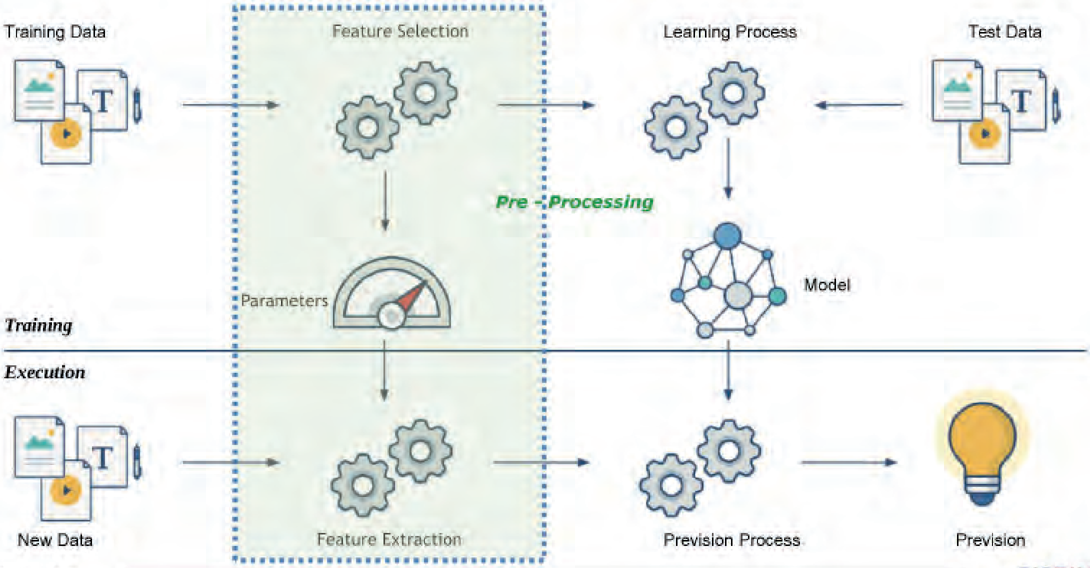
Neural networks are a combination of artificial neurons, with several "layers" of neurons each with the same activation function.

Once the number of layers and the number of neurons for each layer is defined, the definition of the weights is an automatic process: The weights of the network are initialised, then the data are fed to the network and the output is evaluated; the weights are changed and the data are fed to the network, then the output is evaluated; the weights are changed again and the data are fed to the network. And so on and so forth until a certain accuracy is reached or a time limit is exceeded.



10

Machine Learning | Workflow



11

Case Study

Area "Rinascimento III" in Rome

Case study 16 eight-floor building hosting 216 apartment units

Overall percentage of self-renewable energy produced by the building complex equal to 70%

Near Zero Energy Building

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12

Case Study | Rione Rinascimento

Rione Rinascimento

a) located in the Talenti district in Rome
b) next to a large park in a residential complex
c) consists of 40 units built in 2008
d) configured as a building intervention that characterize a new portion of the city energetically self-sufficient
e) integrated with the surrounding areas in terms of urban planning and services

This study focuses on the area of Rinascimento III (about 85 000m2) consisting of 16 eight-floor buildings hosting 216 apartment units

➡ the area inhabitants are about 1300 and the garages located in the underground level are able to contain more than 700 private cars
➡ almost 75% of the energy that powers the building complex is self-produced through the use of renewable sources

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Case Study | Energy

Most of the energy from renewable sources is supplied to the building complex by low-enthalpy geothermal energy

Heating and cooling are performed by means of a geothermal heat pump or GSHP (Ground Source Heat Pump) that transfers heat from the ground to the building in winter (heating mode) and in the opposite direction in summer (air conditioning mode)

The renewable energy production systems used in the building complex are a geothermal system with GSHPs, PV panels and solar collectors

The building complex is powered by the largest residential geothermal power plant in Europe;
the geothermal system supplies the heat pump chillers for the air conditioning of the apartments and for the production of domestic hot water.

14

Case Study | Energy

Photovoltaic panels on the front of each building and solar collectors located in the common areas integrate the RES energetic system.

The total annual energy requirements of the 16 buildings defined adding the requirements:

a) energy needs for winter air conditioning
b) energy needs for summer air conditioning
c) energy needs for domestic hot water
d) energy requirements for power supply

Winter air conditioning
Summer air conditioning

The energy requirement is estimated at 3 840 MWh; in terms of primary energy and taking into account all the transformation efficiencies of the plant systems it reaches 3 510 MWh of energy

The energy demand is estimated at 4 180 MWh; in terms of primary primary energy and taking into account all the transformation efficiencies of the plant systems, this comes to 2 640 MWh of energy

Production of domestic hot water

The energy requirement for the is estimated at 1 522 MWh in terms of primary primary energy and taking into account all the transformation efficiencies of the plant systems, it reaches 1 066 MWh of energy.

15 Case Study | Smart grid

The annual energy requirement for electricity excluding that already calculated for air conditioning is 2 763,61MWh of primary energy corresponding to 1 166,08MWh of energy actually supplied to users

The total energy demand in terms of primary energy for the entire complex: 3510 + 2640 + 1066 + 2764 = 9980 MWh/year

ENERGY PRODUCTION FROM RENEWABLE SOURCES	The energy supplied by the geothermal plant: 2 900MWh/year for heating, 2 375MWh/year for cooling 1 030MWh/year for domestic hot water	6 305 MWh/year

63% of the total energy requirement of primary source energy produced through the geothermic system
Energy production coming from solar sources

70% of the energy consumed by the residential complex produced by the local smart grid

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16 Case Study | Artificial Intelligence

It is proposed the implementation of an intelligent energy management system, able to modulate the loads (mainly electrical) according to the expected self energy-production also integrating the information coming from Earth observation systems such as Copernicus.

The system has the potential to leverage the efficiency of the entire energy system by more than 10% and thus limit the dependence of the building complex on distribution networks to a maximum of 15% of its energy consumption.

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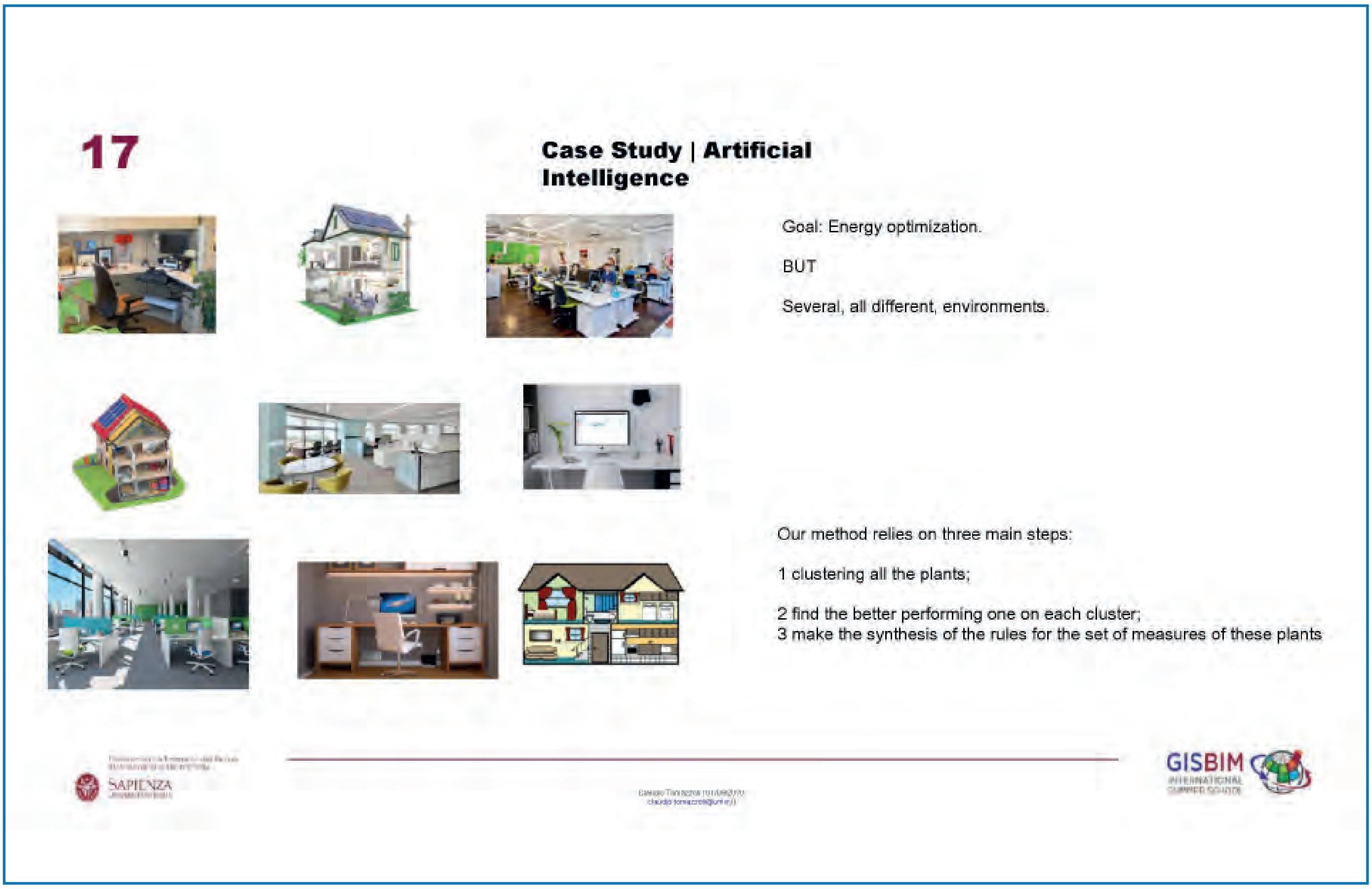
17
Case Study | Artificial Intelligence
Goal: Energy optimization.
BUT
Several, all different, environments.
Our method relies on three main steps:
1 clustering all the plants;
2 find the better performing one on each cluster;
3 make the synthesis of the rules for the set of measures of these plants
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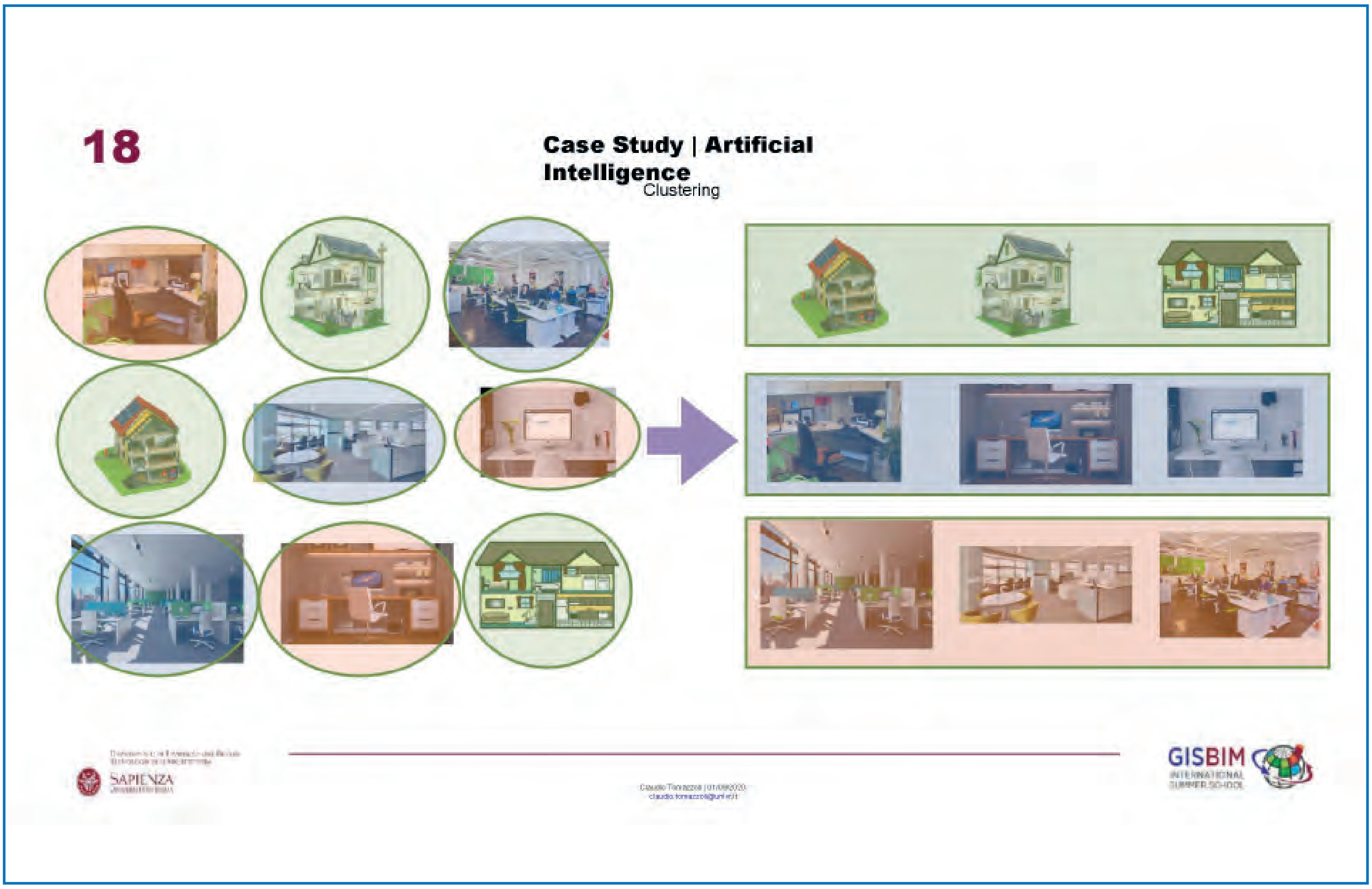
18
Case Study | Artificial Intelligence
Clustering
SAPIENZA
GISBIM

19

Case Study | Artificial Intelligence
Clustering

We have to define a procedure to determine whether a plant is similar to another one, in other words, our problem is to define a clustering for these installations.

In computer science and in machine learning in particular, the term "clustering" leads to think of multidimensional vector space, so we search for a vector representation of an installation.

All devices can be considered as belonging to a class, such as printer, coffee machine, television, fridge.

Without loss of generality we can say that every energy load belong to a specific type such as, for instance: light bulb, microwave induction plate, TV set, refrigerator.

The *feature representation* of a plant pi is a n-dimensional vector whose j-th component is the number of devices of type tj in pi. The *feature representation* can be therefore considered a point in a vector space whose dimension is the number of different devices within all the plants in the system.

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Case Study | Artificial Intelligence
Clustering

Plants may be univocally represented in the n-dimensional vector space induced by the number of unique device type and a clustering algorithm such as *k-means* can be applied to isolate groups of similar plants

Clustering: K- Means algoritm

The main idea is to define K centroids, one for each cluster

K (a priori)

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Case Study | Artificial Intelligence

Clustering

EXAMPLE

Consider, for instance, a system S with three houses p1, p2 , and p3 where:

plant p1 consists of two computers, ten light bulbs and one microwave induction plate;
plant p2 consists of one refrigerator, two TV sets, one washing machine, and one induction plate;
plant p3 consists of five computers, one microwave induction plate, one refrigerator and one light bulb.
The set of all device types in S is thus T = {light bulb, Computer, Refrigerator, Microwave induction plate, TV set, Washing machine, Induction plate}
and the representation of the plants is

- p1 = (2,10,0,1,0,0,0)
- p2 = (0, 0,1,0,2,1,1)
- p3 = (1, 5,1,1,0,0,0)

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Finding the better performing one

There will be no single champion nevertheless for each cluster a plant can be identified whose performances are better that those of the other component of the group.
No complex algorithm is needed for this choice: the "best ones" are the ones whose energy consumption are the lowest, in a given interval of time, in each group.

Given that the energy bill is directly related to energy consumption over a well determined time frame,
a simple comparison of the energy bills will tell the best ones apart.

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make the synthesis of the rules

Association rules denote implications of the form $X \rightarrow Y$

Given that a configuration of a plant at a given time is the set of the statuses of all belonging devices at that time, we extract from that dataset all the configurations of a plant in a given interval of time (say, a week).

The *configuration* at a given time of an energy environment such as a house can be defined as the set of all the active gears each with its related status. We use the term *relevant moment* the emphasize the time at which a change occurs in the configuration of a plant.

In a given installation, we shall have several records with the tuple of the form [device, power value, timestamp] where we can assume timestamps are almost synchronized.

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make the synthesis of the rules

Whenever a change is found in the power value, the timestamp is recognised to be a candidate relevant moment, and the device is marked as either active or not depending on the power value.

This procedure produces a set set of binary configurations at determined times, namely *configurations at relevant moments*, so that a compatible data set D and variable set V are defined, where:

1) V contains the power value for each device in the system S; a binary variable suffices if the need is only to determine if a device is active (1) or not active (0);

2)D is labeled with a relevant moment (which serves as data identifier), and contains variables corresponding to power level of the devices in that particular relevant moment.

Thus, D is an *itemset* where association rule mining can be performed using the well known *Apriori algorithm* obtaining rules in the form

computer → ~ TV set

which is a simple behavioural rule meaning "if the computer is on, then the TV set is off".
These rules can be then combined and exceptions and priorities can be learned

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Case Study | Artificial Intelligence

Automatic detection of device type

To ensure that our method will work the composition of the installation at any given time shall be given for granted.

The constant update of the connected device database is a time consuming task and the process is likely to be prone to a number of errors increasing with time.

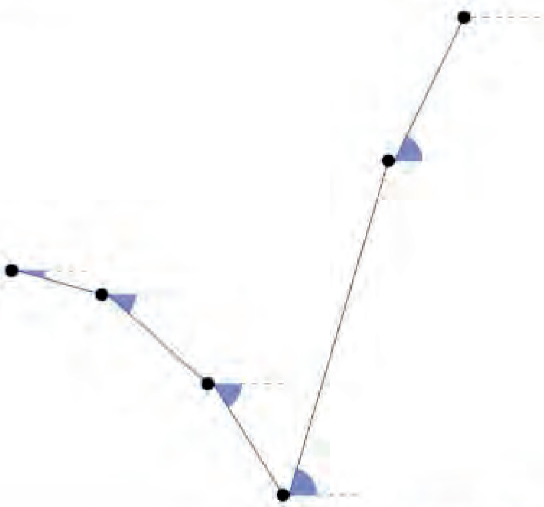
This lead to the risk of invalidating the whole method based on best practices, so a solution to the problem of having the correct representation of what are the actual loads in a plant is in order.

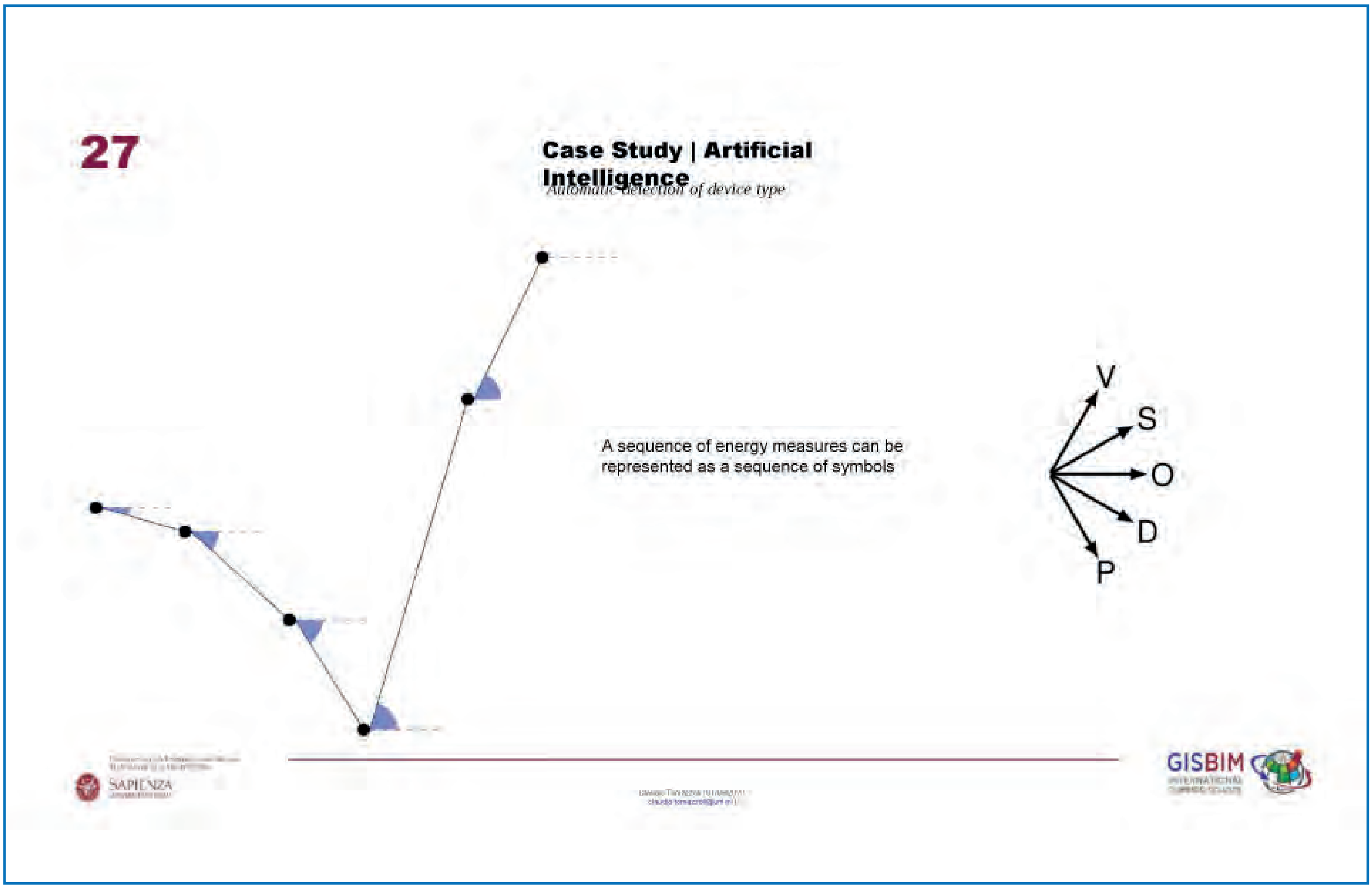
26

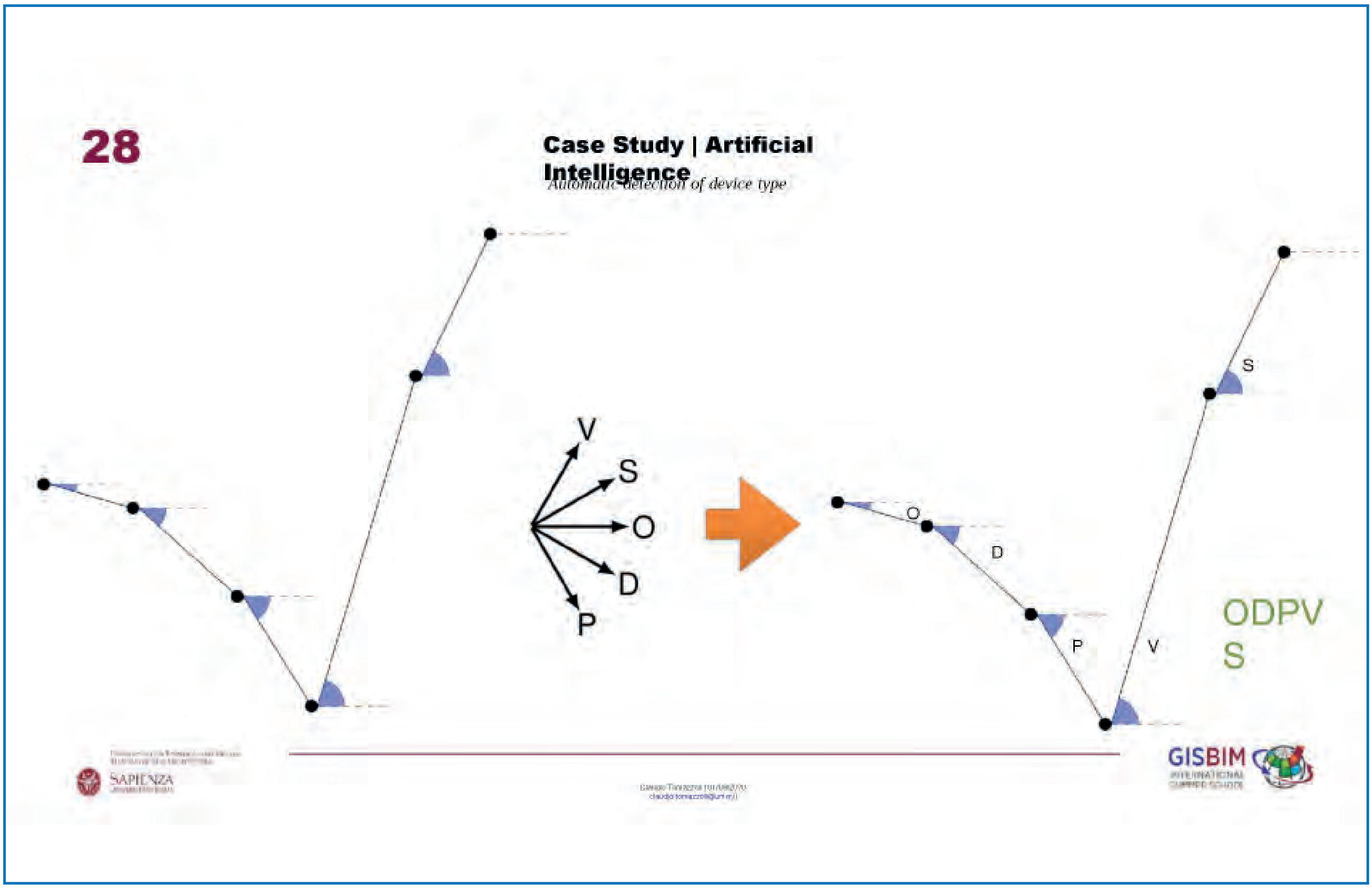
Case Study | Artificial Intelligence

Automatic detection of device type

An apparatus power use can be mathematically described as a continuous function of power over time whereas real world measurement are taken at given time intervals, so that a reasonable representation of the power curve can be achieved using a set of linear interpolated points




27
Case Study | Artificial Intelligence
Automatic detection of device type
A sequence of energy measures can be represented as a sequence of symbols
V
S
O
D
P
SAPIENZA
GISBIM


28
Case Study | Artificial Intelligence
Automatic detection of device type
V
S
O
D
P
O
D
P
V
S
ODPV
S
SAPIENZA
GISBIM

29

Case Study | Artificial Intelligence

Automatic detection of device type

A sequence of energy measures can be represented as a sequence of symbols

such as
OOOOVOOOOOOOOPOOVOOOOOPO

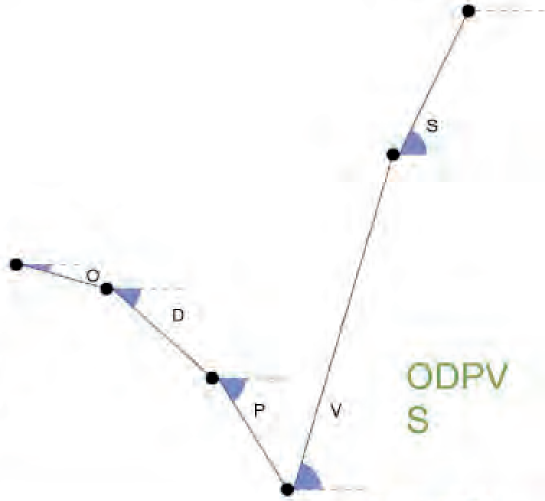
where multiple Os are transformed in a *"O "* therefore obtaining a flow of separated words, somehow realizing a *text footprint* of the monitored apparatus.

Dealing now with text, we can resort to the literature of the known field of *text mining* to exploit similarities:

the *bag- of-words* model indicates that gears with bigger number of "words" in common are more similar than ones with few:

using this analogy we defined the textual footprint of a given device as a *bag of energy word*

The process of automatic classification of energy loads can therefore be explained with the following sentence: **given a set of known (labeled) devices and a new unknown one, this new one will be attributed a class by comparing its textual footprint with the bag of ener words of the known ones.**



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30

Case Study | Artificial Intelligence

Automatic detection of device type

Word	Test Devices			
	Coffee Machine	*Printer*	*Boiler*	*Aquarium*
OVOPO	1	35	0	0
OVPDO	1	1	0	0
OSDO	35	1	0	0
OVPO	92	36	0	0
OVDPO	0	1	0	0
OSSPO	0	1	0	0
ODPO	0	0	1	0
OVSO	0	0	3	0
OPO	0	0	77	2
OVO	0	0	77	2

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GISBIM

BIM and GIS are software. We can benefit form the interoperation of these two software: how can we achieve this?

During a building life cycle some data change seldom, some other often, so we we can devise two kind of interactions: Static and Dynamic (see slide 02).

BIM and GIS are *client - server* software.

Client-server architecture is a computing model in which the server hosts, delivers and manages most of the resources and services to be consumed by the client. (see slide 03)

Client: a piece of software or application that takes the input and sends request to the server(s)

- makes use of the resources of the computer it runs on
- provides the User Interface (Graphical User Interface = GUI)
- communicate through standard format (protocol)

Server: a piece of software that receives and processes requests from clients

- automatically accept request regardless of the sender
- can ask requests to there servers
- can run on the same machine of the client

This type of architecture has one or more client computers connected to a central server over a network or internet connection.

A computer network is an interconnection of multiple devices, also known as hosts, that are connected using multiple paths for the purpose of sending/receiving data or media.

A protocol is the set of rules or algorithms which define the way how two entities can communicate across the network and there exists different protocol defined at each layer of the ISO / OSI model.

The ISO / OSI (Open Systems Interconnection) model is a reference model that specifies standards for communications protocols and also the functionalities of each layer (slide 04).

Known Protocols are : HTTP, HTTPS, SMTP, POP3 and IMAP while Important Protocols are Internet Protocol(IP) and Transfer Control Protocol (TCP) over which the former depends upon.

The Internet Protocol (IP) is a protocol, or set of rules, for routing and addressing packets of data so that they can travel across networks and arrive at the correct destination. Data traversing the Internet is divided into smaller pieces, called packets. IP information is attached to each packet, and this information helps routers to send packets to the right place.

An IP address is a unique identifier assigned to a device or domain that connects to the Internet. Each IP address is a series of characters, such as '192.168.1.1'. Via DNS resolvers, which translate human-readable domain names into IP addresses, users are able to access websites without memorizing this complex series of characters (slide 05).

Both BIM and GIS are complex client server application, as shown in slides 06,07 and 08. They can interoperate in a static way using files or in a dynamic way thanks to the use of one ore more software(slide 09).

Static Interaction:

Data can be Structured, Partially-Structured or Unstructured (slide 10): BIM and GIS software can exchange data using partially structured file. The most common used format for semi- structured data interchange in Extensible Markup Language: "XML" ,a text file with TAGs describing the structure. It is a Standard W3C ; it describes the logic structure of a document, which is represent as a tree.A more detailed description can be found on slides 11,12,13,14.

BIMXML describes building data (sites, buildings, floors, spaces, and equipment and their attributes) in a simplified spatial building model (extruded shapes and spaces) for BIM collaboration. The XML Schema was developed as an alternative to full scale IFC models to simplify data exchanges between various AEC applications and to connect Building Information Models through Web Services. (http://bimxml.org/)

GIS lack a standard XML schema, as explained in slides 15, moreover GIS and BIM cannot effortlessly exchange XML file, as shown in slides 16 through 18, without the aid of a tailor made software.

Dynamic Interaction:

A database is an organized collection of structured information, or data, typically stored electronically in a computer system. A database is usually controlled by a database management system (DBMS). Together, the data and the DBMS, along with the applications that are associated with them, are referred to as a database system, often shortened to just database.

Data within the most common types of databases in operation today is typically modeled in rows and columns in a series of tables to make processing and data querying efficient. The data can then be easily accessed, managed, modified, updated, controlled, and organized.

Most databases use structured query language (SQL) for writing and querying data.

Databases and spreadsheets (such as Microsoft Excel) are both convenient ways to store information. The primary differences between the two are:

- How the data is stored and manipulated
- Who can access the data
- How much data can be stored

Spreadsheets were originally designed for one user, and their characteristics reflect that. They're great for a single user or small number of users who don't need to do a lot of incredibly complicated data manipulation. Databases, on the other hand, are designed to hold much larger collections of organized information—massive amounts, sometimes.

Databases allow multiple users at the same time to quickly and securely access and query the data using highly complex logic and language. SQL is a programming language used by nearly all relational databases to query, manipulate, and define data, and to provide access control. The dynamic interaction between BIM and GIS can be achieved enabling the interaction of their DBMS and thanks to use of the language SQL, as better explained in slides 19 through 25.

The case study in slides 26, 27, 28, 29 is a !mWatt photovoltaic plant of 50.000 square meters in which a dynamic interaction of a GIS and a power metering software enables the full visual control of 98 "follow the sun" solar panels.


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BIM & GIS for integrated design
SAPIENZA UNIVERSITY OF ROME
FACULTY OF ARCHITECTURE
Rome, August 31st – September 11th 2020
PROF: Giuseppe Piroux (OOP Systems)
TITLE: Digital Methods and tools
07/09/2020
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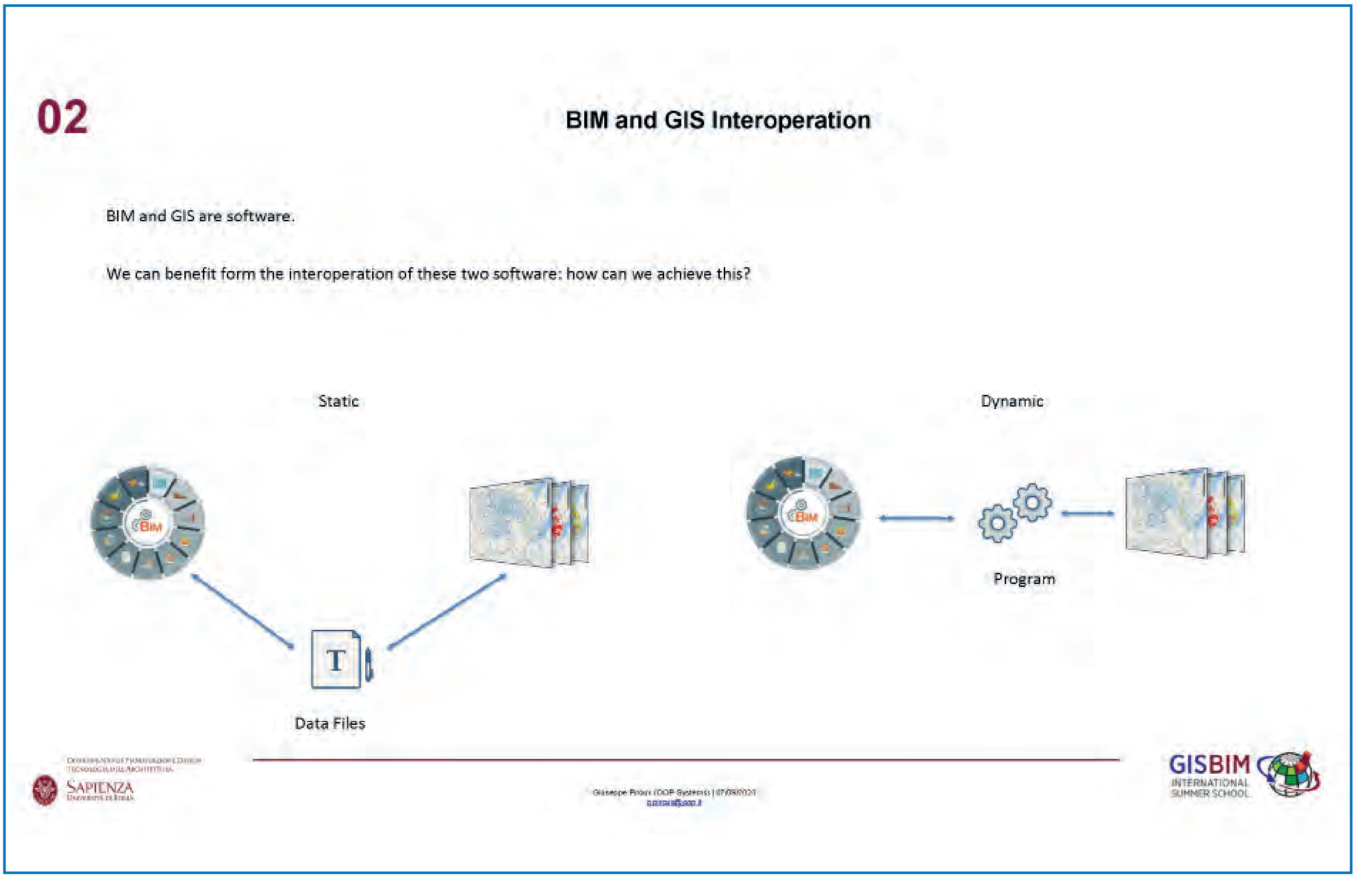
02
BIM and GIS Interoperation
BIM and GIS are software.
We can benefit form the interoperation of these two software: how can we achieve this?
Static
Dynamic
Program
Data Files
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Giuseppe Piroux (OOP Systems) | 07/09/2020
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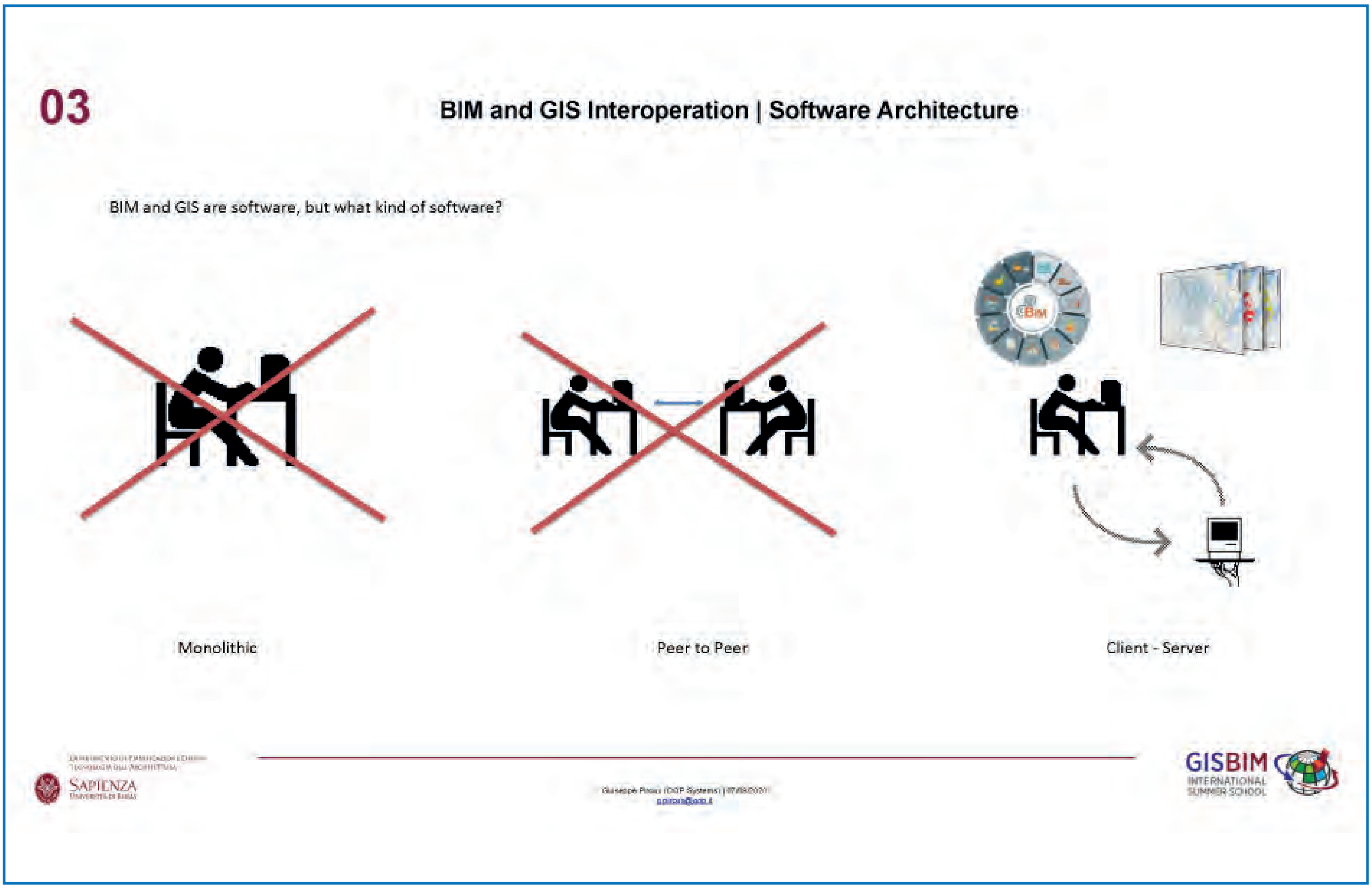
03
BIM and GIS Interoperation | Software Architecture
BIM and GIS are software, but what kind of software?
Monolithic
Peer to Peer
Client - Server
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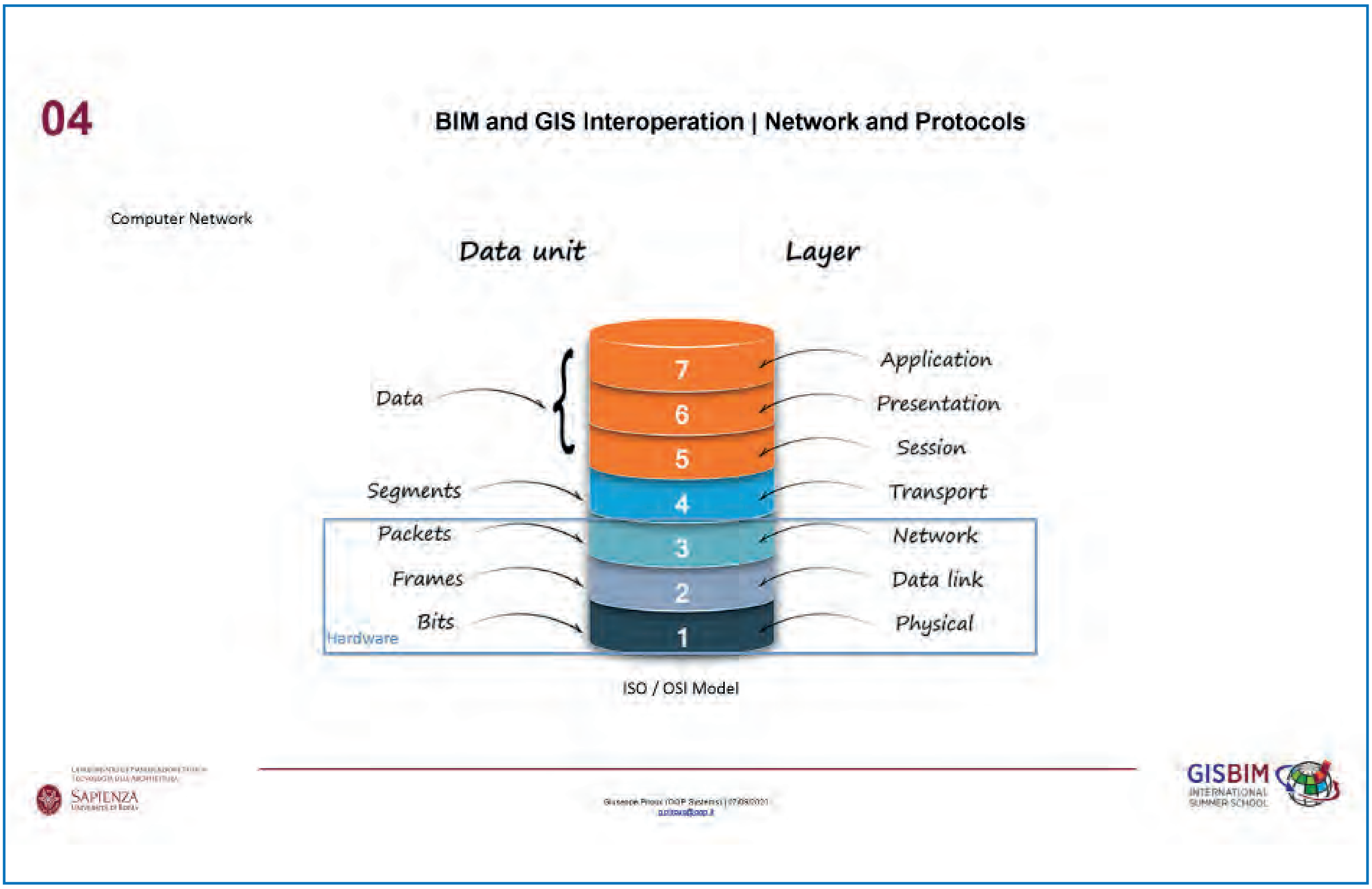
04
BIM and GIS Interoperation | Network and Protocols
Computer Network
Data unit
Layer
Data
Segments
Packets
Frames
Bits
Hardware
7
6
5
4
3
2
1
Application
Presentation
Session
Transport
Network
Data link
Physical
ISO / OSI Model
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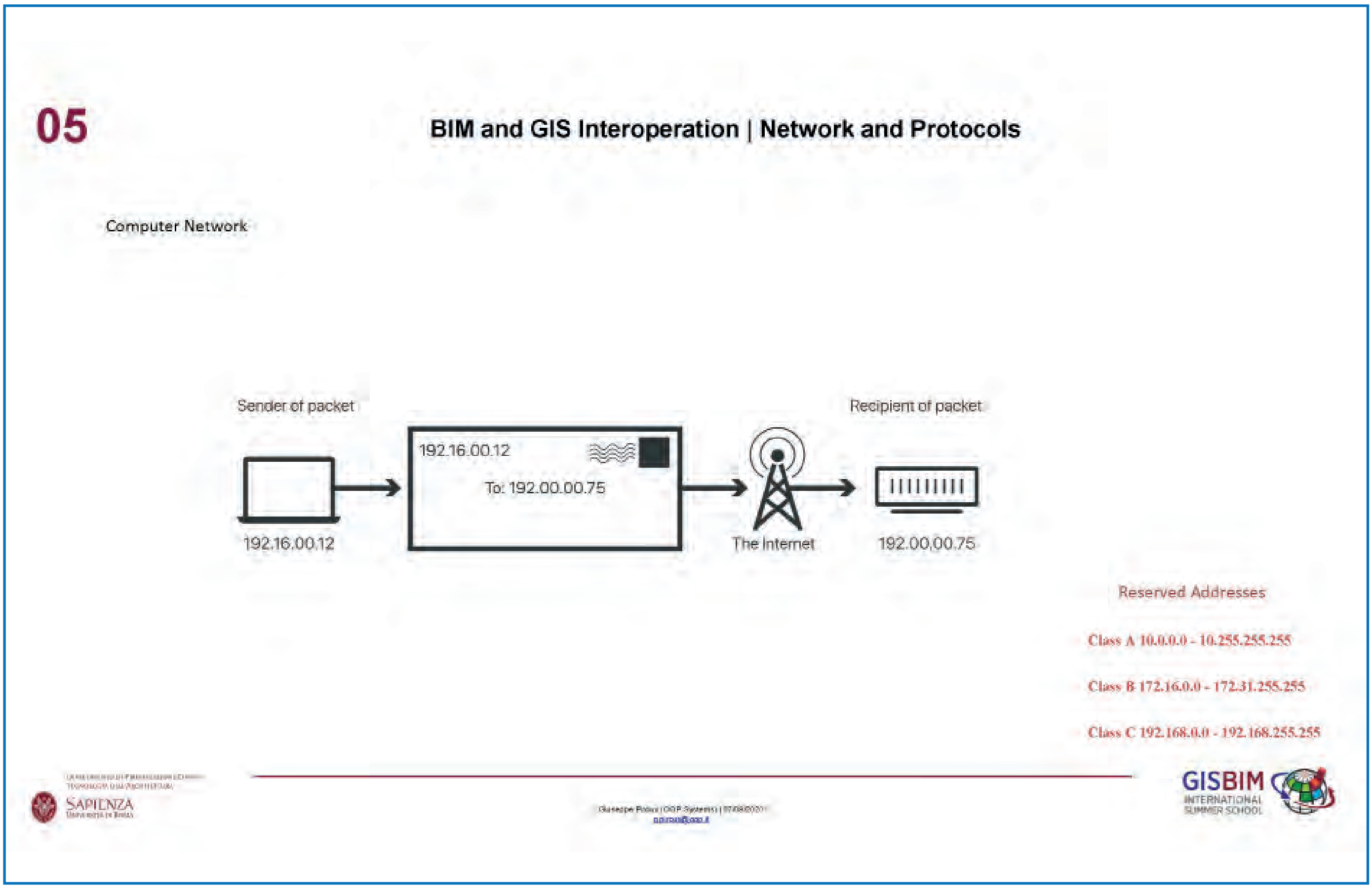
05
BIM and GIS Interoperation | Network and Protocols
Computer Network
Sender of packet
Recipient of packet
192.16.00.12
To: 192.00.00.75
192.16.00.12
The Internet
192.00.00.75
Reserved Addresses
Class A 10.0.0.0 - 10.255.255.255
Class B 172.16.0.0 - 172.31.255.255
Class C 192.168.0.0 - 192.168.255.255
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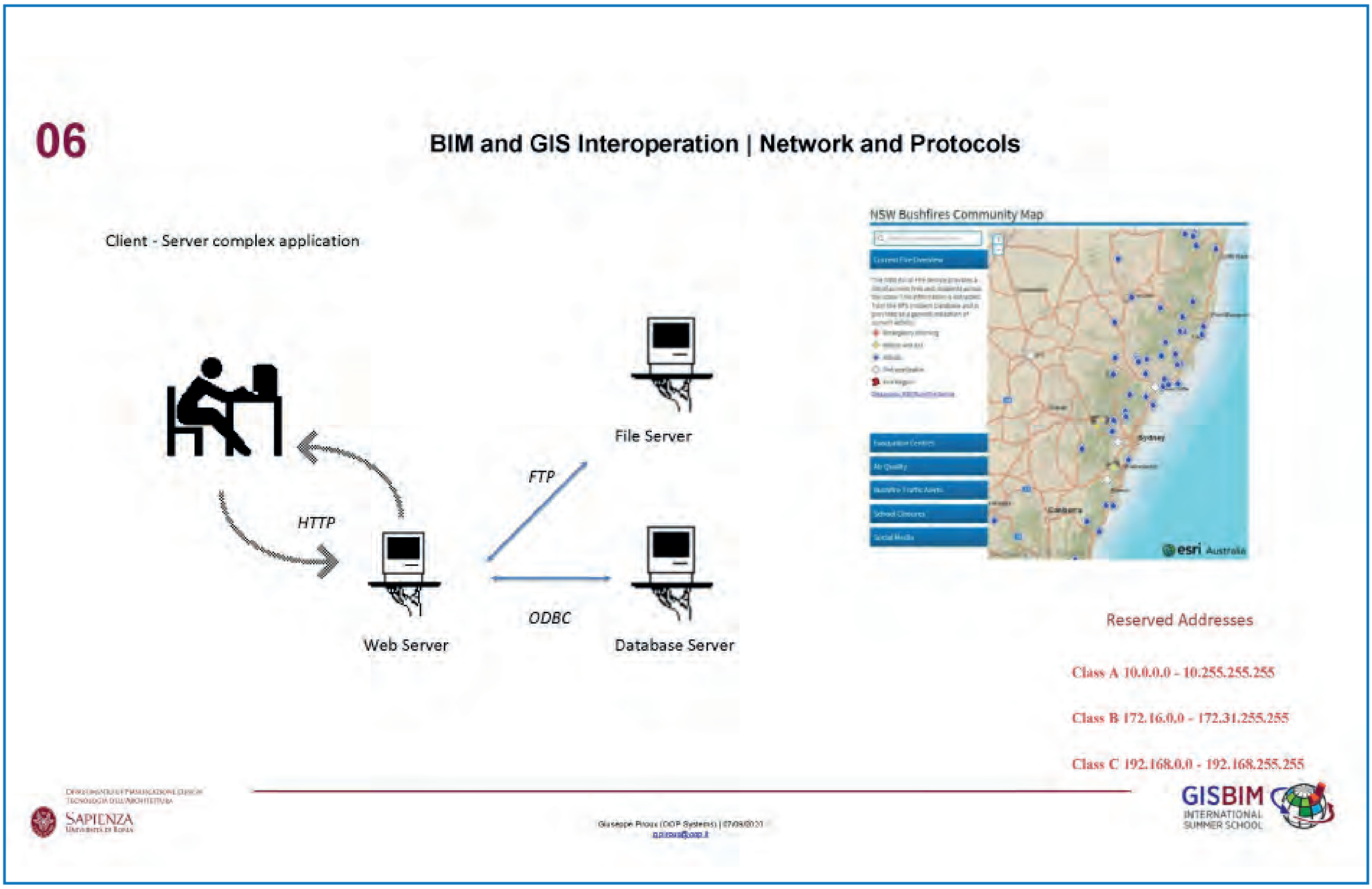
06
BIM and GIS Interoperation | Network and Protocols
Client - Server complex application
HTTP
FTP
ODBC
File Server
Web Server
Database Server
NSW Bushfires Community Map
esri Australia
Reserved Addresses
Class A 10.0.0.0 - 10.255.255.255
Class B 172.16.0.0 - 172.31.255.255
Class C 192.168.0.0 - 192.168.255.255
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07

BIM and GIS Interoperation

BIM and GIS are client - server software

BIM:

Client: a piece of software or application that takes the input, sends request to the server(s) and represent the answer to the user.
Server:a piece of software that receives and processes requests from clients: typically a RDBMS (Relational Database Management Software)

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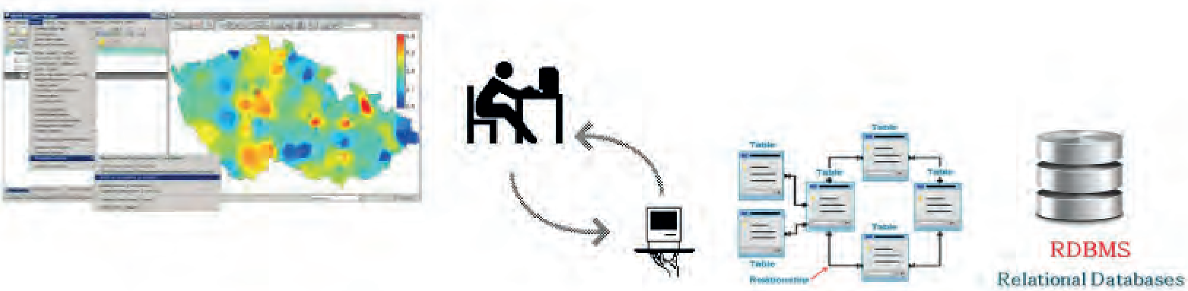
08

BIM and GIS Interoperation

BIM and GIS are client - server software

GIS:

Client: a piece of software or application that takes the input, sends request to the server(s) and represent the answer to the user.
Server:a piece of software that receives and processes requests from clients: typically a RDBMS (Relational Database Management Software)



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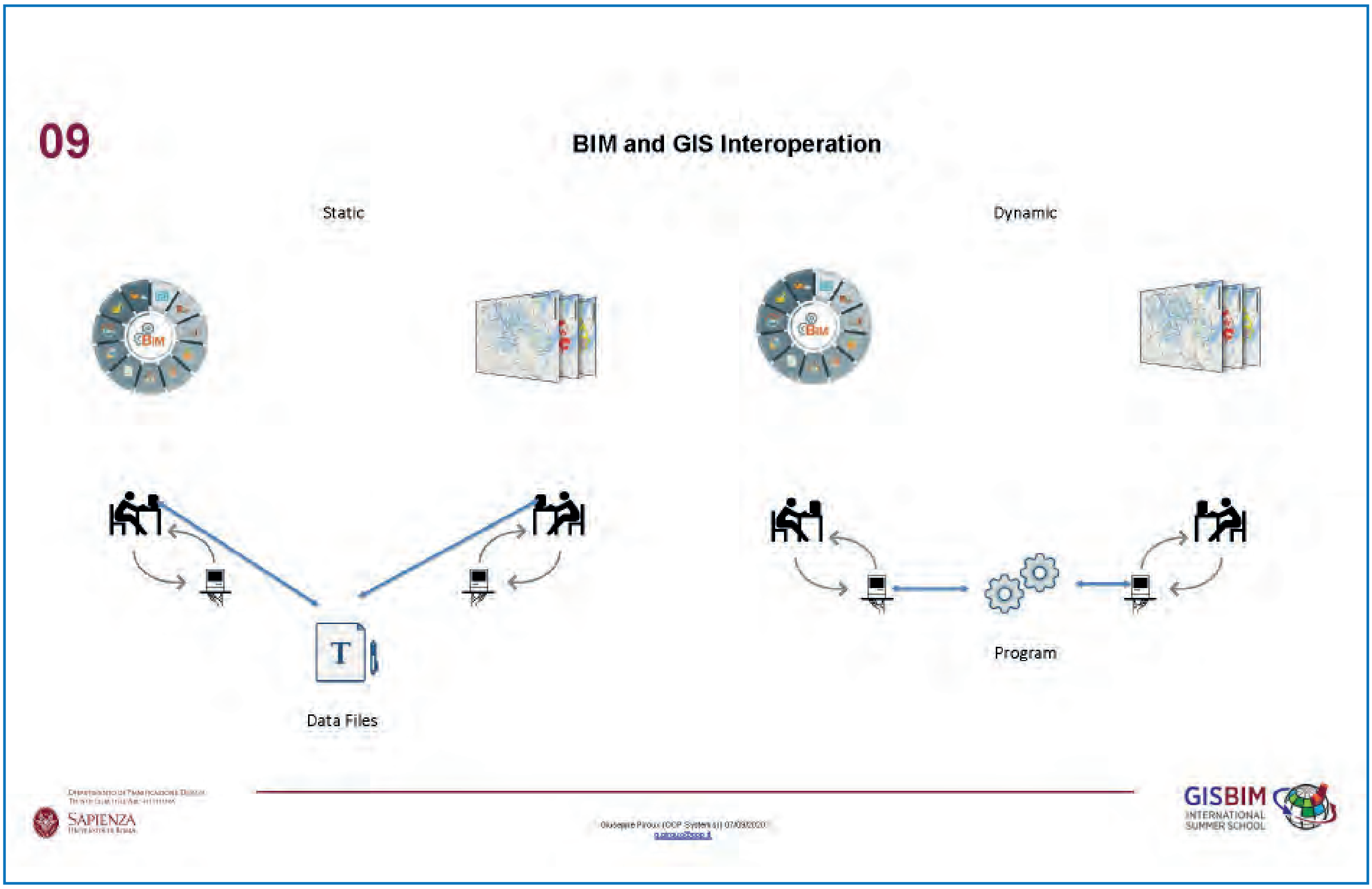


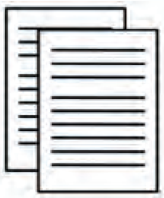
10 BIM and GIS Interoperation | Data

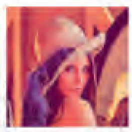
STRUCTURED

UNSTRUCTURED

id-pers	*nome*	*cognome*
0000001	Mario	Rossi
0000002	Giorgio	Verdi

id-pers	*telefono*
0000001	051 1234
0000001	333 3333





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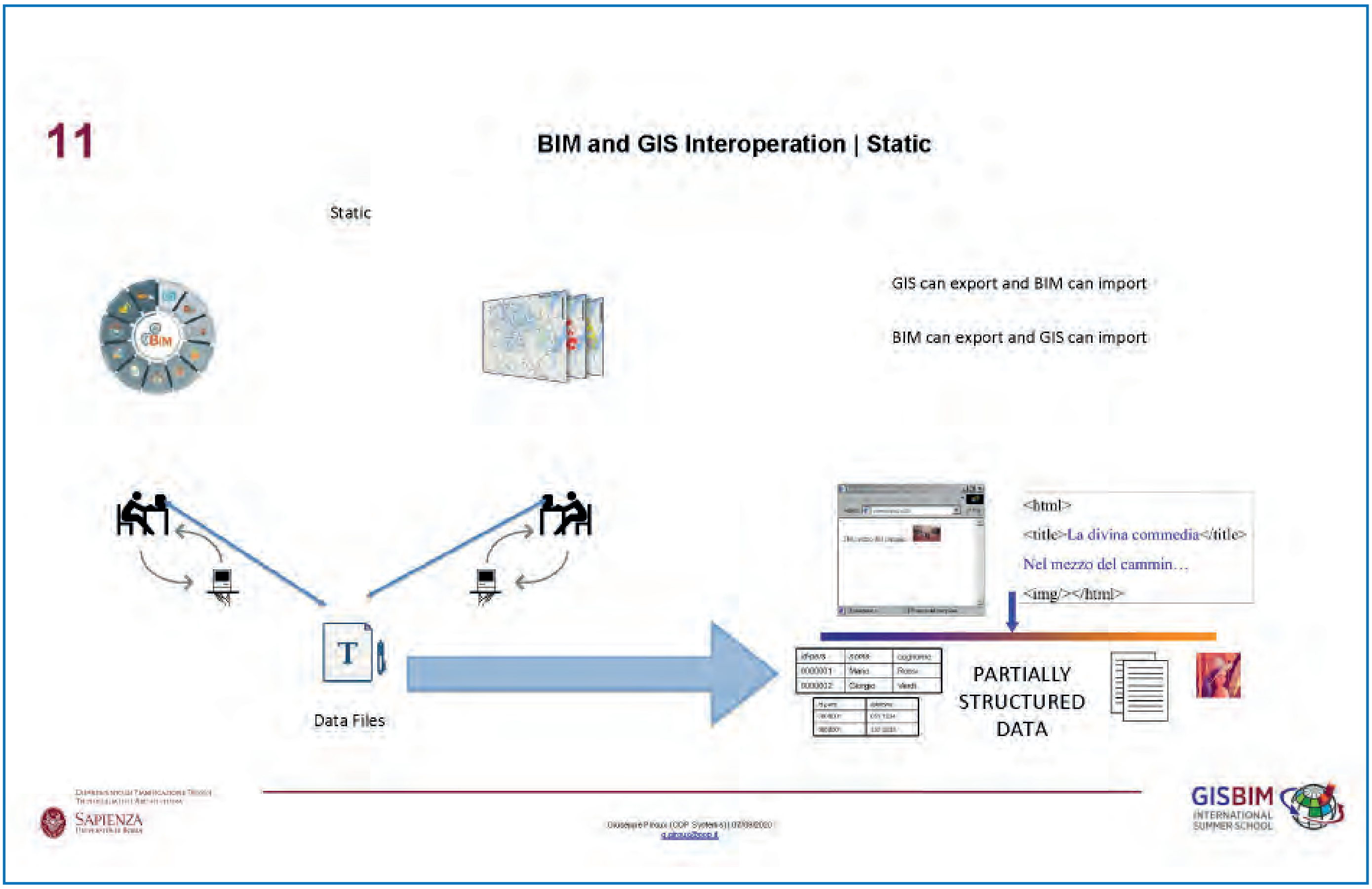
11
BIM and GIS Interoperation | Static
Static
GIS can export and BIM can import
BIM can export and GIS can import
<html>
<title>La divina commedia</title>
Nel mezzo del cammin…
<img/></html>
Data Files
PARTIALLY
STRUCTURED
DATA
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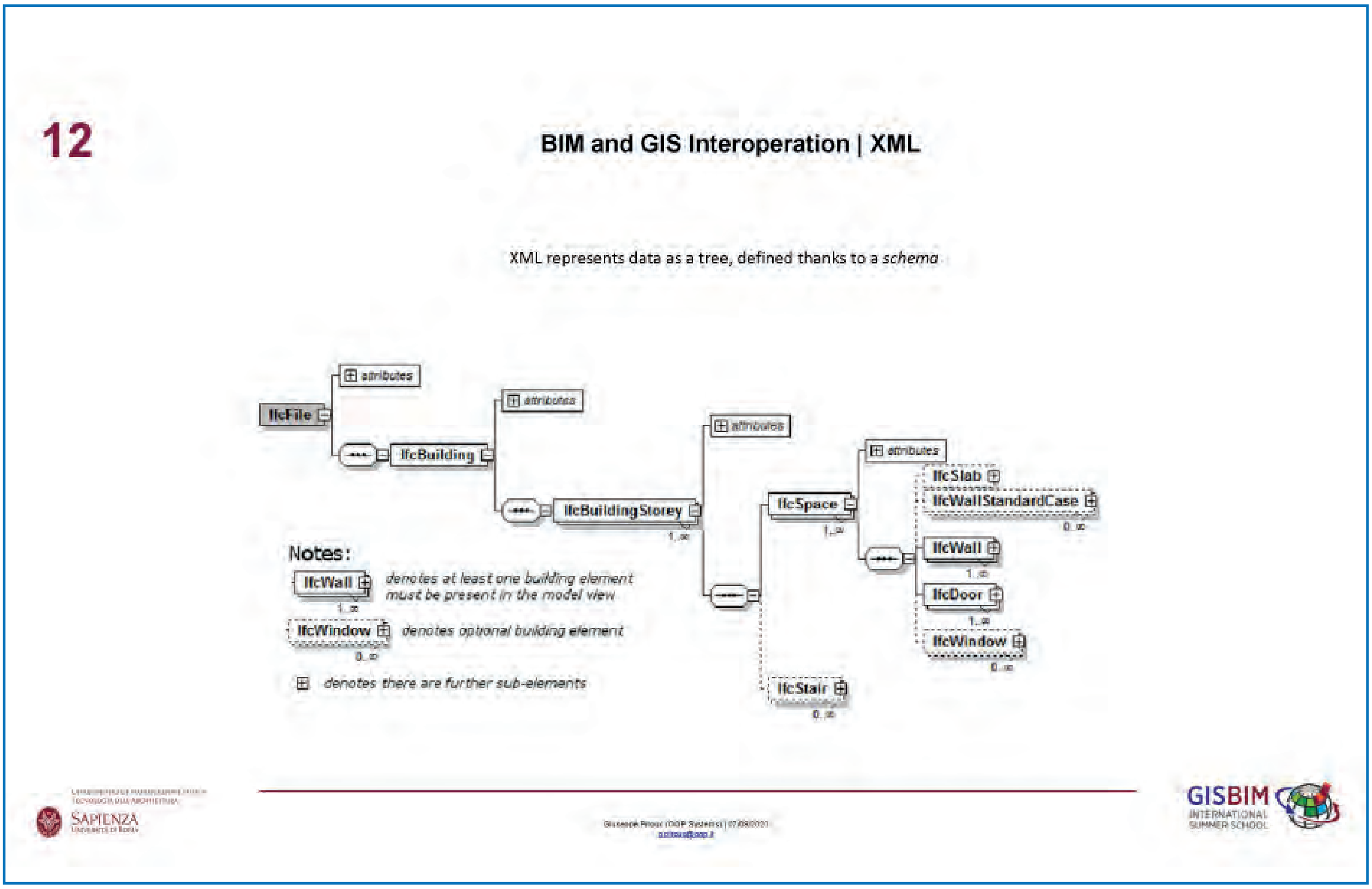
12
BIM and GIS Interoperation | XML
XML represents data as a tree, defined thanks to a schema
IfcFile
attributes
IfcBuilding
attributes
IfcBuildingStorey
attributes
IfcSpace
attributes
IfcSlab
IfcWallStandardCase
IfcWall
IfcDoor
IfcWindow
IfcStair
Notes:
IfcWall denotes at least one building element must be present in the model view
IfcWindow denotes optional building element
denotes there are further sub-elements
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13 BIM and GIS Interoperation | XML

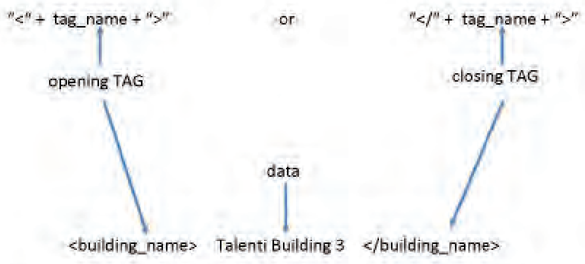
XML files are files in which structure and data are present at the same time

XML structure is a set of nested TAGS

a TAG is a structure delimiter, can contain other tags and can have "attributes" (are couples of name=value data): there are opening and closing tags

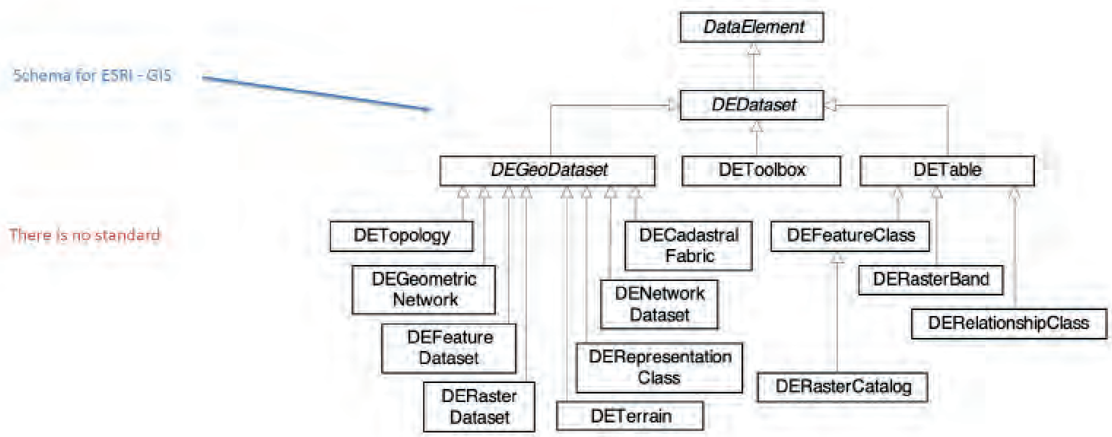
an opening TAG is a text in the form "<" + tag_name + ">" or "<" + tag_name + "attribute_name=" + attribute + ">"

a closing TAG is a text in the form "</" + tag_name + ">"



14 BIM and GIS Interoperation | XML

XML schema for GIS



15

BIM and GIS Interoperation | XML

XML schema for GIS

Schema for ESRI - GIS

There is no standard

```
<Field xsi:type="esri:Field">
  <Name>OBJECTID</Name>
  <Type>esriFieldTypeOID</Type>
  <IsNullable>false</IsNullable>
  <Length>4</Length>
  <Precision>0</Precision>
  <Scale>0</Scale>
  <Required>true</Required>
  <Editable>false</Editable>
  <AliasName>OBJECTID</AliasName>
  <ModelName>OBJECTID</ModelName>
</Field>
```

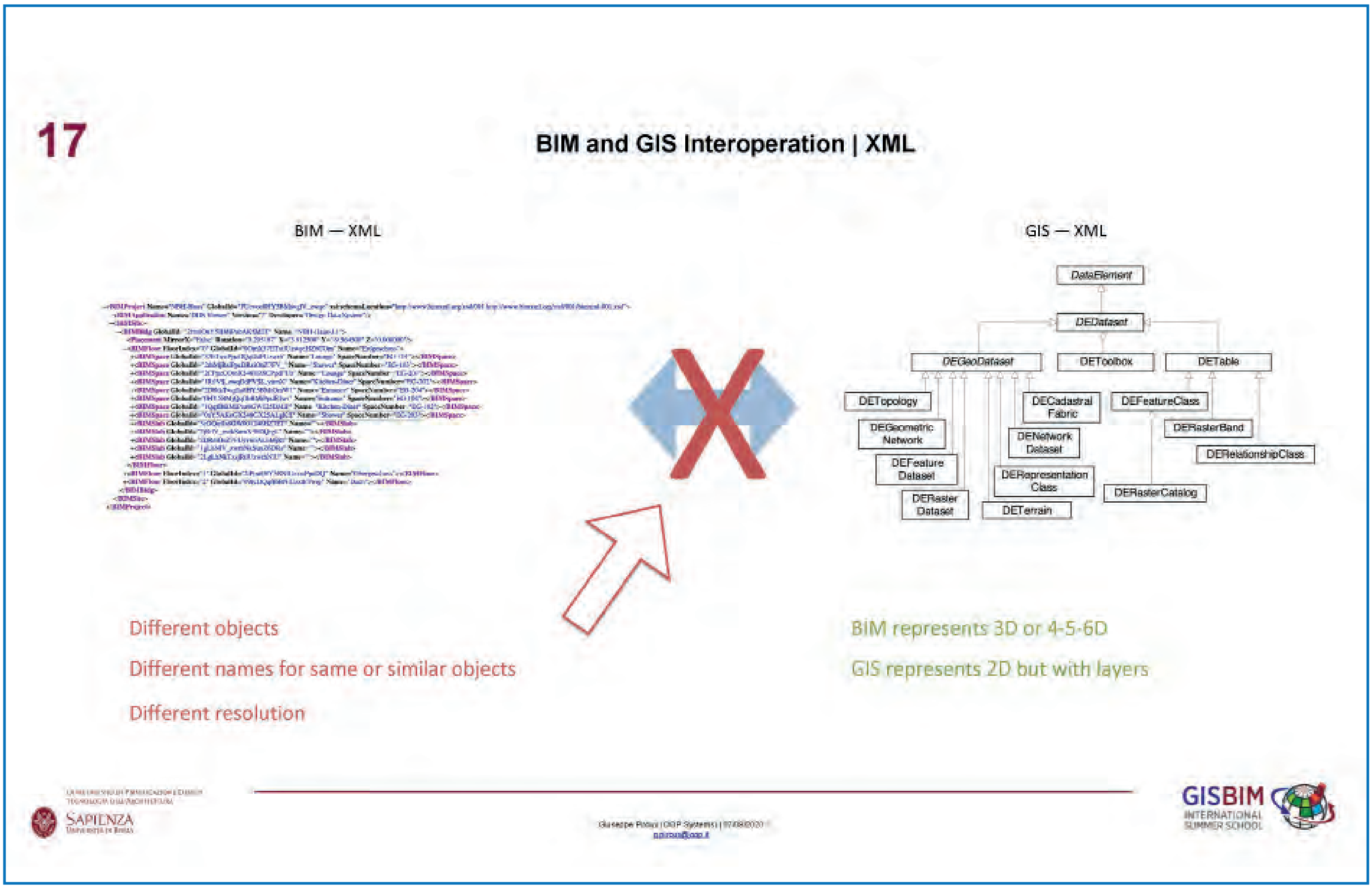
XML schema can be used to specify the format that the XML document should follow. In the latter case above, the schema would specify that a field XML element should have a sequence of children elements, the first called Name (a string), the second called Type (an enumeration value), and so on. The geodatabase exchange format uses only XML elements (not attributes).

16

BIM and GIS Interoperation | XML

BIM — XML

GIS — XML


17
BIM and GIS Interoperation | XML
BIM — XML
GIS — XML
DataElement
DEDataset
DEGeoDataset
DEToolbox
DETable
DETopology
DEGeometric Network
DEFeature Dataset
DERaster Dataset
DECadastral Fabric
DENetwork Dataset
DERepresentation Class
DETerrain
DEFeatureClass
DERasterBand
DERelationshipClass
DERasterCatalog
Different objects
Different names for same or similar objects
Different resolution
BIM represents 3D or 4-5-6D
GIS represents 2D but with layers
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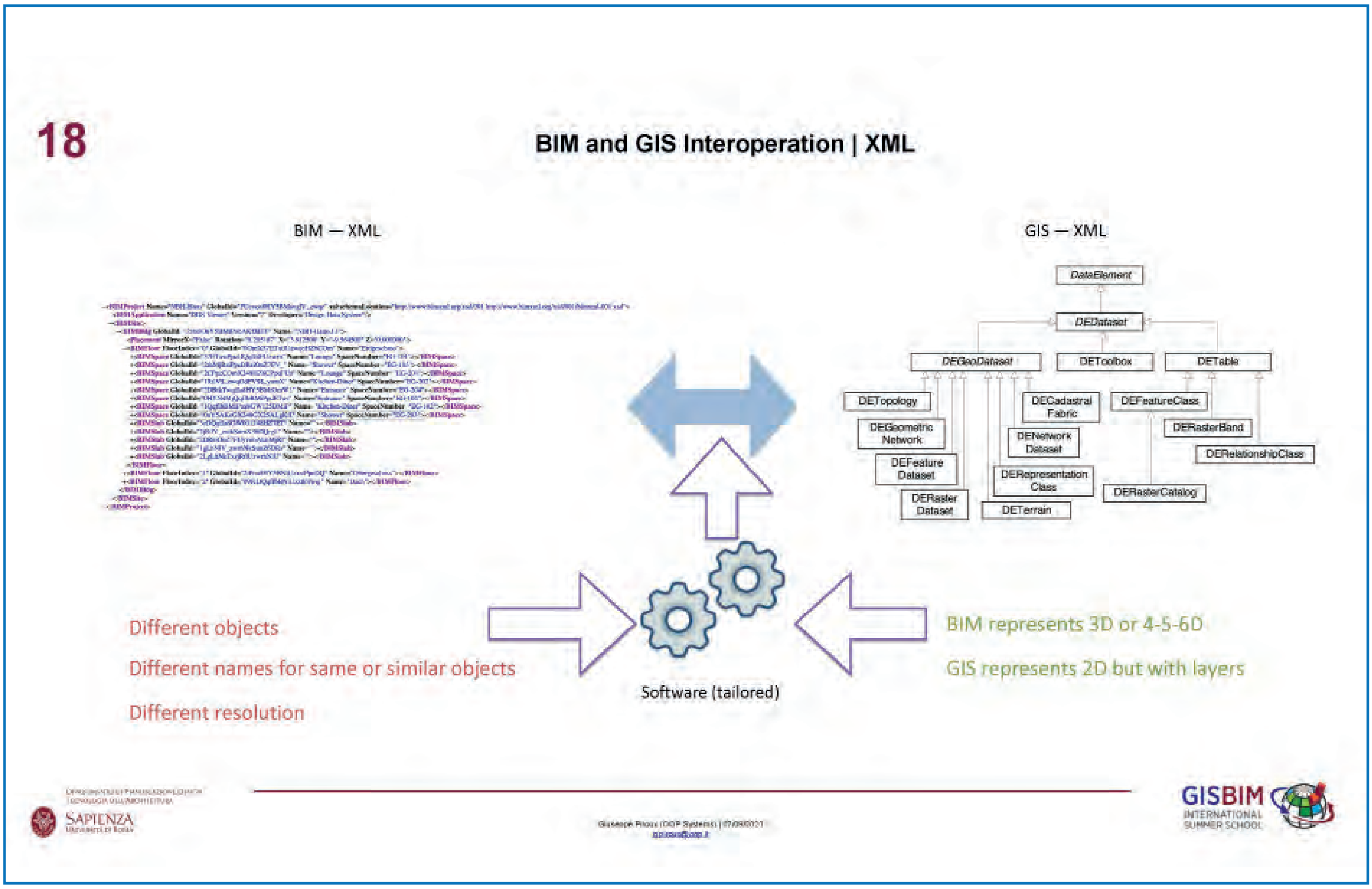
18
BIM and GIS Interoperation | XML
BIM — XML
GIS — XML
DataElement
DEDataset
DEGeoDataset
DEToolbox
DETable
DETopology
DEGeometric Network
DEFeature Dataset
DERaster Dataset
DECadastral Fabric
DENetwork Dataset
DERepresentation Class
DETerrain
DEFeatureClass
DERasterBand
DERelationshipClass
DERasterCatalog
Different objects
Different names for same or similar objects
Different resolution
Software (tailored)
BIM represents 3D or 4-5-6D
GIS represents 2D but with layers
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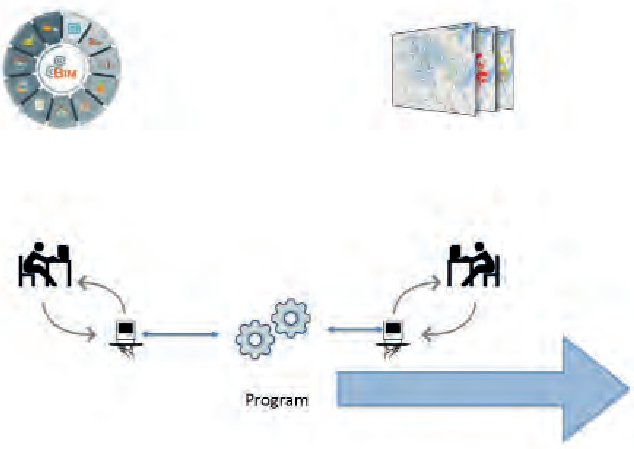
19

BIM and GIS Interoperation | SQL

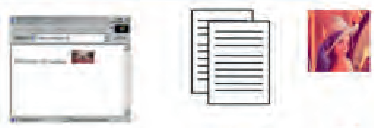


GIS and BIM servers can interact

personal-id	name	surname
0000001	John	Doe
0000002	Martin	Catcher
0000003	Emma	Watson

personal-id	telephone_number
0000001	+39111222333
0000002	+39444555666

STRUCTURED DATA (SCHEMA)



20

BIM and GIS Interoperation | SQL

A database typically requires a comprehensive database software program known as a database management system (DBMS).

A DBMS serves as an interface between the database and its end users or programs, allowing users to retrieve, update, and manage how the information is organized and optimized.

A DBMS also facilitates oversight and control of databases, enabling a variety of administrative operations such as performance monitoring, tuning, and backup and recovery.

Some examples of popular database software or DBMSs include MySQL, Microsoft Access, Microsoft SQL Server, FileMaker Pro, Oracle Database, and dBASE.

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BIM and GIS Interoperation | SQL

Data are stored in tables: tables have rows and columns

	Column 1	Column 2	Column 3
ROW 1	value 1,1	value 1,2	value 1,3
ROW 2	value 2,1	value 2,2	value 2,3
ROW 3	value 3,1	value 3,2	value 3,3

Example

personal-id	name	surname
0000001	John	Doe
0000002	Martin	Catcher
0000003	Emma	Watson

Ordering between rows is irrelevant

Ordering between columns is irrelevant

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BIM and GIS Interoperation | SQL

SQL (pronounced sequel) is the set-based, high-level declarative computer language with which all programs and users access data in a database.

SQL provides an interface to a relational database. SQL unifies tasks such as the following in one consistent language:

- Creating, replacing, altering, and dropping objects
- Inserting, updating, and deleting table rows
- Querying data
- Controlling access to the database and its objects
- Guaranteeing database consistency and integrity

SQL can be used interactively, which means that statements are entered manually into a program.

SQL statements can also be embedded within a program written in a different language such as C or Java.

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BIM and GIS Interoperation | SQL

SQL instructions:

CREATE TABLE	Creates a table	CREATE TABLE public.log (id_log character(20) NOT NULL, file_hash character(32) NOT NULL, file_path character varying NOT NULL, xml_dublin_core text NOT NULL, data_input character varying(17) NOT NULL, data_output character varying(17), protocol character(20), origin character varying(255), data_ins character varying(17), data_var character varying(17), user_ins character varying, user_var character varying, CONSTRAINT log_pkey PRIMARY KEY (id_log))
DROP TABLE	Deletes a table	DROP TABLE public.log

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BIM and GIS Interoperation | SQL

SQL operations on data:

SELECT	Query a table
UPDATE, INSERT, DELETE	Data handling

SELECT <attributes> FROM <tables> [WHERE <condition>]

SELECT file_hash, file_path FROM public.log WHERE origin='web'

reads

"from relation public.log filter every tuple(row) with value 'web'
in attribute 'origin' showing for every row the values of attributes 'file_hash' and 'file_path' "

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BIM and GIS Interoperation | SQL

names

personal-id	name	surname
0000001	John	Doe
0000002	Martin	Catcher
0000003	Emma	Watson

numbers

personal-id	telephone_number
0000001	+39111222333
0000002	+39444555666

```
SELECT
names.personal-id as personal-id, names.name as name,
names.surname as surname,
numbers.telephone_number as telephone_number
FROM
names, numbers
WHERE
names.personal-id = numbers.personal-id
```

personal-id	name	surname	telephone_number
0000001	John	Doe	+39111222333
0000002	Martin	Catcher	+39444555666
0000003	Emma	Watson	

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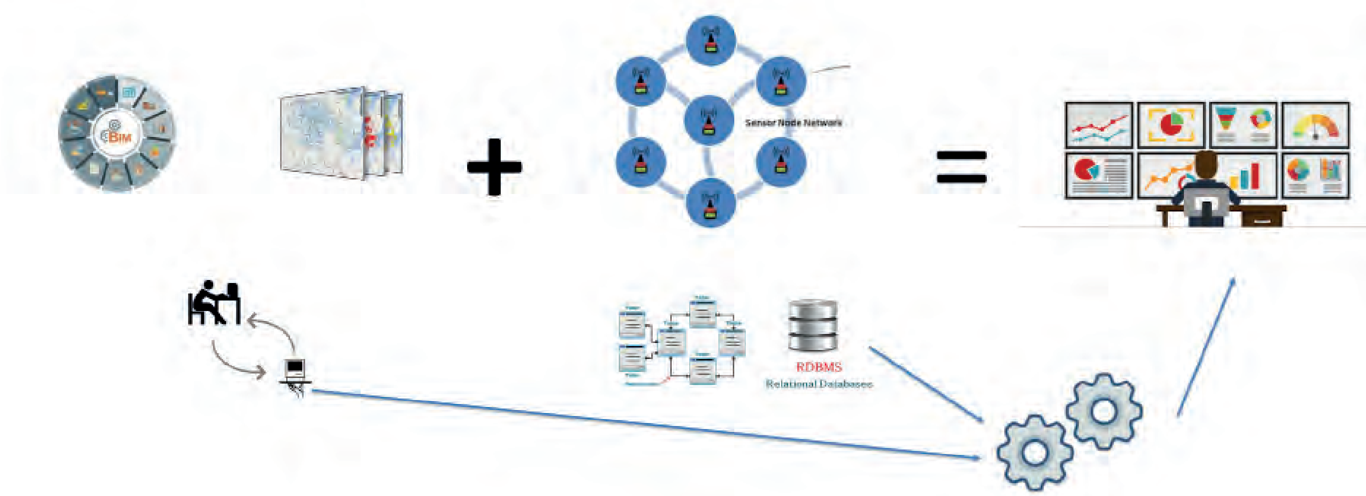
Case Study



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Case Study

Power: 1 MWatt

Size: 50 000 square meters

Elements: 98 “follow the sun” solar panel, each 72 square meters, on average 20 m between one and the other

Efficiency: estimated 97 %, real time measures 98%

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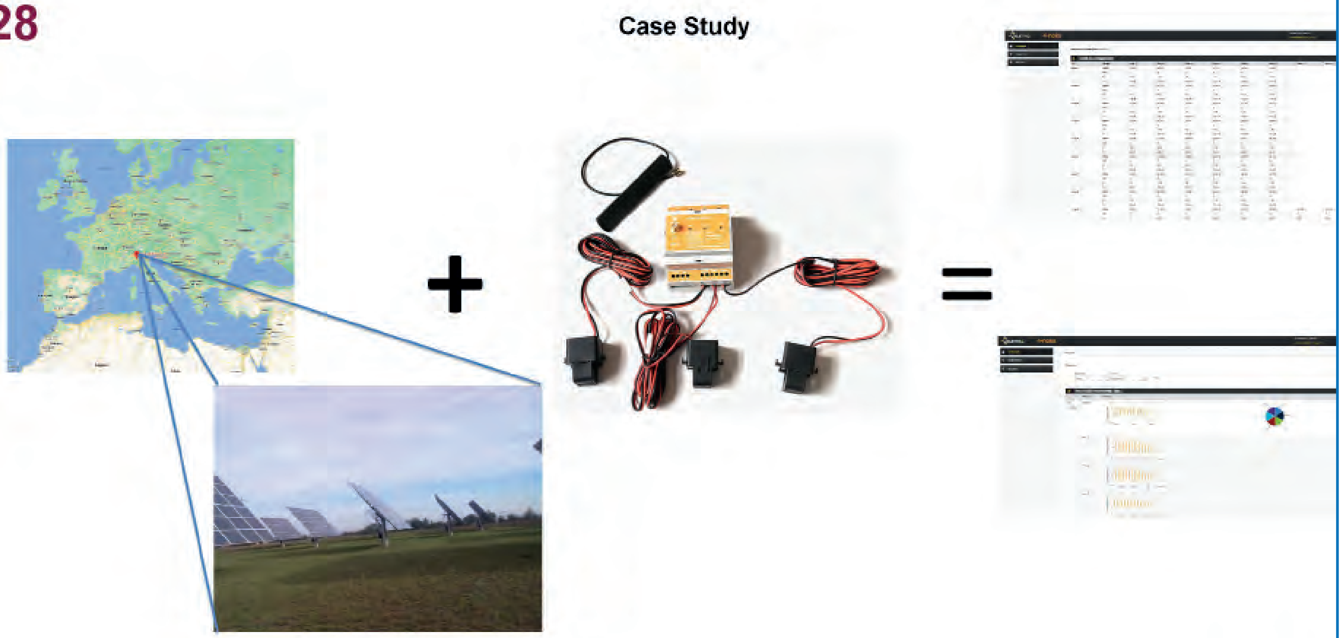
Case Study



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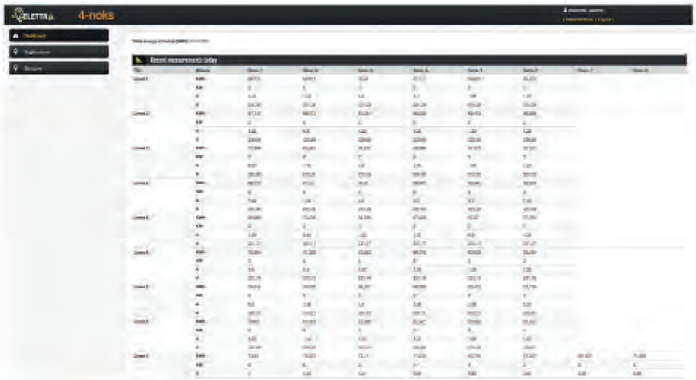
Case Study



Efficiency: estimated 97 %, real time measures 98%

Monitoring of lines of solar panels, each line with 7 or 8 panels

Real Time monitoring,
yellow and red threshold level for immediate maintenance

http://monitor.realt.it/colombarola

Quickly calling maintenance allowed real performances to be above predicted ones (even if slightly)

Dipartimento di Pianificazione, Design, Tecnologia dell'Architettura
Sapienza Università di Roma

Giuseppe Pirozzi (OOP Systems) | 07/09/2020

GISBIM International Summer School

ISS GIS-BIM: beyond summer school

Prof. Flavio Rosa
ISS Coordinator

Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)

This book is the collection of contributions presented by the professors who participated in the first edition of the International Summer School (ISS) GIS-BIM for digital integrated design held online from 31 August to 11 September 2020 organized by the Department of Planning, Design, and Technology of Architecture of the Sapienza University of Rome.

An experience that has so enriched all participants, teachers and students, that the creation of this book has become a duty. The approach to the integration of GIS and BIM cannot be limited only to software and operational solutions but to the entire methodological framework. This book, which collects the contents of the ISS lessons, aims to be a first popular approach to integrated solutions between GIS and BIM starting from the methodology and arriving at the presentation of representative and significant case studies.

With this work we want to start a path of cooperation and lasting exchange with all the academic and professional realities of the world. The preparation of the subsequent editions of Winter and Summer School is already under construction, so we wanted the experience built in the first edition to become the first step on this long journey.

Forty hours of intense lessons, rich in multidisciplinary contributions by teachers with high academic and professional experience in the Digital Twin sector, a digital modeling of reality with tools and applications typical of the planning sector from the territorial to the architectural scale.

The contents of the text are the collection and reorganization of the 5 teaching modules of the ISS:

1. An Introduction to Digital Transformation of Construction Industry.
   - 1.b 4D/5D Modeling & Management workflows for Cortina's FIS Alpine World Ski Championships new downhill race track.
   - 1.c Common data environment(s) and digital platforms in construction sector.
   - 1.d GIS-BIM for integrated design: "integrated" meaning in the AEC history, which kind of integration between BIM and GIS, perspective and limits.
2. The integrated management of sustainable processes of requalification and recovery in the architectural and environmental heritage.
3. Geographic Information Systems and its integration with BIM methodologies. Why to integrate GIS with the BIM methodologies, tools and procedures?
4. Digital methods and tools in the construction process for an efficient project management workflow: case studies.
   - 4.a Analysis of integrated models and applicative case studies within the digital approach for planning and programming the activities through the process phases.
5. - Performance analysis and optimization design of green buildings driven by digital technology (BIM, Rhino, etc.): lectures and hands-on exercises
   - Algorithms and how they change the architectural design.
   - Sustainable urban design in the digital era
   - Green practices in China's building industry.

We hope that our work represents a stimulus to involve as many people as possible in cultural growth in the technical-scientific field and in strengthening international cooperation.

This publication stems thanks to the excellent work of all teachers and the active participation of students but also thanks to the financial contribution of International Urban Cooperation (IUC) Programme which made it possible to publish it.

We wish to thank the whole IUC team for the human, professional and financial support given to the entire project.

Concluding remarks

A university is a community of scholars and students. Its mission is to meet the socio-educational needs of a human capital committed to facing the complexities of the challenges in contemporary society.

In this moment of great suffering and strict restrictions, all the figures in this community are called on to contribute.

Knowledge, new training horizons and international cooperation are the pillars upon which the entire organizing committee built the International Summer School GIS-BIM for digital integrated design.

We also wanted to summarize the didactic and human activity in the contents collected in this book. The goal is to render the 10-day ISS learning experience available in order to build new ones in the future.

The organization committee is already at work on the next editions of the Winter and Summer Schools on the issues of integration not only in terms of practical and innovative methods but also through cooperation and growth with academic and professional realities of the world.

For information and contacts on the activities related to the integration development of GIS-BIM solutions please visit the website: www.gis-bim.eu.

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