BIM and PLM: Comparing and Learning from Changes to Professional Practice Across Sectors

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Abstract. This paper explores the effects of PLM and BIM on professional practice. It draws on existing literature documenting the experiences of both communities of practice to explain shifts in professional boundaries. A review of case study based literature compares the nature of changes triggered by PLM and BIM relative to the new activities, roles/responsibilities and knowledge competencies, and supply chain relationships. The paper synthesises these changes and reflects PLM and BIM experiences against each other so as to contrast the continuing evolution of professional practice and lessons learned.

Keywords: Professional practice, roles and responsibilities, knowledge competencies, stakeholder relations.

1 Introduction

With the increasing use of building information modelling (BIM), architectural, engineering and construction (AEC) professionals are experiencing radical changes to working practices. BIM as a newer technology and approach reflects many of the changes, challenges and opportunities triggered by the introduction of Product Lifecycle Management (PLM) in manufacturing sectors almost two decades ago. In particular, changes to professional practice relative to the new activities, roles/responsibilities, knowledge competencies, and supply chain relationships triggered during the implementation of PLM, appear to reflect many characteristics reported in the literature on the adoption and deployment of BIM in construction.

The differences between BIM and PLM chiefly surround their capacity for technical and organizational integration, leading to differences in their approach to data governance and information management [1, 2]. These characteristics together with sector-based structural differences highlight differentiators relative to discipline-based technology applications – e.g., differences in tools, BIM/PLM platform specification, and data specifications and requirements through-life. However BIM and PLM also share a number of similarities relative to their approach to data sharing, project management, organisation of teams around deliverables and timelines, and object-based visualisation activities. Similarities in the challenges that follow on from these characteristics may provide fertile grounds for sharing lessons learned. Challenges can be seen to stem from the new activities that are changing the nature of

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professional roles and responsibilities at both the firm and project level. These changes not only require the development of new technical skills but importantly new knowledge competencies and stakeholder relationships.

This paper presents an investigation into BIM and PLM and their common ground relative to changes in working practices. The experiences of the BIM and PLM communities reflected in case study research can be used to understand the practice-based issues challenging each sector. From an industry perspective, construction industry still in the early phases of adoption and therefore it stands to benefit most in learning from case studies of PLM and professional practice. However whilst by comparison the application of PLM in the manufacturing sectors is more established, PLM is still seen as a recent concept and therefore also stands to benefit from lessons of BIM implementation due to the construction sector's (arguably) more challenging structural and organizational attributes. The paper proceeds with a review of relevant literature that reports on the nature of the practice-based changes triggered by the PLM and BIM concepts relative to new professional activities, roles/responsibilities and knowledge competencies, and stakeholder relationships. The paper then synthesises the changes to professional practice and reflects the two experiences against each other so as to discuss the continuing evolution of professional boundaries and identify lessons for each industry. The paper closes with a summary of perspectives reflected in the literature.

2 PLM and New Working Practices

The manufacturing industry has in the past decades seen rapid advances in the deployment of PLM. The three main concepts of PLM are to enable: (1) Universal, secured, managed access and use of product definition information; (2) Maintenance of the integrity of that product definition and related information throughout the life of the product; and (3) Management and maintenance of the business processes used to create, manage, disseminate, share, and use the information [3].

2.1 New Activities

The PLM concept emerged from Product Data Management (PDM) to primarily manage design files created by CAD tools and since PLM tools have evolved [3]. The services offered have expanded to cover product definition and design phases as well as manufacturing and operations. This expansion has led to PLM systems acting as a hub connecting intangible asset information (i.e. virtual design products and analysis activities) to physical assets information managed by systems, such as Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM). With enhanced PLM system capabilities new processes, activities and tasks for project engineers, management, and administration staff have resulted. These surround the capture, management, and preservation of information for the entire product portfolio of a company rather than a single project or product as use to be the case.

Further, a common feature of PLM processes concern changes to activities relative to the organization and its systems and conventions [4]. The implementation of PLM in an organization is an extensive change process which is typically divided and managed in a series of smaller stages [4]. It requires various changes to strategic and operational (process-oriented) level activities as well as to IT system activities. These new activities must be carefully planned and coordinated. To that end, PLM information systems have undergone significant changes and cycles of evolution in the last three decades, from static, closed, standalone routine data processing activities to integrated knowledge and information management for the entire product portfolio. These new activities also surround advances in CAD/CAM/CAE tools, data exchange platforms, visualization and modelling systems such as parametric tools [5].

In some applications of PLM, the user community has grown to cover the entire supply chain so as to include designers, suppliers, manufacturing partners, customers and other partners. PLM integrates with mechanical, electrical and software configuration management systems [5]. From such levels of integration new processes, methods and ways of working have emerged, together with new interfaces between engineering design teams and PLM administrators [6]. Furthermore, traditionally manufacturing approaches have not considered customer and supplier activities as part of the value creation process, and are merely value extracting processes [7]. In a PLM approach a company will more explicitly play some part throughout a product's life and potentially develop a more service-oriented approach.

2.2 New Roles/Responsibilities and Knowledge Competencies

PLM focuses on the entire life cycle of a product. As such, PLM isn't the responsibility of just one functional unit or department but rather a whole organization. PLM deployment requires that the PLM implementation team work closely with the cross-functional business teams for example, people from purchasing, order management, sales and marketing, and inventory management [6]. PLM systems can be an enterprise-wide initiative, requireing close integration of products, data, applications, processes, people, work methods, and equipment from across the supply chain [8]. PLM deployment in supply chains raises significant changes to roles and responsibilities and as a result, it is central to deployment initiatives that the roles and responsibilities of a company's product development team be determined at the outset. Likewise responsibilities in relation to partnering companies and their role in the process must be carefully considered [6]. A number of new responsibilities within existing traditional roles can be identified in the PLM literature as well as how these roles are shared between administration executives (typically with an engineering background) and project engineers. Table 1 presents a summary of these new roles).

The shift of perspective from product delivery to a lifecycle approach represents a gap in knowledge for many manufacturing companies [6, 9]. Teaching institutions and professional bodies are seemingly behind in their alignment of current curriculums, assessments and accreditation relative to the needs of PLM and manufacturing industries. In the US this issue has been widely reported [see e.g., 10]. The call for versatile, cross functional employees that remain up-to-date with emerging technologies and are able to tackle the host of new responsibilities associated with through-life requirements and activities is common to both the aerospace and automotive sectors. Hutchins [11] notes that manufacturing professionals in North America are being asked to perform a range of tasks not traditionally included in their professional scope of works. The workforce lacks the capabilities needed to undertake these tasks successfully, and urges more diverse knowledge competencies [11]. The Society of Manufacturing Engineers has been researching "competency gaps" (specific capabilities that companies insist are lacking) and developing a 'Manufacturing Education Plan' [12]. Academia have also responded to the needs of the changing workforce from one that is 'task-oriented' to one of that is 'competency based' through the development of innovative curricula, such as Purdue University's initiative to develop a PLM-literate workforce [12].

Table 1. PLM - New/Changed Role and Responsibilities

Role	Responsibility
Project Manager	Direct implementation resources; Manage project schedules; Track Status; Resolve conflicts and issues
Business Process Owner(s)	Provide project priorities and objectives; Direct participation of resources; Resolve business process issues
Subject Matter Experts	Communicate current process; Provide information details; Support user community during rollout
IT System Support	Support site infrastructure; Extract legacy data; Provide technical expertise
Solution Architect	Analyze requirements; Configure application; Develop strategies for product lifecycle collaboration (including collaborative process planning)
Technical Consultant	Develop customizations; Provide technical expertise
Service Owner	Delivers and/or utilizes the expected business benefit, Manages service unit to deliver service benefits, Provides Subject Matter Experts to project

2.3 New Supply Chain Relations

A PLM approach attempts to uncover hidden relationships and rearrange the value network of actors. The most noticeable change in relations between different parties/stakeholders therefore stems from two fundamental changes to business focus. The first is the change in focus from a traditional product delivery business model to one that centres on the product in use, highlighting the role of the service owner and/or the customer role that the PLM concept is predicated on. This may extend the relations of a firm with suppliers or even include new relations with product customers as is the case in a product-service delivery model. The second shift in focus follows on from this and relates to a more strategic approach to intellectual property creation and intellectual property management of product information, from its initial conception to retirement [13 citing 3]. Following on from these two shifts in business focus which reveal new supply chain relations are a number of secondary factors such as the emergence of networked firms, changes in customer base, mass customization, and changes to the mode of production. These factors have accelerated changes in relations between suppliers, manufacturers and customers [14].

IT is the key enabler of PLM support in these new relational networks. However, most case studies report that manufacturing firms are only partially integrated 'islands of information' and still lack a holistic view of 'users of information' [14]. Further, the information systems underpinning PLM are said to be largely influenced by low levels of vertical integration [15], a lack of interoperability across complex and disparate tools, and a lack of a 'plug and play' approach to PLM deployment [14]. In an extended enterprise context, the benefits of PLM can only be realized when horizontal integration of several disparate systems is achieved so as to be able to support the wider partnering relations mentioned above.

3 BIM and New Working Practices

BIM is an emerging technology and collaborative process that in theory should facilitate the digital representation, exchange, use and reuse of all pertinent information about the life cycle of a facility from planning, design, construction, FM, and disposal [16]. In practice this is often only partially realised as a range of problems in 'closing the loop' persist across various lifecycle phases. Like PLM, BIM is a model-driven approach to construction, which relies on mastering new ways of working and integration and sharing of resources.

3.1 New Activities

Like approaches to PLM, BIM emphasizes open communication and information exchange, collaborative decision making, early participation and contribution of knowledge and expertise by downstream stakeholders (contractors and suppliers), and thus fosters greater levels of risk sharing [17]. BIM emphasizes integrated processes built around coordinated, reliable information about the life cycle of the facility. Consequently BIM introduces changes in working practices, both within an organization and across organizations [18], which are often difficult and painful.

Changes to BIM-enabled collaboration and multidisciplinary teamwork have emerged, with model-based collaboration becoming the norm in BIM deployment. The level of interaction is managed differently on projects according to required levels of technical and organizational integration [19]. Higher levels of interdisciplinary interaction and integration are often enabled by co-location arrangements which have spawned concepts such as the "Big Room" [20] and 'knotworking' [21]. Closer interdisciplinary collaboration between AEC stakeholders means that traditional role boundaries have become less distinct, and separations between responsibilities and areas of expertise are diminishing [18]. It also requires new project and technical management activities, such as new process management tasks surrounding the planning and execution of information protocols between stakeholders, and new model management activities surrounding the coordination of discipline specific datasets. New activities are also emerging onsite with the use of 3D and 4D models during fabrication and construction [22]. Most recently the activities of clients and facility managers have also begun to change with the use of the as-built model for operations and maintenance [23].

As was the case for PLM, these new AEC and FM activities have been initiated by advances in data exchange standards, new platforms and protocols and improvements to the visualisation and editing of information outside CAD and other modelling systems. Thus the community of users of BIM has also expanded to cover more of the supply chain, which includes designers, suppliers, manufacturing partners, and clients. From new coordination and integration demands, come new processes, tasks and activities that must be mastered across the design, delivery and operations team. Currently these new interfaces are being established mostly on an ad-hoc basis due to the project-based business focus of the sector.

3.2 New Roles/Responsibilities and Knowledge Competencies

Traditionally, AEC professionals have taken on separate and strictly defined roles, delineated by a precise scope of works with established discipline-based responsibilities. In defining roles, professional disciplines have sought to transfer risk to other parties formally in contractual arrangements [24]. Due to the interdisciplinary nature of BIM, traditional responsibilities relative to modelling, management, administrative and functional requirements are being challenged and professional boundaries being temporarily redrawn. Research indicates there is also a lack of clarity on whether new responsibilities need to be performed by one role or several, within an organisational framework or a project one [18]. In some case studies, the introduction of BIM is presented as simply an upgrade in the drawing production process from CAD to BIM. For these projects, the "BIM team", while described as a new function, is described as an up-skilled version of CAD operators [19]. In other case studies the need for new roles is well documented [25]. The proliferation of new roles may be seen as a reflection of the need for processes to allow different AEC stakeholders to contribute to model development [18]. Barison and Santos [26] have identified over 30 different job titles or descriptions for BIM specialists, with role variations and combinations depending on project size or professional affiliation. Table 2 summarizes the new roles and responsibilities identified from the literature. Whyte [27] suggests that different approaches to drawing and model development are to some extent 'institutionalised' in existing professional roles, with architects taking a direct lead in model production, and engineers conducting the fundamental design and analysis but passing instructions to technicians for transformation into the required models. This appears to be causing issues relative to process planning and control. Davies *et al.* [18] argue that BIM-related roles within contractor organisations have more freedom to redefine their responsibilities according to their core knowledge competencies. Contractors therefore appear to be maintaining their own institutional boundaries more readily.

There is growing consensus relative to industry requirements for new BIM knowledge competencies. Succar *et al.* [28] have proposed an integrated definition of BIM competencies which comprise of personal traits, professional knowledge and technical abilities. Construction industries worldwide are calling for the requirements of new abilities, activities or outcomes to be measureable against performance standards so as to hold education, training and/or development offerings to an acknowledged standard. Numerous BIM competency frameworks have been developed and categorised into useable competency taxonomies. Competencies are however too numerous, and potentially thousands of competency items would be required to satisfy an integrated BIM competency definition. The required knowledge competencies can generally be mapped to the new roles and responsibilities that have emerged (see Table 2). New competencies can also be identified relative to coordination requirements according to different information management functions.

Table 2. BIM - New Roles and Responsibilities

Role	Responsibility
BIM (Project) Manager	Including developing a BIM management plan, understanding data exchange protocols, understanding model progression specifications and document management. Provide project priorities and objectives; Direct participation of resources; Resolve business process issues
BIM Model Managers	Understanding data exchange protocols, Model auditing for model managers
BIM Contract Administrators	Including new skills in the contractual implications of using 3D models as a primary source of design information, administration and contract management
BIM System Support	Support site infrastructure; Extract legacy data; Provide technical expertise
Technical Consultant	Including technical skills relative to building information modelling (functional basics) as well as functional software skills relative to project execution, software applications, and model authoring
Client/ Facility Manager	Analyze operational requirements; specify requirements of as-built BIM model to be delivered for FM purposes.

3.3 New Supply Chain Relations

The procurement process and contractual arrangements of construction projects have considerable impact on how BIM is implemented throughout a project team, and on the resulting relations between parties. Under a traditional design-bid-build framework, BIM is more likely to be used in isolation by a single or a small group of design consultant/s, or in some cases, in the construction stage alone, as there is no incentive or support for collaborative engagement. More progressive arrangements such as alliancing and integrated project delivery (IPD) [29] can facilitate increased levels of collaboration and integration between design and construction roles [18]; particularly the increased involvement of contractor/subcontractors in the design phase of the project. Using such arrangements, BIM implementation increases levels of integration between collaborating stakeholders.

The emerging role of a third-party BIM specialist is also being used to assist different project partners with BIM implementation. While the use of such a person or team has the potential to bridge traditional role divisions or project stages, case studies to date (see [18-22]) suggest that it is most commonly seen in collaborative project frameworks. This highlights a significant difference between BIM and PLM initiatives where the introduction of a defined administrative PLM team appears to be a more significant and formal process, demanding new relations and where networks must be established with the product engineering team to ensure collaborative process planning and clearly defined data governance strategies.

4 Comparing BIM and PLM Experiences

There are a number of key differences between BIM and PLM concepts and their deployment and impact on professional practice. These differences also stem from the different structures, backgrounds and traditions of their respective industries. A comparison between the construction and manufacturing sectors inevitably highlights each industry's unique characteristics and any contrast between BIM and PLM should be mediated by differences in context. For example, the automotive and aerospace sectors are more globalised and consolidated industries; in contrast, the majority of construction projects remain rooted in local contexts where IT adoption is low in a highly fragmented industry [30]. Each sector also differs in terms of its technological intensity, which in turn affects the success of IT implementation. In construction, information modelling and management are challenged by lower levels of technological sophistication. In the product-centric companies that characterise manufacturing, the focus is instead on the overall business process and due to a more consolidated industry an enterprise perspective can be fostered more readily. PLM applications in aerospace and automotive sectors have also (arguably) gained more traction due to higher levels of supplier specialisation and technological expertise. This in turn means that suppliers compete on technical expertise as well as on cost.

In the last decade, widespread efforts have been undertaken to enhance various aspects of BIM ITs from their focus on internal modelling capabilities and software interoperability, to expand BIM's role to the entire lifecycle of a built asset. BIM servers are now being developed to provide a large integrated data- and knowledge-base that can be leveraged not only in design and engineering but also in planning and management of component fabrication, construction operations, and facilities maintenance. Hence, BIM's scope, functionality and value are only recently being expanded from modelling and simulation capabilities to a platform for collaborative processes and resourceful decision-making, aiming to support a whole life cycle approach. In contrast, PLM solutions have been serving as the basis for collaborative product definition, manufacturing, and service management for much longer. With PLM, companies think in terms of standard processes, standard data and standard systems that they, and the numerous suppliers, customers, and partners, can use to save an enormous amount of time and money [8]. A lack of process commonality and standardization usually results in non-standardized and suboptimal BIM implementations with a high cost of ownership being passed to AEC companies trying to implement such process-oriented integrations. This is a key lesson for the construction sector such that the support of PLM requires collaborative harmonization of a set of complementary and interoperable open standards and open source models that cover the full range of the products' life cycle [15]. However even from a PLM perspective, industry standards surrounding model based collaboration are not yet widely accepted and popular as a useful form of data storage due to the lack of information they hold [13]. Importantly, data exchange standards have been criticized for their inability to capture well-defined business processes, work flow patterns/ systems, and underlying business rules. For organizations of any sector, a key issue in the implementation of PLM or BIM is the transition processes required in adopting new standards, i.e. moving from the old to the new system.

In considering the transition process surrounding PLM and BIM deployment another key lesson concerns the fostering of new attitudes and perspectives towards collaboration and shared responsibility. PLM and BIM implementation must be driven by the requirements of product design processes rather than IT considerations, and therefore the bill of materials must remain at the centre of process requirements and workflow redesign. Such a perspective is arguably more difficult for AEC professionals to foster. BIM implementation challenges therefore centre on answering many of the same data exchange, business process and policy phasing problems that have faced PLM deployment. In overcoming these challenges a unifying solutions must be driven by product design requirements and focus on enabling both information and processes to be to acquired, managed and utilised across project and enterprise level systems. AEC professionals may therefore see further changes to practice. As BIM maturity levels increase across the construction industry a common end point with manufacturing industries may be realised with construction achieving greater rationalisation – including higher levels of consolidation in the supply chain, harmonisation in collaborative ways of working, increased use of 'IPD-type' procurement methods, and an increase use of collaborative process planning methods.

5 Conclusions

This paper provides a comparison of case study based research on the impact of PLM and BIM on the traditional practices of manufacturing and construction industries. The influence of these changes relative to new activities, roles/responsibilities, knowledge competencies and relationships within project and organizational contexts were reviewed. The comparison of PLM and BIM concepts and practice based changes aims to provide better understanding of the impact of their respective implementation. Irrespective of industry, managing these changes is critical to transition and must be planned for with appropriate commitment to process redesign, training and education, and development/use of industry standards. A useful direction for future research is to compare how each industry is supporting such commitments.

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