Ivan Mutis · Timo Hartmann *Editors*

Advances in Informatics and Computing in Civil and Construction Engineering

Proceedings of the 35th CIB W78 2018 Conference: IT in Design, Construction, and Management

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Letter from the Editors

The 35th CIB W78 conference took place in Chicago in 2018, with a theme focused on fostering, encouraging, and promoting research and development in the application of integrated information technology (IT) throughout the life cycle of the design, construction, and occupancy of buildings and related facilities. Organized by Professors David Arditi and Ivan Mutis (Illinois Institute of Technology, Chicago), Timo Hartmann (Technische Universität Berlin), Robert Amor (University of Auckland), and with special and valuable support from Bill East (Prairie Sky Consulting, USA), it brought together more than 200 scholars from 40 countries, who presented the innovative and unique concepts and methods featured in this collection of papers.

With the publication of these contributions, we expect to scaffold scholars' motivations to inspire and discover the pressing research questions that need to be answered in the coming decade. Framed under topic clusters as described in the introductory section, the Editors organized the responses of the 2018 worldwide, open call for submissions. Taking the number of submissions in each focus area as an indicator of research potential, the open call elicited the lowest response in the area of Systems of Integrated Computer and Physical Components (Cyber-Physical-Systems), which suggests underdevelopment of initiatives for scientific questions in this area. We look forward to seeing greater response to this area in the future.

Ultimately, the success of this event and its contribution to the field of informatics and computing in civil and construction engineering is the result of countless hours of investigation, development, and work from scholars across the globe. The Editors and organizing committee thank all who have supported the effort. We thank in particular the paper reviewers.

The research and approaches that have been developed and presented at this conference can immediately deliver extraordinary innovations to construction practices with benefits attributable to individuals, organizations, and the industry, as a whole. Looking forward, the legacy of this conference will be carried not only through its influence on the construction practice but also on research for years to come.

Ivan Mutis
Timo Hartmann

About CIB and CIB W78

CIB, officially named International Council for Research and Innovation in Building Construction, was established in 1953 under the name Conseil International du Bâtiment. The foundational objectives of CIB were to stimulate and facilitate the international cooperation and exchange of information between governmental research institutes in the building and construction sector, with an emphasis on those engaged in technical fields of research. Since its inception, the association has developed into a worldwide network that connects more than 5000 experts. These specialists represent the research institutes, university, and industry- and government-related entities that constitute the approximate 500-member organizations of CIB. Though the size and strength of the organization today has grown compared to the past, the focus of CIB and its members remains the same: the active collection of research and innovation information for all aspects of building and construction.

CIB W78, or work group 78, is one of the largest and most active working commissions of CIB. The scope of W78's work is broad, but its primary mission is to proactively encourage the integration of Information and Communication Technologies (ICT) into a facility's life cycle. It achieves this goal by disseminating research and knowledge among an international community of scholars and practitioners in a variety of means, most notably the annual international conference.

Contents

Introduction

A Vision for Research and Innovation in Informatics and Computing in Civil and Construction Engineering

While we move into the first quarter of the twenty-first century, the practice of civil, construction, and building engineering embraces an incommensurable transformation in the way we deliver products, process data, and interact with agents and technology. New paradigms focused on sustainable practices, and the effective use of data and information and computing technologies, and automation have framed the trends we see in research initiatives and fundamental problems in civil and construction engineering disciplines. The continuous expansion of interdisciplinary work among computing, informatics, and construction and civil engineering merges perspectives to create integrated or hybrid methods of observing, dissecting and solving central problems and of integrating relevant theories. The 2018 conference and this related publication is an effort to register diversity of thinking to understand a phenomenon, problem, dataset, or methods that enable value creation in practice and expand the frontiers of new, integrated knowledge.

We view the worldwide, open call for research initiatives as a survey of innovations and novel approaches to phenomena and problems in computing and informatics in civil and construction engineering. The compilation is organized under seven concept clusters to align the contributions to the forefront of trends on investment for scientific research. The selection in clusters was decided to better capture new advancements of knowledge within the focus areas. The conceptualization and focus were based mainly on reflections from visionary documents [1–3]. The focus areas cover the spectrum of aims of scientific questions and the fundamental aspects that advance understanding or solve problems. Within each area, evolving technology may transform activities and subsequently shape research practices in the coming decade (Fig. 1).

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Fig. 1 Conference topics clustered in focus areas

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56 Social Paradigms in Contemporary Airport Design

Filippo Bosi, Maria Antonietta Esposito, and Arto Kiviniemi

Abstract

Increased demand for traffic puts the Aviation industry in front of multiple challenges. Traditional airport design matrices do not cope properly with the evolution of design requirements and project participants' needs, especially in a multidisciplinary context that requires high skilling. In this setting, Architects are rulers of the terminal and lead managers of Project Information. These are generated and managed through Social processes who leverage the joint use of knowledge to fulfill project requirements. Often the need for reliable project information is not understood by project participants and project clients, therefore causing reworks, overtimes and an overall increase in project cost. Innovative project management methodologies based on social aspects are needed to implement common practices and support collaboration, shared design, problem-solving. The target is producing consistent Project Information. In this exploratory paper, way lay down the foundation and research background for a proposed research that aims to re-align people, process, and technology in Airport Design. A lean design methodology proposal is built on the project sociotechnical system to maximize project value for passengers, airlines, and airport management companies.

Keywords

Design process • Social sciences • Lean design

56.1 Background

The role of airports in the global social and economic scenario has consistently evolved in recent times because of their role of connection between people and markets. Communities and territory have been shaped by the layout of the transport network and globalization depends on connections and their speed. Strengthening of the market and aviation was fostered by the progressive liberalization of markets, also overcoming the hills and slopes of the recent global economic crisis [12, 15, 23]. The air transport network will experience major service disruptions if Airport will not cope with the evolution of traffic and aircraft requirements, with a larger-scale chain reaction on the global economy.

This capacity challenge is being faced in a context of increased competition and a shift in the global aviation market, driven by globalization, technological progress and the rise of new economies. In addition, air traffic, airport user basin and freights will be influenced by changes in customers and airlines habits and practices [2, 14, 17]. Removal of service bottlenecks is a priority for the future of the Airport Network targeting the Capacity and Quality challenges of ground infrastructures. These have a deeper bond to the Airport project since they both take act mostly inside the passenger terminal.

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56.1.1 Capacity Challenge

To confront the increased demand for air traffic [11], Aviation industry has to face multiple challenges to deliver the expected capacity. Demand is increasing ad a steady pace [13, 11], with a foreseen growth of about +4.5–5% per year until 2035, managing to double the total passenger number in 20 years reaching 490 M/passengers only in Europe. This demand for connectivity—both in terms of longer-range flights and faster connections in general—has a massive impact on the economy, shaping the possibilities of global markets [12]. Capacity of ground infrastructures does not meet flights demand, creating bottlenecks in air service. Soon passenger terminals will not be able to process as many passengers as needed [6] especially in case of operational irregularities or a sudden need for extra flights when already at full capacity. In Europe for example airports' capability to meet the demand, already operated by the unique European Airport Traffic Management, needs larger and more efficient ground infrastructures. If this demand will not be met, by 2035 around 120 million travelers will not be able to complete their trip because of congestion. To cope with this growth and to offer continuity to the economy, aviation industry must be supported by proper infrastructures that meet airline needs, connectivity requirements and transform passenger processing into an economic benefit, connecting people and markets [6, 13]. The airport capacity gap will have to be filled by expansions, new infrastructures and by increasing operation efficiency of current terminals. Both passengers and cargo demand for a higher service quality to cope with the ever-growing foreseen traffic scenario [19].

56.1.2 Service Quality Challenge

The quality of offered services is crucial to obtain flight slots by the European regulation and in general by the global market. If the terminal is built without sufficient attention to users' (passengers and airlines) requirements, then the chances to obtain more slots are jeopardized [13]. Politics have their part in this scenario, resulting in incoherent aviation strategies and airports updated at a pace slower than needed. European Commission has proposed to use performance-based assignment rationales for landing slot assignments following the recent trends of airspace management [11, 12]. Taking this into account, the Aviation Industry needs innovative paradigms and methodologies for the development of ground infrastructure projects [4, 7, 9, 28] aiming to overall sustainability and flexibility. Airports gather passengers, airlines, ancillary service providers and visitors: their business model includes providing accessibility, stress-free processing procedures and satisfying Levels of Service in the so-called Passenger Experience [5, 6, 10]. Reliability, steadiness, accessibility, and quality of transport infrastructure have the highest importance along with attractive frequencies and intermodal integration also considering the need to promote public transport, the ageing of population that Europe is facing and the need to move big quantities of commercial goods [8, 10].

56.1.3 The Role of the Architect as a Social Mediator in Design

The productivity of the airport terminal is critical when evaluating capacity and service quality of the airport, intended as the capacity to process inbound and outbound flights and passengers [10]. Passenger terminals introduced a new typology of space, characterized by big dimensions and ruled by complex technical references and international regulations. Considering the need to cover the ever-changing and unpredictable capacity demand, terminals are the outcome of a challenging design process [24]. The traditional terminal development approach has demonstrated its weakness, leading to multiple projects failures throughout history because of the variegated stakes of the involved parties and their clashing objectives [2]. Sometimes certain stakeholders are excluded from the decisional processes, turning design outcome rapidly turns out-of-date and eliciting conflicts between parties, institutions and local communities [29]. Considering the general timeline of an airport expansion, obtaining the papers and permissions to build often takes longer [6] than the actual construction phase: often built projects are outdated when compared to the current needs and traffic scenarios. Therefore, collaboration in design during the authorization phase is fundamental to provide a project that satisfies the requirements of not only passengers, airlines and all the service companies that operate inside the airport, but also of the airport management company, prime user of the infrastructure. To confront the capacity challenge, enlarging infrastructures is not the only nor the most suggested way: there have been many cases demonstrating how hastily extending an airport can lead to undesired turnouts without proper planning, consultation and shared agreement between stakeholders and project participants [6, 17, 26]. When an airport ground infrastructure is not adequate for the demand because overdesigned or under-designed [18], social processes implied in analyzing and understanding needs and requirements help directing design solutions. Coordination, collaboration and information sharing are the most important processes both at design inception and in latter phases. Stakeholders have to understand the needs of communities, signing a “social agreement” with them. In this context, architects are the rulers of terminals. The terminal is not any more a box meant to supply passengers to the airplanes; it becomes a definite space that interfaces land and air while guaranteeing public space functionalities, always running operative areas and a commercial infrastructure, in addition to ancillary spaces and services offered to third parties. The Terminal project has an overall impact on the surroundings under every meaning of sustainability: social, economic, environmental, etc. Project Information sharing and collaborative management are fundamental **social processes and experiences** of Airport Project Participants in the trail to overall sustainability. This is the optimal use of joint knowledge and practice for planning, design, procurements and field operations to reach project objectives and meet clients’ requirements and user experience as well, while limiting and removing such processes, sub-processes and activities that do not contribute delivering building quality, hence satisfaction.

56.2 State of the Art of Aviation Industry Design

Aviation industry sets boundaries, conventions and standards for the Airport design process [10]. Common design practices struggle to cope with the evolution and changes of this conventions, being hazy at best due to the design being highly operation-sensitive especially regarding the project context [6, 26]. Generally, literature does not present ground-breaking airport terminal architectural design methodologies [6, 7]: such studies are set in a challenging research area, given the relentless dynamism of aviation industry and operation-bound complications. The development and implementation of common practices of innovative project management methodologies founded on social aspects are now more urgent than ever. The interaction between Project Design management and Social Sciences implies and supports an extensive range of phenomena like the shared design, collaboration, problem solving and creativity that can contribute to consistent project information. Achieving a reliable flow of information is one of the most critical difficulties in the Design process since all involved project participants are meant to generate, manage and transform project information that composes an “abstract description” of a product. These difficulties are not steadily understood because of missing knowledge by project participants, leading to wastes such as reworks caused by missing updates on documents, an increase of production times due to growing information complexity, non-value-adding design iterations.

56.2.1 Lean in Project Design Management

Lean is a principle-based approach that aims to maximize clients’ value and minimize resource consumption and waste production in a process [22]. Born in industrial production and progressively applied to construction and design, Lean’s objective is to mitigate project failures trough active management of process variables and project design management. Considering this, the architectural project development of an airport terminal can be assimilated to a temporary production system. In this framework, Lean mindset fosters the idea of the project as a transformation-based process with a focus on the management of the process itself. Leading to the production of a one-of-kind “prototype”—the project information model and later the building as its materialization—the Airport Terminal Design process can be considered a product development process. There is a notable difference with industrial production: building production acts in a temporary setting with recurring changes in the project organization structure during its life cycle, instead of happening in a stable and uniform environment, i.e. the factory [16]. Design process management is the focus of production, aiming to obtain a project production system that maximizes project quality and minimizes waste of resources, time, and the effort for project participants [1].

56.3 The Role of Virtual Design and Construction Technologies

Europe is soliciting the use of Virtual Design and Construction technologies towards a program a Construction Digitalization [25], highlighting the need to reshape the Design Processes and integrate innovative methodologies in the creation and sharing of Project Information models. In this scenario, Project information is supported by collaboration, creativity and information management Interactions between Design Process management and social aspects of project participants must be fostered. Virtual Design and Construction technologies—namely Building Information Modeling and Management—are used by the industry to overcome such difficulties, but often must compete with the barriers of the resiliency of its components. In a social Lean-infused process, project participants collaborate to generate Project Information Organizational Memories and gather them in a coordinated and integrated model: these processes exploit synergies between BIMM and the Lean mindset by a "natural alignment". The work of several project participants has involved the definition of a Project Information Organizational model (or BIMM model), with the objective of achieving a complete model constituted by coordinated information. This evolution demands new knowledge and skills also in social aspects for the AECOO practice, implying the discard of the obsolete *Fordist* approach and filling a gap in process-centered improvement. Moreover, process and technology integration in the Industry present another gap caused by the inability to determine systematic Lean and Virtual Design and Construction Technologies integration strategies and methodologies [3]. BIMM integration in the architectural process is enabled by some of the most prominent Lean thinking features: predictability, reliability and collaborative/learning environment striving to the perfection of the project production system. This contributes to overcoming BIMM complexity barrier for project organizations. Given that Lean promotes theoretical principles close to integrated project information modeling, the integration of BIMM technology must be considered as a Lean tool [21]. Being both Lean and BIMM transformative technologies [27], we argue the transfer and anticipation of the benefits of Lean/BIM to earlier phases of the building lifecycle up to project development, hence fostering the realignment of the People (lean) pillar in project organization in its collaborative information sharing environment, with the objective of enhancing value generation for final users. In this framework BIIM—and more in general Virtual Design and Construction (VDC) Technologies—support the activities of multidisciplinary project organizations that span both through space and time, connecting project participants and bridging their knowledge trough time for the use of all the latter phases.

56.4 Methodology

Design Science Research is the methodological reference area used in the research. Design Science Research produces *artifacts* that allow to better understand the scientific and industrial problem and to develop a methodology to improve the quality of the design process, conveying more value with its final product.

The first artifact is a matrix that associates Lean Product Development principles [22] with the traditional stages of the Airport Design Process. The matrix has an order of 4 by 13, with the Airport Design Process stages in row headers and Lean Principles in the column headers (Fig. 56.1).

Every stage of the process has been mapped, cross-referencing the architectural process and all its sub-phases and steps. The whole process was broken down into forty-nine stages. Every single stage was then confronted with Lean Product Development principles, pointing out if the interaction has a foreseen value generation potential or waste removal potential according to both Lean literature and experience. Interactions were described with postulates in the final column of the table, drawing useful elements from Lean literature. The combination of interactions and their potential is the cornerstone for the proposed methodology that aims to satisfy evolving requirements of the Aviation Industry, fostering the use of joint knowledge of Project Participants and their collaboration to maximize the value. Then, fostering the expertise of recognized experts in the field, a semi-structured survey was sent to Project Participants of the Aviation Industry to investigate issues related to project management, design management project development and project information generation, management and hand-over and refine the preliminary findings of the matrix development, according to the principles, tools and techniques of the Lean Mindset. Answers analysis under a qualitative and quantitative point of view allowed to individuate problems related to the tree aspects of project development interested by Lean: the design process, project participants and

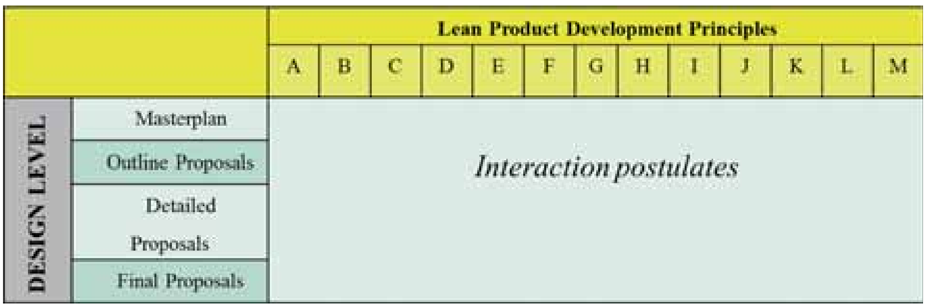

Fig. 56.1 Interaction matrix scheme overview (from Bosi [6])

technologies and tools involved in it. Results were then used to propose and add value-generating activities for project development to be integrated into common practices.

In general, the interviewee population had almost no Lean awareness. This result was expected since Lean mindset and its methods are not generally diffused in the common practices, despite some of their answers showing lean traits. Still, this is not sufficient to achieve a significant Lean integration. Project development and delivery processes in particular are seen as a sequential and static series of activities involving project participants that relate to share mostly finished products, more than coordinated project information. There is a strong lack in the implementation of continuous organization improvement measures. The industry in general is able to delivery project quality to its clients, but with an extremely waste of resources due to scarce coordination and integration between the three pillars of People, Process and Technology. Realignment of the three pillars and additional focus on Process and Project Information structuring.

56.4.1 Development of the Innovative Methodology Model

Lean Airport Project Integrated Delivery is a process methodology built on thirteen principles for Airport Lean Design, derivative from the application of Toyota Product Development Principles and the construction of a common practices/TPS principles interaction matrix set. This matrix set is a Design Science Research artifact used to define postulates of interactions between the common airport design practices and lean product development principles. A survey involving project participants from the Aviation Industry is used to refine and evaluate preliminary findings, proposing new value-generating activities to be integrated into the common practices, aiming to deliver additional value and reduce resource wastes for airport owners, airlines, and passengers with the airport project. Value-adding and waste-removing activities individuated during the matrix development and with survey results are integrated into the beginning matrices and later in the process map (i.e. *Value Stream Map* in the Lean Mindset), defining a two-fold tool for Project Participants: (A) an active artifact useful to structure Project Design Management and evaluate the lean grade of the design process; (B) a leaner airport project design process methodology.

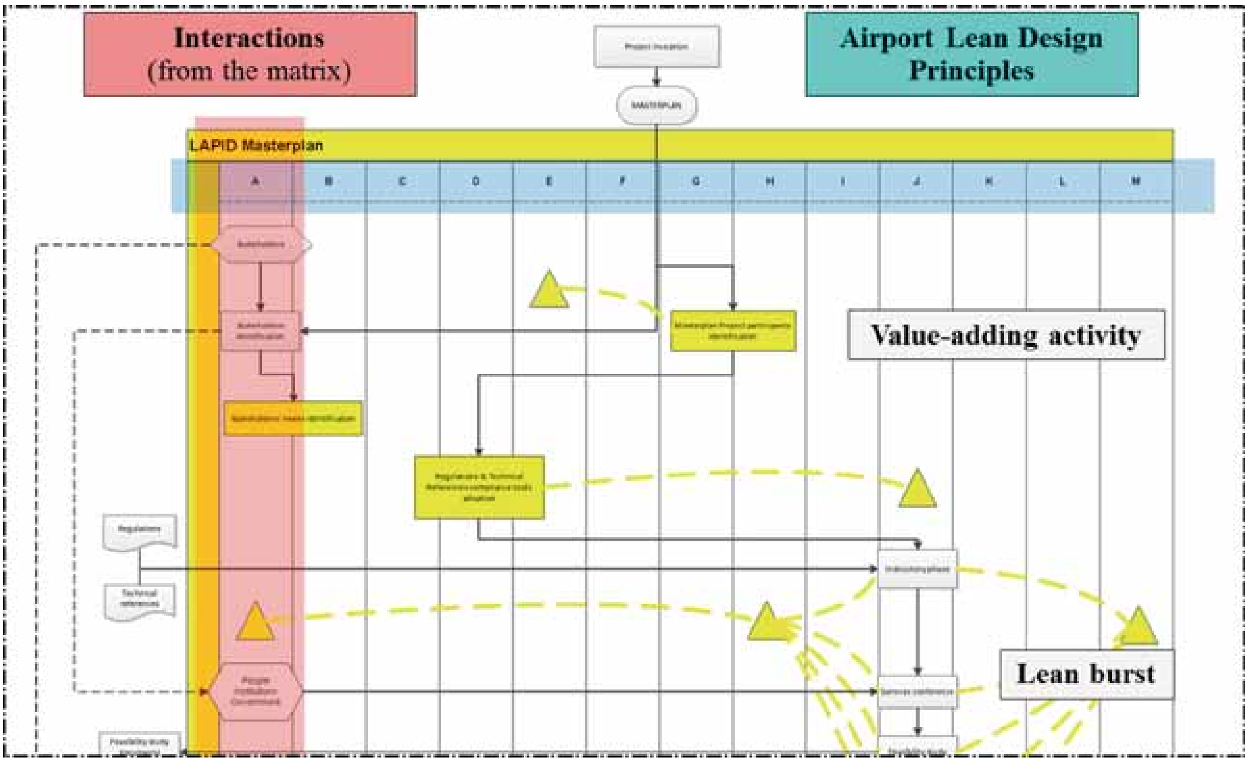

Fig. 56.2 Extract from LAPID process methodology map (from Bosi [6])

This second artifact is represented with a series of intertwined flowcharts sporting swimming lanes—Process, People, Technology Lean pillar lanes, each divided in its corresponding Lean Principles. The flowchart describes lean correlations between activities and Lean Bursts—i.e. the activities/steps that concentrate most value conferment for the clients—to support Project Design management (Fig. 56.2).

Innovative project management methodologies based on social aspects are needed to implement common practices and support collaboration, shared design, problem-solving. The aim is promoting production of consistent Project information that can overcome time barriers of the various stages of the airport terminal life cycle. The proposed methodology—possibly to be field tested on airport design case studies—implies a change of paradigms for all project participants involved in new airports or terminal extension design, with different priorities related to Lean thinking and efficient Project Information management rather than only achieving design targets. With the joint use of Lean mindset and BIMM tools, the project organization could avoid resources (man-hours) wastes and limit possible delays within the project process (e.g. due to redundant or misplaced activities). Its expected contribution during the design phase is the enhancement of the Project Information flow, using Lean principles to manage the team workflow and workload, in addition to communication and information sharing. Improvements theorized by the proposed methodology offer to airport owners' technical units a more consistent workshop. These changes have potential benefits for both material and immaterial processes occurring during and beyond the design phase.

56.5 Conclusions

The research proposes an innovative methodology aimed at the parallel enhancement of the three pillars of the design process—people, process, and technology. It is tailored for the project's socio-technical system to maximize the value for passengers, airlines, and airport management companies generated by the project. Achieving the benefits expected from Lean and BIMM requires greater consideration of the characteristics of the work and management environment, which are deeply influenced by social phenomena. Lean offers methodologies for closer collaboration and people integration that goes beyond the traditional matrices of design methods, bridging the gaps of collaboration between project clients and project participants. In addition, the combined use of Lean and Virtual Design and Construction (VDC) technologies—both intended as *transformative technologies* [27]—fosters a holistic approach to project design and development aimed towards the Operation & Maintenance phase of the airport, because of the constructive implications of Lean. Stakeholders of the Aviation Industry, their Project Participants and consultants are primary recipients of the suggested methodology, in addition to airport owners' technical units and managers as well regulatory bodies interested in design verification. Airport owners are direct beneficiaries as the first and primary users of the methodology, followed by the whole Airport supply chain—being the parties in charge of feeding the digital Project Information model that is the actual backbone of the proposed methodology.

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