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CULTURE CHANGE IN CONSTRUCTION INDUSTRY: FROM 2D TOWARD BIM BASED CONSTRUCTION

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SUMMARY: *Building Information Modelling (BIM) has become accepted as an approach that should deliver substantial gains to all the stakeholders within the architecture, engineering and construction (AEC) industry. Recently, several researchers have pointed out the need for cultural changes as a necessary step for radically transforming the industry. In order to provide answers to these requests, the culture should be described in a more explicit way, and industry issues interpreted correctly. This paper via qualitative research of variety of sources explores the stability and persistence of a traditional 2D paper-based approach in the light of Institutional theory. The paper illustrates how the traditional approach is embedded within AEC culture by considering the regulative, normative, and cultural-cognitive aspects. These aspects support each other, thus providing even more stability and support for the existing values and ways of working. The aim of this work is to provide some insight into reasons for slower penetration of the BIM based construction. The paper also explains the local character of the industry, which slows down transference of best practices within the AEC industry. Understanding of existing patterns reveals new insights into how to make the transition easier and more functional, especially within the contexts of existing priorities and values.*

KEYWORDS: *building information modelling, institutional theory, 2D paper based working, work practices in construction.*

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1. INTRODUCTION

Investigation into the dissemination of technologically innovative principles into everyday life and business practices has been an important topic since the outset of the industrial revolution, when it definitely became part of modernising Europe (Irrgang, 2007). The issue itself is not just limited to those questions regarding any superiority of the innovation or to the ways in which we understand how particular technologies work. The sole superiority of a technological solution does not automatically mean that such a solution will transform an industry or be accepted into everyday practice. For technology transfer to be successful and new practices to become standardised, cultural assimilation is necessary and technological and cultural paradigms should be combined (Irrgang, 2007).

These assimilation processes are not uniform throughout society. This irregularity leads to differences regarding the acceptance of innovation, which is described by Irrgang's theory of development paths, and the result of such irregularity is islands of modernisation (Irrgang, 2006). Within the architecture, engineering, and construction (AEC) sector with regard to information technology (IT), such islands can be recognised spatially throughout the world and across different cultures, as well as different professional trades and tasks. The latter was recognized by Hannus (Hannus et al., 1997) and depicted in 'Islands of automation in construction'. In this image, the authors foresaw the 'industry integration coastline' in year 2010, when all the islands representing different professional tasks within the industry would become combined into a common land. As described by these authors, automation within specific areas would spread so much that the IT supported areas would eventually overlap, causing technologies to become seamlessly interconnected. This process should have by now resolved any fragmentation and data exchange problems amongst particular IT solutions within AEC. However, at the time of presenting this paper in 2016, the coastline has not yet reached the level foreseen by Hannus, and the seamless integration of a fragmented construction industry is still far away.

The majority of research efforts that targeted the problem of the 'islands of automation' were mostly approached the technical issues. The research focus was directed towards the area of technical interoperability, which should have enabled new and more efficient business practices to become the norm. More specifically, the interoperability was considered in technical terms as that defined by the IEEE Glossary (IEEE Computer Society, 1990): 'the ability of two or more systems or components to exchange information and to use the information that has been exchanged'. In line with this definition, innovation and standardisation efforts within the AEC sector have been initiated and integration of applications has been attempted for covering complete buildings' lifecycles.

1.1 BIM as a solution

With regard to the lifecycle, the industry accepted Building Information Modelling (BIM) as a common approach that should deliver substantial gains. The literature review on BIM (Ilozor and Kelly, 2012) discovered that the literature is overwhelmingly positive with regard to the potentials of BIM. It has also been recognized that BIM as a concept does not resolve practical interoperability problems and despite the technology available and the expressed benefits of BIM within certain areas of AEC, it is not yet a common approach regarding practical projects (Grilo and Jardim-Goncalves, 2010). These research papers call for more rigorous quantitative research and for better understanding of the value proposition of BIM for real projects. Further literature reviews performed by Xue (Xue et al., 2012) reveal that academic research mostly pays attention to suitable technologies and the development of advanced IT systems, and concentrates less on those theories that guide the developments of the systems. It is evident that better understanding is still required of BIM beyond the technology. Understanding of organisational culture, change processes, cognitive and behavioural habits are necessary prerequisites for successful application of new technology (Xue et al., 2012).

Large innovative projects such as ROADCON (Zarli et al., 2003), STRATCon (Kazi et al., 2007) or InPro (Rizal et al., 2011) aiming for completely transforming the AEC industry from traditional paper-based working and project delivery into model-based collaborative work, recognising that social and cultural issues are of crucial importance (Hannus et al., 2003; Kazi et al., 2007; Rizal et al., 2011). However, these projects are mostly limited to technical, organisational, and managerial topics, thus lacking deeper exploration of social and cultural issues. The above-mentioned literature reviews carried out by Ilozor and Grilo also identified that existing research lacks in-depth exploration of social aspects regarding model-based building. Authors such as Harty (2005) called for consideration of organisational context and organisational power distribution amongst collaborating organisations, following their studies regarding technological innovation. Similarly Yitmen (2007) points out that both organisational culture and IT innovation are the key issues facing construction industry and needed to be addressed to revalue the construction industry.

1.2 2D drawings as a tradition

The origins of 2D drawing, architectural sketches and plans, can be traced back to ancient Egypt (Pratyush, 2007). The construction methods used during Roman Empire can be understood from architectural drawings of that time (Lohmann, 2009). From these and other (Barnes, 2007; McClendon, 2005) examples, it is evident that throughout the history, 2D drawing in architecture and construction has served for the presentation/visualisation aims of the drawing as well as its function as an analytical tool during the design stage, communication of the design intent, and as the instructions for on-site activities. The social roles of architects and builders provided the contexts for developing drawings (Millon, 1997). This extensive timeline clearly points to deep social roots in respect of existing approaches to design and construction. According to Berger and Luckman (1991) activities habituated by certain roles through repetition form institutions. History is important aspect in formation of the institutions and time is required for their growth. When formed, institutions control behaviour of participants in the society, guide interactions and provide stability. For this reason, from this point onwards, we plausibly assume that Institutional theory (Scott, 2004) constitutes a valid background for our analysis of 2D paper based working in the AEC sector and its relation to BIM based working.

1.3 Present research

Exploration of technological innovations within the AEC sector presented in this paper takes into account social perspective and qualitative approach. The aim of our work is providing better understanding of the cultural aspects of innovation. We explored factors which influence the disproportion of technological advancements in IT with the level of the technology acceptance by the AEC. Two research questions guided our work: (1) Could traditional 2D paper based approach be considered a firm and longstanding institution? (2) How institutional basis of the 2D paper based approach ensures its continuity despite common understanding that BIM based approach is technologically superior?

In the following chapters we first describe the methodological background with its roots in the theory of social institutions. The central part of the paper contains an analysis of the Slovene AEC sector in a broader European context with regard to sources of stability of 2D paper-based working. Possible areas of change were identified.

2. THEORETICAL BACKGROUND AND RESEARCH METHOD

Institutional theory explores questions of organisations' legitimacies with regard to organisational structures and procedures (Scott, 2004). In this broader context, we focused our attention on the dissemination of technological innovation within the AEC sector.

Referencing Scott's definition of institutions as multifaceted social structures (Scott, 2007):

'Institutions embrace regulative, normative and cultural-cognitive elements, which together with activities and resources assure stability and meaning of social life.' (page 48)

We acknowledge that institutions are social structures that integrate symbolic elements, social activities, and resources. The basic property of an institution is its relative resistance to change and in this way it ensures the stabilities of systems throughout time and space. Organisational abilities as social entities are defined and driven by institutions, and the institutions serve as a means of integrating organisations into broader social contexts.

For the purpose of our analysis, we followed a model consisting of three elements that describe an institution. Each element describes a different aspect, and different underlying conceptions and mechanisms. Scott refers to these three elements as the pillars of institutions. These are regulative, normative, and cultural-cognitive pillars (columns in Table 1.). The pillars interlinked in the model represent the integration of vital ingredients of institutions.

TABLE 1: Institutional Pillars and Carriers, Source: (Scott, 2007: table 4.1, page 79)

	Pillars		
Carriers	Regulative	Normative	Cultural-cognitive
Symbolic systems	Rules, Laws	Values, Expectations	Categories, Schemas
Relational systems	Governance systems, Power systems	Regimes, Authority systems	Structural isomorphism, Identity
Routines	Protocols, Standard procedures	Jobs, Roles, Duty	Scrips
Artefacts	Objects complying with mandated specifications	Objects meeting conventions and standards	Objects possessing symbolic values

The institutions are conveyed by the carriers (see content of Table 1.). The carriers are essential for understanding how institutions change, either become stronger or start to diminish. Types of carriers (rows in Table 1.) can be understood as orthogonal to the pillars, which means that all the carriers of change can be applied regardless of the pillar being analysed at any particular moment. The types of carriers according to the presented framework are: symbolic systems, relational systems, routines, and artefacts. Table 1 lists examples of carriers according to the type of the carrier and pillars. More about the theoretical background can be found in Scott's work (Scott, 2007).

During this research we focused our attention on one of the fundamental institutions existing within the AEC sector, which is traditional 2D paper based working. In the following text we used "2D" as a shorter version for "2D paper-based working" in the broadest sense of this term, which included technical, methodological, organisational, cultural, and cognitive aspects. We analysed major implications of 2D for construction processes, construction as an industry, and construction companies, focusing on the question of the influence of the dissemination of IT into the production process. In our analysis, we outlined 2D as an institution using a matrix of carriers and pillars as they are defined within Institutional theory.

Our analysis is performed on data collected from three major and consecutive projects supported by European Commission through framework programmes staring in 2002 and ending in 2010, namely ROADCON, STRATCon and InPro. The projects reached strategic support on European level and were also considerably founded. The projects were selected because their aim was to radically transform the AEC industry toward BIM based working, and they combined the efforts from the research community as well as the major industry partners. For each project, description of project structure in form of work-packages and tasks, final project reports and main project deliverables were analysed. Textual analysis was based on descriptions from the documents and those items were coded and categorised according to the classification schema provided by the theoretical framework. This task provided the basis for further interpretation of the available data. The information from the texts was compared with field notes of the non-recorded interviews and observations collected via participation in the InPro project. Classification linked 2D practices related to existing norms, cognitions and regulations to appropriate categories of carriers. Such categorisation guided the process of interpretation, which reveals sources of stability and change according to the "basis of compliance", "basis of order", "mechanisms and logic" and "basis of legitimacy" (Scott, 2007, p. 51). In scope of regulative pillar analysis, we triangulated project information sources with legislation related to AEC in Slovenia. We found this important, because AEC industry is highly regulated. The institutional carriers were searched for in these data sources from the perspective of all three institutional pillars.

3. RESULTS: 2D AS AN INSTITUTION

During this analysis we explored 2D from the perspectives of all three institutional pillars. Hence, we approached 2D from three different points of view from which each reveals aspects of 2D from the conscious, empirical, and legally-enforced points of view, and also from more unconsciously taken for granted points of view. For each pillar we analysed the institution by considering all four carriers of institutional change.

3.1 Regulative pillar

The regulative pillar is based on the affirmation of formal power and coercion. During enforcement of the regulative pillar, the state plays the most important role. Building safety is one of the more important attributes of a building, as improper procedures and avoidance of professional regulations can cause extraordinary damage. Because of the high social significance of construction and the exceptional time span of its development as a profession, we can assume that the profession is regulated by law in all developed and also slightly underdeveloped countries. This high degree of regulation starting from the local level to the national level has also been observed by other authors (Zarli et al., 2003). In our analysis, we limited our work to the context of Slovene regulations. Comparison with other national regulations would exceed the scope of this work, however it should be considered as an example of an approach which could be applied to other countries, too.

3.1.1 Symbolic systems

In regard to the regulative viewpoint, every construction project in Slovenia has to follow the national law called 'Zakon o graditvi objektov' (ZGO) (eng. Construction Act) (ZGO, 2003). This law:

'Regulates conditions for the construction of every building, determines the essential requirements and their fulfilment, prescribes the manner and conditions for the execution of construction related activities, regulates the organisation and field of work for two professional chambers, regulates supervision, sanctions, and other construction-related questions'

Amongst other matters, the law defines the project and technical documentation, such as 'Pravilnik o projektni dokumentaciji' (eng. Rules on design documentation) (PPD, 2008), and other related procedures and responsibilities. Regulations precisely specify the content of a project's documentation. Graphical content must be presented as a drawing. Implicitly it is assumed that the drawing means 2D orthogonal projection and in some articles it is explicitly prescribed that the drawing means a 2D floor plan or representative elevation. In this way, orthographic projection is explicitly specified as a method when preparing documentation for construction. All documentation must be delivered on paper. Some parts of documentation should also be submitted in digital format; however there is no obligation to deliver digital documentation that contains more information than paper documents. In the regulations, there is no mention of digital building information models. Of course this is not the same in all countries. For example, in the UK the government strategy foresees mandatory BIM procurement for all public projects until 2016 (UK Cabinet Office, 2011). Also in Germany, all road designs must be delivered in OKSTRA format ("Objekt katalog für das Straßen- und Verkehrswesen," n.d.), which is a road product modelling standard and represents the civil engineering equivalent of BIM.

Regardless of many similarities in regulations amongst countries, important differences can also be found especially with regard to the prescribed processes, inspections, auditing, certification, and other legislative differences. These differences lead to localisation of the market. Only a few companies can financially and otherwise adjust to these differences in many countries. Even the 'big players,' such as those companies that work internationally, are usually structured within branches that act locally. This leads to slower dissemination and adoption of new techniques on a global scale.

3.1.2 Relational systems

ZGO explicitly prescribes the roles during a construction project, which are mandatory when implementing projects of a specific type. The law prescribes the responsibilities and relationships between the roles. The relationships between particular stakeholders are reflected in mandatory project documentation. For example, the Slovene legislation prescribes 2D drawings as the decisive tool for establishing binding contractual agreements amongst the partners. Floor-plans, sections, and elevations are explicitly listed as the means of communication when informing about the building.

Regulation also prescribes the requirements for taking on specific responsibilities and roles during a construction project. The law defines those certification levels that are required for granting permission to a participant for taking responsibility for design, calculations, project supervision, etc. These requirements include education levels and the amount of work experience (ZGO, 2003). In this regard, a strong socialisation process for all participants within the AEC sector is guaranteed, which ensures the stabilities of existing practices. Before newcomers can take responsibility, the law grants all the decisive powers to the representatives of the existing approach according to old understandings and values. The process of internalising and assimilating traditional values and approaches is strongly supported by the law. In this way, the regulative pillar powerfully supports the cultural-cognitive pillar. Work processes and 'standard' project outcomes become internalised by a participant before any decisive roles can be taken on projects. Traditional practices are successfully transferred to the next generation as something obvious. The regulative pillar also supports the normative pillar, since values are maintained overtly in a traditional manner. The Professional Chamber plays an important role in the overt maintenance of traditional values on a transpersonal level by granting licenses to professionals for compliance with existing work practices.

Legislation requires project documentation to be consistent and compatible with existing records regarding space and buildings. Since most of the existing governmental information about space and buildings is supported by GIS and 2D drawings, it means all new information should also provide 2D floor-plans about new buildings. Of course, this does not mean that projects should not provide more extensive documentation, which includes 2D floor-plans. However, from the regulative perspective there is no real need to extend the documentation beyond 2D. As mentioned above, this is now changing in some countries. However, interfaces between project stakeholders and the authorities that provide permits of all kinds are defined within protocols that guarantee a minimum common denominator. Since a construction project involves several stakeholders and trades, and has a broad impact to the environment, there is also quite a large number of interfaces needed. Therefore, it is difficult to find a new common way for information interchange. Moreover, the regulation demands acquisition of permits and in this way the power is in the hands of the authorities' representatives. Therefore entrepreneurial innovative forces are limited by the conservative attitude of the state and existing standards.

3.1.3 Routines

Standard procedures throughout the construction industry are more rigorously defined compared to other industries. For example, the software development industry is similar to construction industry when organising production processes since it is also heavily project-oriented. However, the software industry's processes, in general, are not structured nor are artefacts formally prescribed. Developers are free to select what kind of documentation they will use during the project. They are allowed to arbitrarily define project activities or project implementation models of any kind, or even ignore any existing formal approach. In contrast, the construction industry has to follow strict procedures and produce many artefacts that are prescribed by law. Later steps during a construction project, such as the construction work itself, cannot start before the designs and blueprints are formally approved, etc.

As mentioned previously, the main purpose of routines and standard procedures is to ensure a stability of the system and the reliabilities of processes and artefacts. Since safety and reliability are two of the more important characteristics of any construction's environment, formalisation of routines introduces a clear distribution of those responsibilities needed to achieve the required safety standards. The system of responsibility-distribution via roles that require formal certification and mandatory work experience leads to the long-term active participation of newcomers within the existing environment. This leads to the internalisation of traditional routines. These routines must be followed and any deviation can be legally prosecuted. In the case of 2D drawings, acceptance of responsibilities based on any other graphical representation other than 2D drawings attracts high risks in terms of contractual assurance of essential content (Gu and London, 2010). From the perspective of regulation it is necessary to establish control over execution of the law, agreements, and contracts. Traditional routines do not yet provide appropriate solutions for enforcing control procedures that go beyond 2D blueprints. Because of its complexity, checking the correctness of a 3D model is not feasible without appropriate software tools. At the moment we are still lacking certified software tools that can be used for dispute resolution.

As a consequence, those tools of the trade that would bring new ways of working cannot be disseminated to the industry without supporting traditional routines. Only tools that can provide legally-prescribed outputs will be accepted by the user community. Because of this, users are faced with the dilemma of using either 'the old-way' or 'the new-way' of working, where the latter option demands high investment in new knowledge in order to be successful.

3.1.4 Artefacts

As mentioned in the paragraph about regulative symbolic systems, regulation about building activities explicitly defines the requirements for design artefacts. In the Slovenian example, the law prescribes the content and format of the construction diary and building log book. Graphical content must contain orthographic projections of the building, and it is required that documentation is printed on paper that can be folded to A4, stamped, and signed by the responsible representatives (ZGO, 2003).

Regulation explicitly defines parts of the drawings. For example, the regulation uses terms such as ‘floor-plan’ or ‘elevation,’ thus prescribing which elements of the drawing are mandatory and how to display the information listed on the drawing by the responsible engineer. Paper-based documentation is clearly defined as a must. Strictly prescribed documentation is tightly coupled with many official procedures required by public institutions in the forms of interfaces between the project and the public bodies. In this way, documentation is under permanent supervision by powerful state representatives. The temporal dimension of existing practices is also stretched by the archival value placed on documentation.

3.2 Normative pillar

An inner sense of responsibility is formed by the process of socialising individual participants within AEC. Individuals tend to feel responsibility for the surroundings and partners also direct their expectations towards the behaviour of each participant. From the organisational perspective in the field of AEC, these processes form organisational roles, workplaces, and companies that create and formalise the system of responsibilities and rights. Values and norms lead individuals and organisations into agreements that result in standardisation of work processes and artefacts.

3.2.1 Symbolic systems

Those construction sector values that guide the behaviour of participants and have been formed over the course of the long history of construction are undoubtedly experience, capability, responsibility, and accuracy. Participants within a construction project strive for these values and expect the same from other participants. Bad reputation with regard to the above-mentioned values can play a decisive role during the process of selecting project partners. As is evident from previous research performed within the construction sectors of France, Sweden, Finland, and Germany technical competences and high quality performance is a common characteristic of the sector (Gralla et al., 2010).

The prices and costs are amongst the most important guides that steer the construction industry (Gralla et al., 2010; Zarli et al., 2003). As a consequence, stakeholders focus on disciplines where they are the best performers. In this way they reduce risks regarding quality and on-time delivery. Traditionally projects are organised hierarchically. Responsibilities and compensation are in direct relationship with the specific work of a stakeholder. For this reason project participants try to avoid any activity, innovative approach or additional work that could bring benefits beyond the task at hand or only indirectly contribute to the quality of the final building. Cost-orientation also directs investors away from innovative approaches and puts innovation of the construction processes into a second plan. Despite the fact that construction artefacts have a very long lifetime, investors are unwilling to pay for error prevention measures and are usually not focused on the maintenance phase of the building but take these for granted. In this regard, investors push forward the same values as contractors, which are the capability and reliability of a particular contractor (or subcontractor), rather than innovativeness, sustainability and the holistic approach.

We can identify the common belief that the quality of a total project is a simple sum of the implementation qualities of particular tasks or phases. Consequently, process integration, and especially the integration of information flows amongst stakeholders, is not a priority. Integration efforts remain the burdens of particular project participants and, therefore, remain limited to the traditional exchange of blueprints and mandatory 2D designs. This reasoning leads us to conclusion that the formation of islands of automation is a natural outcome of a well-established system of values and expectations. In regard to specific areas of expertise, IT support is highly developed because it satisfies the direct needs of a stakeholder, supports his/her capability and productivity, and directly affects his/her price-tag. On the other hand, collaboration amongst stakeholders and integrated information support is discriminated against because it requires the development of complex interfaces and blurs any responsibility for errors. Additionally, collaborative working supported by BIM requires investments in new competencies. Collaboration also causes new distributions of power based on expertise and experience.

3.2.2 Relational systems

Discussion about symbolic systems brings us to the exploration of management strategies and business organisation principles during a construction process. In theory we can identify several models of construction project implementation (Gralla et al., 2010). The most prominent and still the most accepted is a traditional model, commonly known as the ‘design-bid-build’ model (DBB model). Depending on the geographic location, it is followed by 70-90% of the projects (Jaeger et al., 2007; Zarli et al., 2003) with very slow decline form 2007 until 2013 (Duggan and Patel, 2014). In a traditional model, the owner or investor establishes a contractual relationship with the architect and with the main contractor. The investor also takes responsibility for communication between these two parties. The same principle is used by the main contractor and the architect in their distribution of work to their subcontractors. This is repeated down the hierarchy line. All tasks, the artefacts, and the compensations are defined and distributed via the hierarchy of subcontractors and consequently the whole process is based on a principle of satisfying particular requirements and delivering partial products. Responsibilities are hierarchically distributed and therefore it is hard to establish direct communication channels between partners on the same level. The main communication flow is vertical. Links amongst stakeholders are mostly limited to the timespan of a single project. From the documentation perspective, each participant focuses only on documenting his/her own work and his/her own deliverables.

With regard to the compatibility of the documentation, stakeholders are concerned primarily with following the regulations, and the correctness of the prescribed paper documentation. The compatibility of information in electronic format with other stakeholders is not a concern of the project participant, who primarily focuses on his/her own tasks and deliverables. This causes great diversity of e-document formats that leads to incompatibility. The process does not promote but it inherently obstructs collaboration among the partners. Project participants understand communication links to other partners that are not within their direct hierarchical relationship, as an additional and unnecessary burden, which goes beyond their contractual obligations. Every participant optimises his/her own activities and optimisation of the complete project or the complete product is beyond interest of any particular stakeholder. Even worse, errors resulting from misunderstandings and bad communication are often an excuse for schedule or price extension requests. Similar findings were also described in a construction industry state-of-the-art overview described by Jaeger (Jaeger et al., 2007).

From perspective of construction project implementation, beside traditional Design Bid Build approach, more collaborative implementation strategies are developed, like Design Build and collaborative IPD approach (Asmar et al., 2013). This leads to increased interest in the final product and better communication amongst the partners. In the collaborative process model, project implementation is based on tight collaboration among the partners and the early inclusion of all stakeholders in the decision-making process. Project partners are selected according to the diverse preferences of the partner network. From the high number of projects which still perform traditional approaches to project implementation, we can conclude that these newer two models still search for their blending into the values and norms of the AEC community. Without move towards different project implementation strategies, the use of 2D drawings more or less satisfies the requirements posed by established communication patterns.

3.2.3 Routines

Roles and workplaces emerge within the context of relational systems, and embody routines and habitual activities. Repeated patterns of everyday activity are increasingly played-out unconsciously. They are built into tools that support activities. As mentioned above, the key actors involved in the development and distribution of geometric and graphical information in construction have been exposed for several years to existing work practices before they need to perform decision-making roles within industry. Existing environments and practices are known as crucial socialisation factors for newcomers (Lave and Wenger, 1991). Therefore, it is hard to develop new routines and achieve successful dissemination of these routines into traditional environments.

A review of the European construction industry showed that the architect creates a framework that integrates the efforts of the other participants. Detailed design is performed by design specialists of a specific trade and the architect coordinates the outcomes. Based on the design, implementation partners are selected for the construction work. Optimisation of tasks follows requirements regarding a specific view of the project as related to one specific stakeholder. Quality and efficiency of implementation depend on the knowledge and experience of particular participants performing specific tasks. Focusing on the complete building process and the total outcome, which is complete building, is in the second plan. With regard to data exchange, project roles concentrate on avoiding disharmony with other participants. The data management role flows between the architect and the contractor, which leads to misunderstandings and disagreements. Existing distributions of incentives based on delivering the results of a particular phase, discourage stakeholders from producing more than a set of information directly related to their tasks at hand. The research also showed that coordination of documentation and change management is performed manually and participants take this for granted. (Jaeger et al., 2007)

Because of such primitive data-exchange methods, particular roles are overloaded with data coding and conversions, particularly when handling changes. Therefore participants try to avoid the process and related problems by exchanging the least information as possible. We are facing a paradoxical situation where IT-supported change management problems limit data exchange to the minimum, despite the fact that the automation of information transfer and computer-mediated communication should make change management easier. In view of project participants, many times traditional routines seams to contribute to a higher sense of security and reliability, and mean less work especially on the side of the data consumer. Data receivers do not promote investments into more integrated communication, which could force participants from previous steps to feed them with more complete and reusable information flows.

3.2.4 Artefacts

Analysis of software usage throughout the design and construction shows that CAD tools are the most represented software tools within the AEC industry (Pfitzner et al., 2007). This leads to the conclusion that geometrical data represents the core of information, common to most construction project stakeholders. This core represents the basis for many trades and tasks such as scheduling, cost-planning, static analysis, energy analysis, etc. Modern CAD tools support the highly-efficient production of construction drawings that comply with the required engineering standards and quality norms. The types of lines, symbols, shading, and colouring applied to drawing, support an understanding of the drawing by a skilled user. Beside standardised engineering notation, companies use internal standards, instructions, and control procedures to further support control over the large amount of parameters and details contained within the drawings. Accepted procedures and standards represent a graphical language of the profession.

Geometric data is printed on paper and usually these printed drawings are named 'original'. In this physical format, the originals are hand-signed by a responsible person. Despite changes in regulations with regard to digital signatures, signatures on paper drawing are still mostly required by the law. Signed copies can be scanned for archival purposes in unchangeable format. Re-digitalisation has archival value for the documentation and is primarily used as evidence in disputes or similar procedures; however it is of little value for facility management or other technical tasks. Even when geometric data is stored in reusable digital format, this is mostly done in industry standard formats such as DWG (Autodesk's AutoCAD file format), which hold very small amounts of semantic information. Geometry as a class of structured information is stored in formats that enable very low levels of structuring and preservation of meaning. Unstructured information such as descriptions, specifications, and calculations are stored in unstructured text files, PDFs, or at best in electronic spreadsheets. There is no explicit link between structured and unstructured information in terms of information technology. References exist only as declarations in text documents. As mentioned by Pfitzner (Pfitzner et al., 2007), more than 60% of the industry does not use any internal standards for the structuring and recording of project information.

3.3 Cultural-cognitive pillar

The construction industry is very much integrated into local environments (Zarli et al., 2003). Even the largest construction companies working on international markets actually act locally. On the one hand, locality is necessary because of problems with logistics and, on the other hand, integration into local context is needed because of differences in legislation and locally-applied standards and procedures. The consequence of locality is deeper assimilation into the cultural characteristics and habits of a specific environment. Davis and Greve (Davis and Greve, 1997) argued that institutional carriers that belong to the cultural-cognitive pillar typically have local effects and slowly spread into broader environments. Changes in specific environments, such as country or region, spread very slowly into broader environments and hence the cultural-cognitive pillar represents an important factor of stability. Here we describe aspects which contribute to the stability of 2D-based construction and belong to the cognitive-cultural position.

3.3.1 Symbolic systems

Architecture and construction are both involved in the production of built objects that are characterised by their shapes and functions. Its shape is one of the more important characteristic of a building. The expression and distribution of graphical information is essential for the building industry. The historical overview presented above showed that throughout the history of human- kind, design for construction has relied on 2D drawings, no matter whether people use stone, paper or the computer as the medium for information presentation and exchange. In construction, more than some other industries, the development of CAD tools has not replaced settled practices. Modern modellers provide support for 3D modelling and the development of a complete 3D building model, however development of the details usually remain in 2D. Even when Archicad, Revit or similar tools are used and the model is created using intelligent 3D objects from the object libraries, during the final steps of the design 2D drawings are produced from the model. Sections, elevations, line-types, shadings, and layer naming are accepted as the language of the profession. This language is commonly accepted and acknowledged as the symbolic system.

Any brief look at education for architecture and construction reveals the prominence of 2D drawing for representation in object geometry. Standardised drawing techniques allow for unambiguous graphical representations of details, parts or complete buildings. They support many purposes, such as the study of form from the architectural viewpoint, as well as explaining different technical issues for engineers and providing a means for communication about organisational issues, to name just a few. Descriptive geometry and the usage of orthogonal projections are completely defined theoretically. Development procedures, correctness criteria and purpose of use are all formally determined. This results in broad utilisation of the drawings and the development of different drawing types such as architectural drawings, MEP (mechanical, electrical, plumbing) drawings, drawings of detail, reinforcement detailing, etc. With regard to the well-accepted types of drawings, it is also evident that the cultural-cognitive pillar is strongly supported by the regulative pillar, since regulations prescribe the types of blueprints required for specific types of buildings.

3.3.2 Relational systems

Symbolic systems and their usage are reflected in structural models of those organisations operating within the observed field. The above-mentioned types of drawings are manifested in the organisational structures of construction companies or groups of project stakeholders. Responsibility for certain types of drawings is spread across the stakeholders, such as departments within an organisation or subcontractors on a project. Inter-relationships and responsibilities are interpreted and codified through the categorisation and typifying of outputs. Typifying design outcomes reflects the hierarchical structure of traditional project execution depicted by the owner-architect-contractor triangle with its substructures of subcontractors. On this basis, the identity of a particular actor within the system is formed and organisations are recognised by the roles they usually take during the projects. We should also point out that traditional project delivery is still prevalent (Eastman et al., 2011; Ilozor and Kelly, 2012). Therefore new actors in the field would regularly accept this approach because newcomers usually try to comply with the culture and the rules of the majority and establish structurally equivalent systems (Scott, 2007). In this way, they ensure their own credibility and form the identities of reputable actors because the reputation, value, and trust of a particular actor are measured by his/her similarity and compatibility with the environment. For the same reason, existing actors change their existing roles with difficulty and have difficulties when they try to establish non-traditional relationships. This aspect is even more important for the AEC industry compared to other industries, since working connections between partners are very short-lived. Often partners cooperate only on one single project. Subcontractors must fit into different constellations of partnerships arranged into project organisational structures over and over again, often even on several different projects at the same time. This could indicate higher flexibility by the industry characterised by a high-level of partner variability. However, to avoid risk and to lower the cost of cooperation and interfacing, and to ensure the qualities of particular partner outputs, partners must be highly predictable. Otherwise the costs and risks would rise, which would be in direct contradiction with the established culture and highly appreciated values prevalent throughout the industry. Departure from established symbolic systems and methods, which would include deviating from 2D as the basis for communication, has therefore an important influence on any complete organisation of relationships amongst partners because it directly influences relational structures of one project and the entire professional field.

3.3.3 Routines

Reliability of stakeholders is based on approaches that are part of common praxis and tacit knowledge. Co-ordination workflow based on 2D drawings is not only prescribed by the law but is also commonly adopted by the profession as the way of working. The roles during a project follow procedures and routines usually documented in the forms of workflow diagrams and other descriptions. These records define the standard working procedures and information requirements of particular activities. The outcomes of activities are defined by legislation and agreements, one such example is the construction logbook. Regulative carriers are interlinked with culturally-motivated routines and the organisational processes of companies, and thus become the obvious norm.

Coordination of activities and documentation amongst many relatively independent stakeholders involved in a construction project is necessary during the design stage, as well as during the implementation stage. Professionals need reliable and standardised methods for the unambiguous transfer of information, since understanding is always a matter of subjective interpretation of received messages. Common praxis and routines help project participants towards interpreting received information from other partners. Understanding can be hindered by changes in methods or the communication medium. For example, phone communication (auditory communication) and direct personal contact are prevalent in construction (Kazi et al., 2007). Descriptions of the spatial characteristics of buildings should rely on well-accepted communication patterns, since geometry is visual information by nature. Translation from visual to an auditory channel is necessary when using the dominant communication channel. Without a common reference model, such as well-established 2D, this communication is hardly possible.

3.3.4 Artefacts

From the artefacts viewpoint, we can recognise the high symbolic role of drawings for the construction industry. It is obvious to the participants of a project that designs are printed on paper using a specific format. For practical work, design on paper is a necessity. Professionals claim that paper drawings enable quick overviews and access to the details at the same time by simply changing the focus of the observer. Paper drawings can be used in harsh environments at construction sites without any additional infrastructure and under any lighting conditions. Paper can be folded as necessary and its format is therefore easily changed according to the needs. In the case of damage, it is easy and relatively cheap to replace the paper. For humans, writing on paper is more natural and quicker, and provides more flexibility. Despite the fact that such notes and sketches are difficult for later processing and are often lost, thus causing significant problems in the later stages of a project, they provide functional decision-making support in real-time when quick decisions have to be made on-site.

Paper documentation is considered permanent and unchangeable. In contrast, the common belief is that digital records can be changed easily. The changes could be deliberate or not, and sometimes without any trace of the change. Changes can also be introduced by the modelled software even without the awareness of the application's user and without versioning information. For this reason, the profession relies on 'originals' that are printed on paper.

Another important aspect of construction is safety. On the symbolic level, the primary purpose of buildings is to provide 'home' and 'shelter,' and thus must be safe. In order to ensure safety regarding complex buildings, the process of construction is highly regulated and responsibility must be accompanied with a licence or an accreditation. Professional organisations and government agencies enforce normative standards upon stakeholders and provide the basis of trust within otherwise anonymous environments. Being licenced is a major step in the professional life of a licence holder. Therefore, external or material signs that confirm the possession of a licence portray an important symbolic meaning. Artefacts provide an opportunity for structuring. Changes in technology, tools or equipment challenge these conventional expressions of someone's status and also undermine the trust.

4. DISCUSSION AND CONCLUSION

Several authors have pointed out that cultural change is a necessary next step for the construction industry if we want to employ new technologies such as incorporating information modelling into everyday practice in AEC (Deutsch, 2011; Hannus et al., 2003; Kazi et al., 2007; Rizal et al., 2011; Xue et al., 2012; Zarli et al., 2003). In this paper, we respond to that calls for cultural changes or changes of 'mind-sets' which either try to create a plan and make culture change in form of a technical procedure or say nothing in addition to just plain request.

Culture is the adaptation of a group to its environment. Therefore we cannot provide a plan that should be followed for implementing a proper culture all over the world that would provide the best way of BIM-based working, as we understand regular calls for necessary changes in mind-sets. However, there is something that we can do in order to move 'forward' more quickly. The existing culture may or may not integrate certain new features into existing patterns of living and working. In order to better cope with changes, our understanding of existing patterns helps us make the transition easier and more functional, especially within the contexts of existing priorities and values. Those who try to act outside the established institutions should be aware that the majority usually follows the more conventional paths. However, this does not mean that change is not possible. 2D as an institution should be understood as an accepted way of acting which supports standard ways of coping with everyday problems. Any departure from 2D to BIM-oriented work would be closely coupled with a change of values towards sustainability, collaboration, cooperation, orientation toward end-users, etc. in addition to more traditional values present in the AEC industry.

Legislative regulation is an important aspect of cultural formulation especially in the construction sector. Individuals understand the society through requirements posed by the regulation. Experience from countries like UK shows that changes in legislation are important push for acceptance of changes in the AEC industry. However, legislation is not the only representation or culture equivalence. We should be aware that prevalent customs and social norms equally influence the way we behave. Maybe even in a more sophisticated way, they influence behaviour at an unconscious and not purely rational level. Institutional theory as provided by Scott (Scott, 2004, 2007) provides a framework within which we can articulate all the aspects of a certain institution within a broader cultural pattern. The influence of social norms could be observed in cases where BIM Maturity Level (BIS, 2011; Succar et al., 2012) is low. In such cases, not all partners apply BIM based working. A stakeholder would develop special purpose BIM model for a particular task using 2D drawings received from other partners and this stakeholder would continue to exchange information using 2D with other partners even when the model is created (Gu and London, 2010). Similarly, when project stakeholders are coerced into development of BIM by the national regulation, they could develop as-built models just for the sake of the law and not using it during the project stages.

Focusing on just one aspect of the industry or one institution such as 2D is insufficient for being able to understand the process of change. We consider this as a limitation of our analysis. Since institutions work in patterns, we should be cautious when attempting to transfer best practices across the industry. The local characteristic of the construction industry is an important aspect that should be considered in this regard. Different institutions established within different local environments can have significant influences when incorporating new practices. For example, we explored regulation in one country yet other countries did not share the same experience in their cultures. In the same way, other aspects of local culture also influence integration in diverse ways.

In this paper, we placed 2D drawing and its accompanied design coordination process within the framework of Institutional theory. This work does not promote 2D practices to be good enough or better then novel BIM based approaches. Our analysis has tried to achieve better understanding of the stability of 2D design coordination in construction. We considered the 2D design and paper-based working as an institution that is strongly supported by all three institutional pillars, namely regulative and normative, as well as cultural-cognitive pillars. From the analysis, it was evident that the pillars strongly supported one another, which provides even more stability. When considering the long history of the common practice, this is unsurprising. As a consequence, new practices, technologies, and approaches in the field of observation, such as 3D modelling or collaborative working principles, were confronted by significant barriers.

Our analysis showed that the causes for slow penetration of technology cannot only be attributed to the technical aspects of the novel approach. The superiority of some technical solution does not automatically mean that the solution will replace the old approach. Through the principles of institutionalisation we have established a framework for the exploration of aspects beyond the technology per se. Institutionalisation clearly reaches deep into the organisation of work processes, cognitive comprehension of our daily activities, and those inner forces that guide our decision making processes. It tackles our conscious as well as our subconscious parts. To overcome the old habits and fulfil our expectations about modelling in design and construction, it is equally necessary to overcome crystallised and tacit think patterns in order to fulfil the necessity of making technology efficient and user-friendly. Being realistic about new technologies and their benefits is crucial. Plain requests for changes in mind-sets together with 'BIM utopia' (Miettinen and Paavola, 2014) and hype framing of BIM benefits (Fox, 2014) do not help. This work was an attempt to structure the areas of possible changes and necessities using well-established theoretical backgrounds and, as such, represents the basis for further explorations of the AEC culture and cultures of other industries as well.

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