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PRODUCT DATA MANAGEMENT SYSTEMS FOR THE BULK MATERIAL HANDLING CONSTRUCTION INDUSTRY

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ABSTRACT

Product Data Management systems (PDMS) were originally developed to address the data management issues of manufacturing industry and it proved to be a huge success. There is a need to identify the key concepts, challenges and benefits of adopting PDM system for the construction industry with emphasis on design principles. A PDM system qualifies as a platform for integrating construction processes which are essentially multidisciplinary in nature. This involves identification of key requirements and characteristics of the PDM system for construction industry. The methodology involves the adaptation of a PDM system for a section of a Bulk Material Handling construction project. This helps in identifying the factors that contribute for successful project management. The present research also showcases the ability of PDM database to help in design processes involved in construction project. An application (using API- Application Programming Interface) is developed for conveyor design which works in tandem with the PDM system and modeling software's which showcases reusability and automation in design. The use of such data management systems could be the key towards next generation design automation principles that could help improve design productivity along with quality. The challenges to such a PDM system are manifold especially due to the large number of organizations and groups of different characteristics involved in a construction project.

Keywords: Product Data Management, Belt Conveyor, Bulk Material Handling, Design Automation

INTRODUCTION

Construction projects are information intensive in nature where multiple sources of information is gathered externally or derived internally, which are then interpreted, studied and scrutinized for making sound decisions along the different stages of a construction lifecycle. The complex organizational structure and varying nature of projects right from infrastructure to material handling in the construction industry

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have made data management a great challenge for the industry. Large amount of data in different forms inspired the use of different types of document management systems by the industry for managing and processing data. This is mainly because of the fact that Architecture, Engineering and Construction (AEC) decisions are entirely dependent on the data available to the participating protagonists and faulty data being delivered could have negative financial implications for the whole project.

PDM systems were developed as a data management solution for the manufacturing industry, which is basically product oriented in nature. The capability of PDM systems to extend its capability much beyond that of data management solution is a major advantage that the manufacturing industry has capitalized upon. The use of PDM systems for construction industry is an interesting subject of study for researchers. The very difference in the way both the above industries work has demanded changes in the way PDM systems need to be employed for construction projects (Borrmann, et al. 2009). The present focus of research is mainly on understanding the challenges involved and addressing ways to overcome them. Moreover, the advantages of PDM system over data management solutions such as Electronic Document Management (EDM) systems also need to be understood.

Bulk Material Handling (BMH) construction industry is concerned with material handling projects involving large amount of plant construction works including onsite manufacturing. This paper explores the requirements, benefits and challenges involved in employing PDM systems for BMH construction industry. This paper also explores the chances of extending the functionalities of the PDM system to support design automation possibilities in conveyor design in BMH industry.

RELATED WORK

The AEC industry was foremost in enthralling the IT technologies and deploying them in areas such as data management, project management and control, designing and drafting, costing, human resources etc. (Bjork 2002). The role of engineering data management is to store and provide user-friendly access to data during the product's life-cycle according to certain predefined rules. The idea of using shared data models for construction management came up as solution to data management issues (Bjork 1989). Several other product and process supported data models were suggested in later years including the product model developed from COMBINE project (Augenbroe 1995). This led to the idea of integrated data/document management systems for use in the construction industry, but several challenges with respect to product modelling and product data exchange had to be tackled (Hannus, et al. 1995). The lack of suitable data management system in construction plays a major role in inaccurate data interpretation and defective decisions (Shen, et al. 2010). At present with advances in BIM, more research is directed in integrating the building product modeling technique with that of web based document management systems (Bjork 2010). The two major issues related to electronic data exchanges are interoperability and issue of availability of data at right time for the right parties (Schorr, et al. 2011). These were partly addressed by systems such as Electronic Data Management (EDM) systems. However, EDM systems are incapable of fully adhering to the hierarchy of CAD Models. EDM systems can only keep track of the modification of files as a whole but do not have any information about which modification has been performed within the file causing information granularity problems with respect to locking of files during modification. This may cripple the capabilities of EDM for modifications

tracking. These establish EDM systems as document oriented rather than component-oriented (Schorr, et al. 2011).

Helms (Helms 2002) in his Ph.D. thesis provided valuable information regarding the development of PDM system. The research showcased the development of a suitable product structure along with a data model that compliments the features of a PDM system. It is understood that web based infrastructure can address the complex and dynamic characteristics of PDM over a global environment. Web infrastructure makes PDM systems more flexible and effective for data management (Liu and Xu, 2001). Despite the popularity of PDM systems in manufacturing industry it is not found suitable for civil engineering projects. The main reason for this is pessimistic concurrency control practiced by PDM systems. The required amount of granularity required for PDM systems could not be satisfactorily achieved in large monolithic construction files (Borrmann, et al. 2009). PDM systems could be the ideal interim technology for managing construction data and documents which could pave way for model based planning (Schorr, et al. 2011).

PDM SYSTEMS IN BMH CONSTRUCTION

PDM systems are similar to EDM systems which are in wide use in the construction industry (Bjork 2002). Both of these data management system essentially consist of a database containing the metadata and a vault containing the original data. PDM systems are developed from EDM by enabling the system to handle CAD model data (Schorr, et al. 2011). The ability of the product oriented PDM systems to handle product structures and its breakdown makes it superior to document oriented EDM system. This allows the PDM to incorporate software modules which could use the data stored in the system for project management purposes. These features make PDM the ideal candidate for supporting model based BIM solution for BMH industries. PDM systems are capable of deep integration with CAD rich clients as well as thin clients. The process of associating information with products allows natural detailing of information in line with the structure of the product. For example, if a belt conveyor section is considered, its CAD model consists of an assembly of several different components. PDM based design data management systems are able to follow the structural breakdown of the CAD models and tag in information with each individual part. This helps the users to work in more details at part level in the models without locking away the entire conveyor assembly. The products or components are considered here as objects with attributes forming the basis of model based data. The challenge for construction organizations for adapting PDM is due to the fact that construction is not product oriented unlike the manufacturing industry. For construction industry the engineer is given the task of providing a logical structuring of CAD model data for storing in the PDM system and at the same time ensuring that desired granularity is achieved (Borrmann 2009). Here, a section of a BMH construction project, involving a conveyor section is considered for applying PDM. The system under study is primarily mechanical in nature and could be viewed from the perspective of product structuring. PDM systems provide better visualization of the CAD model data and include modules that could generate BOM documents and scheduling documents. Hence PDM systems are able to stretch its capability beyond design data management tasks to project review tasks. PDM systems are capable of sharing database with external systems such as Enterprise Resource Planning (ERP)

for purpose of carrying out non-engineering tasks such as human resource management as well.

Functional Requirements of PDM for BMH

The large amount of mechanical fabrication and erection happening in a BMH projects makes it an ideal subject of interest for studying the deployment of PDM systems in construction. The present sample project under consideration consists of a conveyor section as explained earlier. The first task is to identify the requirements of a PDM based data management system for BMH. After extensive literature survey a set of requirements are identified from previously available literature (Hannus, et al. 1995; Helms 2002; Schorr, et al. 2011) and a questionnaire survey is conducted to identify the list of major functions that the PDM system must satisfy (Suresh Padma, 2013). These functional requirements form the base of a PDM system. The main functional requirements have been listed as given below.

1. Secure storage of documents and objects in the database along with detailed definitions of access rules for document transaction should be essential for a system like PDM supporting concurrent engineering. The access rules should be able to define guidelines for check-in/check-out of the files inside the database.
2. Management of revisions, versions and variants of data stored inside the database. Revisions are of permanent data sets which is stored permanently inside the database whereas versions are obtained by making minor changes to the existing master file. PDM systems should have the provision for generating any number of versions of master data set to promote design reusability and pave way for evolution of designs.
3. It should be possible to add attributes to the existing data set, which is critical for search and retrieval functions inside the database.
4. The PDM system should be able to represent the hierarchic data models with attributes clearly defining the relation between the parent and child data sets.
5. The PDM system should support configuration management and engineering change control. The PDM system should be able to track modifications of all versions and variants including information regarding the specific modification performed (change traceability). PDM systems should be able to track changes between as designed, as planned and as built configurations of a project.
6. Ability to provide neutral file formats of the data stored. Since multiple users work on the same data, it is necessary for the PDM system to provide a neutral data format which could be used by the user even if the client software's working on the data to be processed are different
7. The PDM client software should be able to provide a brief overview of the project. For construction projects these overview would include a visualization of the CAD model data, the status of the data indicating data maturity etc.
8. PDM system should have deep integration with the rich clients which use the data inside the database. Consistency of data needs to be ensured during check-in/check-out processes.
9. Workflow management is a desirable function that the PDM should be supporting. Engineering change requests is channeled through PDM systems supporting tamper proof workflow support.

10. PDM systems should allow documentations to be tagged with CAD models inside the database. The PDM database should be open for customizing, according to the projects undertaken by the organization. Workflows are mostly unique to each organizations and it is necessary that the PDM system is customizable enough to support it. The GUI should also be customized specific to the organization.
11. API is essential for a PDM system so as to create electronic workflow templates when needed. The API interfaces could also help in extending the capabilities of the PDM system beyond design data management. PDM for construction should have the functional ability to store 4D BIM models and have provisions for design transaction between BIM software's.
12. Product structuring needs to be done for the data to be stored inside the database. The logical product structure pertaining to the civil structures in the project has to be defined with clarity to avoid any granularity issues.

The applicability of PDM systems to BMH projects are attributed to the similarity of BMH construction industry and manufacturing industry. These requirements have been identified as suitable for a PDM system to be employed for BMH project. The ability of PDM to support interoperability of the rich clients utilizing the system is one major advantage. Based on all these functional requirements, Autodesk Vault is chosen as the PDM system and will be handling the design data management of the sample BMH project under consideration. The individual part models were generated using the Autodesk Inventor 3D CAD software.

Employing PDM

A PDM system named 'Conveyor -PDM is created with the above mentioned software tools. The main tasks involved are defining the attributes, relations and product structure which govern the version management characteristics of the system. Attributes are data that describe the data stored in the database. Here in this particular project attributes refer to data such as name of document, author information, product id, file type, file size or any custom defined properties of that particular data. Relations exist between each Super-type (product), Sub-type (components), Documents, Versions and Variants (Helms, 2001).The relations in the 'Conveyor-PDM' are provided automatically by the Vault software when the object is checked into the Vault database for the first time. The relations are defined strictly in line with the defined product structure. Version management is considered as one of the most important features of a PDM system. In this particular project when a part document is checked out, only a copy of the original master file is being sent to the client software. The file in the PDM is locked, thus protecting the original data and practicing pessimistic concurrency control due to which only one user can work on a single file. After modification a new version of the document is created which is stored in the database. The modified model along with the version history could be visualized through the Vault GUI and hence allows for comprehensive modification tracking. Product structuring is another important aspect in the Conveyor-PDM system. Defining a product structure is one of the main steps for developing a PDM system. Product structure is responsible for ensuring required level of granularity and thereby ensuring that the large models are not locked for a long time for modifications. Conveyor-PDM mainly consists of data pertaining to mechanical construction and hence is much easier to define a suitable product structure. The whole PDM system is developed based on the product structure of the conveyor

assembly. For this the data model is defined according to which data is stored inside a PDM system and the data model in Conveyor PDM system is as shown in figure 1 below. The developed Vault Conveyor-PDM system is as shown in figure 2.

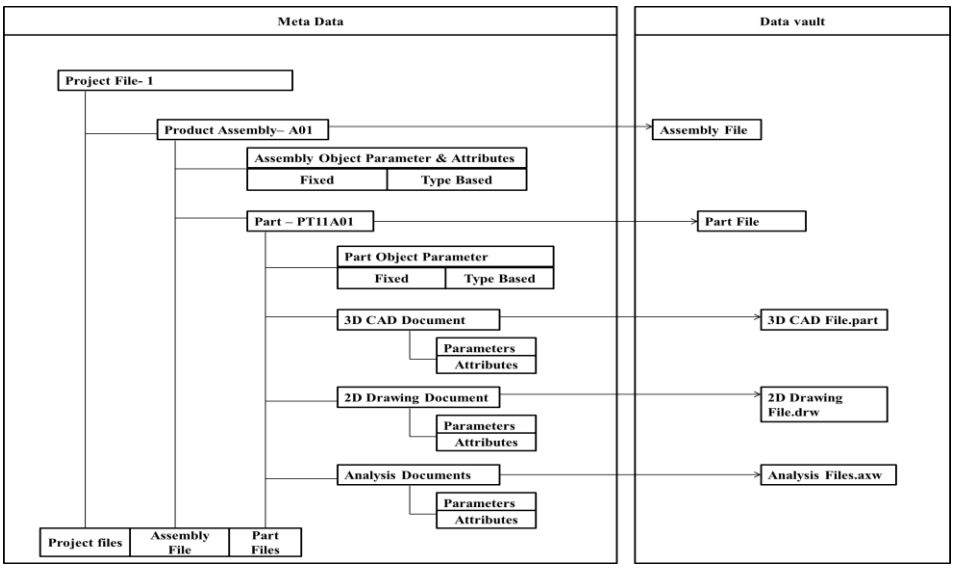

Figure 1. Data Model for ‘Conveyor-PDM’ system

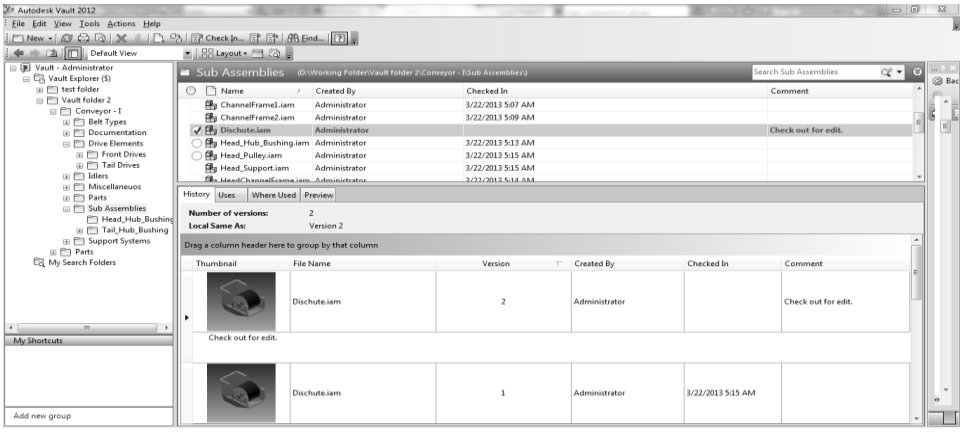

Figure 2. 'Conveyor-PDM' system

BENEFITS OF PDM SYSTEMS FOR BMH

The key advantages of PDM systems for BMH were identified from the sample project 'Conveyor -PDM'. This is done by comparing this system with the already existing system in which this project is implemented. From the comparison these advantages over the existing system have been identified by the user group. They are

1. Excellent version management in PDM allows the user to track the evolution of design from the beginning itself.
2. Availability of data in structured format makes it easier to assess the present status of the project. PDM systems also support model based construction management and has provisions to generate reports for the same.

3. Documentation could be attached along with the model itself in the Vault PDM system. In construction projects, along with the models, documentation such as quality reports, contracts, regulations, pictures etc could be attached. The design transaction process in PDM system is rule oriented in nature. There are provisions for defining access rights and roles for all the users.
4. PDM systems could also be operated across multiple working groups or even organizations. Some of the PDM systems provide web clients along with their rich client which helps to conduct project reviews from across the globe. The level of customization offered by PDM system is also appreciable.
5. PDM systems could be used conveniently for 5D BIM modeling as it allows for construction time and cost data with the model. PDM could be integrated with external systems such as ERP or MS SharePoint etc.

DESIGN AUTOMATION USING PDM SYSTEMS

Design processes in construction organizations are tedious and time taking in nature. This is mainly due to the fact that construction designs involve designers from a wide spectrum of multidisciplinary interests. PDM is capable of reducing the bulk of the data management issues related to design. The aim is to explore the possibility of using a PDM database for designing a conveyor system and generate a 3D model for the same. The model so generated promotes model based data management for construction. The generated model could be utilized for multiple purposes including BIM applications, engineering analysis etc. For this purpose a Plug-in (for conveyor design) is created which demonstrates the possibility of such a system (Suresh Padma 2013). The key to implement such an automation system is based on 2 main factors. The first one involves the effectiveness with which the design workflow of conveyor section is captured and modified to suite the PDM system based design procedure. The second factor involves establishing rules of communication based on design data between the users, PDM database and modeling rich client. This type of design rule based interaction is achieved in the plug-in developed for testing this concept. The Plug-in developed is based on the 'Conveyor-PDM' system.

CONCLUSIONS

The use of PDM as a design data management system in bulk material handling construction projects is desirable considering all the advantages and functionalities they can offer. The close resemblance of BMH construction projects with manufacturing industry makes PDM employment much smoother in the present scenario. PDM system possesses certain disadvantages when it comes to civil engineering designs due to the pessimistic concurrency control it exercises. This could be overcome by using PDM systems specifically made for AEC work. 'Conveyor-PDM', the PDM system developed for the sample project showed that product structuring is a very important procedure to be carried out in employing a PDM system. Product structuring helps in maintaining required granularity of data and hence maintain relationship between different entities stored in PDM database. The Plug-in developed for automation of design of conveyors put forward the idea of design reusability in construction projects. These kinds of automations could be adapted by construction organizations which indulge in performing design workflows

of repeating nature. This could considerably save time and cost involved in design transactions. It enables the users to concentrate on improving the design and corresponding documentation rather than creating a design. Further research needs to be conducted to identify issues related to coupling of PDM systems with external systems such as ERP, moving towards the goal of achieving fully integrated system for construction project management.

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