



Proceedings of the  
2023 European Conference  
on Computing in Construction  
and of the  
40th International CIB W78 Conference  
on Information Technology for Construction

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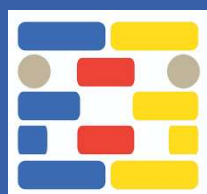
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2023 European Conference on Computing in Construction  
40th International CIB W78 Conference  
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## TABLE OF CONTENTS

<b>Blockchain and Distributed Ledger Technology</b>	<b>1</b>
Web3-based role and token data access: the case of building material passports <i>Hunhevicz, Jens J; Bucher, David F; Soman, Ranjith K; Honic, Meliha; Hall, Daniel M; De Wolf, Catherine</i>	2
A conceptual framework for blockchain and AI-driven digital twins for predictive operation and maintenance <i>Sadri, Habib; Yitmen, Ibrahim; Tagliabue, Lavinia Chiara; Westphal, Florian</i>	10
A blockchain-based token economic model for incentivizing ESG in the construction industry <i>Zhao, Rui; Wang, Jiajia; Xue, Fan</i>	18
Human-Data Interaction (HDI) and blockchain: an exploration of the open research challenges for the construction community <i>Li, Jennifer; Kifokeris, Dimosthenis; Barati, Masoud; Calis, Gulben; Hall, Daniel; Hunhevicz, Jens; Kassem, Mohamad; Msawil, Mahir; Arnal, Ignasi Pérez; Srećković, Marijana</i>	26
A blockchain-based approach for managing construction claims <i>Torkanfar, Navid; Rezazadeh Azar, Ehsan; McCabe, Brenda</i>	34
Design dimensions for blockchain oracles in the AEC industry <i>Dounas, Theodoros; Hunhevicz, Jens; Byers, Brandon</i>	45
What is the potential value of tokens and token engineering for the architecture, engineering, and construction industry? A positional paper <i>Kifokeris, Dimosthenis; Dounas, Theodore; Tezel, Algan; Moon, Sungkon</i>	53
Digital environment definition for property tokenization uptake in Italy <i>Mistrangelo, Paolo; Tagliabue, Lavinia Chiara; Tezel, Algan</i>	60
<b>Data Analysis, Simulation and Resilience</b>	<b>68</b>
A comparative evaluation of decision trees and expert intuition to predict durations in the predesign phase <i>Lauble, Svenja; Steuer, Dominik; Shervin, Haghsheno</i>	69
A network modelling-based approach for quantifying flood resilience of urban rail transit systems <i>Bi, Wei; MacAskill, Kristen</i>	77
Identifying the factors of country risk fluctuation from news text data using natural language processing <i>Chung, Sehwan; Kim, Jungyeon; Chi, Seokho; Kim, Du Yon</i>	85
Representing modelica models as knowledge graphs using the MoOnt ontology <i>Eckstädt, Elisabeth; Menzel, Karsten; Pruvost, Hervé; Mayer, Dirk</i>	93



Reference framework enabling temporal scalability of object-based synchronization in BIM level 3 systems <i>Esser, Sebastian; Vilgertshofer, Simon; Borrmann, André</i>	101
Predicting recoverable material stock in buildings: using machine learning with demolition audit data as a case study <i>Kobylinska, Natalia Ewa; Raghu, Deepika; Gordon, Matthew; Hunhevicz, Jens; De Wolf, Catherine</i>	109
CBIM: object-level cloud collaboration platform for supporting across-domain asynchronous design <i>Wang, Zijian; Ouyang, Boyuan; Sacks, Rafael</i>	117
Advances in data-driven fault detection and diagnosis for HVAC systems: a review of recent developments <i>Rajabi, Farivar; McArthur, J. J.</i>	125
Extrapolation with machine learning based early-stage energy prediction models <i>Singh, Manav Mahan; Smith, Ian F. C.</i>	133
Requirements and framework for Gaia-x-based building permit processes <i>Fauth, Judith; Strnadl, Christoph F.; Heitzhausen, Hannes; Florek, Morris; Brenner, Michael; Seiss, Sebastian; Nakrani, Pintukumar; Poetz, Aurica; Diaz, Joaquin; Mueller, Wolfgang</i>	141
Development of a framework for processing unstructured text dataset through NLP in cost estimation AEC sector <i>Gatto, Chiara; Farina, Antonio; Mirarchi, Claudio; Pavan, Alberto</i>	149
A LegalRuleML editor with transformer-based autocompletion <i>Fuchs, Stefan; Dimyadi, Johannes; Ronee, Aryan Sharma; Gupta, Rishaan; Witbrock, Michael; Amor, Robert</i>	156
Barriers to circularity in construction: an analysis of experts' perspectives <i>Allam, Amr; Nik-Bakht, Mazdak</i>	164
Ontology-based semantic labeling for RGB-D and point cloud datasets <i>Kaufmann, Fabian; Chamseddine, Mahdi; Guttikonda, Suresh; Glock, Christian; Stricker, Didier; Rambach, Jason</i>	171
Analysing the usage of AI art tools for architecture <i>Ploennigs, Joern; Berger, Markus</i>	179
Feature extraction for enhancing data-driven urban building energy models <i>Bolluk, Said; Seyis, Senem; Aydogan, Reyhan</i>	187
A model-based approach for building fire emergency management <i>Mousharbash, Nabih; Di Domenica, Marta; Carbonari, Alessandro; Turk, Ziga; Giretti, Alberto</i>	195
A virtual training game for post-earthquake damage inspection <i>Al Fil, Abed; Houry, Hiam Mayez</i>	202
Evaluation of building renovation strategies across three demonstration sites: a principal component analysis based multivariate sensitivity analysis <i>Doukari, Omar; Greenwood, David; Aguejdad, Rahim; Kassem, Mohamad</i>	208





Human-independent activity recognition of construction worker <i>Park, Seongeun; Lee, Hoonyong; Ahn, Changbum Ryan; Park, Moonseo</i>	216
Designing the quiet site: a proposed method for modelling, analyzing and mitigating noise harm from construction activities <i>Albertini, Oriana; Hall, Daniel; Fruchter, Renate</i>	222
<b>Data Integration Methods</b>	<b>231</b>
Generation of acoustic ontology for a holistic building performance domain <i>Utkucu, Duygu; Sacks, Rafael</i>	232
Semantic web-enabled outlier and missing value detection and replacement in smart buildings <i>Donkers, Alex; Yang, Dajuan; de Vries, Bauke</i>	240
Systematic integration of building information and simulation models for the automated evaluation of factory layout variants <i>Neuhäuser, Thomas; Dimyadi, Johannes; Eckart, Christian Johannes; Wagner, Franziska; Hohmann, Andrea; Amor, Robert; Daub, Rüdiger</i>	248
Structuring BIM-related construction data through a standards-based classification system <i>Puust, Raido; Liias, Roode</i>	256
Automated generation of SPARQL queries from semantic mark-up <i>Nisbet, Nicholas; Zhang, Zijong; Ma, Ling</i>	264
Using machine learning for automated detection of ambiguity in building requirements <i>Zhang, Zijong; Ma, Ling</i>	272
Machine learning-based fault detection and preliminary diagnosis for terminal air-handling units <i>Rajabi, Farivar; El Mokhtari, Karim; McArthur, J. J.</i>	279
Definition of a container-based machine-readable IDM integrating level of information needs <i>Liu, Liu; Hagedorn, Philipp; König, Markus</i>	287
Reliability of IFC classes in ontology definition and cost estimation of public procurement <i>Cassandro, Jacopo; Donatiello, Maria Grazia; Mirarchi, Claudio; Zanchetta, Carlo; Pavan, Alberto</i>	295
Comparative analysis of room generation methods using rule language-based evaluation in BIM <i>Sydora, Christoph; Stroulia, Eleni</i>	304
Optimized data connection for a BIM-GIS based university asset management system <i>Gasbarri, Paola; Accardo, Daniele; Meschini, Silvia; Tagliabue, Lavinia Chiara; Di Giuda, Giuseppe Martino</i>	312
From static to dynamic information containers <i>Al-Sadoon, Nidhal Neamah; Scherer, Raimar; Menzal, Karsten</i>	320
BIM and GIS integration: lessons learned from multiple case studies <i>Pedó, Bárbara; Tezel, Algan; Goethals, Davy; Koskela, Lauri; Leaver, Matthew; Victory, Andrew; Vrabie, Elena; Bocian, Erika</i>	327

Interoperability framework for subsea sensors data <i>Calvetti, Diego; Nascimento, Daniel Luiz de Mattos; Araújo, Flávio Magno; Abreu, Rafael H. V.; Papadopoulos, Nicolas Alexandros; Demay, Miguel B.; Tortorella, Guilherme</i>	335
Describe and query semantic building digital twin data in temporal Knowledge Graphs <i>Zhang, Yingying; Beetz, Jakob</i>	343
Resolving inconsistency in building information using uncertain knowledge graphs: a case of building space management <i>Xie, Xiang; Chang, Janet; Kassem, Mohamad; Parlikad, Ajith</i>	350
BIM based rating of urban and architectural surfaces to refine solar potential analysis <i>Paparella, Rossana; Zanchetta, Carlo; Giorio, Martina; Donatiello, Maria Grazia</i>	358
Real-time corner height estimation for multi-layer directed energy deposition using laser line scanner, vision camera, and artificial neural network <i>Yang, Liu; Cheng, Jack C.P.; Sohn, Hoon; Ma, Zhanxiong; Jeon, Ikgeun; Liu, Peipei</i>	367
Integration of semantic temporal information in BIM using ontologies <i>Vaatz, Albrecht; Hamdan, Al-Hakam; Al-Sadoon, Nidhal; Wogan, Martin; Menzel, Karsten</i>	375
Supporting appraisal cost estimation by linked data <i>Seiß, Sebastian; Lünig, Jan; Melzner, Jürgen</i>	383
Extensible real-time data acquisition and management for IoT enabled smart buildings <i>Chamari, Lasitha; Petrova, Ekaterina; Pauwels, Pieter</i>	391
Interrelationship-based model view definition development of a smart city using an urban-level ontology <i>Shariatfar, Moeid; Lee, Yong-Cheol; Ahmad, Ahmad Mohammad; Ferwati, Salim</i>	399
Future research directions of construction digital twins <i>Huang, Yusheng; Ghelmani, Ali; Hammad, Amin</i>	407
<b>Data Sensing and Acquisition</b>	<b>415</b>
Combining BIM and lean methods for scheduling for verifying and communicating demolition processes in an early project stage <i>Steuer, Dominik; Lauble, Svenja; Haghsheno, Shervin</i>	416
Modelling indoor air quality in schools using grey box models <i>Tugores, Juan; Macarulla, Marcel; Gangolells, Marta; Casals, Miquel</i>	423
Analysing the conditions of road assets with a network thinking <i>Lam, Pui Hei; Chen, Weiwei; Brilakis, Ioannis</i>	431
Human action detection and ergonomic risk assessment at construction sites, by use of machine vision and deep learning <i>Lambrides, Evagoras; Christodoulou, Symeon</i>	450
Diagnosis of simultaneous sensor faults in structural health monitoring systems	457

*Al-Zuriqat, Thamer; Chillón Geck, Carlos; Dragos, Kosmas; Smarsly, Kay*

Automated thermal comfort monitoring using IoT technologies <i>Chillon Geck, Carlos; Al-Zuriqat, Thamer HATHAL MAHMOUD; Alsaad, Hayder; Völker, Conrad; Smarsly, Kay</i>	464
Extraction of energy-influential parameters from building façade images through google street view <i>Orenga Panizza, Rafaela; Nik-Bakht, Mazdak</i>	471
Initiation of data acquisition based on 4D-BIM for lean construction progress control <i>Tschickardt, Thomas; Oerter, Nico; Glock, Christian; Kaufmann, Fabian; Schellen, Marius</i>	478
Enabling reuse of prefabricated concrete components through multiple tracking technologies and digital twins <i>Dervishaj, Arlind; Hernández Vargas, José; Gudmundsson, Kjartan</i>	487
Concrete flow transformer: predicting fresh concrete properties from concrete flow using vision transformers <i>Coenen, Max; Vogel, Christian; Schack, Tobias; Haist, Michael</i>	495
Granulometry transformer: image-based granulometry of concrete aggregate for an automated concrete production control <i>Coenen, Max; Beyer, Dries; Haist, Michael</i>	503
Automatic indoor construction progress monitoring: challenges and solutions <i>Chauhan, Inshu; Seppänen, Olli</i>	511
Deep-learning guided structural object detection in large-scale, occluded indoor point cloud datasets <i>Drobnyi, Viktor; Li, Shuyan; Brilakis, Ioannis</i>	518
Annotation rules and classes for semantic segmentation of point clouds for digitalization of existing bridge structures <i>Schellen, Marius; Kaufmann, Fabian; Glock, Christian; Tschickardt, Thomas</i>	525
Towards fully automatic Scan-to-BIM: A prototype method integrating deep neural networks and architectonic grammar <i>Wu, Yijie; Li, Maosu; Xue, Fan</i>	533
4D Point Cloud (4DPC)-driven real-time monitoring of construction mobile cranes <i>Liang, Dong; Chen, Zhe; Kong, Lingming; Wu, Yijie; Chen, Sou-Han; Xue, Fan</i>	541
A carbon data trustworthiness framework for the construction sector <i>XU, Jinying; MacAskill, Kristen</i>	549
Transfer of implicit semi-formal textual location descriptions in three-dimensional model contexts <i>Göbels, Anne; Rivadeneyra, Fabian; Beetz, Jakob</i>	556
Harbingers of NeRF-to-BIM: a case study of semantic segmentation on building structure with neural radiance fields <i>Hachisuka, Shun; Tono, Alberto; Fisher, Martin</i>	564
Challenges in collecting and managing data for AI application in small and medium-sized construction enterprises	572





*Steuer, Dominik; Lauble, Svenja; Gerber, Hannes Benedikt; Haghsheno, Shervin*

The potential for creating a geometric digital twin of road surfaces using photogrammetry and computer vision <i>Ding, Jialei; Brilakis, Ioannis</i>	579
Enabling intelligent jobsites: advancing the integration of construction 4.0 devices within the connected jobsite <i>Morman, Kyle; Costin, Aaron; McNair, Janise</i>	587
Creation of digital twin models for renovation: an integrative literature review <i>Löhmus, Daniel; Pikas, Ergo</i>	595
Regeneration of a former prison in Melipilla, Chile: use of digital technology in a heritage restoration project <i>Correa Baeriswyl, Maria Victoria; Torres Palacios, Gabriela; Atria Lannefranque, Jorge; Tagliabue, Lavinia Chiara; Rinaldi, Stefano</i>	603
Enhancing single-stage excavator activity recognition via knowledge distillation of temporal gradient data <i>Ghelmani, Ali; Hammad, Amin</i>	611
Design of an IoT infrastructure during bridge renovation: a practical experience from MoSoRe project <i>Rinaldi, Stefano; Ferrari, Paolo; Flammini, Alessandra; Reggia, Adriano; Plizzari, Giovanni; Maternini, Giulio</i>	618
Towards a digital twin for IAQ monitoring and control in educational facilities through asset management system platform <i>Accardo, Daniele; Meschini, Silvia; Boscarior, Marta; Tagliabue, Lavinia Chiara; Di Giuda, Giuseppe Martino</i>	626
Railway bridge condition assessment based on state-of-the-art reality capture technologies: application to a case study <i>Cabral, Rafael; Oliveira, Rogério; Ribeiro, Diogo; Santos, Ricardo; Azenha, Miguel; Rakoczy, Anna; Correia, José; Manuel R.S. Tavares, João</i>	634
<b>Education, Policy and Standardisation</b>	<b>641</b>
T-shaped model design for further education in BIM <i>Partl, Rainer; Miya, Sylvester; Hengel, Franz; Heschl, Christian</i>	642
Evaluation of level of development in students' design models in engineering education <i>Wyke, Simon; Munch Lindhard, Søren; Svidt, Kjeld; Lund Jensen, Rasmus</i>	649
Barriers to digitalization in the Nigerian construction industry <i>Idowu, Ayobami Oluwaseun; Aigbavboa, Clinton; Oke, Ayodeji Emmanuel</i>	656
Teaching BIM: a comparison between actual and future perspectives <i>Morganti, Caterina; Coraglia, Ugo Maria; Bragadin, Marco Alvisè; Rissolo, Dominique; Witt, Emlyn; Kähkönen, Kalle</i>	660



Inigorating AEC education using Minecraft: A case of LiDAR surveying and virtual learning <i>Xue, Fan; Chen, Zhe; Wang, Jiajia; Chan, Isabelle</i>	668
Towards a digital competency framework for the construction industry <i>Baldwin, Mark; Xenidis, Yiannis; Castronovo, Fadi; Suwal, Sunil; Denzler, Alexander; Heim, Thomas; Ciribini, Angelo Luigi Camillo</i>	675
Integrated life-cycle orientated teaching of the big-open-BIM method <i>Maile, Tobias; Bartels, Niels; Wimmer, Reinhard</i>	683
Digital literacy to develop long-term implementation of digital twins <i>Gade, Peter Nørkjær; Lauritzen, Dorthe Holmberg; Andersen, Michael; Kjærgaard, Thomas; Svidt, Kjeld</i>	691
Supporting the OpenBIM transition <i>McGinley, Tim; Negendahl, Kristoffer; Smolira, Piotr; Jakubowska, Martyna; Vejlggaard, Ann-Britt; Karlshøj, Jan</i>	699
Adoption of BIM-related international standards across Europe <i>Sibenik, Goran; Mizumoto, Juliana; Bosche, Frederic; Meda, Pedro; Puust, Raido; Akbarieh, Arghavan; Bolpagni, Marzia</i>	707
Information systems for construction 4.0: classification of contents for integration and interoperability – case study <i>Ribeiro, Yanh; Teixeira, Jorge; Mêda, Pedro; Moreira, Joaquim; Sousa, Rui; Sousa, Hipólito</i>	714
Towards a digitally enabled personalised construction safety training framework for O&M construction projects <i>Wakefield, James; Doukari, Omar; Martinez Rodriguez, Pablo; Kassem, Mohamad</i>	722
Barriers and pathways to use extended reality in stem classrooms: perspectives of key stakeholders <i>Wu, Wei; Luo, Yupeng {Vivien}; Castronovo, Fadi; Liang, Arlo; Gomez, Frank; Kassis, Sara; Wolcott, Abraham</i>	730
<b>Energy Modelling and Monitoring</b>	<b>737</b>
Lighting energy load prediction framework using agent-based simulation and artificial neural network models <i>Vosoughkhosravi, Sorena; Norouziasl, Seddigheh; Jafari, Amirhosein</i>	738
Householder readiness for smart, data-driven performance monitoring of homes <i>Adeyeye, Kemi</i>	745
Residential building energy performance prediction at an urban scale using ensemble machine learning algorithms <i>Ali, Usman; Bano, Sobia; Shamsi, Muhammad Haris; Sood, Divyanshu; Hoare, Cathal; O'Donnell, James</i>	753
Increasing the accuracy of low-resolution commercial smart heat meter data and analysing its error <i>Schaffer, Markus; Leiria, Daniel; Vera-Valdés, J. Eduardo; Marszal-Pomianowska, Anna</i>	761
The RINNO solution: a holistic assessment framework for supporting building renovation projects	768

*Sougkakis, Vasileios; Mamounakis, Ioannis; Iliadis, Petros; Seitaridis, Andreas; Lithoxoidou, Evdoxia E.; Doukari, Omar; Scoditti, Enrico; Nikolopoulos, Nikolaos; Kassem, Mohamad*

Normalisation of measured energy consumption to inform both design and operational decisions 776  
*Manfren, Massimiliano; Marenzi, Giorgia; Tagliabue, Lavinia Chiara; Di Giuda, Giuseppe Martino; Boscarior, Marta*

Towards developing a carbon trading system for the construction industry: identification of major components 784  
*Kukah, Augustine Senanu Komla; Jin, Xiaohua; Osei-Kyei, Robert; Perera, Srinath*

Artificial dataset generation to enhance the design exploration of residential buildings through data-informed energy load forecasting models 791  
*di Stefano, Andrea Giuseppe; Masera, Gabriele; Ruta, Matteo*

A multilevel demand response profiling and modeling solution enabled by digital twins integration 799  
*Mountzouris, Christos; Karatzas, Stylianos; Protopsaltis, Grigorios; Gialelis, John; Chassiakos, Athanasios; Byrne, Niall; Tardioli, Giovanni*

## **Product and Process Modelling 806**

The role of social media in BIM-based projects 807  
*Durmus, Dilan; Klinc, Robert; Turk, Žiga*

MEP domain object classification through interdomain rule-based semantic enrichment on knowledge graphs 814  
*Utkucu, Duygu; Sacks, Rafael*

IFC-based building renovation scenario generator 822  
*Fenz, Stefan; Bergmayr, Julia; Giannakis, Giorgos*

Direct procurement in local governments and building information modeling (BIM) integration model proposal for local governments 829  
*Pinar, Omer Galip; Dikbas, Huseyin Atilla*

Procedures to control fire safety performances of buildings in a BIM environment 837  
*Lemma, Massimo; Tarsi, Martina; Carbonari, Alessandro; Giretti, Alberto; Vaccarini, Massimo*

A concurrent design paradigm for interdisciplinary design collaboration: insights from focus group study 845  
*Chen, Siyu; Yeung, Timson; Pilke, Eeva; Sacks, Rafael; Nyberg, Kim*

Evaluation of deterministic models for the excavator's theoretical productivity estimation in the digging and trenching operations 853  
*Molaei, Amirmasoud; Geimer, Marcus; Kolu, Antti*

Integrated web-based retrofitting services for onsite process management 861  
*Doukari, Omar; Richard, Philippe; Greenwood, David*

Exploring a Design for Robotic Construction approach: two case studies matching robot and construction design features 869  
*Huang, Heyaojing; Brosque, Cynthia; Tono, Alberto; Agrawal, Ashwin; Fischer, Martin*



Collaborative digital platform for integrated design and production planning and control: a literature review <i>Lindholm, Jonatan; Johansson, Peter; Yitmen, Ibrahim</i>	877
Implementation of lean construction in Finland <i>Coccolini, Davide; Bragadin, Marco Alvise; Kähkönen, Kalle</i>	885
A proposed systems-centric ontology for a graph-based digital twin <i>Yanamala, Akhileswar Reddy; Harode, Ashit; Thabet, Walid</i>	893
A 6D BIM integrated data management system in controlling construction quality throughout project life cycle <i>Gao, Wenjun; Lu, Weisheng</i>	901
Digital Twin systems for building façade elements testing <i>Boje, Calin; Mack, Nico; Kubicki, Sylvain; López Vidal, Ana; Casado Sánchez, Carlos; Dugué, Antoine; Brassier, Pascale</i>	909
Information needs in digital products passport – discussing data framework and reasonability <i>Mêda, Pedro; Munir, Mustapha; Calvetti, Diego; Sousa, Hipólito</i>	917
Circular economy in the built environment: a framework for implementing digital product passports with knowledge graphs <i>Kebede, Rahel; Moscati, Annika; Tan, He; Johansson, Peter</i>	925
Automated supplement of information requirements for tendering data <i>Mellenthin Filardo, Martina; Wiesner, Leon Heiko; Melzner, Jürgen; Bargstädt, Hans-Joachim</i>	933
Towards integrated digital twins for construction and manufacturing <i>Čustović, Irfan; Soman, Ranjith K.; Pauwels, Pieter; Hall, Daniel M.</i>	941
Extending - information delivery specification - for linking distributed model checking services <i>Kremer, Noemi Christine; Beetz, Jakob</i>	949
Healthcare process and variable mapping for identifying digitalisation opportunities and building a hospital digital twin <i>Mukherjee, Anandarup; Moretti, Nicola; Chan, Yin-Chi; Yilmaz, Gokcen; Sasidharan, Manu; Merino, Jorge; Rosun, Zahrah; Carr, Colin; McFarlane, Duncan; Parlikad, Ajith Kumar</i>	957
Natural language processing for construction sites management <i>Corneli, Alessandra; Spegni, Francesco; Naticchia, Berardo; Binni, Leonardo; Messi, Leonardo</i>	965
Human-data interaction in incremental digital twin construction <i>Calvetti, Diego; Kifokeris, Dimosthenis; Mêda, Pedro; Hjelseth, Eilif</i>	973
Applying generative design in industrialized house building? – Prerequisites <i>Popovic, Djordje; Lindholm, Jonatan</i>	981
Impact of BIM on project performance <i>Hu, Xinran; Chen, Yunfeng</i>	988



Lean modular integrated construction manufacturing: operation based production process optimization <i>Yang, Zhongze; Lou, Jinfeng; Lu, Weisheng</i>	996
Determining near-optimal modularization solutions considering manufacturing operations in modular construction <i>Lou, Jinfeng; Yang, Zhongze; Lu, Weisheng</i>	1003
Comparison of current common data environment tools in the construction industry <i>Jaskula, Klaudia; Papadonikolaki, Eleni; Rovas, Dimitrios</i>	1010
The adoption and effectiveness of mobile applications on south African construction sites <i>Ramokgopa, Mogale; Smallwood, John; Allen, Chris</i>	1018
The BIM maturity process to the digital twin for lean strategic facility management <i>Mbabu, Alex; Underwood, Jason; Munir, Mustapha</i>	1029
BPMN 2.0 to redefine Italian design-bid procurement in an innovative model-based, open-source approach <i>Meschini, Silvia; Di Giuda, Giuseppe Martino; Tagliabue, Lavinia Chiara; Locatelli, Mirko; Pellegrini, Laura</i>	1036
Towards a generalized Digital Twin definition <i>Scherer, Raimar</i>	1044
<b>Virtual and Augmented Reality</b>	<b>1052</b>
Integrating smart construction objects and augmented reality for onsite assembly of modular construction <i>Pan, Yipeng; Chen, Junjie; Fu, Yonglin; Lu, Weisheng</i>	1053
Attributing responsibility for performance failure on worker-robot trust in construction collaborative tasks <i>Chang, Woei-Chyi; Ryan, Sophia Marie; Hasanzadeh, Sogand; Esmaeili, Behzad</i>	1059
Applying video game design to building digital twin creation <i>Alexander, Kris; McArthur, J. J.; Lachapelle, Geoffrey; El Mokhtari, Karim; Damm, Mark</i>	1067
Human-computer interaction for building documentation <i>Santer, Klara; Singh, Manav Mahan; Smith, Ian F.C.</i>	1075
Digitization and design for social innovation. A co-design model for prison spaces <i>Rubiu, Giulia; Quaquero, Emanuela; Cadeddu, Barbara</i>	1083
Field knowledge transfer via immersive virtual field trips in architecture, engineering, and construction education <i>Mohammadiyaghini, Elnaz; Luo, Yupeng; Wu, Wei; Tehrani, Fariborz M</i>	1091
Comparing collaborative learning in various learning modalities <i>Suwal, Ashma; Wu, Wei; Luo, Yupeng</i>	1097





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<b>Cloud-based Building Information Modelling</b>	<b>1103</b>
Business modelling for cloud BIM <i>Odubiyi, Tawakalitu Bisola; Hartmann, Timo</i>	1104
Developing a BPMN for assessing the risk of overheating in a cloud-BIM environment <i>Samaro, Nour; Hartmann, Timo</i>	1106
A reference architecture for life cycle cost analysis systems based on asset management knowledge formalisation <i>Shaw, Conor; O'Donnel, James</i>	1109
A semantics-driven framework for scalable demand flexibility control applications <i>De Andrade Pereira, Flavia; Pritoni, Marco; Martín-Toral, Susana; Finn, Donal; O'Donnell, James</i>	1113

## TEACHING BIM: A COMPARISON BETWEEN ACTUAL AND FUTURE PERSPECTIVES

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### Abstract

Building Information Modeling BIM in AEC education is a promising teaching strategy. The aim of the European project BENEDICT is to analyze teaching approaches to Building Information Modeling (BIM) for the construction industry. The goal of this research is therefore to perform an exhaustive analysis on the methods of transmission of BIM awareness and education in some American universities with the aim of comparing them with the BENEDICT approach developed in Italian, Estonian and Finnish Universities. Therefore, a teaching plan that aims to standardize and unify relevant teaching programs, tools and methods is developed, tackling existing skill gaps and mismatches between academia and industry.

### Introduction

The concept and use of Building Information Modeling (BIM) is currently a popular design and control tool used extensively in the construction industry, in Italy, in Finland, in Estonia, in USA, and worldwide. BIM is a holistic process of creating and managing information for construction. It is a set of technologies, processes and policies that enables multiple stakeholders to collaboratively design, construct and operate a Facility in virtual space (ISO 19650-part).

Existing BIM tools make it possible to develop building and infrastructure designs, plan construction work and support building management activity, digitally, centrally, and collaboratively (Becerik-Gerber et al., 2012).

The power of BIM tools to create parametric models with information regarding not only geometry and spatial relationships, but also the properties of applied materials, geographic data, cost estimating, documentation classification, and certificates, makes the use of BIM the key tool for exploring innovative work procedures. In the construction industry, BIM has helped to decrease design errors and discrepancies between the design and the built construction, thus reducing errors in cost estimates (Arashpour et al., 2017).

Although Finland was the first country to systematically introduce the use of Building Information Modeling, the first country to develop the tools for its implementation was the United States. Actually, understanding the U.S.

experience in the field can give us some important insights concerning BIM oriented teaching implementation and consequently figure out how to best structure a BIM enabled learning platform (BLE).

To support an integrated design workflow, it is certainly necessary to have common working standards, such as the open Industry Foundation Class (IFC) standard, to overcome software interoperability problems (Plume et al., 2007). Over time, the construction industry has experienced quickly evolving technology, supported by continuous advances, improvements, and enhancements (Abdirad et al., 2016).

A key aspect, the main subject of the study under analysis, is that related to training future professionals within academia. BIM training programs, found in undergraduate courses in architecture and construction and civil engineering, play an important role in educational institutions (figure 1) (Shen et al., 2012), because they prepare a new generation of graduate professionals that are ready to work in the construction industry with a new ability to manage collaborative and interdisciplinary software.



Figure 1: University and BIM Education

The research focused on the topic of BIM teaching in the university. The research aimed to analyze different courses related to the teaching of BIM in order to prepare useful materials for BIM education that can be uploaded to an open-access platform, created within the "BENEDICT" project. Therefore, the research questions under the present research work is "How BIM is being taught in the U.S., and how this experience can be used in the Benedict project?"

The BIM-enabled Learning Environment for Digital Construction (BENEDICT) project aims to capitalize on the emerging possibilities of BIM to improve the education of REC professionals by developing an innovative, BIM-enabled learning environment that offers more realistic, engaging, and integrated learning experiences.

The project will result in the development of the BLE as an open online learning platform with initial learning resources and demonstration materials. In the long term, BLE is seen as a tool that can be used to improve education, training, and continuous professional development of personnel throughout the REC value chain in the European Union and in other countries.

## Methodology and research development

### Literature review

For the development of the research, a literature review of texts in the field of academic education on BIM was initially conducted. Papers with keywords such as "BIM education", "BIM curriculum", "BIM course", and "visualization in engineering education" in publications from 2012 to the present day were analyzed.

The analysis was used to organize qualitative data related to BIM into similar groups of conceptual categories in order to analyze trends in current academic research on BIM education (Berwald, 2008). The study reviewed and analyzed 60 publications related to BIM education from 2012 to the present from authors in 20 countries, by searching the keywords in different web platforms (google scholar, science direct and scopus).

The seminal work of Dossick et al. indicated a variety of BIM specific content and general topics, an appropriate level of course work related to each topic and the type of education needed (Dossick et al., 2014). The literature review process on global trends in BIM education research led to the identification of six conceptual categories:

- identifying BIM needs in tertiary educational institutions;
- identify essential BIM skills for BIM education;
- develop BIM educational frameworks;
- develop BIM curricula;
- experiment with BIM courses;
- develop strategies to overcome BIM educational problems.

These categories show that researchers and educators in the BIM field have addressed related questions on:

- a. "why" we need BIM education;
- b. "what" to teach in academic BIM education;
- c. "how" to develop academic BIM education on the different levels.

### U.S. BIM-related courses

In the United States, there are several undergraduate programs with BIM-related courses at many different levels, the main ones include "Civil Engineering", "Architecture", "Architectural Engineering", "Construction Engineering", and "Construction Management". Almost 120 universities in the United States are fully accredited to provide degree programs that offer BIM courses as part of the curriculum, the following table shows some examples (courses updated to the academic year 2022/2023) (figure 2). With the exception of the Georgia Institute of Technology, which has been conducting research on BIM since the early 1990s, most U.S. universities have been introducing BIM since the 2000s (Sabongi, 2009). In 2003, BIM was introduced into undergraduate and graduate programs at the University of Minnesota and at California State University, where specific BIM courses have been taught since 2004. The University of Nevada began introducing BIM in 2005, while the University of Pennsylvania first introduced the Integrated Design Studio using BIM in 2006 (Shenton et al., 2014). In the same year, the University of Utah began a process of remodeling its curriculum by including teachings on BIM. Since 2006, other schools have begun offering BIM-specific courses, such as the New Jersey Institute of Technology and Brigham Young University. In 2007, Auburn University began an experimental study on teaching BIM. At the same time, at the University of Wyoming, students in engineering courses collaboratively developed a complex project using BIM tools.

Since 2010, many other universities have started integrating their course disciplines with BIM and experimenting with distance learning.

To date, universities such as the University of Pennsylvania, the Georgia Institute of Technology, the University of Southern California, Montana State University, the University of Wyoming, and the University of California system are identified as leaders in BIM education. Through a literature review and an analysis of the web pages of the different universities, it was possible to identify almost 120 universities having the presence of BIM-related courses in their curricula. Two of the authors of the research work under this paper were involved into BIM - related research and teaching activities at the University of California, San Diego, (UCSD) therefore this case of UCSD has been focused.

In the specific case of the UCSD, within the Jacobs School of Engineering in the undergraduate course in Structural Engineering there is a mandatory course *SE Graphical Communication for Engineering Design*, this course is mandatory for students and involves teaching computer graphics (CAD software) the creation of 2D and 3D models and BIM design is introduced.

There are also optional supplementary courses at the University of California, San Diego called "Extension courses", specifically the educational proposal at UCSD includes three:

- Revit I: Introduction. This course involves the student starting a project, editing elements, and presenting models. By the end of this Revit training course, students will have built a BIM project from the scratch and will present multiple views of the model.
- Revit II: Intermediate. Topics in this course include constructing building components within the Revit environment, using the family editor to create 2D and 3D components, refining graphics, and adding building documentation. Upon successful completion of this intermediate-level Revit training course, students will be able to develop a BIM model independently and understand how to organize it as an integrated, interoperable set of construction documents.
- Revit III: Advanced. The course involves modeling an existing building and the creation of a model with a two-story expansion of that building model. Students will learn the creation of demolition plans to accommodate new construction and rendering of the final model. Upon completion of the course, students will be able to develop a BIM model independently and understand how to organize it for later development into a set of integrated, interoperable construction documents.

University name	State	Course Code	Course name
Massachusetts Institute of Technology	Massachusetts	4.567/4.507	Introduction to Building Information Modeling in Architectural Design
Stanford University	California	CEE220A	Building Information Modeling Workshop
Stanford University	California	CEE220B	Advanced Building Modeling Workshop
Harvard University	Massachusetts	SCI-06331-00	Building Information Models
UCLA - University of California, Los Angeles	California	C&EE X 489.16	Introduction to Building Information Modeling (BIM) (Extension course)
UCB - University of California, Berkeley	California	CIV ENG X494	Introduction to BIM: Virtual Design and Construction Technology (Extension course)
UCSD - University of California, San Diego	California	ARCH-40009	Revit I: Introduction
UCSD - University of California, San Diego	California	ARCH-40010	Revit II: Intermediate
UCSD - University of California, San Diego	California	ARCH-40011	Revit III: Advanced
Yale University	Connecticut	1019c	Intro to Revit
Georgia Institute of Technology	Georgia	ARCH 6503	Building Information Modeling - Concepts and Applications
University of Pennsylvania	Pennsylvania	ARCH 4310	Construction I
University of Southern California	California	CM 470	Building Information Modeling and Integrated Practice
Purdue University	Indiana	CGT 26000	Introduction To Modeling For BIM
Purdue University	Indiana	CGT 46000	Building Information Modeling for Commercial Construction
Arizona State University	Arizona	REV100	Building Information Modeling (BIM) Certificate Program

Figure 2: BIM courses in American universities (academic year 2022/2023)

This study categorized American academic BIM experiences into three categories: "single-course"; "interdisciplinary" and "distance collaboration" (figure 3).

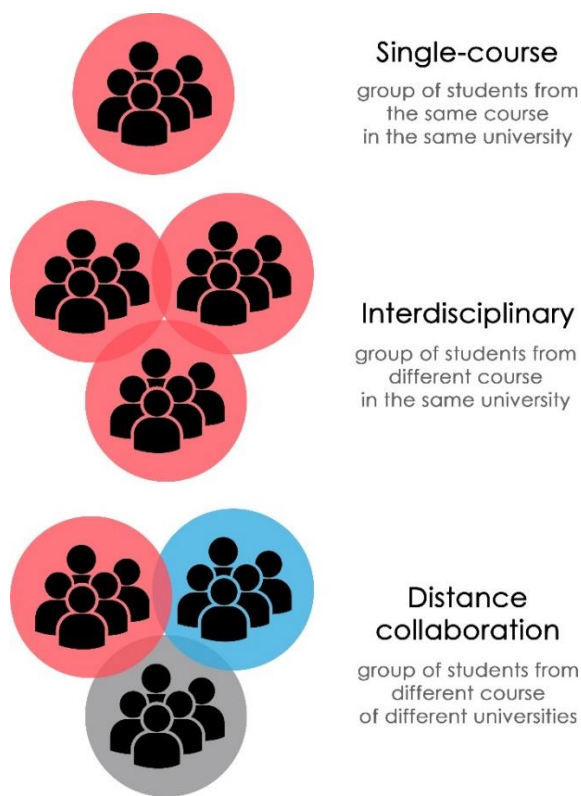


Figure 3: Categories of BIM experiences

*Single-course:* this category includes universities that have introduced BIM, but in only one discipline (Zhao et al., 2015). These courses teach the use of BIM software and the creation, development, and analysis of the models themselves. They also plan to simulate real collaboration, but with students in the same course (Taylor et al., 2007).

*Interdisciplinary:* this category includes universities that teach BIM concepts by simulating real collaboration with students from different courses at the same university. Examples of interdisciplinary courses can be found at the University of Pennsylvania, Oklahoma University, Auburn University, Georgia Institute of Technology, and the University of Maryland. These are examples of universities that currently integrate two- and three-course programs in which students develop collaborative projects using BIM software (Gier, 2015).

*Distance collaboration:* this category includes universities that teach BIM subjects by simulating real collaboration with students from different universities who are expected to collaborate in an interoperable way. An example of this experience is provided by the collaboration between the University of Nebraska-Lincoln, Montana State University, and the University of Wyoming.

By examining the state of the art of teaching techniques and courses delivered in U.S. universities on BIM, it was possible to analyze existing BIM-related teaching approaches and needs and propose BIM-based solutions

to deliver university courses in the AEC sector, particularly addressing the objectives of the BENEDICT project.

The BENEDICT project, BIM-Enabled Learning Environment for Digital Construction, is an Erasmus+ strategic partnership between the Department of Civil Engineering and Architecture at Tallinn University of Technology (Estonia), the Civil Engineering Unit of Tampere University (Finland) and the Department of Architecture at the University of Bologna (Italy). The BENEDICT project deals with how to teach courses at university level with BIM Building Information Modelling tools, in particular through the use of an IT platform for BIM models.

### BENEDICT project

The fundamental needs of Architecture, Engineering and Construction (AEC) students concerning Building Information Modeling involve the design, development and implementation of various building and management systems, for instance Architectural system; Structural system; Mechanical/Electrical/Plumbing systems, Construction and Project management systems. The needs of students and teachers consists in having the availability of data, reports, pieces of information, BIM objects and models concerning architecture and engineering systems. Therefore, a BIM-based learning system needs to be implemented in a virtual platform where BIM workflows can be performed.

The BENEDICT project provides a learning environment, a web-based platform where teaching and learning activities can be performed.

This platform is termed BIM-Enabled Learning Environment, BLE. As indicated by the literature review, the BLE platform can deliver three different categories of BIM experiences (figure 3).

### The BLE Platform

The BLE is an open, online platform that enables web-based education and supports distance learning which, e.g., under pandemic conditions, helps address learning continuity needs (Boeykens et al., 2013).

The design, data formats, protocols, functionalities and IT-solution which constitute a common, open learning environment which can act as a repository of learning materials and which host the open learning resources and pilot modules developed as part of the BENEDICT project (Olowa et al., 2022). The resultant BLE platform is the infrastructure for having a systemic solution for BIM-enabled learning.

This refers here to unfolding the possible avenues for education and training where Building Information Modeling (BIM) and its results are utilized in a pervasive manner for the learning benefits of new and existing professionals (Rüütman et al., 2022).

The BLE platform integrates BIM technologies and their learning with traditional design and engineering studies rather than having separate modules and courses for learning BIM skills (Kiviniemi, 2013).

Additionally continuing education is relevant here for updating the skills of experienced professionals (Nielsen



et al., 2009). The BLE platform is presented via its three educational dimensions: spectrum, modes, and extent.

The educational spectrum presents the various contextual dimensions that are covered by the BLE platform (Wu et al., 2013). Those are:

1. Building modeling and production of good quality models that are useful in different phases of construction projects. This covers different design and engineering disciplines (e.g., architecture and geotechnical, structural and building services engineering). Various BIM analyses, such as visualizations/VR/AR experiments for end users and clients, structural optimization, sustainability and energy efficiency analyses, are in a growing manner an inbuilt feature of modeling itself.

2. The use of resultant building models for numerous tasks and needs in construction operations (e.g., quantity take-off, cost estimating, scheduling, procurement, and supply management).

3. The interplay and its processes for having effective collaboration between different parties in a BIM intensive construction operation.

The educational modes present the main pedagogical solutions that are present in the BLE platform:

1. Demonstrational teaching via E-learning and/or Open Course Ware (OCW) lessons. Educational packages for independent studies.

2. Learning by doing. Interactive learning according to a systematic study program where instructors and students are linked to each other in a consistent manner for follow-up studies, providing reflections and feedback.

3. Collaborative learning by project work. Students are together experiencing a simulated construction project and work in such an environment. This is seen as most advanced educational form where students rather than as a stand-alone exercise can experience the dynamics and complexity of BIM intensive construction projects. These courses can particularly enhance knowledge and competence on project work practices, collaboration with different parties, design meetings, dialogue, and problem-

solving skills. The educational extent presents the main ways how the BLE platform is entering the built environment profession: 1. Academic BIM studies: for different degree programmes (BSc., MSc.) in a single university or for having joint educational courses/modules between universities. 2. Continuing education: for universities or other educational and training institutions organising studies on topical matters of interest to professionals.

With its IT-SOLUTION the BLE platform:

1. Open learning environment for BIM-enabled education: solutions are to be open and software vendor independent, and they are to be available for the use of educational and training institutions throughout the Real Estate and Construction (REC) sector. The building models used will be according to open BIM standard and principles; these models shall be available in a standard interoperable format (ifc).

2. Repository of building models and relating learning resources (these will be developed as Intellectual Output O3). This includes presentation of educational pilot modules (developed as Intellectual Output O4) and their use.

3. Available online via Internet.

The materials produced will be available on the open access web platform, which can be accessed at <https://www.bim-enabled-learning.com/ble/course/>. The platform is still in development and all BENEDICT project partners, will upload the materials produced in their home language and/or in English. Following are some preview images of the platform (figure 4, figure 5, figure 6, figure 7, figure 8). The BLE platform has a dashboard page where all the items are addressed: the courses and the data repository (figure 5). There three pilot courses addressing different topics of construction management, design management (figure 6), risk management (figure 7) and time management (figure 8). These three sections allow teachers and students to share open learning resources and learners' output.



Figure 4: Students testing the BLE platform

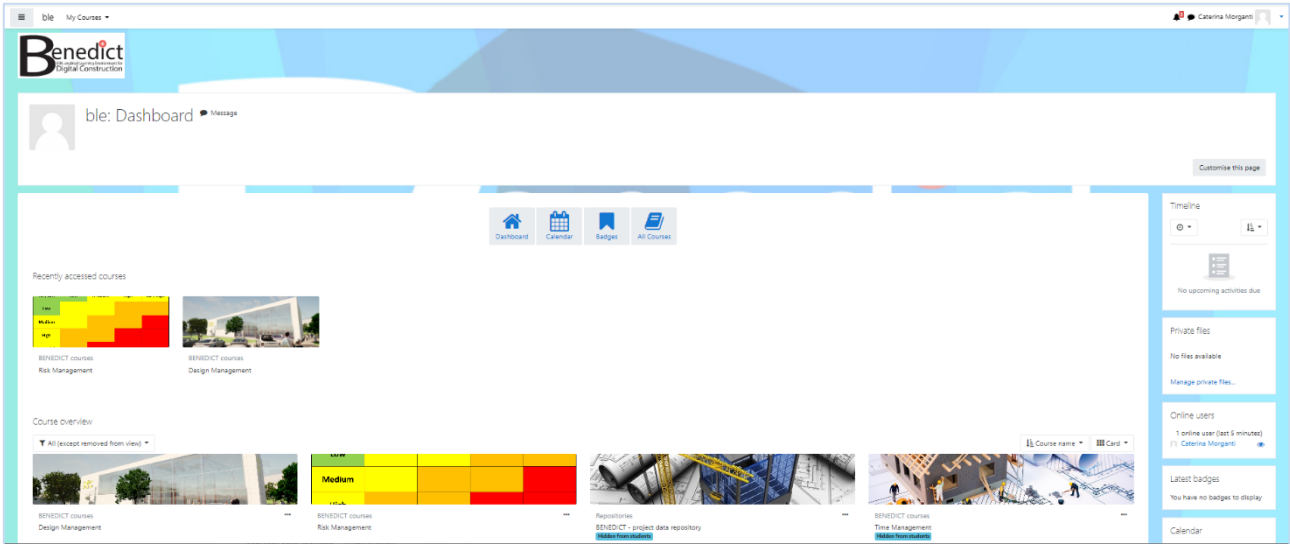


Figure 5: BLE platform preview - Dashboard

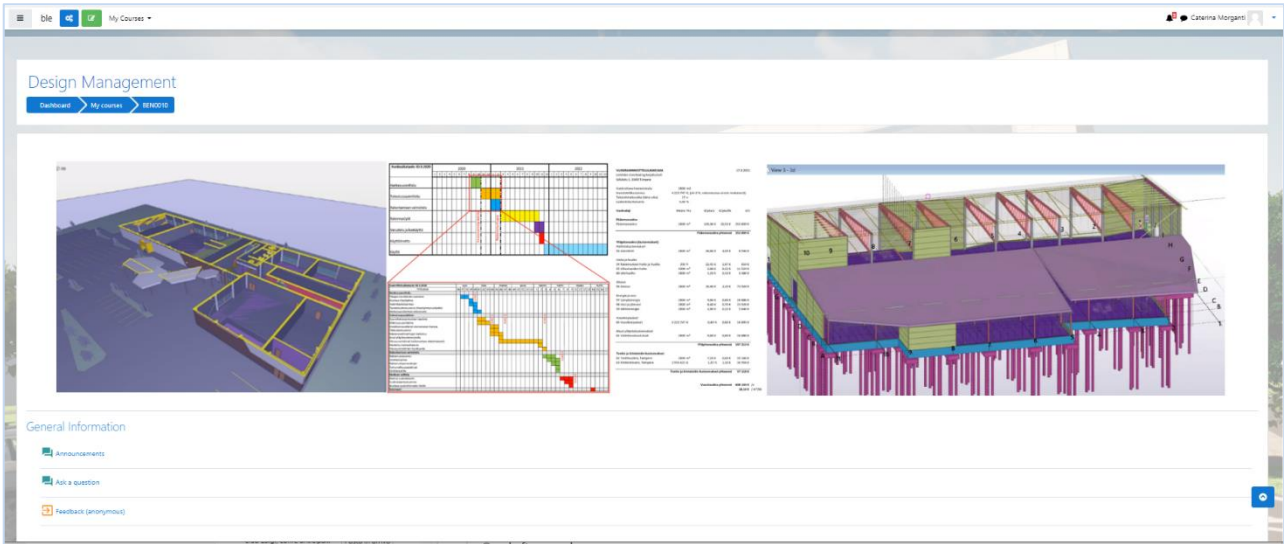


Figure 6: BLE platform preview - section Design Management

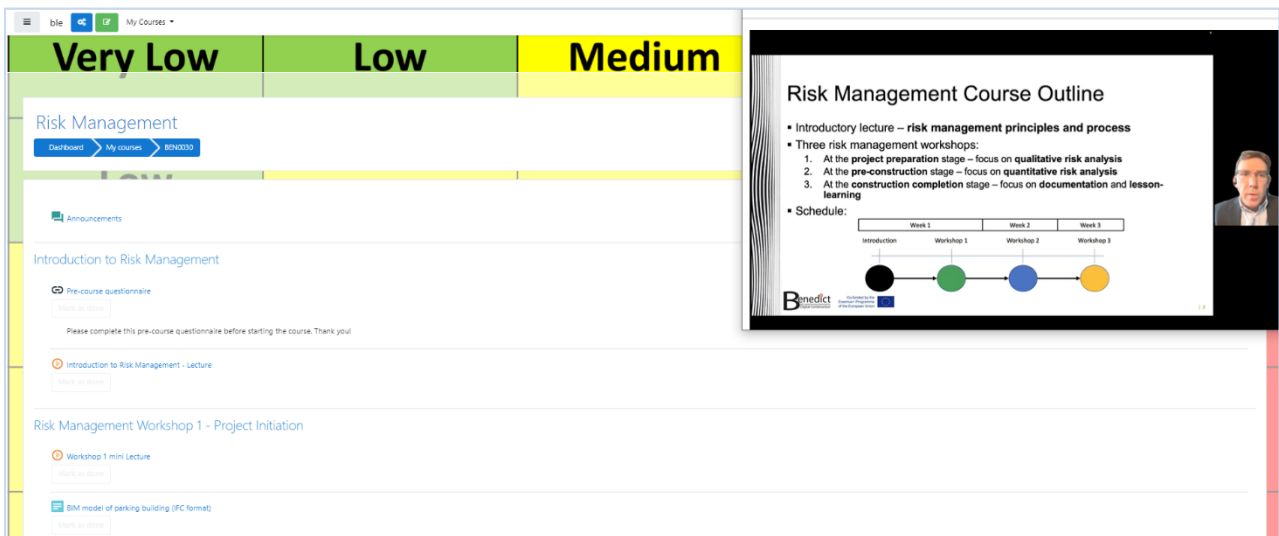


Figure 7: BLE platform preview - section Risk Management

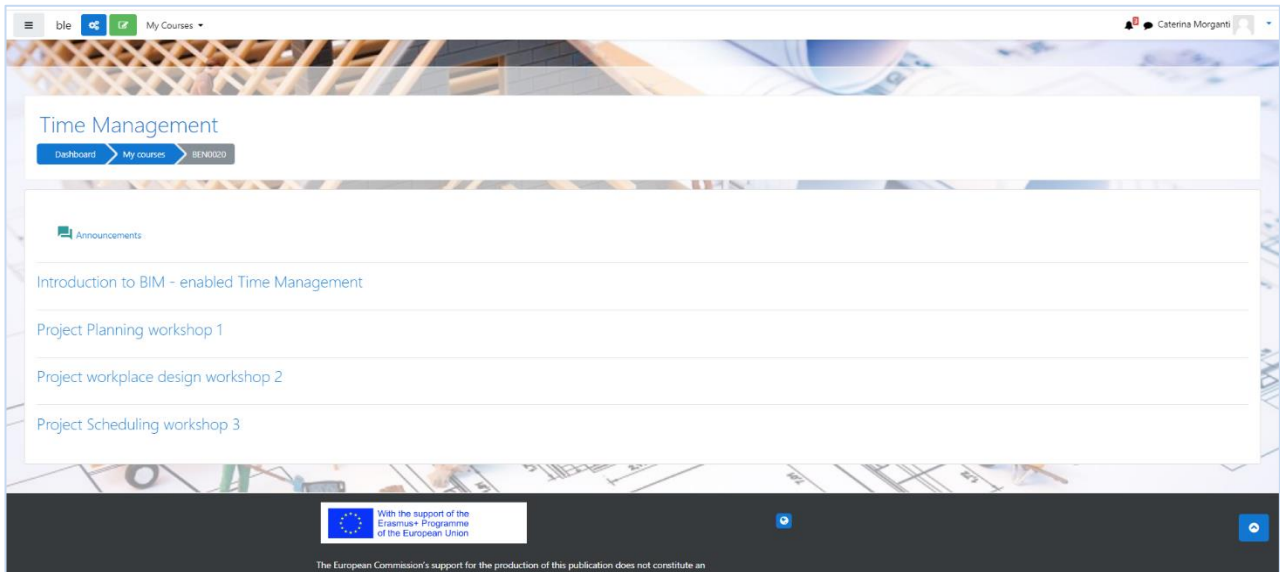


Figure 8: BLE platform preview - section Time Management

## Conclusions

BIM education and awareness/assumption have different levels of implementation around the world. The study and examination done on the U.S. case studies help to provide greater knowledge of the subject and more tools for the purpose of creating the teaching platform object of study.

The studies conducted indicate that educators face many challenges regarding the incorporation of BIM into the curriculum, mainly concerning educators' knowledge/skills and available resources, both financial and physical.

The educational approach to teaching BIM can be integrated into the construction curriculum as a learning tool in the training of new professions.

However, this teaching approach must be easily replicable in any degree program, as the new engineering, architecture, and design community will increasingly find diverse professionals who will, however, need to use common design and working tools.

By creating searchable and updatable materials on an open access platform and interactive features for using it, the proposed BIM teaching approach should help students achieve a deeper understanding of the subject of BIM.

BLE platform can be useful to connect academia and industry because it creates the virtual environment where BIM models can be stored and shared and thus giving the opportunity to train a new digital generation of professional engineers and architects. Therefore, the answers to the research questions are the following.

"How is BIM taught in the United States?" BIM is taught by addressing appropriate levels of students in higher education programs, specific content and topics, and different types of instruction. The teaching of BIM in the U.S., unlike what is often happening in European universities, aims to increase the interdisciplinary use of this tool while enhancing the collaboration aspect among students.

"How can this experience be used in the Benedict project?" The U.S. experience, which goes back at least 20 years, can be used as a guide in implementing the specific features of the BLE, BIM-Enabled Learning Environment. It is possible to learn from the U.S. teaching experiences how to improve the degree of interoperability, interconnection, and collaboration of students as they approach learning the BIM workflow.

Research limitations concerns the availability of BIM-oriented courses in the U.S., as only the ones of UCSD could have been gathered directly, because of the experience of the authors. Future work will be aimed at developing teaching/learning workflow processes of the pilot courses implemented within the BENEDICT project.

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