A Definition of Model Information Content for Strategic BIM Implementation

Hooper, Martin; Ekholm, Anders

Published in:
Proceedings of the CIB W78-W102 2011: International Conference –Sophia Antipolis, France, 26-28 October

2011

A DEFINITION OF MODEL INFORMATION CONTENT FOR STRATEGIC BIM IMPLEMENTATION

Submission No: 21
Martin Hooper, PhD Student, martin.hooper@caad.lth.se
Anders Ekholm, Professor, anders.ekholm@caad.lth.se
Design Methodology, Department of Construction Sciences, Lund University, Faculty of Engineering, Lund, Sweden

ABSTRACT

In response to the increased early workflow implied by BIM processes it is important for design consultants to focus on creating and communicating information that is critical for its purpose (Jernigan 2008) - be it model content for 3d Design Coordination at scheme design stage, or Cost Estimation at Design Development stage, or generation of a suitable Record Model for Facilities Management. Today, with many of the technological matters of integrated information management dealt with (perhaps excluding the matter of interoperability), defining the content and status of BIM information deliveries remains both a practical and theoretical problem.

A development of a participant-friendly method of articulating BIM content is required to clarify what information is needed when and conversely what information is indeed not needed to implement a BIM process at a particular stage in a construction project. Priority must be placed on the information that is vital for current tasks without getting distracted by desires to populate models with additional or other information or objects masking the absence of key information. Here there is a lack of existing knowledge to solve this practical problem.

New BIM tools and new design processes and procedures have led to a certain confusion of what information is needed when for particular BIM uses. This report seeks to explore and enable a method of defining the content of model information deliverables through a review of 2 key primary specific BIM uses: 3d Design Coordination and Early Energy Appraisal through an analysis of practical application.

The scope of this study is limited to a review of information flow within residential projects in a Swedish context and looks at two case projects with a view to identifying and establishing a common definition of the key BIM objects and properties necessary for particular tasks. The study follows a case construction project together with an experimental pilot design project with the purpose of extracting and recording what data is needed to carry out parallel and sequential BIM uses with optimised efficiency. By mapping both processes and the precise information needed to successfully carry out tasks, improved productivity can be realised and a greater quality of design output produced.

The key deliverable from this study is the BIM-Info Delivery Protocol (IDP) which attempts to align consultant BIM-Info delivery expectations and represents a tangible solution to assist consultant disciplines manage BIM-Info.

Keywords: BIM, Building Information Modelling, information exchange, model information content.

1. INTRODUCTION

1.1 Background to Study

The context of the study is directed toward the Swedish Design-Construct-Operate (DCO) sector where the concept of Leveransspecifikationer (Delivery Specifications) is suggested within the national guidelines for digital information management: Bygghandlingar 90 – Byggsektorns Rekommendationer för Redovisning av Byggprojekt – Digital Leveranser för Bygg och Förvaltning (Swedish Standards Institute, 2008). These guidelines recommend the use of delivery specifications to accompany exchanges in digital information at all stages of the design, construct and operate process. However, there is a lack of concrete advice on how to develop information delivery specifications for defining and recording BIM-Info content in connection to or supporting a project based strategic BIM Implementation Plan.

1.2 Goals and Research Questions

This study consists of two goals. The first is to explore and enable a method of defining the content of model information deliverables through a review of 2 key primary specific BIM uses: 3d Design Coordination and Early Energy Appraisal through an analysis of practical applications. The second is to design an associated process that ensures integration of information deliveries into a project plan thereby securing greater certainty and efficiency of information exchanges.
The central questions for this goal are as follows:

- How could BIM-Info delivery content be articulated in a commonly understood manner on a project basis?
- Could a standard matrix be established that could be used for various BIM-Uses at various project stages that would help align information delivery expectations?

To answer these research questions five sub questions are answered:

- What BIM-Info is need at what time to enable efficient BIM Discipline Authoring toward e.g., swift 3d Design Coordination at Design Development Stage?
- What BIM-Info is not needed? – Clarity is needed on what BIM-Info is not relevant at particular stages.
- What level of detail is needed to carry out BIM-Uses at various stages?
- Is there a logical information order?
- What is the logical information order of authoring BIM-Info for early Energy Analysis when it comes to generating BIM objects?

2. METHODS

2.1 Research Framework

The research, being the foundation of this document, is orientated towards a practical investigation of real-world processes through observations made during attendances of design team co-ordination meetings and empirical data recorded from an experimental building design project.

2.2 Data Collection and Case Description

This study involved empirical data collection from a (real world) residential case study project together with data collected from a controlled experimental model:

- Case #1: Koggens Gränd - Malmö's first owner-occupier flats.
- Case #2: KonsultHus - An Experimental Coordination Model

2.3 Case #1: Koggens Gränd

Located in the Västra Hamnen area, Malmö, Koggens Gränd is an innovative new residential block with occupancy expected through 2012. As part of a larger development incorporated in the regeneration of Västra Hamnen the scheme presents 31 owner-occupier flats, between 45-72m2.
Prior to May 1, 2009 in Sweden it was not authorized to build owner-occupier flats as new build or through renovation of existing buildings. Koggens Gränd represents one of Sweden's first residential building containing owner-occupier flatted units on a larger scale.

Figure 1: Koggens Gränd – Source: White

The researcher followed this project through its early stages, recording matters relating to 3D Design Coordination and collected further empirical data relating to requirements and procedures for this BIM-Use. In addition, common current practice methodologies were documented with a view to identify key issues to address. Through this case study, a thorough examination of the common issues hindering work-flow of 3D Design Coordination and early Energy Analysis operations was enabled.

2.4 Case #2: KonsultHus - An Experimental Coordination Model

Empirical data reflecting the results from this experimental model, which was developed and used by the author for this study, has enabled collection of further, more detailed information, eliminating unwanted variables, and facilitating a more precise examination of objects and properties required for 3D Design Coordination. 3D Design Coordination implies close collaboration and, on complicated projects - a frenzy of information exchange. For this reason it is critical to record and optimise information flow for this BIM-Use. Here it was examined what BIM-Info one needs to share with each other to allow for example:

- the MEP consultant to proceed with design for plant requirements, ventilation duct sizing and routes, plumbing fixtures and pipe routes, drainage integration, incoming service routes and;
- the Structural consultant to proceed with design for the foundations and structural frame.

It is clear that in order to optimise design information production and flow, parties must have at least a modest understanding of each other's information needs and, moreover; if you are not specific about the information you need, how can you be certain you'll get it?

Complaints of holding each other up because of lack of design information, or deliberately holding back design contributions until 'the architect has frozen the design', no longer washes with today's parallel BIM processes and collaborative design environment. Through this case study, an experimental exchange protocol was tested to help monitor the creation, distribution and timing of discipline BIM objects on a need-to-know basis.

3. A STATE OF THE ART REVIEW

3.1 Bygghandlingar 90 & Delivery Specifications

This publication (Swedish Standards Institute, 2008), represents Sweden's chief guidelines for delivering digital information in connection with construction projects and is a valuable source of logical recommendations for managing building information in an organized and careful manner. However, it does not represent a BIM Standard and requires some development in a number of areas including that of BIM-Info Delivery Specifications. The output from this study aims to provide practitioners with a useable tool to address this deficiency and help the industry move towards procedural standardization.

3.2 buildingSMART Alliance Initiatives

Among the foundational standardization efforts of the buildingSMART alliance and its worldwide counterparts are the Information Delivery Manuals (IDMs) and Model View Definitions (MVDs). These are examples of the sector's collective recognition that better information is needed to support the development of better tools now emerging to deliver construction projects (Smith & Tardif 2008). Technologies such as IDM and MVD are intended to help identify exactly what that information is by defining, for example, a model definition view for automated code checking and the information that must be included to generate that view. However, this is work in progress and is still a long way off being available for all DCO participants; as is the full capabilities of IFC.

3.3 Problem Status

Whilst organisations such as the buildingSMART Alliance are investing considerable resources towards developing AEC industry standardization in information exchanges, until understanding, control and trust can be gained in the use of IFC, IDM and MVD by DCO participants, a simpler system of describing information content requirements is essential to BIM implementation today on a consultant practice level.

Without a straightforward way of creating project specific IDM's, a clear understanding of the content of MVD's, and the ability to control information flow through such methods, trust will may wither and die. Thus the driver for this study: the urgent need for a simple, user-friendly method of describing, in a commonly understood way, information deliverables.

3.4 Hypothesis

Perhaps a simpler method of generating IDM's and MVD's using commonly available tools within organisations would have greater mileage than those developed by external agents. Here it is conjectured that, as a valid alternative, BIM-Info Deliveries developed by architects and engineers for architects and engineers may offer the control, confidence and simplicity necessary for effective information exchange success.

In order for industry professionals to get the best out of BIM tools and work efficiently, one needs a big picture understanding of information need, honing individual tools and processes towards greater efficiency and certainty. Key to doing this is a thorough documentation of one's own business processes – use of a

BIM-Info Deliveries Protocol as part of a BIM-Implementation Plan may offer an immediate and tangible solution.

4. BIM-INFO: A CONSULTANT PERSPECTIVE

Whilst many consultants are demonstrating a strong interest in BIM there is a possible lack of practical knowledge in applying current technology and leveraging the much bragged out benefits of BIM. Other research (Gu & London 2010) has revealed that DCO participant concerns primarily focus on practice, process and technical related issues. Here, through the events and discoveries revealed in particular through case #1 within this study, the following observations are highlighted:

- Significant uncertainty exists amongst design team participant as to exactly what information to provide for each 3D Design Coordination Meeting.
- Because of a lack of clarity, there was certain carelessness in providing quality BIM-Info.
- Quality checks on BIM-Info deliveries appear to be missing or inadequate prior to issue.
- Apprehensions exist in delivering incomplete work or work in progress - suggesting a need for an additional BIM-Info status classification: WIP (work in progress)
- Some design participants were reluctant to engage in design work and contribute to a developing design process prior to the Architects layout being 'frozen'.
- Limited time / budget for design changes or iterations for specialist design participants - instead of productivity gains being fruitfully utilised to optimise the design, it presented an opportunity for some consultant organisations to simply take on more work.
- Among all participant disciplines, the architect was the most active member in attempting to resolve communication issues and align design team expectations in terms of information delivery and content requirements.
- Digital communication and information storage was established through a web portal to a project server. This enabled logging of all communications and a database for all current and live information.
- Folders were set up with associated access rights for each discipline enabling design participants to upload information in a commonly understood fashion.

4.1.2 Key Issues

The key issues identified here can be summarized as follows:

4.1.2.1 Practice issues:

- Whilst project team members display enthusiasm and general interest for implementing BIM, there appears to be a lack of a common understanding of what it entails not least in terms of BIM-Info deliverables.
- Time commitment in the early stages presented difficulties and frustration, suggesting a resistance to change or flawed time planning.
- Some localised competence issues in the use of 3D BIM authoring tools / lack of thoroughness in delivering quality information.

4.1.2.2 Process issues:

- Willingness to collaborate and contribute towards the project design on the same information level (LOD) as others within the same timeframe was problematic, suggesting the need for stronger culture of BIM Implementation Planning together with a method of clearly articulating BIM-Info Deliveries.
- Quality Control and validation of delivered BIM-Info was often left to the receiver to sort out - leading to down time for file clean-ups, deletion of duplicate objects etc.

4.1.2.3 Technical Issues:

- Naturally, not all design participants used to same BIM tools for model authoring. The transfer of MEP BIM-Info into the multi-disciplinary model for collision control presented problems. Here a lack of trust in data integrity emerged. The completeness and accuracy of 3D models remain a major concern for the design team.

4.2 Difficulties

In addition, derived from the case #1 design team meeting observations and case #2 practical experiments, a number of specific difficulties were identified relating specifically to 3D Design Coordination and early Energy Analysis.

3D Design Coordination – Common Problems:

- 1000's of collisions identified late in the design process with little opportunity to correct of solve them.
- Early agreement on tolerance levels is critical including clearance between own discipline objects and other discipline objects.
- Accountability for the maintenance and coordination of objects and properties must be clear.
- Agreement of procedure for managing changes to the design required to mitigate or remove hard, clearance or duplication collisions.
- Missing voids - Lack of accounting for voids for services including type, purpose, discipline, responsibility for correctness.
- Where objects are within the domain of both architect and structural engineer and in addition require input from the services engineers with regards holes etc, difficulties can arise through duplication.

Energy Analysis – Common Problems:

- No clear direction of what objects and properties are necessary for which analysis at what stage.
- Tendency not to focus on authoring the right information at the right time.
- Analysis carried out too late to have any pro-active impact on the design.
- Analysis results miss-interpreted.
- Analysis carried out by external consultant at a single point in time / results not acted on.
- No clear agreement or procedure for managing changes to the design to reduce energy consumption.
- Analysis carried out to confirm suspicions instead of to inform design and drive toward optimised solution.
- Major change in design instructed, focus on energy diminished or extinguished.

This evidence suggests that action is required to address these uncertainties and communication malfunctions. What is needed to combat these failures is clear and user-friendly articulation of process, what it involves and what information needs to be delivered by each party, when.

4.2 BIM-Info Deliveries

As a valid alternative to the rather cumbersome and overly complicated MVD's being developed by the buildingSMART Alliance and others, this paper offers a simple method of defining, on a project basis, information deliveries for specific BIM Uses.

It has been suggested that if the industry is to move forward with BIM implementation, firms must focus on perfecting what they can deliver (Jernigan 2008). Initially this means reaching for the low hanging fruit such as 3D Design Coordination (through use of collision control tools) and early Energy Analysis (through use of built-in or associated energy simulation tools).

Both these BIM uses instantly add value to the DCO process and product and can be considered strategic, straightforward targets for consultant organisations to master in an efficient manner. What is problematic, however, is for team members to arrive at the same place at the same time with regards BIM-Info quality and completeness. This is particularly critical in the context of the successful execution of various BIM-Uses including 3D Design Coordination. Project direction and information flow often meanders left and right of an efficient path resulting in frustration, loss of momentum behind value-adding processes, and often considerable time wasted.

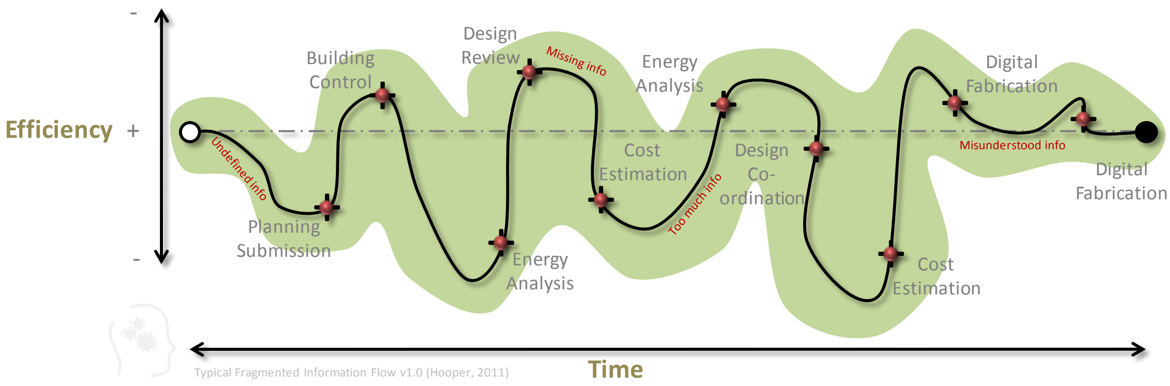

Figure 2: Information Flow – Traditional

Laying down considerable time and effort to carry out what should be routine tasks is a major concern to DCO players. Those who are bearing the pain of BIM implementation are struggling to leverage the benefits of added service and increased productivity as a result of downtime consumed by manually filtering, editing, adding, deleting, finding out if its valid and re-working building design information for what in theory should be sequential BIM Uses.

By encouraging all design participants to engage in work flow design and actively be aware of each other's information needs, the use of a BIM-Info Protocol has the potential to straighten work flow and increase the accuracy and efficiency of information exchange. Coordination efforts here requires time but lays the foundation for greater gains through the process.

Once organisations have succeeded and gained confidence in recording, purposefully designing and optimising their work-flows with attention to information exchange, project standards can develop into office standards and further to a National Standard. Within the sphere of information exchange, this study endeavours to organise and present key prerequisites necessary to set in motion a system design converging on standardisation.

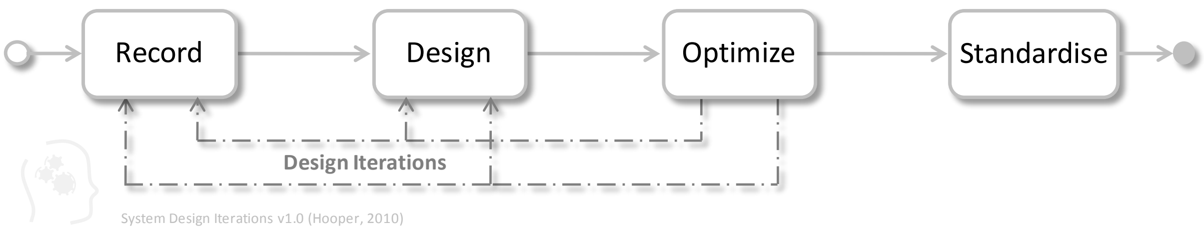

Figure 3: BIM Information Content – System Design Iterations

So far this element of business practice within the AEC consultant sphere has been either largely missing or out of date. The figure below suggests a process which might help DCO participants move forward in earnest and articulating BIM-Info content with a view to optimising information flow and reducing exchange failures.

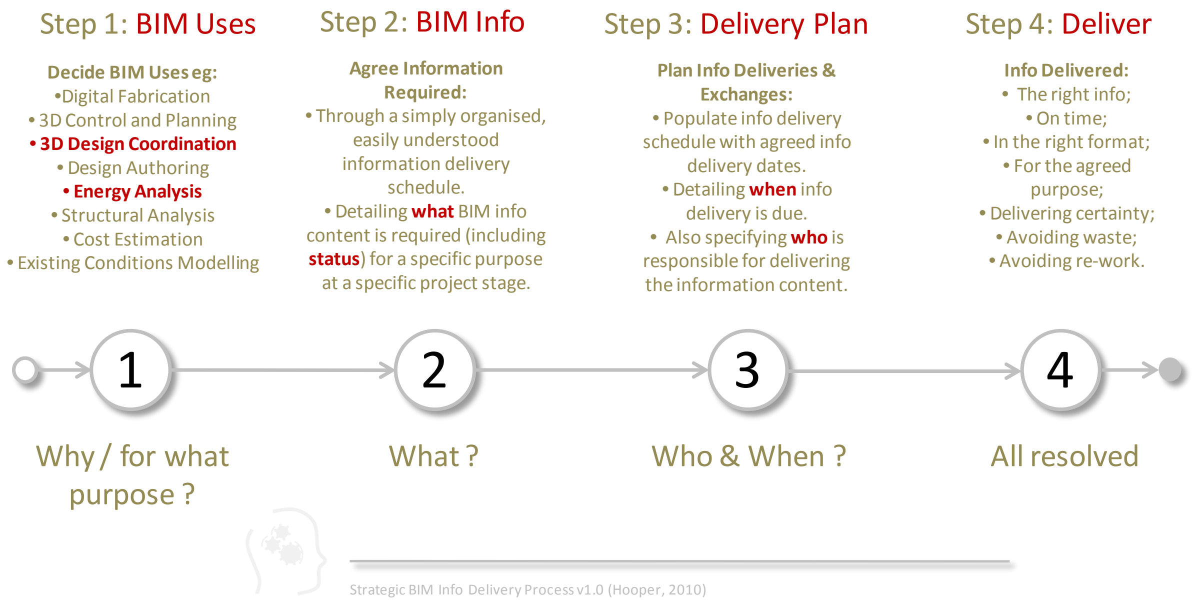

Figure 4: Strategic BIM-Info Delivery Process

5. BIM-INFO DELIVERY PROTOCOL (IDP)

Emerging from the observations and results revealed through discussions and experiments, the BIM-Info Delivery Protocol (IDP) is presented below as a sequence of pedagogical steps designed to respond to the research questions.

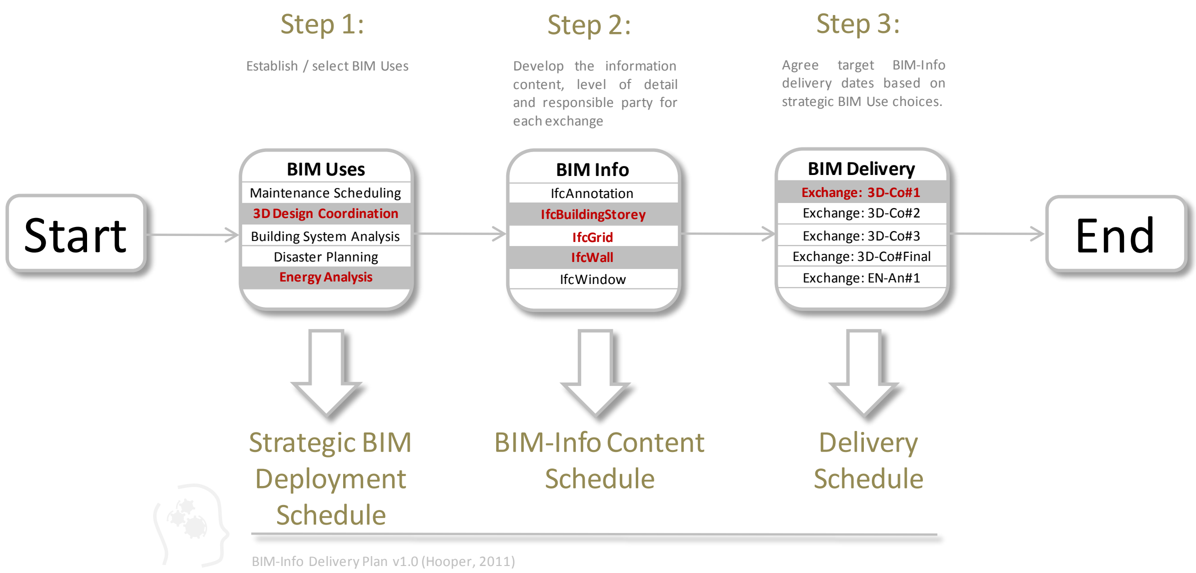

Figure 5: BIM-Info Delivery Protocol (IDP)

5.1 Step 1: BIM-Uses

The buildingSMART Alliance's Building Information Modelling Execution Planning Guide (Anumba et al 2009) suggests a list of 25 typical BIM Uses including of course 3D Design Coordination and Energy Analysis. It naturally follows that teams must establish at the outset the strategic BIM-Uses they wish to deploy on a project specific basis. The decision to implement a BIM-Use must be based on resources, competency and anticipated value to the project (Anumba et al 2009). Against each BIM-Use members should consider and articulate the timing of such activities through the BIM-Authoring stages to enable focus on imminent information demands and optimize information flow.

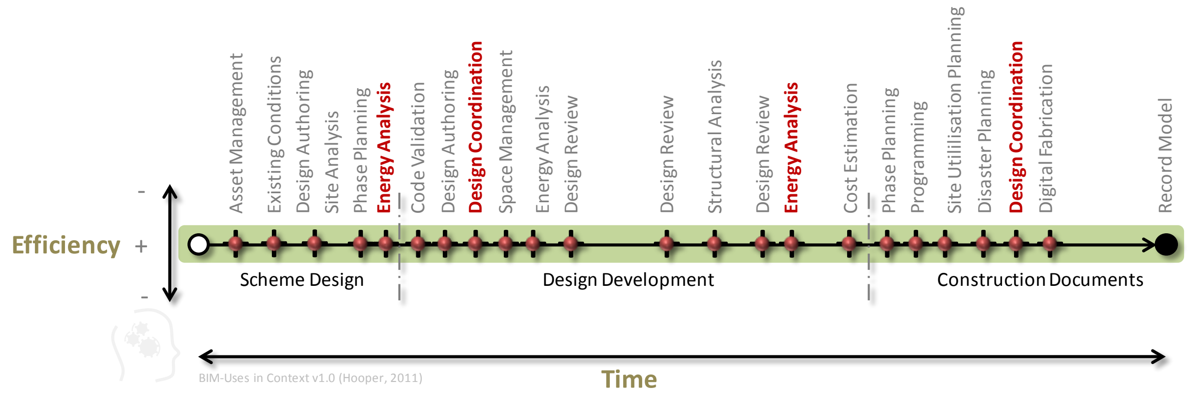

Figure 6: BIM-Uses in context

Often overlooked, there is common business sense to the idea that, if certain design information can be supplied at right time then its value to the project can be optimized.

BIM-Uses should be selected for the right reasons – as drivers to the process and to help provide the data to support strategic decisions along the way.

5.2 Step 2: BIM-Info

Here a definition of the model information content for strategic BIM implementation is articulated through scheduling the key objects with associated level of detail and responsible party.

In this instance a BIM-Info Delivery Specification (IDS) template has been developed to express the information content and exchanges necessary to carry out and efficiently implement BIM-Use: 3D-Co (3D Design Coordination).

The main tools used to develop this schedule where Autodesk Revit Architecture together with Microsoft Excel. An important aspect of this study and resultant product is that by utilising industry standard tools and readily understood categories and classifications, consultants can maintain control of model content definitions and thereby build and retain trust in the exchange processes they create.

5.2.1 Identifying BIM Objects & Properties for Strategic BIM Uses

The AIA (AIA 2008) amongst others has defined the concept of Levels of Detail (LOD) described through a sliding scale of LOD 100 – 500. In essence, the levels can be summaries as follows:

- LOD 100: Conceptual
- LOD 200: Approximate geometry
- LOD 300: Precise geometry
- LOD 400: Fabrication
- LOD 500: As-built

The LOD concept, established through the AIA's E202 Protocol published 2008 is now starting to be adopted throughout the world (Statsbygg 2011). This standard together with an appropriate building element classification can be deployed to identify the BIM-Info required for specific tasks, however, in practice additional BIM objects and properties need to be identified out with the scope of most building classification systems. For this reason it is necessary to facilitate flexibility in BIM-Info scheduling and include, where appropriate, scope to articulate request for data such as:

Project Information	**Project Units**	**Annotation**	**Other**
✦Project Issue Date	✦Length	✦Location	✦Voids
✦Project Status	✦Area	✦Coordinates	✦Holes
✦Info Status	✦Volume	✦Position	
✦Client Name	✦Angle	✦Grids	
✦Project Address	✦Slope	✦Levels	
✦Project Name	✦Currency	✦Rooms	
✦Project Number		✦Areas	
		✦Zones	

The need for extra BIM object classifications beyond those to be found in national classification systems is clear. The above categories, identified through the authoring process of the KonsultHus case project, have been included in the BIM-Info Delivery Specification to enable transfer of that information between consultant disciplines in a clear and comprehensive way.

BIM Information Delivery Specifications - 3D Design Coordination

BIM Information Delivery Specifications - 3D Design Coordination v1.0 (Hooper, 2011)

			BIM Use: 3D Design Coordination Stage: Scheme Design Info Exchange: 3D-Co#1 Date: 1 Jan 2011				BIM Use: 3D Design Coordination Stage: Scheme Design Info Exchange: 3D-Co#2 Date: 1 Feb 2011			
BIM-Info	**Responsible**	**Notes**	**Level of Detail**	**Info Author**	**Info Reciever**	**Format**	**Level of Detail**	**Info Author**	**Info Reciever**	**Format**
Annotation										
Location	Arch		✗ - Confirmed	Arch	Struct & MEP	*.rvt				
Coordinates	Arch		✗ - Confirmed	Arch	Struct & MEP	*.rvt				
Position	Arch		✗ - Confirmed	Arch	Struct & MEP	*.rvt				
Grids	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt	✗ - LOD 200	Struct	Arch & MEP	*.rvt
Levels	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt	✗ - LOD 200	Struct	Arch & MEP	*.rvt
Rooms	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
Areas	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
Zones	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
SUBSTRUTURE										
Foundations										
Standard Strip Foundations	Struct		✗ - LOD 200	Arch	Struct & MEP	*.rvt	✗ - LOD 200	Struct	Arch & MEP	*.rvt
Special Foundations										
Slab Foundations										
Pile Foundations	Struct		✗ - LOD 200	Arch	Struct & MEP	*.rvt	✗ - LOD 200	Struct	Arch & MEP	*.rvt

Figure 7: Extract from BIM-Info Delivery Specifications (IDS)

An innovative feature, still under development, is the possibility of automating the extraction of requested BIM-Info through an XML schema, enable through the IDS spreadsheet, thus eliminating manual filtering and if perfected, scope for error. A prerequisite of this novelty is a thorough and complete tagging of objects to the utilized building components classification.

Information										
Construction Information	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
Engineering Information	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
Record Information	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
			Link to Model: Holmes Office - Architecture.rvt				Link to Model: Holmes Office - Structure.rvt			
			Extract Info Content From Project Server				**Extract Info Content From Project Server**			

Figure 8: BIM-Info Content Extraction

5.3 Step 3: BIM-Delivery

Registry of BIM-Info exchanges can be readily recorded and communicated through project networks in accordance with the delivery schedule. However, often neglected is a sub-process of quality control. This is necessary more than ever – not least to demonstrate due diligence – but to ensure the content of BIM-Info Deliveries match with the general expectations of the project team as articulated in the BIM-Info Delivery Specification schedule.

This process is essential to eliminate rework for receivers and puts the onus on the supplier to ensure the contents is what it says it is.

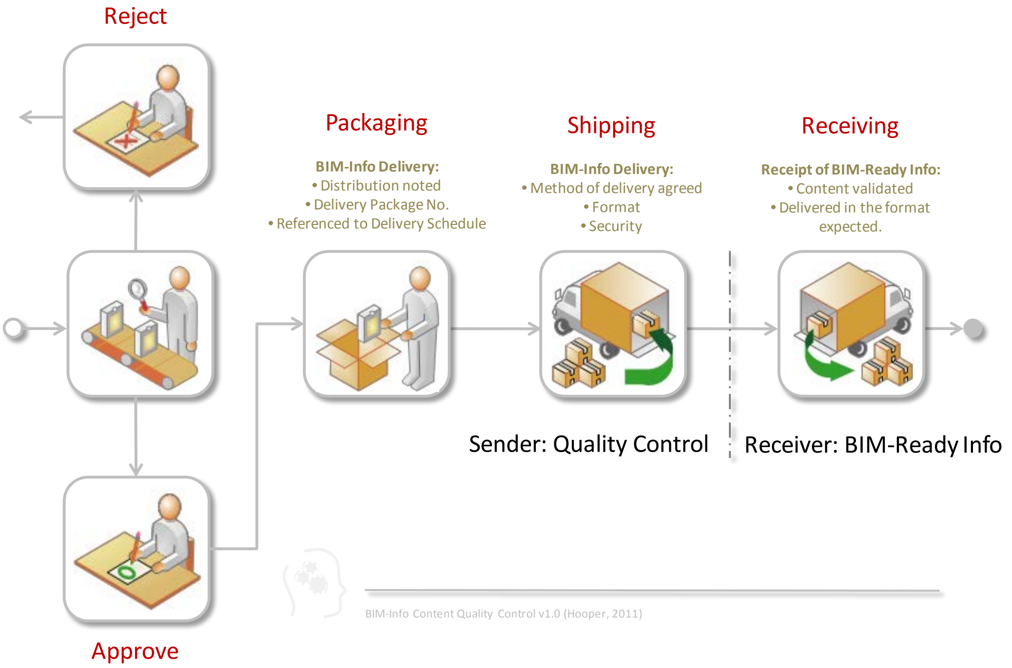

Figure 9: BIM-Info Content Quality Control Measures

6. CONCLUSIONS

The key deliverable from this study is the BIM-Info Delivery Protocol (IDP) which attempts, through use of straight-forward and easy to use tools, to align consultant BIM-Info delivery expectations and represents a development of the concept behind Leveransspecifikationer mentioned but not substantiated in *Bygghandlingar 90*.

By recording information flow properly we can better understand each other's information needs and reduce the risk for misunderstanding. If handled optimally BIM-Info can significantly enhance the quality of the product and safeguard the success of project. A clear and commonly understood picture of the BIM-Info Deliveries through establishing a project standard BIM-Info Delivery Specification offers a tangible solution to help consultant disciplines manage BIM-Info.

To add maximum value to the project, the timing and content of BIM authorship is critical. By articulating planned BIM-Uses, the necessary BIM-Info needed to carry out these Uses together with target BIM-Delivery dates; project teams can more readily focus on the strategic task in hand and help each other to deliver the intended result in an efficient manner.

The BIM-Info Delivery Protocol (IDP) is a compelling tool for use in the evolving world of virtual design and construction teams and can be used as a basis for a BIM Management Plan. However, industry reference-group feedback has suggested a number of limiting factors including that "it would be an additional burden, indeed laborious, to fill out the IDS when projects are already on a tight time schedule and budget. If teams cannot directly see the positive effects of using such a protocol, it would be difficult to achieve widespread uptake." This protocol represents a tool for improvement, a first step could be to first record one's own strategic information requirements, recognition of this together with patience may prove to be prerequisites.

7. FURTHER RESEARCH

It may prove possible to generate machine-readable model information content definitions through the XML schema making it possible to standardise such contents and deliver project information through automated processes.

ACKNOWLEDGMENTS

Particular thanks to Gunilla Qvarnström of White Architects and the Koggens Gränd Project Team. This research project is funded by SBUF, Formas-BIC, Interreg VI and members of OpenBIM.

REFERENCES

- AIA (2008), AIA BIM Protocol (E202) E202–2008, Building Information Modelling Protocol Exhibit, AIA National, AIA California Council
- Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), Building Information Modelling Execution Planning Guide, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.
- Bedrick, J. (2008) Organizing the Development of a Building Information Model, http://www.AECBytes.com, visited Jan 2010.
- BuildingSmart (2010) BuildingSmart, http://www.buildingsmart.com/, visited Jan 2010.
- Ekholm A., Häggström L., Johansson B., Tarandi V., & Tyrefors B. (2010), RoadMap för digital information om byggd miljö, Lund University, Lund
- Jernigan, F. (2008), BIG BIM little bim: The Practical Approach to Building Information Modeling-integrated Practice Done the Right Way!, Booksurge Llc; 2 edition.
- SI, Swedish Standards Institute (2008), Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.
- Smith, D and Tardif, M. (2009), Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers, John Wiley & Sons.