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BIM based organizational learning

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ABSTRACT *:* Most of construction projects posses a project based organizational structure, where knowledge acquired by humans migrate with them outside their organizational bodies once they leave their employer. Hence, organizational learning and building corporate knowledge that has a life span greater than the employees' turnover are of paramount importance to construction firms. It is considered the means by which previously acquired experiences from previous projects can be used in decision making processes in similar projects, wherever similar contexts and conditions are encountered.
The Industry Foundation Classes (IFCs) is an initiative to standardize communication between multidisciplinary software applications through the use of a common Building Information Model (BIM). It facilitates data communication between software applications and heterogeneous IT platforms, without human intervention.
This paper addresses the problem of organizational learning within the AEC-FM (Architectural, Engineering, Construction and Facilities Management) domain. It focuses on the design process and its activities. It proposes a novel approach for utilizing the object oriented features of the IFC/BIM model to structure captured contextual information about such objects in a manner that facilitates organizational learning. Furthermore, advanced object versioning techniques are implemented to capture contextual snapshots of design phases at certain stages within a well defined workflow. This leads to a BIM based information management system that can achieve a competitive advantage through organizational learning.
Keywords: BIM, IFC, Organizational learning, knowledge management

I. INTRODUCTION

This section provides a description of the AEC-FM industry in terms of scale of investment, product characteristics, organizational aspects, the construction client categorization and characteristics, construction economics and response to economic forces and finally research and development with relevance to the learning organization model. This introductory part aims at developing a feeling of the construction industry environment and the market forces, to give a background and basis for the discussion about the implementation of object based BIM (Building Information Modeling) organizational learning in the construction industry.

I.1. The Construction Industry

I.1.1 Scale

The building and construction industry encompasses a wide range of activities from the construction of residential dwellings and urban development to commercial and industrial buildings and the infrastructure associated with air, sea and road transportation, telecommunications, mining and energy. The Construction industry is considered to be the world's largest industry. Building and Civil Engineering turnover involving design services, contracting and materials manufacture represents 10% of GNP for most nations. [1]

I.1.2. Product

A major problem with the construction industry is that it does not produce an "end product" that could be put on shelve in a store, with a predetermined price. It delivers a product that is capital intensive, involves a lot of fragmented disciplines such as: contractors, sub-contractors, designers, suppliers and so forth. In addition, it is delivered over a long period of time. In comparison with other manufacturing industries products, the number of units produced is far less. However, it involves very high value transactions [2].

I.1.3. Fragmentation

For centuries prior to the Industrial Revolution and the appearance of complex architectural programs like airports, railway stations, cinemas and so forth. A single person used to design and manage the construction process for the client. This single person had fixed solutions for certain problems, on the other hand, the architectural programs did not vary dramatically, i.e. specialization was not of great importance [3]. The industry was craft based. Skills were passed from one generation to another by apprenticeship [4]. The architecture and construction industry reflected the overall civilization, culture and natural environment of different regions. Due to the lack of communication between different parts of the world, local architecture and construction techniques were used in different places for solving different problems.

Today, it is very different. It is no longer the art of building. It is the science of building, where a lot of disciplines and experiences are involved in the industry to put up with the advanced and complex architectural programs, ranging from complex structures like the millennium dome in London to intelligent buildings [4].
In the meantime, the construction process itself consists of different phases and different activities specific to each phase. It involves the co-operation between a variety of parties of different experiences, backgrounds, interests, objectives, and organizational cultures, (e.g.: contractors, sub-contractors, designers, and services engineers). It is worth mentioning that these differences may lead to a conflict. A very simple example is the perception of a "brick", the architects' concerns are about its dimensions, heat and sound insulation, its color and texture and so forth. The civil engineer's concerns are about its mechanical properties loads, and how to transfer these loads to the ground. The quantity surveyor is concerned about the number of bricks used. The contractor is concerned about how much it costs him to build the wall and how can he build it cheaper. This fragmentation and diversity of disciplines, backgrounds and objectives can cause miscommunication between different parties. The author means by communication; the full understanding of each others' intensions, not just to get in touch with each other.
Conflicts of interests and poor communication, together with other reasons like poor budgeting and cost estimates, selection of inappropriate procurement methods, lack of experience, information or techniques, poor contract management, and risk assessment and management, can lead to projects (products) that are: over budget, behind schedule and may or may not satisfy the client.

I.1.4. The Construction Client

Clients are the core of the construction process; buildings are constructed to satisfy their needs and desires. There are many categories of construction clients. The categorization done by Masterman [5] seems to be simple to understand and describes different categories of customers (employers) requiring discrete solutions to their procurement needs.

Traditionally, clients have been differentiated to public and private organisations. However, sub-divisions of these categories also exists with two main divisions relating : 1- to the client's experience of implementing building projects and 2- to whether they are 'primary' or 'secondary' constructors. Masterman, [5] argues that the question of experience had been examined by many researchers, who have all concluded that the client's approach to all aspects of construction is determined by whether the client is "experienced" or "inexperienced", often called "naïve" client.

The differentiation between these two categories is dependant upon the frequency of projects commissioned in the last five years. The organisations that carry out a new project every 5 years or more are categorised as an "inexperienced" organisation and those who carry out projects more frequently than a project every five years as "experienced".

I.1.5. The Economics of the Construction Industry

In general, the economics of the construction industry is different from many other industries, such as: the automotive or electronic industries. It is characterised by a relatively large number of sellers or work seekers (i.e. construction firms) competing for a relatively small number of relatively high value orders, where prices are market led. i.e. if there are too many firms chasing too few orders, then prices will tend to fall and vice versa. However, Smith [2] has the opinion that the construction industry does not follow the way the economic theories predict it should. One of the main reasons stated is that: construction is a long term business- even for the "fast track" projects- the time scale for most major construction work is likely to be measured in years. In recession periods, the construction sector may still appear to be strong and booming, despite the fact that the rest of the economy may be slowing down. Conversely, when the economy as a whole begins to recover, the lengthy lead times required to commence major construction projects results in construction appearing to be weak, when the economy as a whole appears to be gaining momentum. [2].
Consequently, by considering the above mentioned economic characteristics for the construction industry, it might be difficult for the construction market to adjust quickly to changes in demand.

Barrie et al. [4] consider the lack of mobility (in addition to the inefficient use) of resources in construction as one of the factors that prevent companies from moving to other market places, where there are more work opportunities. However, there are many companies that operate on a global scale and benefit from the diversity of market places and resources. The point is that, Giant companies beyond a certain size are the only ones who are able to conduct business overseas. Most probably within an alliance, where it moves with its chains and networks of sub-contractors, logistics, suppliers, partners, and so forth. Small and medium size companies may be able to conduct business beyond national boundaries, if they are deeply specialized in a certain field, where it is hard to find other alternatives.

I.1.6. Research and Development

Researchers like Barrie et al. [4] and Smith [2] accuse the industry of bad record keeping. Accurate data is not available, feedback mechanisms are very poor. Moreover, it is assumed that only a fraction of 1 percent of the industry's gross revenue is invested in research and development. By comparing this figure with other industries like the electronics industry, it is found that 10 to 20 percent of the gross revenue goes into research and development. That might be one of the reasons that explain the relative retardation of the construction industry's use and benefit of I.T., when compared with other industries. Among the reasons for not spending on R&D, might be that advances in construction tend to develop from innovations which in most cases cannot be protected by secrecy or patent, and therefore disseminate rapidly through the industry. Accordingly, there is little incentive for one firm to invest heavily in new developments to share it afterwards with its competitors.

II. ORGANIZATIONAL LEARNING

A main objective of this paper is to utilize the latest ICT technologies with special emphasis on the BIM technology to achieve a competitive advantage in the AEC-FM industry. There are various means of achieving a competitive advantage, such as: “Cost Leadership”, “Differentiation” and “Learning”. This part of the paper focuses on “The Learning Organization” and how to create a corporate body of knowledge in the AEC-FM domain.

II.1. Competitive Advantage

Baker et al. [6] define a competitive advantage as “A benefit perceived by a customer", where there is an infinite number of sources to achieve. Nevertheless, (ibid) focused on two issues that they considered to be the two basic sources for a product's competitive advantage: 1- Cost leadership 2- Differentiation.

II.1.1. Cost Leadership

Naturally, if two products are perceived to be identical in every aspect, then the intending customer will be attracted by the lower price one as it represents a better value for money.

II.1.2. Differentiation

The intending purchaser perceives any difference whether tangible or intangible, objective or subjective between any two products. This difference may influence his perception of value. Consequently, the client may change his mind and buy the higher priced product. Baker et al. [6] argue that achieving and maintaining an objective difference is difficult to sustain due to the fact that it has been estimated that any new technology or know-how can be replicated within 18 month. The competitors will be able to benchmark the new product and establish the basis of its technological advantage. Moreover, the protection of intellectual property rights through patents is inefficient and copying is becoming a common practice.

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Chee et al. [7] emphasize the importance of a third source of a competitive advantage, which is the "focus" strategy. They mean by focus, that the firm or organisation targets a specific market segment, on the ground that businesses may compete with each other by offering higher value to the customer at a higher price. Chee et al. [7] do not deny the risk associated with this approach as the firm will have to guarantee that there is a determined set of customer needs that are consistent or slowly changing over time, and the company knows it can meet. Focus strategies are also appropriate where broad market penetration is too expensive, or where the firm's infrastructure, resources, experience is not sufficiently developed to go for a more diverse product approach.

In the AEC-FM domain, construction firms can be specialised in hospitals, residential buildings, schools, laboratories, and so forth. This focus on a particular type of projects may be attributed to the firm's previous experience developed from carrying out a number of similar projects. It is also noted that the main construction firm on a project (main contractor) rarely uses its own force in carrying out projects. It mainly depends on specialist sub-contractors in each particular activity of the works. e.g.: foundations, superstructure, finishing, electromechanical works and so forth. The main skill of the main contractor is usually how to manage specialist subcontractors and suppliers efficiently and effectively to achieve planned profits and customer satisfaction. In other cases, e.g. a hospital, a firm which is supplying medical equipment may extend its business to the procurement or refurbishment of hospital projects. Generally speaking, having the experience of carrying out a particular type of project frequently, gives a competitive advantage to the construction firm and its employees as well, when applying for new projects or applying for jobs of the same nature. This is attributed to the accumulation of experience and knowledge in this particular area.

II.1.3. Learning

"Learning is a means to an end, its value depends on where it is taking you.", [8].

II.1.3.1. Learning about Competitors

Following the concept of Benchmarking, learning is increasingly focused about learning from competitors, which may lead to an endless catch-up game. [9]

The learning from a competitor's product features and how efficiently they convert their resources to outputs (products), as well as determining what has to be done to beat them is an essential activity for a firm who wants to survive in the new market space. Competitive offerings can be considered as a base line against which the firm's resources can be measured. For example: If the competitor is using labour from the same labour market, and nearly the same suppliers and still quoting lower tender prices for the same job (already estimated). In this case, many issues have to be investigated, beginning from the supervision, productivity of labour and control of wasted material on site to the adjudication strategy of the tender price itself. In this case, the competitor's data can be collected from common suppliers, declared contract prices, the way the project is planned and managed and so forth. This data can be the external benchmark against which the construction firm compares its own performance.

It is essential for a company that wants to sustain a competitive advantage to keep scanning the industry for direct and indirect competitors, who may have the resources or the need to overcome entry barriers to the market. Particularly, if the market segment shows high profit margins or growth potential, it is more likely to attract new entrants. [10].

Information about competitors can also be captured from professional bodies' databases to produce an analysed report about competitors' performance, which is compared to the internal performance indicators; these are aggregated from different performance areas within the organisation. This comparison increases the knowledge of senior management, who are supposed to make logical reasoning using trends of the surrounding environment together with information about competitors and internal performance to support decision making / taking. Furthermore, artificial intelligence forecasts about uncertain information e.g.: the use of Neural Networks in cost estimation, might be a tool kit for senior management decision making.

II.1.3.2. The Learning Organisation

The main focus of Edward Finch's book "Net Gain in Construction" [8] is on the creation of learning organizations in the construction industry. He states that the "learning organization" is a phrase coined by Minzberg [11] and popularized by Senge [12]. Finch's argument is that: "There is no sustainable competitive advantage today other than organizational learning." And that; "A firm could only sustain its competitive advantage if it has a faster learning rate than its competitors."

One of the definitions for the organizational learning, cited in Finch's book, which the author finds to be expressive is: "Organizational learning means the process of improving actions through better knowledge and understanding."[13]. Knowledge management is considered by Finch as the key for survival and that firms that are capable of creating a corporate knowledge system that has a life span greater than that of individual staff are likely to have a sustainable competitive advantage. The high rate of turnover of employees results in the migration and dispersion of experiences. For individuals, it is not a problem; they are able to take their experiences with them to other firms. The loser is inevitably the organization itself, which allows the inevitable migration of "know how" and experience without having a mechanism to embody this knowledge. Modern ICT (Information and Communication Technologies) and the IFC (Industry Foundation Classes) – BIM (Building Information Model) model might be able together to play an important role in knowledge management and embodiment, due to the ability to capture and structure various forms of data; digital, audio, video and so forth. In addition to the ability to organize data in certain architectures, where easy versioning, retrieval, amendment, updating can be performed.

Furthermore, part of knowledge management entails a life cycle approach to information, where learned lessons from earlier projects can be captured and utilized in similar situations. Example: Case Based Reasoning, (CBR), which is out of the scope of this paper.

In the meantime, Hawkins et al. [14] have the view that learning does not just reside inside people, but also is held between people, teams and groups. Organizations learn as a whole unit and the sum of amount of learning is not equivalent to the sum of the overall individual learning.

II.2. Knowledge

Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knower. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms. [15]

Knowledge can be categorized into two main types: (1) Explicit knowledge, which is directly captured and transmitted in a formal systematic way; like documents and reports. (2) Tacit Knowledge that resists capturing and is difficult to communicate. It is very context dependent and relevant to specific actions and indirect factors. The knowledge creation process is continuous. Every time new experiences are brought together by different team members to solve a different problem, knowledge is created.

Knowledge takes different forms. Some of them can be captured and described, others are hard to grasp and capture. For example, skills can only be passed on from person to person when they interact. The challenge in knowledge management lies in assessing, changing and improving people's skills or behaviors. The management of explicit knowledge, namely information, is well researched from an IT perspective. However, tacit knowledge results from interaction of people. Polyni [16] believes tacit knowledge to be something that we acquire unconsciously, find it difficult to articulate and we often do not even know we have it. This shows that not all knowledge can be saved as information in a system but gets lost when the people leave a project or an organization. Knowledge is created by- humans– interacting with each others, with information, and their environment.

Knowledge should be differentiated from both data and information, where data is a crude body of observations or facts that lacks context. In the meantime, information is data supported with contextual reasoning (metadata). Knowledge is resulted from the accumulation of information through experiences in a rich and meaningful context.

From the above, it is clear that any knowledge management system should support and facilitate team work, even across different disciplines. The work done at the current stage of this research is limited to explicit knowledge.

Knowledge management can only be managed successfully if these problems are understood and the human and social component of knowledge management is taken into account. Current IT research focuses too much on information management. Al-Hawamdeh [17] believes that "For knowledge management to succeed, we need to treat knowledge as an activity and not an as an object.". Still IT systems can support knowledge management by supporting the exchange of information, communication of knowledge and "catalogue expertise of organizational members and as a result facilitating access to the right people and enhancing knowledge sharing" [17]. "One of the key technologies that is driving knowledge management is collaborative technology."

In the meantime, as knowledge and information are inextricably linked, the latter needs to be investigated, too. Information flows in projects and organizations need to be identified, mapped and prioritized according to its value for goals and objectives. It can be investigated which participants touch the information assets, how these assets are created, modified, processed or distributed by these participants. Chains of events can be identified and the gap between stated procedures and actual behavior will become visible. This provides insights in the information and communication structure, involved stakeholders, the required technical support and "how information is used by whom." [18]. This helps focusing, "to identify inefficient or improper uses of information; and the ability to improve the value of the information by evaluating, filtering, abstracting, and providing a broader ... context. The knowledge of how information is traditionally used in a project allows deriving how it should be organized and structured and how it should be sourced.

III. BIM / IFC MODEL

III.1. Object Oriented Modeling

“Is a modern way of thinking about problems using models organized around real world concept”.[19], [20]. Its fundamental construct is the object, which combines both data structure and behaviour in a single entity. The main uses of Object Oriented Models are considered understanding problems, modelling enterprises, designing programmes and databases. The main features of objects are: (1) Identity, (2) Classification, (3) Polymorphism and (4) Inheritance.

III.1.1. The object oriented Model

Normally, an Object Oriented Model is developed through four main stages:

(1) Analysis (abstraction of the real world element with emphasis on it relevant and important properties).
(2) System Design (Overall architecture).
(3) Object Design (Class Design) a design model based on the analysis, but containing implementation details.
(4) Implementation: The developed object classes are translated into a particular programming language.

The object model captures the static structure of a system by showing the objects in the system, relationships between the objects and the attributes and operations that characterize each class of objects.

III.1.2. An Object

An Object is a concept, abstraction with crisp boundaries and meaningful for the problem at hand. Objects help understanding real world problems and provide a practical base for computer implementation. The decomposition of a problem into objects depends on understanding the nature of the problem.
All objects have unique identity and are distinguishable. Example: if two apples are identically the same in color, shape, texture and so forth, they are still two individual apples, a person can eat one then the other.

III.1.3 Classes

There is always an ambiguity associated with an object and it is often confused with a class. To resolve this ambiguity, a more accurate use of the term “object” is using “Object Instance”, when referring to an exact and particular thing and the term “Object Class”, when referring to a group of similar things.

An object class is a blueprint that describes a group of objects with similar properties (attributes), common behaviour (operations or functions), common relationships to other objects and common semantics. However, the abbreviation “class” is often used instead of “Object Class”.

By grouping objects into classes, the problem in hand is abstracted. This abstraction is the driving force that gives Object Oriented Modelling its power and ability to generalize from a few specific cases to a host of similar cases. Common definitions and operations are keyed and stored once per class.

The definition of a class is a metadata (data that describes other data). The class describes things that are being modelled rather than being the thing itself.

III.2. BIM

Building Information Modelling is an AEC-FM multi-disciplinary object oriented model for a construction project(s) all over its lifecycle. Its main goal is the interoperability between software applications. It differs from CAD (Computer Aided Drafting) in terms of provision of semantics, taxonomies, and topologies in addition to geometrical representation of objects. It also models the relationships between objects.

III.2.1. IFC

The Industry Foundation Classes (IFC) were first issued by the IAI (Industry Alliance for Interoperability) as a non-profit organization containing major players in the AEC-FM industry worldwide including major software vendors, construction companies, design firms, consultants and research institutes. It was renamed to be International Alliance for Interoperabilty and finally renamed as “buildingSmart” for simplicity. IFC are defined using the EXPRESS (ISO 10303-11) modelling language [21]. Its classed are called ENTITIES. The object instances are exchanged in the form of STEP-21 (ISO 10303-21) files.[22]

IV. OBJECT BASED ORGANIZATIONAL LEARNING

IV.1. BIM based Design Process

The design process is iterative and includes a lot of cross-disciplines which often clash with one another. It ranges from the conceptual preliminary design to the final detailed construction drawings phase.

The IFC BIM model is supposed to capture all design data through the entire design phase lifecycle and structure such data around BIM object. This data can include scanned documents, drawings, details, videos, and so forth with relevance to BIM objects.

IV.2 BIM based Knowledge reuse

Knowledge reuse is considered to be the main aim behind organizational learning. The literature of knowledge reuse is full of research efforts using Case Based Reasoning (CBR) which is out of the scope of this paper. This paper is limited to the explicit knowledge reuse using IFC BIM model and utilizing its object oriented features.
The scope of reused knowledge includes mainly two types of knowledge:

1- Domain knowledge.
2- Project related knowledge.

The domain knowledge is acquired through education and knowledge that is specific to a certain domain regardless to the project in hand. In the meantime, the project related knowledge is specific to the project in hand and may not apply to another similar project.
This research emphasizes the idea that "all design is redesign", where designers are inevitably influenced by their past experience in similar projects, where new designs can be made by modifying (updating) old designs [23].

IV.2.1. BIM based Object Versioning

Traditionally, versioning (Version Control) is made through document management systems (DMS). In this research versioning is made on the basis of objects rather than documents. Due to the fact that construction design elements are represented in the form of software objects, object versioning makes it possible to have several versions of the contents (attributes' values) of an object. It basically provides a graph structure of the object's versions and their interrelations. The development of objects in terms of addition or modification of attributes' values can be captured in a graph structure. Moreover, this structure is capable of showing the development of alternative designs (variants) as a branching in the versioning graph.

Each design object version represents the state of development at a certain point in time. New versions could be saved by just identifying the differences through comparison with the parent version, i.e. it is enough to save the deltas between object versions in order to be able to navigate through the entire versioning graph and get the full state of each version. The latter enables tracing and analyzing design development through time.

In reality, object versions do not stand alone. They exist within model versions that express the design development state at a certain point in time. Thus, object versions are interconnected through model versions as Directed Graphs that are entangled with each other through edges (arcs) of both graphs to represent changes in the model. The same object version can be a member of several model versions.

On the contrary to document managements systems, object versioning deals with a much finer degree of granularity, which is the object and its attributes rather than documents. This gives more flexibility to the process of creating data subsets or partial models on one hand and on the other hand enables the integration of data subsets coming from different sources.
It has been proven that if the object versioning approach is applied on the IFC / BIM model, this would help to overcome many of the problems and barriers that are hindering the BIM way of working. Design management activities would benefit a lot from the application of the model based way of working through an object versioning system that would allow dealing with objects rather than documents.

The BIM Object Versioning approach provides a more flexible way for tracking changes on objects rather than the traditional document management systems. In the meantime, objects can still be a member of numerous documents or model versions. Furthermore, there is no need to save the entire design model whenever a change occurs. It is sufficient to save the changes (deltas) only. This would later enable the generation of the design model at any chosen development state or any point in time. Moreover, it is possible to generate new models as a new combination (configuration) or merging of objects from different model versions. In addition, this would enable parallel working and help multidisciplinary teams in Change Management and design conflict resolution. [24].

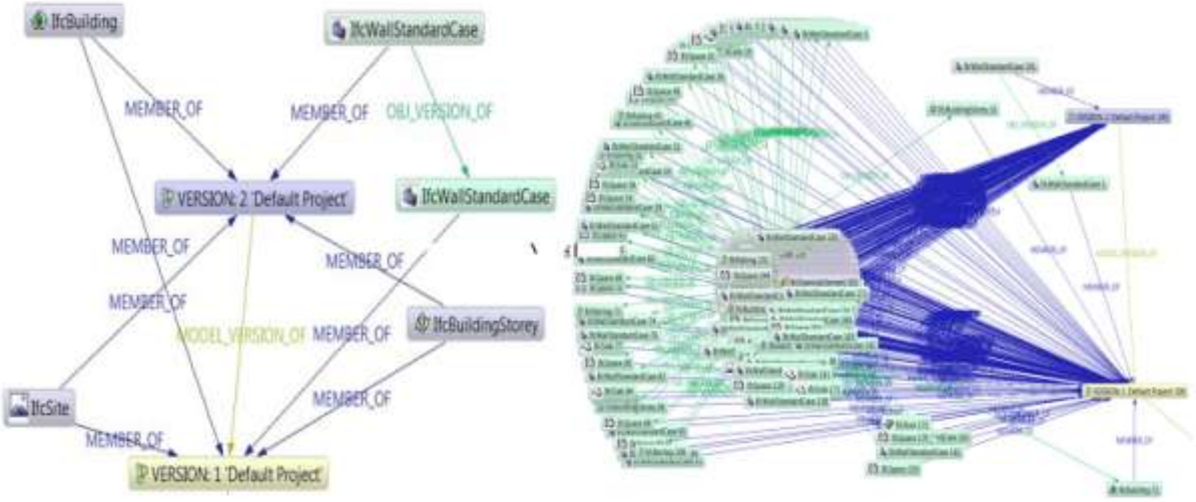

Figure 1 Left: A simple IFC Object Versioning Graph Right: A complex IFC versioning graph. [24]

It has been proven within the context of the InPro project [25, 26] that design management activities can benefit a lot from the application of the model based way of working through an object versioning system that would allow dealing with objects rather than documents. [27]

The above figure (Fig. 1) gives an overview of combining IFC and object versioning through the versioning graph visualization. It can be noticed from Figure (1-left) that a new object version is only created whenever there is a change in the object's attributes' values. If not, then the same object version is shared among several model versions. It can be seen that IfcSite, IfcBuilding and IfcBuildingStorey are shared between the two model versions (1 and 2). Meanwhile, each model version has a different version of the same IfcWallStandardCase. In the same figure (right), a graph of a much more complex model is presented. It can be seen that the shared IFC objects lie in the middle and are shared by two model versions. In the meantime, the objects that are changed and consequently new versions are created lie at the left hand side of the graph.

V. CONCLUSION

The paper has demonstrated the main characteristics of the construction industry, starting from the scale of investment passing through the product characteristics, organizational aspects, clients' categories, their characteristics and behavior, the construction economics and market forces to the Research and Development aspects.

The main conclusion is that: The Construction Industry is a major industry in terms of scale. Its products are very different from the products of many other engineering and manufacturing industries in terms of value, number, standardization and delivery periods.

The construction industry's organization is also different; due to its fragmented nature and the involvement of many disciplines and specialization, which more often than not have diverse or conflicting objectives and interests.

There are various categories of construction clients with very different characteristics. Each category has been discussed in terms of its knowledge of the industry and its nature and in terms of funding sources. The role of the client as the core of the construction process has been emphasized. The construction product should satisfy the client's needs and desires. The problems associated with the inexperienced or "Naive" clients were also addressed.

The main characteristics of the construction economics and how it is differs from other major economic forces was discussed. The effect of fluctuation in demand on the construction domain has also been demonstrated. The main conclusion is that construction companies have the potential to resist closing down at recession times due to its fragmented nature and that booming or recession in construction is always lagging the economy as a whole.

The organizational, funding and Priorities problems of the R&D in construction, where addressed with the aim of giving an image about the retardation of research and development activities in the construction domain, in comparison with other industries like the electronics industry.

The model of the learning organization was introduced with special emphasis on knowledge management and its characteristics.
Finally, the benefits of using object oriented models that focus on semantics as well as geometrical representations of construction products were explained. The role of the object versioning BIM based management system as a substitute to document management system was discussed.

VI. POINTS FOR FURTHER RESEARCH

The capturing of tacit knowledge and structuring its information around BIM objects would be of great benefit to the idea of creation a corporate body of knowledge that is capable of capturing the entire context of a decision making process and enabling knowledge reuse in future similar situations.
Furthermore, the role of CBR together with object based models can be further investigated.

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