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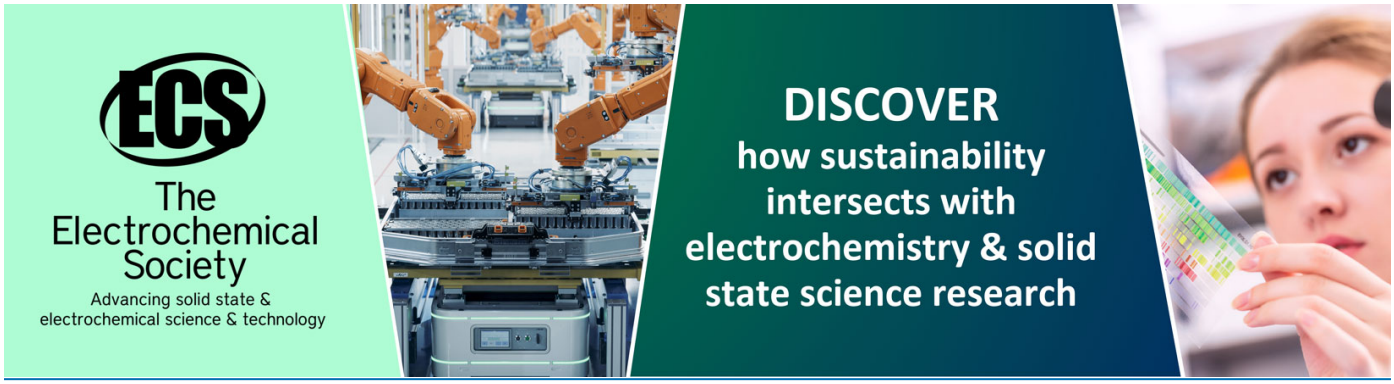

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Abstract. The achievement of value and value-added factor to the building engineering information is accomplished through a chain-flow, that is, building the information value chain. Based on the deconstruction of the information chain on the construction information in the traditional information mode, this paper clarifies the value characteristics and requirements of each stage of the construction project. In order to achieve building information value-added, the paper deconstructs the traditional building information value chain，reengineer the information value chain model on the basis of the theory and techniques of BIM，to build value-added management model and analyse the value of the model.

1. Deconstruction of traditional building information value chain

Porter's value chain theory argues that information is a supporting factor in the value-added process，rather than being source of added value. With the further development of building information, information becomes an important production factors in modern society. Through the development and utilization of information resources, it can also create value on its own behalf, promote each phases of the building engineering value chain, so that each phases of the value chain create greater value. The information flow which can create value is the information value chain [1].

1.1. The traditional building information value chain model

The implementation process of building engineering will continue to produce vast quantity of information. Construction information is created, utilised and maintained by numerous project participants. Sharing different information storage and exchange formats which flows back and forth between building participants, accompanied with capital and logistic flow. This produces a fixed quantity according to the generation and change in pattern and then transported to according departments (Figure.1). Due to the limitation in the mode of information transmission, the information transmission process will cause information loss, form an information fault.

1.1.1. Information value at the decision-making stage. The decision-making stage primarily defines the overall goal of the project, the stage objectives, quantity of project investment, project functions and other aspects, balancing the relationship between project functionality and cost, majority of which implements non-geometrical information to describe the proposed project, the generated information will affect the design and follow-up work.

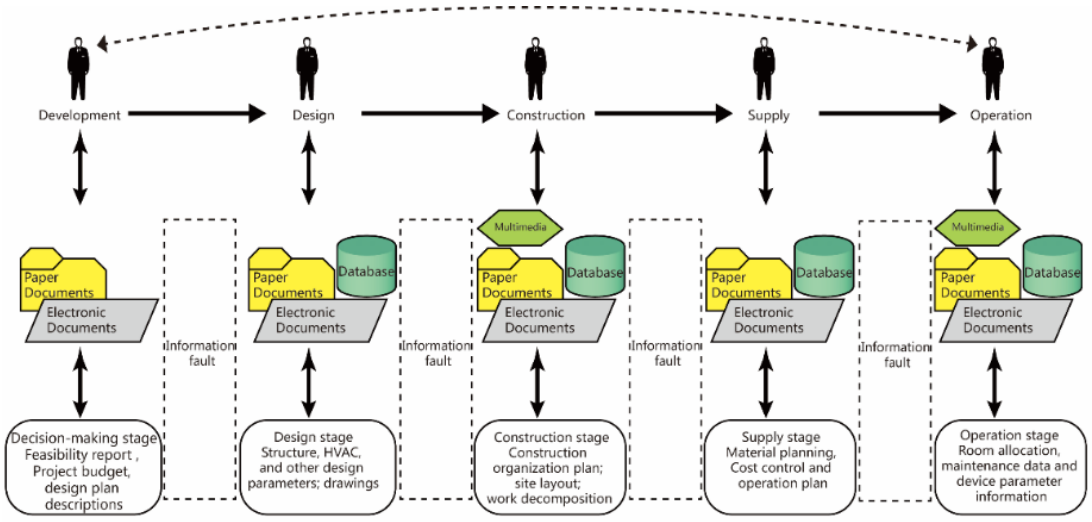

Figure 1. Traditional building information value chain model

1.1.2. Information value at the design stage. The design stage is to produce a technical representation by converting the owner's construction intents, such as the functional requirements and standards into models that can be implemented. Design work requires multi-professional collaboration, the design will ensure that the intended function of the facility is achieved, maximising the owner's intention.

1.1.3. Information value at the construction stage. The construction phase is mainly to establishes the construction plan, building material plan and estimation on the construction cost. The main information comes from the design results, not the direct output of the design information. The information yielded during the construction stage may provide feedback to the design stage, causing alterations in design to optimize the design.

1.1.4. Information value at the supply stage. The supply stage is the process of implementing the plan, supporting the transformation of the design information and the construction plan into building entity. This includes more detailed information, such as additional tools, material procurement and equipment allocation.

1.1.5. Information value at the operation stage. The operation management is mainly focused on the operation and maintenance of the construction project, guaranteeing sustainable use of project protection. This includes facility operation and maintenance, inclusive of facilities management, equipment operation, building maintenance and so on.

1.2. The predicament of traditional building information value chain

Intergrating the above analysis of the construction project information value chain and related literatures [2], problems that arise in project information value chain value-added process are as follows:

1.2.1. Information cannot be shared effectively. In the traditional project stage management mode, the responsibility of each stage is based on the objectives of that stage, so that the sharing and use of the project information are phased. Thereby, it is difficult to control and manage the project information between the stages effectively, resulting in the formation of an "information island" whereby affecting the realization of the construction project value chain value-added.

1.2.2. The loss of information is serious. The traditional staged management mode lacks of direct communication and contact amongst the construction project participants, lead to the loss of

construction project information in the transition phases. In addition, based on the use of both the paper documents and the electronic documents in data transmission, missing information during transcription and data form compatibility restrictions will occur, reducing the efficiency and quality of information transmission.

1.2.3. The backwardness of information media. Traditional information media such as paper media, mail, fax, etc., not only increase the cost of communication, but also reduce the efficiency of information transmission. At the same time, most of these traditional means of communication are point-to-point, which cannot guarantee communication and coordination among multiple participants, and it is difficult to achieve knowledge sharing and value-added information.

1.2.4. Information transmission delay. There are two main reasons for the delay of information transmission: First, the information media is backward, the speed of information transmission is limited by the geographical distribution of the participants; secondly, the hierarchical organizational structure within each participant is not conducive to the rapid transmission and acquisition of information.

1.2.5. The information lacks relevance. Owing to the fact that information creation, exchange and sharing has no unified platform, information on the transition phase thus need to be repeatedly entered. At the same time, due to the application of the parties unable to achieve the association and modification of information, it will also lead to information transmission lag.

2. BIM-based building information value chain reengineering

2.1. BIM concept and characteristics

Building Information Modelling (BIM) can effectively assist the information integration, interoperability and collaborative work in the field of construction industry [3], which plays a crucial role in actualising the building lifecycle management (BLM). The term BIM appears to distinguish between the next generation of information technology, the computer-aided design (CAD) and the traditional computer-aided drawing technology. From a narrow level, as first defined by the National BIM Standard-United States® (NBIMS-US™), a BIM "is a digital representation of the physical and functional characteristics of a facility. As such, it serves as a shared intellectual resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward [4]." From a different perspective, BIM has different characteristics. In terms of the model itself, BIM has the following characteristics [5]:

2.1.1. The objectization of building components. Building components are the basic digital objects of the BIM model, BIM model can represent the physical and functional characteristics of each component, and has intelligent interactive ability. For example, in the BIM model, the door, window and the wall can be automatically combined between the geometric relations and the functional structure to form a whole.

2.1.2. The completeness of model information. In addition to the description of 3D geometric information and topological relation, but also includes a complete description of the project information is included. Such as the object name, structure type, building materials, engineering performance and other design information; the construction process, schedule, cost, quality, labour, machinery, material resources etc. Furthermore, other construction information; engineering safety performance, material durability and, as well as other maintenance information; engineering logic relationship between objects, etc.

2.1.3. The relevance of model information. The objects in the information model are identifiable and interrelated, the system can carry out statistics and analysis on the information of the model, develop

corresponding graphs and documents. If an object in the model changes, all objects associated with it are updated to maintain the integrity and robustness of the model.

2.1.4. The consistency of model information. The model information is consistent at different stages of the building life cycle, to ensure that the same information need not be repeated. Moreover, the information model can automatically evolve. The model object at different stages can be simply being modified and extended without the need to re-create, thereby reducing the errors in information inconsistency.

2.2. BIM-based construction of building information value chain model

The information value chain model based on BIM is constructed on the basis of its framework, which is processed by the following four points：① The basic framework of the traditional Building Information Value Chain as the overall framework of the model. ②Uses the BIM model, the sub-model center database and the network interaction platform as the support base of information value chain operation. ③ The operations of the construction project participant and its phase work is reorganized according to the information input end, the information flow domain and the value output end of the information value chain. ④ The information input end, the information flow domain and the value output end of the construction engineering information value chain model framework are embodied and visualized (Figure.2).

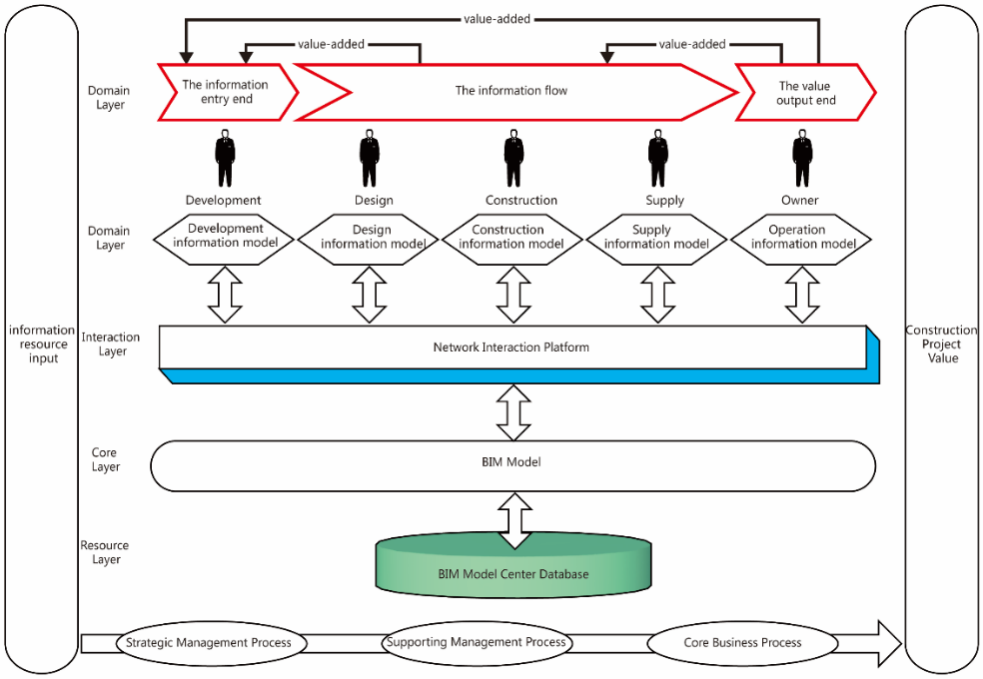

Figure 2. BIM-based building information value chain model

The resource layer is the BIM central database, the core layer is a building information model based on IFC and XML standards, created and modified by the design department, other participants in the building supply chain can invoke the building information model [6]. Interaction layer is the network interaction platform, which can rely on similar project information portal or the Autodesk Buzzsaw application software to achieve. The domain layer is different; the designer creates the design information model, such as architecture or structural design system. The construction contractor creates the construction information model, such as the 4D construction management model; the supplier creates the supply information model, in particular the supplier that provides the prefabricated component, and the owner creates an operational information model, such as a property management system.

The advanced feature of the BIM-based building information value chain is that all sides of the building engineering chain can deliver the BIM documents. The BIM document contains all the building information. The information delivery party then transforms the 3D visual building information model into IFC and XML-based BIM documents, and transmits them to the information receiver through the network interactive platform. After the information receiver opens, it also presents a 3D visual information model of the building.

3. Value-added management and application value of BIM-based building information value chain

3.1. Value-added management of BIM-based building information value chain

In order to manage the information resources in the building information value chain to an orderly, systematic, repeatable and efficient manner, a value-added management framework for the BIM-based building information value chain is established (Figure.3). According to this framework, the management personnel through the use of the information systems accumulates historical information. Via the mechanism of the four steps; information resources extraction, information processing, information resources management, information resources utilization, the results can be obtained to support management decisions. The conceptual framework can solve the problem of low efficiency of the information flow management from the source. The standardization of information, too, occurs before storage, greatly improving the efficiency of information resources processing. This framework will not only play a reference role in grasping the development of information resources utilization technology, but also plays a guiding role for the development of related special software, thereby promoting the development of special software.

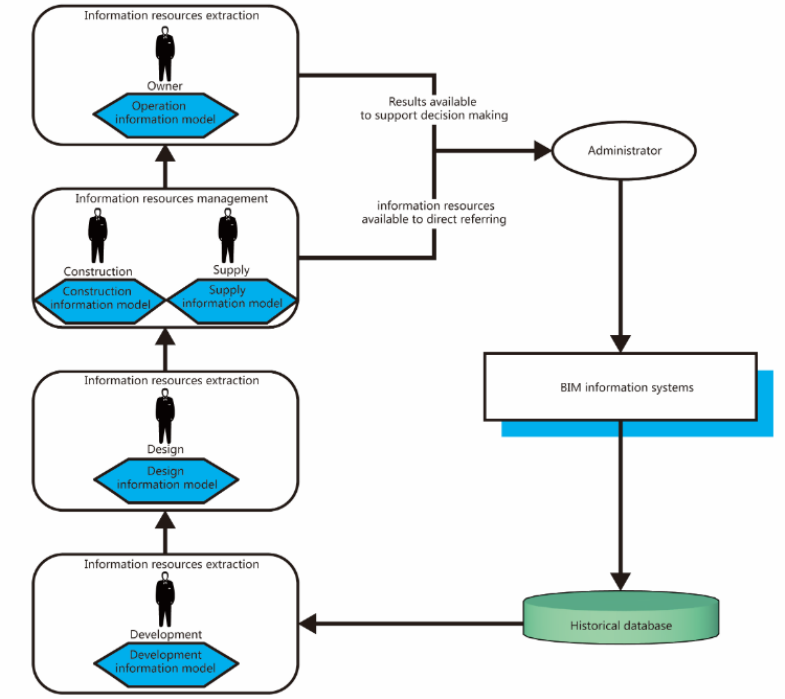

Figure 3. Value-added management framework BIM-based building information value chain

3.1.1. Information resources extraction is carried out in the decision planning stage. Decision planning stage is the information entry end of the building information value chain. The source of the information resources is the information system based on the BIM technology. According to the analysis on project management in construction, to understand and analyse the main content of the project management and information management, there is a need to carry out the typical user research. This summarizes the

essential reusable information resources of the construction enterprise, conducting the first information increment.

3.1.2. Information resources processing in the design stage. The design stage is the information flow domain of the building information value chain. These information resources are derived from the BIM technology organizations, which applies the IFC standard for data exchange. Through the analysis of the information resources and the expansion of IFC standards to effectively represent information resources for information understanding and analysis,–ultimately causing the formation of technical solutions for the second value-added information.

3.1.3. Information resource management is carried out during the construction and supply stages. This is for the construction and supply stages information flow domain of construction engineering information value chain. The third information value-added involves the following three aspects: ① Information resources. Information resources are expressed in the form of terminology used by the management, such as material procurement records, equipment procurement records, project information, etc. The information resources are combined by collecting the underlying IFC data. ② The Decision-making stage. The decision-making stage is the management link in the construction project, which requires the making of decisions. It is necessary to make use of the appropriate information resources as the basis for decision making according to the appropriate management content and situation. ③ The analysis model. The analysis model is a model of information analysis established under certain decision links in the analysis model.

3.1.4. Information resource utilization in the operation stage. The operational phase is the value output end of the building information value chain, combining the characteristics of the BIM for information resources utilization. On the account of the core element of the BIM technology is based on three-dimensional model and is object-oriented, it needs to take into consideration the visualization and intelligence discovery in combination with the three-dimensional model's own characteristics and its core position in the project, thus completing the fourth information value-added.

3.2. The application of the BIM-based building information value chain

The ultimate goal of applying the BIM is to increase productivity, save energy, reduce costs and reduce environmental pollution throughout the design, construction and use of the project. This is consistent with today's advocacy for sustainable development. As a new concept and method, the BIM can overcome the problems in the construction of information value chain, ensuring that the whole life of information is effectively managed and shared [6]. The application value of the BIM-based building information value chain reengineering is mainly reflective in the following aspects:

3.2.1. Implement associated modifications. Based on the BIM development software, in the design stage, the subversion of the CAD era sub-graph design form, directly enables the three-dimensional visual design, formulating the construction of the required plans, elevations, sections profile. The BIM-based software provides automatic coordination and modification function, any changes that occur can be automatically coordinated throughout the project, to achieve flat, vertical and section view of the automatic modification and correlate between different profession's modifications. This not only eliminates the coordination errors among the various professions to improve the quality of the design, but also saves a lot manpower, financial resources and time, promising the realization of subsequent goals.

3.2.2. Information resources extraction is carried out in the decision planning stage. At present, many applications such as structural analysis, energy analysis, project cost and schedule management are supported by corresponding software. However, the application of the BIM differs in that fact that the BIM is a data carrier that integrates information from all participants. Aforementioned, reducing the

need for repetitive input of the same information between the various software and decreasing data errors in the process resulted from human caused. It can improve the reuse rate of information among the participants and at the different stages in the project life cycle, obtaining the necessary information in a timely and effective manner.

3.2.3. Achieve cooperation of each participant. The BIM-based information management required each participating party to work together, to attain this BIM-based information management solution needed to provide network collaboration platform for the project participants in different locations. Web-based collaboration platform is employed to achieve cooperation, information sharing, submission, approval, review and use of the various documents, thereby supervises and manages the construction quality, schedule and cost and other management objectives.

3.2.4. Improve the degree of automation. Prior to the construction process, the BIM technology can be combined with schedule and cost planning to optimize the construction plan, control the whole construction process, improve the quality and assure the safety of construction. This reduces the rework phenomenon, accomplishing the visualized simulation of the actualized construction process to improve the automation of the entire construction process.

3.2.5. Support operation and maintenance activities. The information model based on the BIM integrates the information of the design and construction stage, this information is expanded to form the final information model. Lifecycle information management based on the BIM can maximize the utilization of building information, support the operation and maintenance activities, eliminating the phenomenon that the information cannot be applied in the subsequent stage due to the process fragmentation.

3.2.6. Realize the data interoperability. On the grounds that the BIM ideas itself is based on the perspective of the entire life cycle, installing the foundation of the BIM development in various application software, generally to support the corresponding data standards. Therefore, the fundamentals of the BIM information management can smoothly perform the data calling, interoperability and reduce the cost of data interoperability during the process of data storage, exchange and sharing, hence avoiding the phenomenon of "information island" under the traditional circumstance.

4. Summary and conclusion

In order to achieve the goal of building engineering and create greater value, future studies should be taken on the appropriate strategies and extensive technical details in constructing the building information value chain and identify the problem. In the research process on the building engineering information value chain reengineering, establishing the BIM-based engineering information value chain model, and proposing the framework of value-added management, based on domestic and foreign construction information technology. Construction of building information value chain is complex system engineering. Therefore, in order to achieve the goal of building engineering and obtain more preeminent significance, future examination should be conducted on the appropriate strategies and extensive technical details in constructing the building information value chain, thus bring about the BIM-based building information value chain for broader application prospects.

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