Formal Methods in Architecture and Urbanism

Formal Methods in Architecture and Urbanism

Edited by

David Leite Viana, Franklim Morais
and Jorge Vieira Vaz

Cambridge
Scholars
Publishing

Formal Methods in Architecture and Urbanism

Edited by David Leite Viana, Franklim Morais and Jorge Vieira Vaz

This book first published 2018

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-0762-9
ISBN (13): 978-1-5275-0762-3

CONTENTS

Part II – To Higher Semantic Levels of Theories

Part III – To Design Methods of Project Production

Part IV – To Material Production

INTRODUCTION

FORMAL METHODS IN ARCHITECTURE AND URBANISM

DAVID LEITE VIANA, FRANKLIM MORAIS AND JORGE VIEIRA VAZ

Formal Methods in Architecture and Urbanism is the new concept this book is introducing.

Formal Methods

Formal methods is a concept very well established in computer and information sciences and technologies, and means roughly the use of theoretically driven techniques, expressed in languages stemmed from mathematics. With that designation or another, formal methods have applications in many human activities. Technologies were always eager for theory, especially since the 17th century. Linguistics and even literary studies are other fields that make steady use of the concept of formalization. Even mathematics is prone to formalization. Since the 17th century, and apace since the 19th, what had already been born formal a few millennia before is growing more and more formal. Number theory, calculus, logic, set theory and later developments such as modern algebras, language theory, and category theory are setting formal layer over formal layer in math theories. Rather than trying to reach a goal of formal ideal, formalization is a never-ending process of theoretical deepening. In addition, with the mathematical approach, it is a process of theorizing the theory.

It is not the scope of this introduction to make a broad analysis of characteristics or advantages of formal methods. Nevertheless, two features will be noticed, each with a little help from a short allegory.[1]

The first:

> *Paul, the mason who knows geometry, has to lapidate several stones of intricate shape to fit together. He produces each stone independently in the yard, and then goes to the church to place it.*
>
> *Peter, the tinker mason, had the same job. He made the first and laid it. He made the second and, surprisingly (to him), the stone did not fit. The priest did not let him adjust the piece inside the church. He went to the yard for retouching. Then he tried to place it again. At the fifth try, the stone still did not quite fit, but, at least, it did not fall. It was the right time to move on to the next stone. The sun has set by now and Peter is still working on his church. Paul, meanwhile, is at Peter's house.*

In general, we may say that the use of formal methods brings great advantages to human actions on his natural and social environment. The problems are at first solved in idea and only then are they practiced in reality. The formalization tries to make certain that the solutions for the problems of reality are produced mentally in such a manner that ensures simultaneously their greatest possible adequacy and the least test time in direct confrontation with reality. For example, language theories acquired formal parameters of analysis, such as expressivity, finiteness, completeness, simplicity, complexity, determinism, decidability, soundness, recursion, that enable us to meta-theoretically ensure the desirability of the use in the set of problems that the given language has to deal with.

The second:

> *Some years later, Paul and Peter (now a mason as skilled as Paul) are still working together, producing stones for the church. A formal method is not necessary to deduce that a friendship has not grown between Paul and Peter. They do not even talk to each other. But when one of them takes a new piece to the church, it beautifully fits with the stones of the other.*

---

1. The editors would like to apologize for the unbearable lightness of the next text. It is a little homage to recently deceased Umberto Eco, who so many times softened arid speech with brightening results.

Formal methods try to ensure perfect communication instruments between the acting agents. That is even more useful nowadays, when those agents are not only humans but rely on artificial digital tools with their own languages.

Formal Methods in Architecture and Urbanism

The use of formal methods in architecture is very old: formalized geometry has now twenty-five centuries, and has been applied extensively in construction. Even earlier achievements, such as the pyramids of many different ancient cultures, cannot be understood without considering the possibility that their builders exercised some incipient geometry. Since the development of natural sciences, in the 17th century, many other formal methods have been deployed in architectural *ars et scientia*.

Starting with structural theory and expanding to thermal, hydrous, acoustic, chemical behavior of buildings, the formalization of architectural methods has become an obvious reality. Such reality led even to professional differentiations with historical significance. When the architects of the Renaissance detached from the construction masters, they took most of the mathematics with them. Now it seems that the architects have renounced math, leaving it to the engineers. Nevertheless, current practice in the domain of the built environment still attributes to architects the overall consideration of the social and human desiderata.

Two achievements led to the improvement of the use of formal methods in architecture. At first, since the 19th century, sociology and psychology were established as theoretical sciences as well. Secondly, the already mentioned developments led mathematics from the ancient privilege of quantification to a broad treatment of very abstract set of entities, such as qualities, change, structures, abstract spaces that adjust particularly well to architectural languages.

Formal Methods in Architecture and Urbanism: The Book

Formal Methods in Architecture and Urbanism is the result of editing work on the proceedings of the 3rd Symposium Formal Methods in Architecture (Porto (Portugal), 2015).

The papers presented in this volume are contributions to the progress of formalization in architectural methodologies. From the millennial geometry to current shape grammars, several formal approaches to architecture and urbanism will be presented, with their different points of view, different fields of application, different grades of abstraction and formalization. The aim is to look at the potentials and objectives of these formal methods, both those on the horizon as well as those already accomplished, their successes but also their problems.

The intention is to promote the use of formal methods in the creation of new explicit languages for problem solving in architecture and urbanism. These problems range from representation, to theory, critique, production, communication, etc., never ceasing to see architecture and urbanism as technological activities and well as artistic ones.

The more historically established areas of application of mathematical sciences, such as traditional geometries or mathematical developments connected to engineering, are left somewhat outside the focus, without forgetting the deep connections these scientific bodies of knowledge establish with the new formal methods. Many of these formal methods have a level of development that requires the existence of established academic communities, with their own specialized forums.

We could define the concept of *Formal Methods* by their matrix: they make intensive use of the repertoire of languages coming from mathematics. However, a new concept cannot limit itself to the sum of a bunch of dispersed elements with parental affinity. The several pieces must belong to some special structure. The 3rd International Symposium Formal Methods in Architecture, more than an attempt to deepen each specific field, is above all about finding points of convergence. This is not limited to a possibly interesting abstract integration of different areas of research, but mainly to advance the multiple crossings between several methods, whose fertility has already been proven.

A certain dialogue with semi-formal and even informal methods in current use will be visible as well, to deepen the discussion on aesthetic and ideological controversies that surround the possibilities and reach a formalization of architecture and art. Although not patent in this book, and as in previous symposia, some contributions were applications of formal methods on fields other than architecture, like literature, music and the fine arts, in as much as they may be useful for architectural application.

The Structure of the Book

Human behavior has an evolutionary path, from reality to reality, through the mind. Mental processes recognize the circumstances of reality, elaborate knowledge, evaluation and decision procedures, and then command human action on the world, creating new realities. Knowledge starts with sensory acquisition of the concrete reality, passes a long process of abstract organization, and goes back to the concrete of reality, not any more as a sensory concrete, but now as a conceptually structured concrete. This book tries to follow this same path, applied to architectural activities.

Part I deals with formal tools for data acquisition and first steps in gathering, treating and organizing information. Two well established methodologies deal with these purposes.

One of them is BIM (Building Information Modelling). BIM is an activity rather than an object, a human activity that involves logical thinking, digital entities and a large sort of specific software, with a strong impact in building design and construction activity. The transition to BIM, however, is not a natural progression from CAD (Computer Aided Design), because it involves a paradigm shift from "drawing" to "modelling"—a virtual model consisting of relationships between entities, organized into an object—based on inheritance hierarchy. Technological and market trends are good predictors of the short-term future in this field, and it is opportune to analyze and discuss how BIM will be developed in different, yet correlated, areas like VDC (Virtual Design to Construction) and in peripheral hardware linked to building, prefabrication, assemblies, functions of construction management connected to ERP (Enterprise Resource Planning), ontological and semantic searching and compatibility of BEMs (Building Entity Models) to multiple platforms, IPD (Integrated Project Delivery), automated checking for code conformity and constructability to support Lean Construction, improved import and export capabilities using protocols like IFC (Industry Foundation Classes) and parametric 3D technical catalogues from manufacture industry, the setting up and development of National Building Standards in connection with Green Building, LEED (Leadership in Energy and Environmental Design) or BREEAM (Building Research Establishment Environmental Assessment Methodology) and expanding the scope and discipline-specific BIM tools or even "light" BIM for specific building types like low cost residential houses, or small area building facilities.

The other one—the Geographic Information Systems (GIS)—follows the emergence in the 1960s of the 20th century territorial analysis and planning digital tools that are evolving to adapt to the new and diffuse means in which territory is appropriated by the information-based society. Together with the traditional interlacement of diverse layers of territorial information, the contemporary information practices of geo-spatialization almost allow their complete mapping on-line, dramatically reducing the gap between production and data visualization. Furthermore, the recent 3D presentations enable a friendly visualization of complex data, approaching the common citizen to urban participatory processes. The GIS experimentation field is nowadays exploring crossings with other tools of spatial analysis, such as space syntax. Other new emergent tools, such as processing, will be able to connect to GIS in a near future. Another one is ontology.

Ontologies are meta-languages for knowledge representation, and they are simultaneously a prerequisite for formal methods (thereafter out of order in this path) and a consequence of the degree of their semantic depth. Anyway, they also appear in Part I. The development of ontologies applicable to architecture and urbanism emerged from the necessity of finding common linguistic bases for the multiplicity of languages used by the numerous agents in the constructed environment. This is even more necessary nowadays, as artificial agents are more and more present. These ontologies have been used as a nuclear language in knowledge-bases of constructed environments, as well as logical assistants to design, participatory GIS, automatic acquisition of urban knowledge, and interoperability between several data processing artificial agents (CAD's, GIS, etc.). Several digital tools, such as OWL, Protégé or KLOne, with their origin in information technologies, are being used to create ontologies on the architectural domain.

Part II deals with much deeper levels of semantic organization of information, creating abstract theoretical knowledge about reality. Several very distinct formal methods are in use today, such as space syntax, processing, cellular automata and shape grammars. Although theoretical, it should be noted that they have a very strong commitment with reality, producing at the same time analysis of concrete samples and the empirical validation of the material, social and psychological theories involved.

Space syntax consist of a set of theories and methodologies used for the study and treatment of building and urban space. Spaces can be geometrically defined through more or less abstract concepts: either geographic (volumes, surfaces, axial lines, nodes), or topological (graphs or connections). These spatial elements establish simple relationships between themselves, like visibility or connectivity. It is possible to build a whole set of concepts based on these basic properties, which are usually quantifiable, such as integration, depth or controllability. These quantities represent architectural and urban realities, at a physical level (such as accessibility, connectivity), at the level of cognitive psychology (intelligibility, entropy) and of sociology (privacy, control, segregation). The space syntax have been extensively used on multiple fields of architectural analysis, especially at an urban scale, such as traffic studies, distribution of facilities or even the prediction of geo-localized demand.

Processing is a creative programming platform (IDE/Integrated Development Environment), supported by Java, that enables programming for the different areas of digital art, by structuring digital applications of visual and interactive media. Initially used for educational purposes as an open source tool, focused on teaching its own language's graphical component, Processing saw itself used by different communities, contributing for its development in fields like the performing arts, kinetic arts, real-time interactive data visualization, experimental architecture, and other fields of artistic creation and applied research. In architecture’s perspective, research on generative design stands out, overcoming certain limitations associated to “traditional” methods. Here, Processing shows its biggest potential by allowing users to set specific dynamic applications that will allow the calculation of complex rules and conditions used in the creation of architectural objects.

Cellular automata is a term used to refer to a set of generative grammars where multiple agents exist with identical or differentiated rules that act concurrently in the built space. The concept of cellular automata structures itself in dynamic mathematical models with the goal of configuring processes capable of promoting self-replication. Originally, it explored a set of quadrangular elements on a grid where, following a set of rules of proximity relative to each cell (cellular automaton) along the grid, growth processes were simulated, based on the logic of complex systems. Cellular automata established itself as a process that started with small elements following simple rules (bottom-up approaches). Research has been revealing a great potential in the fields of architecture and urbanism, as it allowed the possibility of creating dynamic patterns through reciprocal interaction and conditions of neighborhood between cells. They constitute patterns from which architectural and urban formal hypotheses may appear, following mathematical approaches free from traditional deterministic constraints.

Usually they are implemented in digital tools for generic algebraic calculations or in parametric CAD applications.

In the end of Part II, a dialogue of formal theories with a completely different informal approach to architectural activities is also established. This kind of dialectics has not been neglected in this book because it serves to maintain critical spirit alive.

Part III deals with applying formal methods to the production of architectural projects. CAD is an already proven technology with its many recent developments, such as parametric processes and more semantically deep shape grammars. Although shape grammars are also analysis theories, and fit very well in Part II, the contributions in this book address mainly architectural design. Other less formal techniques, like patterns, are also addressed. Shape grammars are technologies belonging to the broader field of generative grammars, dedicated to the production of geometric shapes.

A shape grammar includes a generative algebra applied to a set of production rules. These grammars have been used in diverse areas, from technologies to the visual arts, as identifying styles of composition or as means to refine structural elements. In architecture and urbanism, this tool is used in history, theory, and critique (with examples like the definition of a grammar of Palladio's villas, or the formalization of Alberti’s production rules), as well as on automated design, based on rules defined by the architect, or according to rules or patterns identified from case studies or established practices. Research on parametric processes has been tackling the evolution of different methods and technological processes, which lies in the possibility of quick visualization, construction, and modification of concepts associated with design. These systems establish a complementary relationship with generative design, where different parameters from several different components are intrinsically connected through an algorithm, in which the variables are then verified to be adjusted to the needs of specific results.

From the initial analysis to the execution and production of final components, through the (no less important) phase of form finding, parametric processes enable singular approaches to the set of conditions of each context. These conditions are formally framed via top-down strategies, or, conversely, using informal combinations of less structuring components to promote results generated through bottom-up approaches.

In current and future architectural practice, exclusive use of formal methods is out of question. Semi-formal methods are broadly practiced and could not be ignored both in this book and in architectural real practices.

Finally, Part IV deals with the formal methods to manage and produce the real thing—the material production of buildings and constructions. Advances in computation and its use to control production machines are being applied also to architecture, allowing the automatic manufacturing of complex geometries, hardly reachable in ancient techniques and at a fraction of the cost. CAM (Computer Aided Manufacturing) and CNC (Computer Numerically Controlled) machines are enabling greater personalization, flexibility and innovation in architectural design and creative processes, providing society with new products and services.

Formal Methods Group

For several years now, a group of researchers in Escola Superior Artística do Porto (ESAP/Arts Higher School of Porto, Portugal) have been deepening the role of formal methods in architecture and urbanism. Since 2006, the first studies led to a series of conferences, courses and workshops (initially organized by David Leite Viana and Gonçalo Castro Henriques) that had the collaboration of well-known practitioners and professors like Bernard Franken and Branko Kolarevic. They focused mainly on new digital tools in parametric CAD and CAM tools. Other fields of interest in the same area were added up throughout the years, such as space syntax and shape grammars. Soon, the need to establish close links between the various areas became notorious. The new globalizing concept was baptized as *Formal Methods in Architecture and Urbanism*. Since 2011, Formal Methods Group, now integrated at Laboratório de Investigação em Arquitetura (LIA, Architectural Research Laboratory, ESAP, Portugal), is supporting a biannual meeting, counting, from the beginning, with support of José P. Duarte and the research team at Faculdade de Arquitetura da Universidade de Lisboa (FAUL/Faculty of Architecture, The University of Lisbon, Portugal). A much broader program was intended for the 3rd International Symposium Formal Methods in Architecture, giving rise to this book. This edition had the helpful collaboration in its Scientific Committee of Michael Weinstock, from Architectural Association, London (AA, UK), and Tasos Varoudis, from the Bartlett School of University College London (UCL, UK), between many others.

Formal Methods Group is continuing R&D, producing publications and exhibitions for dissemination of the field achievements, promoting courses and producing software in formal methods free for academic use.

For all the friends, cited and not cited, the editors would like to manifest their greatest thanks.

3RD SYMPOSIUM FORMAL METHODS IN ARCHITECTURE: OPENING SPEECH

FRANKLIM MORAIS

What I am about to say does not represent the opinions of the Organizing or Scientific Committees of the Symposium, nor even entirely my own.

Meetings of researchers in this domain tend to have a specialist approach, which is great for a number of things. However, we always intended to bring a broader framework to our subject. It was so in our former two symposiums and it is the same in this one. So, do not interpret what I will say as a closing directive. See it in the opposite way: the opening for some meta-discourse on the discourses of formal methods in architecture. What will seem controversial is, in fact, an appeal to disagreement.

– 1 –

What is the big advantage of formalized languages?

On TV, I saw the author of one of those street *trompe l'oeil* chalk drawings explaining his art. When asked how he painted that, he said he put a camera in the privileged point of the perspective and he drew a little, then he ran to the ocular of the camera and saw that all was well, and then he corrected the errors or drew a little more and went again to the ocular and again and again.

By Jove, by the sake of Euclid, by Giotto and Brunelleschi, by Descartes and Desargues, hasn't this person ever been told about perspective, that formal language? Didn't he suspect that he could deal with his problem in a fraction of the time and without all those gymnastics?

Now a quote from Marx's *Das Kapital* (*Book 1*, 1867):

> *A bee puts to shame many an architect in the construction of her cells. But what distinguishes the worst architect from the best of bees is this, that the architect raises his structure in imagination before he erects it in reality.*[1]

Marx was not talking about architecture alone but about our capacity to make an abstract and formal representation of the world in our minds, and to be able to anticipate mentally our future and act accordingly. Men's problems can be processed and solved first in mind, and only after are those solutions to be confronted with reality through action. With this ability, things no more happen to men. Men make things happen for their immense happiness. The use of formal methods in architecture is very old. We can read in a more than reliable written source that Solomon's Temple was constructed this way:

> *And the house, when it was in building, was built of stones, hewed and made ready: so that there was neither hammer nor axe, nor any tool of iron heard in the house when it was in building*. (*3 Kings*, 6:7)

The reasons why "*you are praised with silence in Zion"* (*placement of the construction of the Temple*) (*Psalms*, 65:1) can be diverse. Because uproar is not welcome by the Lord himself:

> *And they that hate thee have made their boasts, in the midst of thy solemnity. They have set up their ensigns for signs,*
>
> *And they knew not both in the going out and on the highest top. As with axes in a wood of trees,*
>
> *They have cut down at once the gates thereof, with axe and hatchet they have brought it down*. (*Psalms*, 73:4-6)

On the other hand, maybe because Solomon wanted a quiet place very badly, something that only a man in his situation can evaluate properly:

> *And he had seven hundred wives as queens, and three hundred concubines: and the women turned away his heart*. (*3 Kings*, 11:3)

Either way, what is certain is that this is the first written reference to project and design in architecture. It even gave birth to the first methodological prescription to architecture:

> *Prepare thy work without, and diligently till thy ground: that afterward thou mays build thy house*. (*Proverbs*, 24:27)

Please note the curious thing: this quote from my favorite book of Asian literature manifests the same idea as Marx would express a few millennia after. Although there is no more reference to the languages of the masons of Salomon's Temple, it is well known that this same precept moved to medieval times.

The one that attends a gothic cathedral finds divine the complex fitting of stones that the constructive virtuosity of the masters made perfect for the maximum stability. Moreover, those stones where all built in the yard to avoid the hammer's noise inside the church. They did not cut the stone and then go to see if it fit, and then cut another slice and go see if it fit. All the work was performed first in mind in a geometric language, the oldest of all formal methods. Only then, they produced and assembled the parts. In addition, indeed, they made a marvelous job.

– 2 –

I will continue with a quote from *Philosophy of Nature*, by Hegel (published in 1817):

> *§ 218.*
>
> *Gravity, as the essence of matter existing in itself only inner identity, transforms, since its concept is the essential externality, into the manifestation of the essence. As such, it is the totality of the determinations of reflection, but these as thrown apart from each other, so that each appears, as particular, qualified matter which, not yet determined as individuality, is a formless element. The determination of an element is the being for itself of matter as it finds its point of unity in the concept, though this does not yet have to do with the determination of a physical element, which is still real matter, a totality of its qualities existing in itself.*[2]

At first sight, nowadays and for the current reader, Hegel's text seems a bunch of silly sentences. I am old enough to be aware that, many times, when we do not understand others that is the fault of our ignorance and not of the ignorance of others. Nevertheless, although I know that Hegel's text is more than what it seems at first sight, I can be sure that that kind of speech has lost all its historical validity. It is not accepted anymore. All because of this: exactly 130 years earlier, in his book of 1687 with the same title, one of the most remarkable accomplishments of the human kind, Newton wrote about the same subject:

> *Proposition 75, theorem 35*
>
> *If to the several points of a given sphere there tend equal centripetal forces decreasing as the square of the distance from the point, I say, that another similar sphere will be attracted by it with a force inversely proportional to the square of the distance of the centres.*[3]

Alternatively, in current symbolic notation:

$$F = G\frac{m_1 m_2}{r^2}$$

The formal discourse on the philosophy of nature, now called simply science, won the battle for the current running times. Let us now move to architecture, with some excerpts from Heidegger's text *Building Dwelling Thinking*:

> *That is,* bauen, buan. bhu, beo *are our word bin in the versions:* ich bin, *I am,* du bist, *you are, the imperative form* bis, *be. What then does* ich bin *mean? The old word* bauen, *to which the bin belongs, answers:* ich bin, du bist mean*: I dwell, you dwell. The way in which you are and I am, the manner in which we humans are on the earth, is* Buan, *dwelling.*
>
> (...)
>
> *Mortals dwell in that they receive the sky as sky.*
>
> (...)
>
> *The sky is the vaulting path of the sun, the course of the changing, moon, the wandering glitter of the stars.*[4]

I stop here, because Newton enters here. Newton was the first to stop the wandering of the stars. That the stars roamed regular paths, already had our primitive ancestors realized. However, when he formalized the founding theory of physics, Newton did more than just open the way to an even more complete understanding of the rules of the universe. Jailing the stars inside their tracks was also an act of freedom for humans—yes, it is they who glitter now: going to the moon and wandering among the stars. Of course, there is also much more in Heidegger's speech beyond a bunch of meaningless phrases. Even so, I can bet that this kind of speech will meet the same fate as that of Hegel. Nevertheless, if a genius like Hegel could say what he said of gravity one hundred and thirty years after Newton, we can only suppose that the hostilities will extend in time. In architecture, if Heidegger is a second or third order Hegel, who is the Newton? I will not answer that question. I do not even know if the question can be put that way. Something I can say is that, even to arrive at Newton, there were centuries of experimentation, attempts and failures, and that there is no end—as we all know, Newton was indeed corrected, not by Hegel, but by Einstein. Newton is not an end but a moment in an endless path.

Once again, the use of formal methods in architecture is very old. The old theoretical architectural thinking has already achieved many good ideas—what we are trying to produce today is nothing other than the formalization of Alberti's *concinnitas*. In addition, every day a new contribution clears the way. Therefore, the answer to the earlier question (that I will not answer) is this: WE ARE.

Good work!

Notes

All citations from the Bible are from *Douay-Rheims Bible*, http://www.drbo.org/chapter/11006.htm.

1. Karl Marx, *Capital* (V1), Part III, Ch. 7 Section 1, https://www.marxists.org/archive/marx/works/1867-c1/ch07.htm.
2. Georg Wilhelm Friedrich Hegel, *Philosophy of nature*, Part II, B. §218, https://www.marxists.org/reference/archive/hegel/works/na/nature2.htm#N218.
3. Isaac Newton, *The mathematical principles of natural philosophy* (1st English edition, 1729), Book 1, Section XII, proposition LXXV theorem XXXV, https://en.wikisource.org/wiki/The_Mathematical_Principles_of_Natural_Philosophy_(1729)/Book_1/Section_12#Prop75.
4. Martin Heidegger, "Building dwelling thinking," *Basic Writings* (1993), 343-64, https://drive.google.com/file/d/0BxEZ9xOtQkn2M09GS1g3RmlXaUk/edit.

– PART I –

FROM INFORMATION GATHERING AND PROCESSING

CHAPTER ONE

BIM: CUSTOMIZING THE STANDARDS

ALEXANDROS KALLEGIAS

Introduction

BIM-affiliated software is gradually gaining popularity. Offices in different countries have developed specialized teams to work in a BIM framework in order to deal with the complexity of gathering and managing building information. The paper aims to address a key area in relation to the growing implementation of BIM in current practices. If we successfully manage to reach universal BIM guidelines and procedures for design & built projects, hence the constant implementation of building standards, what would prevent the standardization of the profession and potentially the gradual levelling of the architectural design? The question entails how a well-defined system of standardized processes for design and build projects may be practically applied in offices that are characterized by their bespoke design and workflow. This paper will discuss and evaluate the customizing of the standardized BIM approach in the current architectural practices and the way these may affect the future of the discipline.

Methodology

Architecture encompasses both the process and the output of designing physical structures. When described as the knowledge of using the tools available not only to construct one's project but also to communicate properly its particularities as well as its qualities, one should consider the ability to calculate cost, construction and building operation efficiently with these tools. Recent software developments aim for more effective information exchange and interoperability in digital format. While the term BIM has been in use since 1970s, its practical implementation took place almost two decades later and is still in the process of maturing.[1]

When referring to BIM-associated projects, it has become common practice to characterize them according to their level of compliance. Practically, this method defines the distinction and expectations among projects in terms of their collaborative nature and CAD interoperability within and outside one's practice. Lately, governments, like the one in the UK, are enacting laws as part of a long-term strategy to establish more efficient ways of working through BIM. This new way of working is being established through a gradual transition from the "old-school" drawing boards to the modern computer-aided design environments; from the analogue to the digital age of applied architecture. Specifically, in the UK, a project may be described as BIM Level 0, 1, 2 or 3. Level 0 BIM refers to a project that is effectively characterized by zero collaboration. The output and distribution of project information is made via paper or electronic prints or a combination of the two. This approach is far surpassed by most countries' industries. Level 1 BIM is the common practice in the industry where 3D CAD is used merely as a representative tool and 2D CAD drafting is being created as the main part of the project's submission. The 2D CAD here follows standards set by the respective body of authority while usually being managed by the contractor. The collaboration is kept within the discipline of each respective office, which maintains and publishes its own data. Level 2 BIM, which is currently being applied in major projects, is distinguished by its collaborative workflow among different disciplines. Design information is exchanged via a common file format. This allows each discipline to create and develop their own single or multiple models as long as they are able to share them to the agreed file format, this is usually done with an IFC file format export (Industry Foundation Classes).

Level 3 BIM is considered as the highest level: the level of complete collaboration. Currently, numerous architectural and engineering practices worldwide are heavily investing in the training of their employees in order to expand their skills on the use of BIM design software.

In the race of becoming excellent in BIM software, it is crucial to preserve one's ability of communicating the design intent beyond the technical obstacles that one had to overcome. Therefore, all major and detailed aspects of Level 2 BIM projects require a commonly agreed execution plan. It is imperative to establish clear and complete protocols and guidelines before one embarks on implementing BIM on architectural projects. Compared to the enduring battle between computer-aided design and hand drafting, the argument for BIM implementation has to surmount an even greater series of deep-rooted and often archaic work methods and dispositions. This involves educating equally the office colleagues, the different consultants and clients.

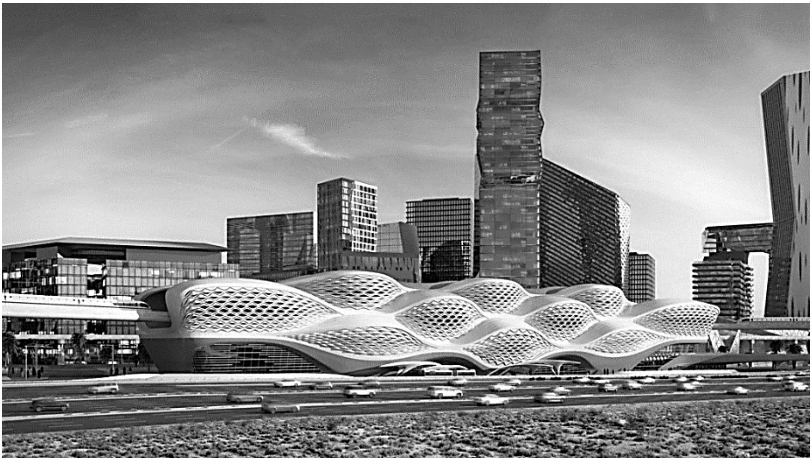

Figure 01.1
King Abdullah Financial District Metro Station.
(Image courtesy of Zaha Hadid Architects at www.zaha-hadid.com)

Application

It has been over a decade in countries like Norway, Finland and the United States since BIM has been adopted via legislation by the government as the path for major projects delivery.[2] This initiative has extended in the past years in more countries across Europe and Asia such as the UK, Denmark, the Netherlands, Hong Kong, South Korea and Singapore. These efforts have need of a thoroughly examined execution plan of adoption. The necessity of such a plan is clear; however, the task of bringing clients, consultants and colleagues in agreement requires a certain level of communication skills beyond the technical knowledge.

Lack of communication and miscommunications can often cause various project delays and difficulties. Therefore, it is necessary that all BIM standards are well implemented and established at the beginning of every project. In this regard, it is equally necessary to provide all possible information to the client to create a healthy working relationship. This also helps to establish a clear understanding of the different stages of the project; it can provide insight for future project parameters and requirements as well as establish and manage expectations. This is a typical case for many international architectural offices such as Zaha Hadid Architects.

Figure 01.2
King Abdullah Financial District Metro Station.
(Image courtesy of Zaha Hadid Architects at www.zaha-hadid.com)

In an engineering BIM standard manual, it is imperative to clarify many different aspects of setting up and operating a BIM model. Initially, the software-modelling guide is set. The software-modelling guide refers to the standards that the project teams need to follow in terms of the model content, its setup and its method of modification. The model content is defined in terms of the level of detail required for each project stage to the modelling of elements in order to carry the necessary info for the metadata applications. Elements are tagged with a unique ID in order to be tracked throughout the making of the project. Detail and enhancement techniques are often used to improve speed and reduce the model's complexity. In addition, the level of development is set for the model planning of each stage. To maintain the model's data integrity, changes are carefully monitored and regular auditing takes place to ensure good model health. Equally important is the model organization. Here, the guidelines define the different types of BIM models to be created and how they should be used in accordance with each other during the project. The need for discipline-distinct BIM models (Architecture BIM, Façade BIM, MEP BIM, etc.) has