

EXECUTIVE MASTER IN DIGITAL TWINS FOR INFRASTRUCTURES AND CITIES

Executive master supported by the European Project DIGITWIN4CIUE, co-financed by the EU under the
“Europe Digital Programme”

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1 SUMMARY

The aim of the master's degree is to train engineers and architects related to the civil engineering and building sectors working in strategic areas such as transport, smart cities, mobility, energy, water and the environment in Digital Twins for Complex Infrastructures and Urban Ecosystems. The master's degree has an international character as it is part of a joint degree awarded by the Universidad Politécnica de Madrid (UPM), École Nationale des Ponts et Chaussées (ENPC), İstanbul Teknik Üniversitesi (ITU), The Budapesti Műszaki és Gazdaságtudományi Egyetem (BME). All these universities are part of the EELISA alliance and are members of the DIGITWIN4CIUE project whose main task is the design, preparation and delivery of a master's degree in Digital Twins with application to the built environment.

The programme has been designed to provide industry professionals with comprehensive training in the technologies needed to plan, design, project, develop, implement, maintain and manage digital twins in different field of engineering and construction. The planning of the master's degree has been developed in executive mode to allow it to be combined with professional performance. The master's degree culminates with a final project (Capstone Project) to be developed in groups of students and directed by a coordinator of the universities. Each group will develop a project representing a real case of use of digital twins, which will be proposed, defined and mentored by an industrial company or a public organism.

The master's degree will be taught by professors from the participating universities, as well as by reknown professors from other universities, and also by experts from leading companies in the sector (Typsa, Nommon, D3S Dassault).

2 MASTER PROGRAM

The courses, and the competences acquired in them, have been designed with a practical orientation to enable students to acquire the most relevant digital skills needed in the field of Digital Twins applied to infrastructures and cities. In addition, they will facilitate the understanding of the benefits of the creation and development of digital twins and will enable them to address the complex problems often encountered in the planning, design, construction, operation and management of infrastructures and urban ecosystems.

2.1 STUDY PLAN

The proposed study plan includes 90 ECTS of which 60 ECTS must be taken. These are divided into three parts of 20 ECTS which are shown below:

- **PART I – BASIC SKILLS (20 ECTS)**
Basic knowledge of Information Technology (described in the table as "BS skills").
With a total planned offer of 36 ECTS online, from which students must select a

minimum of 16 ECTS of Core courses and complete up to 20 ECTS with Core or Elective courses.

- **CORE COURSES:** They cover programming, software development, cloud computing, cybersecurity, BIM and GIS principles, IoT and signal processing, machine learning and data management.
- **ELECTIVE COURSES:** They offer specialised training in areas such as Python and Matlab programming, database management, numerical methods and optimisation, and transport and finite element modelling.
- **PART II: APPLIED DIGITAL TWINS TECHNOLOGY (20 ECTS)**

Applied Digital Twin Technologies, with a total of 33 online ECTS offered (described in the table as "DT skills"), from which a minimum of 12 ECTS of Core courses will be selected and up to 20 ECTS will be completed with Core or Elective courses.

 - **CORE COURSES:** They focus on the design and deployment of digital twins, their validation and use in the digital transformation of organisations, asset and facility management and knowledge representation.
 - **ELECTIVE COURSES:** They provide in-depth knowledge on topics such as advanced BIM for transport and construction, intelligent transport systems, mobility data analysis, smart buildings, smart city policy and planning, and structural health monitoring.
- **FINAL PROJECT: "CAPSTONE PROJECT" (20ECTS)**

Development of a digital twin project applied to the field of civil engineering and construction, the "Capstone Project", consisting of 20 ECTS in total, including:

 - 10 ECTS dedicated to the development of the Capstone Project during the course.
 - 6 ECTS dedicated to the preparation of the Master's dissertation.
 - 4 ECTS credits allocated to the face-to-face meetings to be organised.

The final project involves the creation of a Digital Twin model for a specific infrastructure or city system, should be a practical application of the skills, competences and knowledge acquired and focuses on several different phases:

 - **PROPOSAL:** Identify a problem and outline a solution based on Digital Twins.
 - **RESEARCH:** Conduct a detailed study of the problem and possible solutions.
 - **DESIGN:** Creation of a blueprint for the Digital Twins model.
 - **DEVELOPMENT AND IMPLEMENTATION:** Develop the Digital Twin using real data, simulation parameters and visualisation tools.
 - **EVALUATION:** Evaluate the effectiveness of the Digital Twin model to solve the problem.
 - **PRESENTATION AND DEFENCE:** Present and defend the project before a panel of faculty members.

The sessions will be delivered live online by internal and external lecturers who are experts in the field. The preliminary structure and the academic programme of the Master have been agreed by the Academic Committee, and are reflected in the following Table

BASIC IT SKILLS							
BASIC IT SKILLS COURSES:		Select a minimum of 16 ECTS of CORE courses and complete up to 20 ECTS with CORE or ELECTIVE courses					
	Course name	Module	Coord.	Teaching faculty	Credit	Online / in-Person	Course description
CORE IT skill courses: Select a minimum of 16 ECTS (or more, to complete until 20 ECTS)							
CORE BASIC IT SKILLS (minimum 16 ECTS)	Programming & Software development	BS skills	UPM	UPM	4	Online	1-Programming Software development.pdf
	Cloud computing and cybersecurity	BS skills	UPM	UPM	4	Online	2-Cloud Computing and Cybersecurity.pdf
	Principles of BIM and GIS	BS skills	UPM	UPM, BME	4	Online	3-Principles of BIM and GIS.pdf
	IoT and signal processing	BS skills	UPB	UPB, ITU	4	Online	4-IoT_UPB.pdf
	Machine learning and data analysis	BS skills	UPB	UPB, UPM, ITU	4	Online	5-Machine Learning.pdf
	Big Data Technologies and Applications for Digital Twins	BS skills	ITU	ITU, UPM	4	Online	6-Big Data Technologies and Applications for Digital Twins.pdf
Elective IT skills courses: to complete until 20 ECTS							
ELECTIVE BASIC IT SKILLS	Python programming	BS skills	ITU	ITU	2	Online	7-Python programming.pdf
	Matlab programming	BS skills	BME	BME, ITU	2	Online	8-Matlab Programming.pdf
	Relational database and SQL	BS skills	ITU	ITU	2	Online	9-Relational database and SQL.pdf
	Introduction to numerical methods and optimization	BS skills	BME	BME	2	Online	11-Introduction to numerical methods and optimization.pdf
	Transport modelling	BS skills	BME	BME	2	Online	12-Transport Modelling.pdf
	Finite-element modelling	BS skills	UPM	UPM	2	Online	13-Finite-element analysis calibration.pdf

DIGITAL TWIN TECHNOLOGIES							
DIGITAL TWINS TECHNOLOGIES COURSES:		Select a minimum of 12 ECTS of CORE courses and complete up to 20 ECTS with CORE or ELECTIVE courses					
Course name	Module	Coord.	Teaching faculty	Credit	Online / in-Person	Course description	
CORE DT technologies courses: Select a minimum of 12 ECTS (or more, to complete until 20 ECTS)							
CORE DT TECH (min 12 ECTS)	Design and deployment of digital twins	DT skills	UPM	UPM	3	Online	14-Desing and deployment of DT.pdf
	Validation and usage of digital twins	DT skills	ENPC	ENPC	3	Online	15-DT Usage.pdf
	Innovation and Industry 5.0	DT skills	ENPC	ENPC	3	Online	16-Innovation and industry 5.0.pdf
	Asset and Facility management in DTW for Infrastructures	DT skills	ITU	ITU	3	Online	17-Asset and Facility management in DTW for Infrastructures.pdf
	Knowledge representation and semantic interoperability	DT skills	UPM	UPM	3	Online	18-Knowledge representation and semantic interoperability.pdf
ELECTIVE DT applied Technologies courses: to complete until 20 ECTS							
ELECTIVE Transport spec.	Advanced BIM for transports	DT skills	UPM	UPM, Tyspa	2	Online	19-Advanced BIM for Transports.pdf
	Intelligent transportation systems	DT skills	BME	BME, ITU, UPM	2	Online	20-Intelligent transportation systems.pdf
	Mobility data analysis	DT skills	Nommon	Nommon	2	Online	21-Mobility Data Analysis.pdf
	Road and railtrack management systems	DT skills	BME	BME	2	Online	22-Road and Railtrack Management Systems.pdf
ELECTIVE Building spec.	Advanced BIM for construction	DT skills	ENPC	ENPC, UPM	2	Online	23-Advanced BIM for construction.pdf
	Smart buildings	DT skills	ENPC	ENPC	2	Online	24-Smart buildings.pdf
	Smart cities and territory: policy and planning	DT skills	UPM	UPM, ITU	2	Online	25-Smart cities and territories.pdf
	Structural Health Monitoring	DT skills	UPM	UPM, US	2	Online	26-Structural Health Monitoring.pdf
	GIS in Digital Twins cities	DT skills	ITU	ITU	2	Online	27-GIS in Digital Twin City.pdf

2.2 CALENDAR 2023-2024

The provisional timetable for the course can be found below:

Table 1. Course acronyms

	WS	WELCOME SESSION	WS	
CORE	Basic IT skills Part I	Programming & Software development	P&S	
		Cloud computing and cybersecurity	C&C	
		Principles of BIM and GIS	BIM	
	On-site I	<i>on-site workshop (content to be defined)</i>		
	Basic IT skills Part II	IoT and signal processing	IoT	
		Machine learning and data analysis	ML	
Big Data Technologies and Applications for Digital Twins		Data		
ELECTIVE	Elective IT skills	Python programming	Phy	
		Matlab programming	Mat	
		Relational database and SQL	SQL	
		Introduction to numerical methods and optimization	NM	
		Transport modeling	TMd	
		Finite-element analysis_calibration	FE	
CORE	Core DT technologies	D&D_DT	D&D	
		Validation and usage of digital twins	V&U	
		Innovation and industry 5.0	I&I	
		Asset and facility management	A&F	
		Knowledge representation and semantic interoperability	K&S	
	On-site II	<i>on-site workshop (content to be defined)</i>		
ELECTIVE	Transportation spec.	Advanced BIM for transports	BIM-t	
		Intelligent transportation systems	InTr	
		Mobility data analysis	MDA	
		Road and railtrack management systems	R&R	
	Building spec.	Advanced BIM for structures	BIM-S	
		Smart buildings	SmB	
		Smart cities	SmC	
		GIS in Digital Twin City	GIS-C	
		Structural Health Monitoring	SHM	
	Conference cycle	<i>20 Invited lectures</i>		
	Mentoring/Capstone	Sessions of mentoring of courses and capstone projects	M&C	

		October																											
		M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
October	Time																												
	17:00-18:00		P&S	BIM	C&C	P&S			BIM	P&S	C&C		P&S			BIM	P&S	C&C	SQL				BIM	P&S	C&C	SQL			
	18:00-19:00	WS				Met							Met						Met							Met			
	19:00-20:00		BIM	C&C	P&S	NM			P&S	C&C	BIM		NM			P&S	C&C	BIM	NM				P&S	C&C	BIM	NM			

		November																												Dec				
		M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F
		30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1
November	Time																																	
	17:00-18:00	BIM	P&S			C&C	SQL			BIM	P&S	C&C		SQL			BIM	P&S	C&C	SQL				BIM	P&S	C&C	SQL			BIM	P&S	C&C	SQL	
	18:00-19:00					SQL	Met						SQL	Met					SQL	Met					SQL	Met					SQL	Met		
	19:00-20:00		C&C			BIM	NM				C&C	BIM		NM			Met	NM	NM					Met	NM	NM				Met	NM	NM		

		December																			
		M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
December	Time																				
	17:00-18:00	IoT	ML	Data	Phy				IoT	ML	Data	Phy				IoT	ML	Data	Phy		
	18:00-19:00																				
	19:00-20:00	ML	Data	IoT	TMD				ML	Data	IoT	TMD				ML	Data	IoT	TMD		

		January																								February	
		M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F
		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2
January	Time																										
	17:00-18:00	Phy	IoT	ML	Data	TMD			Data	IoT	ML	Data	TMD			IoT	ML	Data	TMD				IoT	ML	Data	TMD	
	18:00-19:00																										
	19:00-20:00	TMD	ML	Data	IoT	Phy			IoT	ML	Data	IoT	Phy			ML	Data	IoT	Phy				ML	Data	IoT	Phy	

		February																				March							
		M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	1	2	3
February	Time																												
	17:00-18:00	IoT	ML						D&D	I&I	A&F	MDA	M&C			D&D	A&F	I&I	BIM-t	M&C				D&D	I&I	A&F	SMB	M&C	
	18:00-19:00																												
	19:00-20:00	ML	Data						BIM-t	SMB	BIM-C	BIM-t				BIM-t	MDA	MDA	MDA						BIM-C	BIM-C	BIM-C	SMB	

		March																														
		M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S			
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31			
March	Time																															
	17:00-18:00	D&D	I&I	A&F	BIM-S	M&C			D&D	I&I	A&F	MDA	M&C			D&D	I&I	D&D	BIM-t	M&C				A&F	I&I	A&F	SmB					
	18:00-19:00																															
	19:00-20:00	SmB	BIM-S	SmB	BIM-t				SmB	BIM-S	MDA	BIM-t				SmB	BIM-t	BIM-t	MDA						SmB	BIM-S	MDA	BIM-S				

		April																														
		M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28			
April	Time																															
	17:00-18:00	A&F	D&D	I&I	BIM-t	M&C			I&I	D&D	SmC	R&R	M&C			K&S	K&S	InTr	GIS-C	M&C			V&U	K&S	V&U	InTr	M&C					
	18:00-19:00																															
	19:00-20:00	SmB	A&F	A&F	BIM-S				MDA	MDA	GIS-C	InTr			SHM	InTr	SHM	SmC					SmC	V&U	SHM	GIS-C						

		May																																
		M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S					
		29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
May	Time																																	
	17:00-18:00	V&U	K&S		R&R	SmC			V&U	K&S	InTr	GIS-C	M&C			K&S	SmC	V&U	R&R	M&C			K&S	V&U	Onsite courses				V&U	K&S	GIS-C	SHM		
	18:00-19:00																																	
	19:00-20:00	SHM	R&R		SHM	GIS-C			GIS-C	InTr	R&R	SHM				SmC	SHM	SHM	InTr				InTr	GIS-C										

		June					July					
		M	T	W	T	F	M	T	W	T	F	
		3	4	5	6	7	15	16	17	18	19	
June	Time											
	17:00-18:00	V&U	K&S	SmC	V&U	M&C	Master Thesis pre-defense Capstone project review Online					
	18:00-19:00											
19:00-20:00	R&R	InTr	SHM	GIS-C								

		September							
		M	T	W	T	F	S	S	
		16	17	18	19	20	21	22	
September	Time								
	17:00-18:00								
	18:00-19:00								
	19:00-20:00								

2.3 FACULTY MEMBERS

This is the provisional list of professors involved within the courses:

Course	Name
Academic Director	Mathieu Arquier
Advanced BIM for Construction	Pierre Benning LinkedIn
	Rémi Montorio LinkedIn
Advanced BIM for Transports	Antonio A. Arcos Álvarez
	Eva Orozco Ramírez LinkedIn
	Felix Tejada LinkedIn
	Jose Juan Arranz LinkedIn
	Marcos García Alberti LinkedIn
	Ruben Muñoz Pavon LinkedIn
Asset and Facility management in DTW for Infrastructures	Onur Behzat Tokdemir LinkedIn
Cloud Computing and Cybersecurity	Miguel Jimenez Gañán LinkedIn
	Sonia Frutos LinkedIn
Conferences	Jérémy Bleyer LinkedIn
Big Data Technologies and Applications for Digital Twins	Altan CAKIR LinkedIn
	ESTEBAN GONZALEZ GUARDIA - Universidad Politécnica de Madrid (upm.es)
	Sefer baday LinkedIn
	Tamás Lovas LinkedIn
Design and deployment of digital twins	Alejandro Enfedaque LinkedIn
	Marcos García Alberti LinkedIn

	Ruben Muñoz Pavon LinkedIn
Digital twins: validation and usage	Christine Le Brun LinkedIn
	Estefania Tapias, PhD LinkedIn
Finite-element analysis and model calibration	Ángel Yagüe Hernán LinkedIn
	DIEGO GUILLERMO MANZANAL Milano - Universidad Politécnica de Madrid (upm.es)
	Javier Naranjo LinkedIn
	Pedro Navas Almodovar LinkedIn
GIS in Digital Twin City	Fatih Terzi LinkedIn
Innovation and industry 5.0	Dr. Saman Sarbazvatan LinkedIn
Intelligent Transportation Systems	Arpad Barsi LinkedIn
	Dr. SOMOGYI József Árpád Budapest University of Technology and Economics (bme.hu)
	Juan Nicolas Gonzalez LinkedIn
	Manuel Romana LinkedIn
	Natalia Sobrino Vázquez LinkedIn
	Tamás Lovas LinkedIn
Internet of Things (IoT) implementations in Digital Twin (DT) Systems	Dumitru Cristian Tranca LinkedIn
	Florin-Alexandru Stancu LinkedIn
	Razvan Tataroiu LinkedIn
	Alexandru-Viorel Pălăcean LinkedIn
Introduction to numerical methods and optimization	Kristóf Kapitány LinkedIn
	Piroska Laky LinkedIn

Knowledge representation and semantic interoperability	María Poveda Villalón LinkedIn
	Oscar Corcho LinkedIn
	Raul Garcia Castro LinkedIn
Machine learning and data analysis	Dan Novischi LinkedIn
	Esteban García-Cuesta LinkedIn
	Ömer Faruk Beyca LinkedIn
Matlab Programming	Arpad Barsi LinkedIn
	Kristóf Kapitány LinkedIn
Mobility Data Analysis	Javier Burrieza Galán LinkedIn
	Luis Willumsen LinkedIn
	Miguel Picornell LinkedIn
Principles of BIM and GIS	Marcos García Alberti LinkedIn
	Sandra Martínez Cuevas LinkedIn
	Tamás Lovas LinkedIn
	Yolanda Torres Fernández. LinkedIn
	Kristóf Kapitány LinkedIn
	Zsofia Kugler
Programming & Software development	Daniel Garijo LinkedIn
	David Chaves-Fraga LinkedIn
	Pablo Calleja Ibáñez LinkedIn
Python programming	Sefer Baday LinkedIn
Relational database and SQL	Basar Oztaysi LinkedIn
	Ákos VINKÓ LinkedIn

Road and Rail Track Management systems	Kornél Almássy LinkedIn
Smart buildings	Xavier Devaux LinkedIn
Smart cities and territory: policy and planning	Ana Belén Berrocal Menárguez LinkedIn
	Cristina López García de Leaniz – Centro de Investigación del Transporte (upm.es)
	Julio A. Soria-Lara LinkedIn
	Rosa M Arce Ruiz LinkedIn
Structural Health Monitoring	Carlos Martín de la Concha Renedo LinkedIn
	Grupo de Ingeniería Estructural Carlos Zanuy (upm.es)
	Gonzalo Sanz-Diez de Ulzurrun Casals LinkedIn
	Iván Muñoz Díaz LinkedIn
	Jaime García Palacios LinkedIn
	Javier Fernando Jiménez Alonso LinkedIn
	Javier Naranjo LinkedIn
	José Manuel Soria LinkedIn
Transport modelling	János Juhász PhD LinkedIn

3 ADMINISTRATIVE MANAGEMENT

The governance system of the Master follows the rules specified in the DIGITWIN4CIUE grant agreement n° 101084054 and in the associated Consortium Agreement. An Academic Committee, a Steering Committee and an Admission Committee have been set up for the Master with members of the four HEIs and of other partners of the DIGITWIN4CIUE project.

Contact details:

DIGITWIN4CIUE project-Executive Master in Digital Twins for Infrastructures and cities
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Email contact: info@digitwin4ciue.eu

Contact person:

Fernando García Molina: fernando.gmolina@upm.es (global coordinator of the project)

Rocío López Espinosa: rocio.lopez@upm.es (project manager)

Apart from that, the secretariat of the master is held by the Fundación Agustín de Betancourt, a Spanish non-profit organization dedicated to promoting research and innovation in civil engineering and technology. Founded in 1977, the foundation supports educational programs, grants, and projects aimed at advancing scientific knowledge and fostering technological development in coordination with the School of Civil Engineering of Madrid.

Contact details

Fundación Agustín de Betancourt

ETSI Caminos, Canales y Puertos

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- Laura Camacho (secretarial and coordination matters), laura.camacho@upm.es

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