FOSTERING INNOVATION: UNIVERSITY-INDUSTRY COLLABORATION NETWORKS IN ARCHITECTURAL RESEARCH

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_ Milijana Živković

PhD student, Teaching Assistant, University of Belgrade, Faculty of Architecture, Serbia, milijana.zivkovic@arh.bg.ac.rs

_ Eva Vaništa Lazarević

PhD, Full Professor, University of Belgrade, Faculty of Architecture, Serbia, eva@arh.bg.ac.rs

_ Jelena Marić

PhD, Teaching Assistant, University of Belgrade, Faculty of Architecture, Serbia, jelena.maric@arh.bg.ac.rs

_ Jelena Milošević

PhD, Assistant Professor, University of Belgrade, Faculty of Architecture, Serbia, jelena@arh.bg.ac.rs

ABSTRACT

Applied architectural research requires specific knowledge acquisition, accessibility of advanced technologies, and various support systems, considering it is influenced by the quality of available resources and work distribution among researchers. Meanwhile, the industrial sector is confronted with an increasing complexity of challenges that demand innovative approaches. Therefore, it is beneficial for universities to create networks with various partners, provided the university retains its autonomy and all parties are proactive in the collaboration. Real-world project involvement opens up new learning paths that rely on a collaborative and multidisciplinary approach. Shared objectives to be considered include industrial development and the advancement of applied research, which contribute to the country's research and development quality. This study focuses on the specific university-industry relationships developed at the prominent European architecture schools. The research methodology is based on a comparative analysis of these collaborations, which creates the groundwork for specific criteria and an evaluation of the local collaborative models. The principal advantages and difficulties that both parties face, knowledge transfer models, and commercialization strategies like patents and licences are some of the topics that have been examined. The study aims to demonstrate potential ways in which certain concepts may be applied in the architectural context by examining how these networks are regulated in different cases. The study results indicate that European universities have acknowledged industry relationships as an important factor in their research development. This paper contributes to a better understanding of the university-industry collaboration networks in the architectural context by identifying existing patterns and potentials for their further development. Future research will focus on preserving the integrity of the joint research results.

KEYWORDS _ *university-industry collaboration, architectural innovation, joint projects, collaborative research, knowledge-transfer*

INTRODUCTION

In recent decades, university-industry collaborations (UIC) have been researched across varying science fields (Meyer-Krahmer & Schmoch, 1998; Bodas Freitas & Verspagen, 2017; Protogerou et al., 2013), following the Mode 2 theory, defined by practical and problem-solving topics that involve knowledge creation by research teams networked across a variety of organizations (Ziman, 1996). The study's primary goal is to expand the understanding of the UIC governance in the architectural field and identify applied strategies. The main hypothesis is expressed by the notion that architectural research could prosper from developing UIC networks through significant insight into the knowledge and demands of the industry, obtaining outside funding, and research relevance in the innovation market. A comparative analysis research methodology has been utilized to study UIC networks formed by Europe's prominent universities. The Republic of Serbia has acknowledged the importance of UIC by creating the Innovation Fund with programs aimed at technology transfer, which set important grounds for intellectual property protection (IPR) and commercialization strategies and tactics for research and development (R&D) institutions. The overall importance of the research question is made clear by the fact that technological development in numerous scientific domains supports the growth of the country's economy, which is illustrated by the fact that countries with knowledge-based economies tend to be the most socially advanced or economically competitive (Jovanović-Kranjec & Despotović, 2018).

THEORETICAL FRAMEWORK

UIC in Architectural research

Technological progress and economic and environmental changes have placed entirely new restrictions on the architectural profession (Kattein, 2015). Having in mind that architecture is an applied field, architectural research has traditionally evolved through solution and application practice, and it is in a unique position to engage in multidisciplinary collaboration since it crosses the boundaries of physical science, art, and engineering (Vassigh, 2017). Additionally, changing perspectives on the formation of architectural knowledge within the connections between scholars, practitioners, laboratories, and technology are brought about by the social nature of technological growth in the design-to-construction process (Yuan & Yan, 2020). Specific to the building industry, the traditional division between design and construction and unique designs with no prototypes would argue against a coherent innovation strategy in the field. However, there is a trend amongst various parties, such as the government, contractors, universities, architects, and engineers, in favor of developing collaborative networks and strategic alliances to cope with the complex challenges that all face (Miozzo & Dewick, 2004). Given the lack of written work on the subject of comparing various approaches used in architectural research, this paper aims to compare key indicators and characteristics of UICs in order to gain perspective on different kinds of collaborations.

UICs factors & indicators

The typology of architectural design research that is most frequently mentioned is represented by a tripartite research model for, into, and through design, where research for design could be seen as an effort motivated by the need to create new technologies and materials in the sector (Rendell, 2004). The most financially supported research is that which has potential for construction industry application. The markets for this kind of research have been found to exist in high-technology fields, where it has been demonstrated that smaller research organizations foster due to their links with large commercial firms (Ziman, 1996). Four generally accepted UIC relationship models include (1) research support, constituting of industry equipment donations or financial funds; (2) cooperative research, constituting of contract research on a targeted project; (3) knowledge transfer, which is a highly cooperative model developed through formal and informal interactions, cooperative education, or curriculum development;

and (4) technology transfer, focused on specific and direct industry needs, whose rationale is combining academic research with industry experts to produce marketable technologies (Seppo & Lilles, 2012). The factors impacting UIC networks' success are divided into input and output factors. The input factors are further deployed into four categories: (1) institutional factors, including the business environment, legal regulations, and restrictions, as well as government support; (2) human factors, preferably incorporating high-quality resources, as well as the availability of equipment, laboratories, testing facilities, libraries, etc.; (3) linkage factors, generally developed in the communication strategy between two sides, incorporating regular exchange of information and feedback; and (4) framework factors, which include the information and communication technology available for use, logistics, and questions of IPR and regulations (Ćudić et al., 2022). Patents, licenses, publications, joint supervision, spin-offs, meetings, seminars, workshops, etc., are some UIC output indicators of R&D collaborations (Seppo & Lilles, 2012). Researchers looking at the UIC from an ethical perspective have identified conflicts of values that can result from the differences between academic institutions and the industry. In particular, universities believe knowledge should be shared publicly, while businesses prefer commercializing it. As a result, a lock-in effect risk has been noted (Hillerbrand & Werker, 2019; Meyer-Krahmer & Schmoch, 1998). Therefore, it is crucial to keep in mind that the foundation of education, which has a strong humanistic dimension, should remain without putting profits first. The benefits of UIC for society should be long-term (Jovanović-Kranjec & Despotović, 2018).

METHODS

The study employed the following research approaches: (1) a literature review emphasizing the common UIC network models, variables, and performance indicators. This action aimed to identify the criteria for the analysis; (2) a comparative analysis of the UIC networks characterized by research aimed at digital fabrication and computational design.

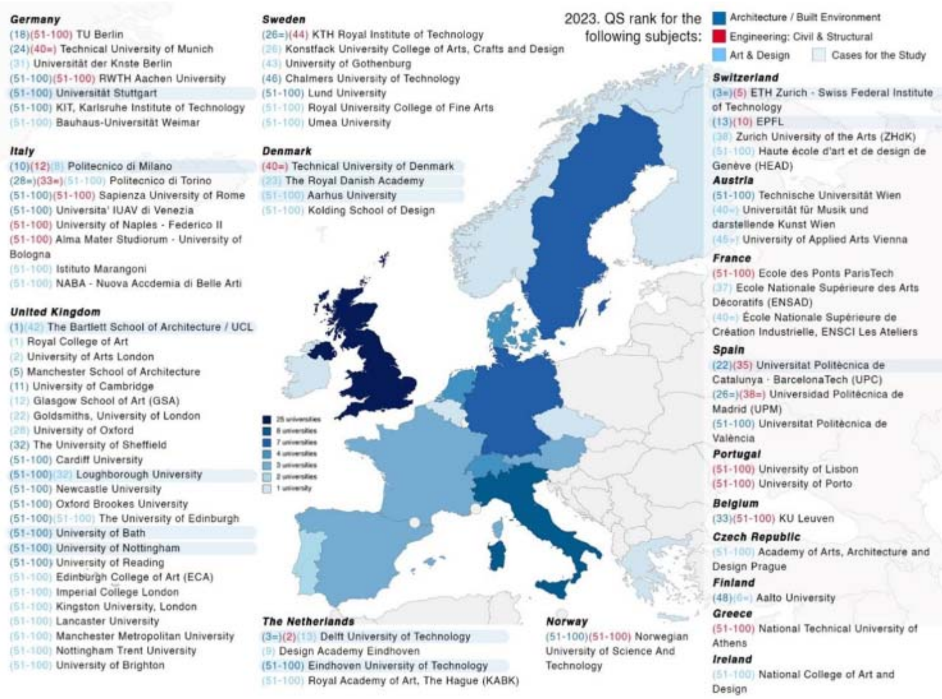

Figure 1: Overview of the subjects, ranks and highlighted cases which were chosen for the study

The analyzed data has been limited to publicly accessible information, following the notion that academic research should promote open science and the development of society in general. The cases were chosen based on their subject, rank, and location from the Quacquarelli Symonds (QS) World University Rankings by Subject for 2023, where location has been targeted to include European countries. This representative context was chosen since it lies at the center of scientific productivity between North America and East Asia and is home to some of the oldest research institutions (Powell & Dusdal, 2017). The specific subjects and ranks of the universities included in the study are represented in Figure 1. The chosen area of the study is digital manufacturing and fabrication, which belongs to the building science field and is generally considered to be highly industry-funded (Rendell, 2004).

Focusing on digital fabrication, specific research topics and groups within universities have been noted to gain insight into the type of architectural research being delivered. Dominant outputs such as joint projects, built prototypes, patents and licenses, curriculums, workshops, and joint publications were identified, which include open-access information on the collaboration type and tangible outputs to be compared between institutions.

Comparative analysis of architectural research UICs in European countries

In this paper, a comparative analysis of the UIC networks was delivered based on the main factors and indicators of those collaborations. Research findings have been presented as qualitative. The four categories included are: (1) research topics; (2) industry types; (3) types of UIC networks to address the most common models in applied architectural research; and (4) types of UIC outputs in order to gain insight into the science production end results. The collected data is shown in Table 1.

Table 1: Types of dominant research topics, industry partners, UICs, and outputs in applied architectural research in the selected schools (RS – research support; CR – collaborative research; KT – knowledge-transfer; TT – technology-transfer)

University (Country code)	**Research topics**	**Industry types**	**UIC type**	**UIC outputs**
The Bartlett school of architecture – UCL (UK)	craft; computational technologies; advanced robotics	architecture firms; material suppliers; consultants; IT companies; contractors	CR; TT	joint projects joint publications built prototypes curriculums
Loughborough University (UK)	sustainable and digital manufacturing; automation; advanced materials	architecture firms; consultants; developers	RS; KT; TT	joint projects workshops
University of Bath (UK)	advanced materials; optimisation of structures; energy minimisation	architecture firms; material suppliers; consultants; software developers	RS; TT	joint projects software techniques
University of Nottingham (UK)	3D printing; textile architecture; lightweight structures; sustainable construction	architecture firms; material suppliers; consultants; non-profit organizations	RS; CR; KT; TT	joint projects joint publications built prototypes techniques workshops
Technical University of Denmark (DK)	surface engineering; absolute sustainability; circular construction; recycled materials	material suppliers; sustainability consultants; contractors; developers	RS; CR; KT; TT	joint projects joint publications industrial PhD projects datasets commissioned research

The Royal Danish Academy (DK)	complex modelling; digital formations; behaving architecture; bio hybrids; computation in architecture	material suppliers; infrastructure consultants; software developers	RS; CR; KT; TT	joint publications built prototypes techniques industrial PhD projects commissioned research
Aarhus University (DK)	advanced, sustainable and recycled materials	material suppliers; engineering consultants	CR; KT	joint publications seminars workshops industrial PhD projects commissioned research
Delft University of Technology (NL)	AI in building guidance; bionic buildings; real-time and distributed BIM; refurbishment strategies; circular building products; construction principles	material suppliers; software developers; contractors; engineering consultants; architectural firms;	RS; CR; KT; TT	techniques proof of concept conservation management plans built prototypes
Eindhoven University of Technology (NL)	building physics and services; information systems; 3D concrete printing; applied mechanics; innovative structure design	innovation agencies; environmental consultants; media producers; software developers	RS; CR; KT; TT	joint projects techniques commissioned research
ETH Zurich (CH)	self-supporting assemblies, construction robotics; spatial timber assemblies; performance-integrated 3D printing	material suppliers; equipment suppliers; contractors; media producers; IT companies; engineering consultants	CR; KT;	joint projects built prototypes commissioned projects
EPFL (CH)	lightweight structures; innovative concrete structures; structural dynamics; applied computing	architecture firms; engineering consultants; foundations	KT; TT	joint projects
University of Stuttgart (DE)	fibre composite building systems; 3D printed bio-composites; adaptive systems; textile architecture; robotic fabrication in timber; evolution-inspired design tools; performative design; shell structures	architecture firms; material suppliers; banks; IT companies; robot manufacturers; engineering consultants; foundations; contractors	RS; CR; KT; TT	built prototypes software techniques
Politecnico di Milano (IT)	innovative building materials and systems; additive manufacturing	developers; foundations	RS; CR; KT; TT	patents curriculums commissioned projects
Barcelona Tech (ES)	technologically advanced fabrication techniques; large-scale 3D printing; anti-gravity additive manufacturing; on-site robotics	material suppliers; foundations; robot manufacturers; engineering consultants; philanthropic organisations	RS; CR; KT; TT	joint projects patents databases built prototypes techniques

The cases that were studied involve four universities from the UK, three from Denmark, two from The Netherlands, and two from Switzerland, as well as one each from Germany, Italy, and Spain, which sets the groundwork for the UICs analysis and comparison in different institutional settings.

DISCUSSION & CONCLUSION

The data displayed in Table 1 has been collected through universities' official outlets, such as their research groups' project presentations, which hold the data on their collaborators. The research shows that UICs tend to be regulated on several levels, starting with the government-directed innovation strategy leading to universities that form appointed bodies and representatives and ending with individual research groups and clusters. Countries that are included in the study generally have highly institutionalized innovation and R&D strategies that are guided by official legislation. These strategies, for example, in the UK, include reports given by universities called Research Excellence Frameworks (REF), where research done by the university is measured through its impact. At the university level, important guidelines have been identified. The IPR regulations and research integrity statements have been noted in all of the cases. When superimposed, the shown data imposes several research topics that come up most frequently, including additive manufacturing and construction robotics, sustainable and circular construction, and advanced materials and fabrication processes. In the reviewed cases, a pattern related to the choice of industry collaborators has been noted. They mostly involve collaborators such as construction material and technical equipment manufacturers and service-oriented consultants in various fields such as engineering, software, sustainability, etc. This shows that universities tend to collaborate with the purpose of gaining resources needed for specific types of applied research as well as industry knowledge acquisition. The main outputs of UIC found in the cases include joint projects and publications, as well as developed techniques and prototypes. Research shows that patents and licenses are less frequent as an outcome of UIC in applied architectural research, where prototypes, methods, and techniques seem to be dominant.

This analysis highlighted the main research themes, industrial partners, UIC kinds, and outputs found at the top-ranked European universities. UIC appear to be a major feature in university research output, establishing a regulated environment aimed at revolutionizing the construction sector and elevating applied architectural research with a focus on sustainable building. IPR, regulations, research integrity, and ethics are all crucial components of effective UIC because they allow universities to control the types of collaborations in which their researchers are involved. These collaborations may result in a better integration of university curricula with industrial needs, resulting in higher-quality building practices. Having in mind that research integrity is an important aspect of successful UIC, this is something to be covered in greater detail in future research.

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REFERENCES

- Arkitekstkolen Aarhus. 2023. "Research projects." Accessed May 31, 2023. https://aarch.dk/en/research/research-projects/
- Bodas Freitas, Isabel Maria, and Verspagen, Bart. 2017. "The motivations, institutions and organization of university-industry collaborations in the Netherlands." *Journal of Evolutionary Economics* 27, no. 3 (May): 379–412.
- Eindhoven University of Technology, Built Environment. 2023. "Research." Accessed May 31, 2023. https://www.tue.nl/en/our-university/departments/built-environment/research

- EPFL. 2023. "Research." Accessed May 31, 2023. https://www.epfl.ch/schools/enac/recherche/institut-darchitecture-et-de-la-ville-ia/research/
- Hillerbrand, Rafaela, and Werker, Claudia. 2019. "Values in University–Industry Collaborations: The Case of Academics Working at Universities of Technology." In *Science and Engineering Ethics 25*, no. 6 (October): 1633–1656.
- Institute for Advanced Architecture of Catalonia, Barcelona. 2023. "NATIONAL AND INDUSTRY FUNDED RESEARCH." Accessed May 31, 2023. https://iaac.net/research-departments/advanced-architecture-group/#fundedresearch
- Jovanović-Kranjec, Milena, and Despotović, Danijela. 2018. "Importance of cooperation between Universities and industry as a factor of economic and social development of the Republic of Serbia." In *Ekonomika 64*, no. 1 (April): 123–133.
- Kattein, Jan. 2015. "Made in Architecture: Education as collaborative practice." In *Architectural Research Quarterly 19*, no. 3 (March): 295–306.
- Loughborough University. 2023. "Research and Innovation." Accessed May 31, 2023. https://www.lboro.ac.uk/research/
- Meyer-Krahmer, Frieder, and Schmoch, Ulrich. 1998. "Science-based technologies: University–industry interactions in four fields." In *Research Policy 27*, no. 8 (December): 835–851.
- Miozzo, Marcela, and Dewick, Paul. 2004. "Networks and innovation in European construction: Benefits from inter-organisational cooperation in a fragmented industry." In *International Journal of Technology Management 27*, no. 1 (February): 68-92.
- National Centre of Competence in Research Digital Fabrication. 2023. "Research." Accessed May 31, 2023. https://dfab.ch/streams
- Politecnico Milano 1863. 2023. "PATENTS FOR INVENTATION DATABASE." Accessed May 31, 2023. https://www.polimi.it/en/scientific-research/research-at-the-politecnico/technology-transfer/patents-for-inventions-database
- Powell, Justin. J. W, and Dusdal, Jennifer. 2017. "The European Center of Science Productivity: Research Universities and Institutes in France, Germany, and the United Kingdom." In *International Perspectives on Education and Society,* edited by Justin J. W. Powell, David P. Baker, and Frank Fernandez, Vol. 33, 55–83. Bingley: Emerald Publishing Limited.
- Protogerou, Aimilia, Caloghirou, Yannis, and Siokas, Evangelos. 2013. "Twenty-five years of science-industry collaboration: The emergence and evolution of policy-driven research networks across Europe." In *The Journal of Technology Transfer 38*, no. 6 (November): 873–895.
- QS World University & Business School Rankings. 2023. "Ranking reports and results tables". Accessed May 11, 2023. https://www.qs.com/download-rankings-reports/
- Rendell, Jane. 2004. "Architectural research and disciplinarity." In *Architectural Research Quarterly 8*, no. 2 (July): 141–147.
- Royal Danish Academy. 2023. "CITA Collaborators." Accessed May 31, 2023. https://royaldanishacademy.com/CITA/cita-collaborators
- Seppo, Marge, and Lilles, Alo. 2012. "Indicators Measuring University-Industry Cooperation." In *Estonian Discussions on Economic Policy 20*, no 1. (January): 204-226.
- Technical University of Denmark. 2023. "Network." Accessed May 31, 2023. https://www.dtu.dk/english/collaboration/industrial_collaboration/network
- The Bartlett Faculty of the Built Environment. 2023. "Research projects." Accessed May 31, 2023. https://www.ucl.ac.uk/bartlett/research/research-projects?collection=drupal-bartlett-research-projects&facetsort=alpha&
- TU Delft, Architecture and the Built Environment. 2023. "Research projects." Accessed May 31, 2023. https://www.tudelft.nl/en/architecture-and-the-built-environment/research/projects
- University of Bath. 2023. "Department of Architecture & Civil Engineering research." Accessed May 31, 2023. https://www.bath.ac.uk/topics/department-of-architecture-civil-engineering-research/
- University of Nottingham. 2023. "Research and Innovation." Accessed May 31, 2023. https://www.nottingham.ac.uk/fabs/research-innovation/engagement-and-partnerships.aspx
- University of Stuttgart. 2023. "ICD/ITKE Research Pavilions." Accessed May 31, 2023. https://www.itke.uni-stuttgart.de/research/icd-itke-research-pavilions/

- Vassigh, Shahin. 2017. “The Changing Higher Education Research Environment: New Opportunities for Architectural Research.” In *Technology|Architecture + Design 1*, no 1 (May): 22–26.
- Yuan, Phillip F, and Yan, Chao. 2020. “Collaborative Networks of Robotic Construction.” In *Architectural Design 90*, no. 2 (March): 74–81.
- Ziman, John. 1996. “‘Post-Academic Science’: Constructing Knowledge with Networks and Norms.” In *Science & Technology Studies 9*, no. 1 (January): 67–80.