"The management of information over the life-cycle of a construction project using open-standard BIM"

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Abstract

It is well recognized that the management of information in the life-cycle of construction projects is often inefficient and error prone. The use of a Building Information Model (BIM) and Systems Engineering ontologies provide solutions for specific Information Management problems. In projects where the Systems Engineering methodology is applied, breakdown structures are defined that provide an ontology in the building information. In the concept presented in this paper, based on the Dutch open-standard COINS, the building information is preserved in its ontology and an object type library is used over the life-cycle. The BIM contains the Systems Engineering breakdowns, all required documents, physical representations of objects (models or GIS) and library references for all objects. It is used to store and transfer building information across the life-cycle stages. The benefits of the concept and a case-study are described.

Keywords: BIM, COINS, Systems Engineering, object types, information delivery, life-cycle

1 Introduction

In the life-cycle of construction projects many actors are involved that share information. The management of this information in the life-cycle is often inefficient and error prone. Through the different phases information gets lost, is misinterpreted, copied to other formats and structures, stored in different locations and comes with an implicit structure or no structure at all.

The information and knowledge exchange between life-cycle phases is limited and mainly based on the exchange of documents and 2D drawings (Adriaanse, 2014). Although within the different phases intelligent information is often available. Research of USP Marketing Consultancy (2010) shows that this poor information-exchange and communication is the main cause of failure cost in the Dutch construction industry. Therefore, a better information management during the life-cycle of construction projects is the key to cut failure costs and to improve overall project results.

This paper describes the use of Building Information Modelling (BIM) for this information management in the life-cycle. The challenges for improvement are explained and a BIM-based approach to overcome these challenges is presented. The benefits of this BIM approach are explained and a case is described in which it is applied. Next, conclusions are drawn on this approach with recommendations for future development.

2 Fragmented information

The construction industry is fragmented in three ways (Adriaanse, 2014). The first is the fragmentation in phases in the life-cycle of construction projects, generally recognized phases are: initiation, design, construction and the operation and maintenance phase. Typically there is a clear separation between the phases with formal information deliveries after each phase. As a result information and knowledge is lost in the delivery to the next phase.

The second recognized form of fragmentation is the fragmentation in different groups of actors in a project. Each construction project has its own network of actors changing over time. These actors have their own stakes, tools and way-of-working.

The third form of fragmentation is the fragmentation in various unique projects with a lack of learning and standardization between projects.

This fragmentation has an impact on the sharing of information in the life-cycle. After a phase the whole package of information is delivered to the next phase. Figure 1 schematically shows a typical information exchange process in a construction project recognizing the aforementioned fragmentation in phases and actors. The arrows indicate the information deliveries in the life-cycle. The different actors involved need information to start their process, perform their task and deliver information to the other actors involved. In practice this often is an iterative process.

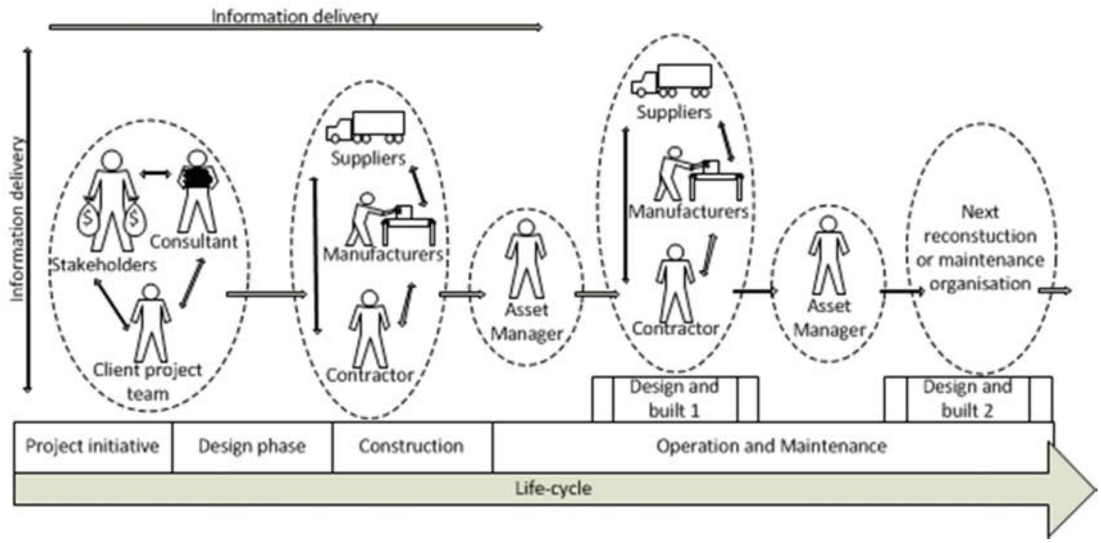


Figure 1: Information exchange in the life-cycle of a construction project showing the fragmentation between actors and phases.

The process shown in Figure 1 is an illustration of a possible situation. The exact split of phases and actors involved in the different phases might differ for each project. In general the operation and maintenance phase forms the major part of the life-cycle. During the operation and maintenance phase projects may take place for reconstruction works or large maintenance activities that require their own project organization (shown in Figure 1 as Design and built 1 and 2).

Although this fragmentation exists, there is a strong interdependence between the fragments (Bankvall et al. 2010). The processes, activities, techniques and operations have an overlap between phases, actors and projects requiring information and knowledge sharing between the recognized fragments. BIM provides a potential solution for the information management problems caused by this fragmented nature.

3 Life-cycle information management with BIM

There is extensive research available on life-cycle management of construction projects, but little attention has been paid to life-cycle *information* management (Xu et al., 2010). BIM offers the potential for information management in the life-cycle of construction works. A basic premise of BIM is collaboration by different stakeholders in different phases of the lifecycle to insert, extract, update, or modify information in the BIM (NBIMS, 2007, p.21).

Figure 2 is a well-known figure from the BIM Handbook showing the information transfer between different parties over the different phases of construction projects in time. It indicates that with BIM, amongst organizational and contractual changes, the loss of knowledge between these phases (gap) can be prevented.

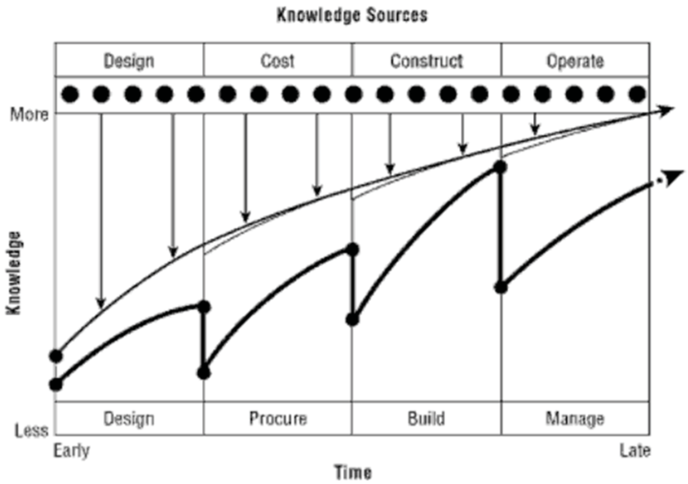


Figure 2: the information transfer between different parties over the different phases of construction projects in time (Eastman et al, 2011).

However, the potential value of BIM in life-cycle management is routinely underutilized. As a technique, BIM has been used by different participants, but the potential of BIM in lifecycle information management has not been taken into full account.

The fragmented nature of construction projects has led to the separated application of BIM in different stages of the project life-cycle (Xu et al, 2010). BIM can bridge the gap between the different fragments in the life-cycle (Adriaanse, 2014). Therefore an approach is needed for BIM in the whole life-cycle. The authors of this article suggest a specific BIM based life-cycle approach to attain the potential of BIM.

4 BIM-based life-cycle approach

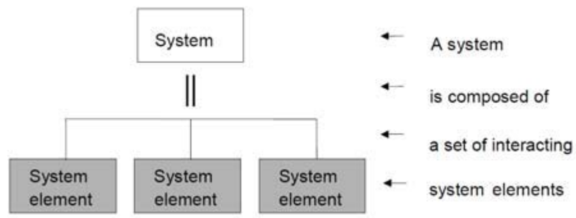
The suggested BIM approach focusses on a BIM in which the building information is stored with a preserved data ontology. In this approach the BIM contains the following information:

- Systems Engineering breakdown structures;
- All required documents;
- Physical representations of objects (3D models or geographical information in GIS);
- Object functions, specifications and properties;
- Library references for all objects.

The BIM is used to store and transfer system information across the life-cycle phases. This BIM is shared using COINS with object type-libraries for standardization and a structured information delivery using the Dutch/ISO open-standard VISI (Nederveen et al., 2010).

4.1 Systems Engineering ontologies

The Systems Engineering methodology (ISO/IEC 15288, 2008) provides a life-cycle approach for all types of technical systems. The interdisciplinary approach focuses on needs and required functionality of a technical system during its life-cycle. Also, it provides different ways to structure building information, like the System Breakdown Structure defining all objects in the system. Because Systems Engineering is interdisciplinary, this System Breakdown structure can be used for the breakdown of sub-systems of all disciplines involved. Figure 3 shows the methodology of defining the System Breakdown Structure SBS).



This SBS and the other breakdown structures (i.e. function-, work-, organization-, and requirements-breakdown) can be used throughout the life-cycle as a core-model for the management of all related building information (e.g. documents, drawings, model representations, costs, project schedule, verifications). The building information can be managed around the objects as defined in the SBS. BIM is used in this process to store all this object-based information with the semantics as defined with the Systems Engineering methodology forming the whole ontology of information.

4.2 COINS

To be able for all involved actors in the supply chain to be able to work with this BIM and deliver it to a next phase efficiently, an open-standard BIM is required. The presented approach uses COINS for this.

COINS is an open BIM standard that is developed by a Dutch consortium of various governmental authorities, contractors, educational and research institutes (Nederveen et al., 2010). Its target is to facilitate information exchange by a flexible structure as a stepping stone to connect all the information related to a specific building object during its total life cycle. This flexible structure is characterized by the following features:

- Both object-oriented data as well as document-oriented information, offering the opportunity to support the maturing of a company's BIM level from principally document-oriented exchange to more and more object-oriented exchange;
- Open interfaces to companion standards as for example BuildingSmart IFC or OpenGis GML;
- An extendable base model using so called reference frames: specific models aimed for certain disciplines as costs calculation, planning, strength analysis, etc.;
- An integrated relation with object type libraries as a dynamic means to extend the semantics of an exchange;
- A built-in version management structure for capturing the complete history of each information object;
- A structure to facilitate collaborative engineering by assigning the permitted information access for each partner;
- A fully linked-data approach by specifying a URI identifier for each information object;
- A BIM-container interchange format.

The first release of COINS 1.0 was launched in June 2010 and recently (December 2014) an update (COINS 1.1) was published (COINS consortium, 2014). At the moment the technical committee is preparing a mayor release (COINS 2.0) to be fixed by the middle of 2016. Expectations are that COINS 2.0 will simultaneously be released as an ISO standard.

4.3 Object type library

A BIM will contain data that describe a specific construction object in various stages of its life cycle. This information need not always be specific for this object instance but may also be of use for the category the construction object belongs to. Typically this kind of category specific information could better be stored in a separate object type library that can be referenced by other BIM's that hold construction objects of the same category.

An object type library may be part of a hierarchy structure referencing supertype libraries on a wider scale (national, international), or in its turn be referenced by subtype libraries on a narrower scale (company, project). Object type libraries typically address a more dynamic way of recording object type data in contrast with the more static way object data standards are captured. The combination delivers the best of two worlds: the semi-static BIM modelling structures should be fixed in standards (e.g. COINS) while the modelling structures that typically have a shorter life cycle are better recorded in an object type library (or libraries).

In the Netherlands a start has been made with the development of a nation-wide object type library (CB-NL). Concurrently the Dutch ministry of Infrastructure (Rijkswaterstaat) develops an object type library for its asset types (highways and waterways), while the Dutch railway authority (ProRail) is doing the same for railways. Eventually these initiatives will be harmonized by reallocating object type specifications and extending from the national library.

Besides the enhanced semantics that are offered by object type libraries, information delivery contracts may refer to one or more libraries to state the information needs that must be fulfilled by the sender of information at a transaction. Preferably, the object-library of the future asset manager is used from start of the project. The asset manager can assure feedback of the right information by the actor responsible for construction. Each actor or sector can maintain their specific object type libraries (narrow scale) as long as they are allocated to a supertype library for harmonization.

4.4 Information delivery

Next to the described formalization of the content of BIM using Systems Engineering, COINS and object type libraries, a formalization of the information transaction is applied in the suggested life-cycle Information Management approach. The suggested approach makes use of VISI. VISI is an open Dutch process standard that also is published as an ISO standard (ISO 29481-2). Its purpose is to formalize the communication process between the actors of a construction project. This is achieved in two steps:

1. The specification of the various transaction types between the participant role types of the project and further detailed in the various message types that may occur in each transaction type. This specification is called the interaction framework;
2. Using the interaction framework to control the actual exchange of messages between the parties that fulfill the roles of the transaction.

VISI and COINS are mutual companion standards: where VISI manages the actual information transfer between partners, COINS manages the content of the message. The interaction framework is formalized in an Information Delivery Manual (IDM). The IDM is a formal document (an appendix to the tender contract) that specifies the information set(s) that should be delivered at the various information transactions during the realization of the construction project.

5 Benefits of the approach

Several benefits of the suggested approach for life-cycle Information Management are recognized. The recognized benefits are:

1. Information structure: a clear object-based structure in all building information based on the System Engineering breakdowns.
2. Information semantics: semantically rich information by using harmonized libraries and a fully linked-data approach.
3. Information ontology: All information is linked to the Systems Engineering breakdowns providing an ontology. A complete integrated information model is delivered instead of bulks of documents.
4. Standardization: Different projects, actors and phases use the object type library of the asset manager allocated to a supertype library containing standardized items.
5. The right information: IDM and VISI for formal information transactions between actors, addressing the information requirements of actors involved over the life-cycle.
6. No loss of information: Delivery of the BIM containing all building information in its ontology and in an editable format overcomes misinterpretation and a lot of rework.
7. Interoperability: COINS is an open-standard for BIM that everyone can adopt in their discipline or company specific software without having to buy software from a vendor. The interoperability means less rework, errors and other issues for information transactions.

6 Case description

The project Traverse Dieren consists of the underpass of the motorway N348 at the municipality of Dieren near Arnhem in the Netherlands. The N348 passes the center of Dieren near the railway station as shown in Figure 4. Construction works will start in 2016 and completion of the project is planned for the end of 2018. The client is the Provence of Gelderland and currently the project is tendered.

Figure 4: Screenshot from the 3D model of the Traverse Dieren project showing the future underpass near the railway station of Dieren, The Netherlands.

In this project the suggested BIM approach is applied. Starting from the project initiation and design phase all relevant building information was gathered and structured in a so-called COINS container (a ZIP file with a standard folder structure). The BIM (COINS container) delivered by the client to the future contractor contains the following information:

- Function definitions, interfaces and project requirements;
- Object and scope definitions referring to the Province object type library;
- Preliminary design drawings (PDF) for the different objects;
- All relevant project documents;
- Geographical references (GML) for all objects.

The project team of the Province succeeded to gather all this information in a validated COINS container. After the current tendering process, this COINS container will be provided to the selected contractor as the file with all building information.

An IDM is part of the contract documents formalizing that the contractor is required to continue working with this BIM based on COINS. The contractor will deliver a complete building information model to the client every 4 weeks using COINS. This regular exchange of the building information enables the project team of the Province to check and validate the project progress based on complete, semantically rich and structured information. Also it enables the Operation and Maintenance Department of the Provence (future Asset Manager) to ensure that the projects will meet their requirements. Without the IDM and the use of COINS, the as-built information would only get to the Province at the end of the construction phase in one bulk of data.

The final hand-over of project information at project delivery will also be a COINS container for the Asset Manager. An interface for their Asset Management software is being prepared to be able to read COINS containers and import all as-built data to the Asset Management system automatically.

7 Conclusion and recommendations

The presented approach using Systems Engineering, COINS, an object type-library and VISI provides seven specific improvements for the management of building information.

The described case Traverse Dieren shows the successful implementation of the approach in practice. From this case it can be concluded that the suggested approach is feasible in the initiation and design phase.

Another implementation by the Dutch government authority Rijkswaterstaat in the project SAAone (highway A1/A6 project) shows feasibility of the approach for the delivery of building information by the contractor to the operation and maintenance phase.

Based on the case as described in this paper it can't be concluded (yet) to what extend the known information management problems in the life-cycle are solved.

The suggested approach that combines the four concepts described is still innovative. The Provence of Gelderland is one of the first public authorities in the Netherlands who enforces the use of COINS in its projects. Rijkswaterstaat is the main authority applying and promoting COINS and who adopted COINS as the preferred standard for BIM data exchange with contractors. Various large infra-projects are, or will be, using the COINS standard for the delivery of asset management data to Rijkswaterstaat, a.o. the following are known of: N31 Traverse Harlingen, A9 Tunnel Gaasperdammerweg, Knooppunt Joure A6/A7, Keersluis Limmel and 4 more projects starting this year.

Because the approach presented is innovative a lot of actors in the construction industry still have to adapt to the open-standard COINS. The more this standard will be used in future, the higher its value for interoperability. Also, the development of the national object type library CB-NL and harmonization with the existing libraries of actors will increase the benefits of the approach presented.

Next to these developments more research in the existing cases and new case-studies are required to be able to measure the benefits of the approach in terms of failure costs and efficiency of information management over the life-cycle.

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