Knowledge-based Design Integration using Bluethink Applications

Per-Olav Opdahl
Selvaag Bluethink, Pb 544 Økern, N-0512 Oslo, Norway
(email: poo@selvaag.no)

Yngve Holte Olsen
Selvaag Bluethink, Pb 544 Økern, N-0512 Oslo, Norway
(email: yho@selvaag.no)

www.bluethink.com

Abstract

This paper describes how the construction value-chain can improve its design integration and operation by using knowledge-based tools as part of Integrated Design Solutions. The tools described support a continuous knowledge improvement cycle to obtain the best results and effects from an industrial approach across the phases of design, engineering, construction, and operations. The tools referred in this paper consist of three main components: Experience, focused on learning and knowledge management; House Designer, focused on building design and development; and Supervisor, focused on project configuration and information management.

We describe the collaboration processes and the integrated flow of knowledge and information through the various value-chain phases. We further discuss how all parts of the construction value chain can benefit from specific knowledge management and how product life-cycle efficiency is best assured by the combined use of knowledge management tools. Both experienced issues regarding technical integration and use cases are presented.

Keywords: design optimization, rule-based design, reuse, experience, collaboration, methods, IT-based tools, building information modeling, BIM, knowledge-based
Engineering, knowledge management, industrialized, house building, construction operations, construction processes, quality, resources, automation, forward-looking technology

1. Introduction

Selvaag is a residential construction company that has produced 55000 housing units in the Oslo area since Second World War. The innovative company founder had to wrestle with the building authorities during the post war development in the 50s, when he claimed that quality housing could be provided with much less material and effort. By introducing new materials and construction methods in combination with volume production and tightly managed project logistics, Selvaag was able to provide improved standard housing units at a much lower cost. In essence, the good practices established was promoted as the industrial approach, defined as: "The most intelligent way to convert material resources to finished products with necessary repetition and exploitation of local advantages to gain the best possible results in economy and quality", but in fact, the Selvaag approach was an Integrated Design Solution. The many Selvaag housing still in use today show how this approach created value both for home owners as well as for the company.

The base for the industrial approach in Selvaag was standard housing units and building types, used repetitively and continuously improved. Changes to existing standard products were consciously done based on feedback on project applicability of solutions and new knowledge, but typically applied when the product was used again in following projects.

In the 1980s, the challenge of achieving predictable, industrial performance, yet acceptable customized design homes, was evident and at the same time Selvaag experienced how knowledge on best practices and good product solutions faded away with the passing of time and attrition of individuals involved in specific tasks. As a result, Selvaag looked to information technology to find means to create a collective experience base that would be available for younger engineers or newcomers in the engineering work within Selvaag. With a high innovation rate of housing units, the goal was to still use standard solutions and/or always check possible new solutions versus the existing recorded experience. The Knowledge Based Engineering (KBE) technology was found promising in both recording corporate knowledge as well as a way to actively promote specific solutions.
The developed Selvaag Bluethink applications include tools (Figure 1) for experience recording, coordination of experience and new knowledge, as well as tools for exploration of new design options and promotion of validated solutions in integrated design projects.

![Bluethink approach to knowledge management.](image)

**2. Knowledge growth methodology**

Building projects have a bad track record on efficiency [1], and has in recent years received attention specifically for its lack of productivity development in comparison with other industries. Most building projects are set-up and managed as a one-off project where the owner, architect, engineering resources and contractor are gathered for a (reasonable) short period of time to share information and knowledge to reach the specific project goals. Typically, little is done to research experiences made in previous projects or record experience for following projects. Risk management is partly handled by everyone looking to solve issues as close to their existing experience as possible and by setting up contracts that require strict bordering between the participants rather than promoting shared risks and rewards of good performance. This further leads to specific contract deliverables, often in the form of paper documentation, being the only information carrier between the participating parties.

Well, change is coming. Today, Building Information Modeling (BIM) [2] is rapidly becoming the approach in many building projects, in which Integrated Design Solutions and new risk schemas are implemented in new Integrated Project Delivery [8] methodologies. However, there is still a distance to go from...
sharing information to sharing knowledge in order to fulfill the Integrated Design Solutions vision. Most of the information shared in BIMs is still created by the hands of individuals from different disciplines, and the solutions only meets the knowledge of others at a point where code validations, clash detections, and other tools are used to check if in fact a project can be realized. The many iterative cycles of creating information and checking it is still inefficient, and even when successful, the detailed engineering miss out on obvious construction process efficiency issues. And so, the next project starts without learning from the previous with iterative cycles and without achieving the expected results of Integrated Design Solutions.

2.1 Product, process, people – knowledge management

Sharing knowledge between building project participants, let alone between projects, is difficult. Many obstacle questions arise as people are encouraged to reuse information or knowledge. When does knowledge apply? How does one find the appropriate knowledge? Where is the experience from previous projects recorded? Will we spend more time sorting out the records rather than just create the solutions over again? Is the knowledge outdated?

In order for a knowledge worker to reuse knowledge, the worker needs to trust it, find it, accept it, and then be able to contextualize it with the ongoing task. Many knowledge management software tools focus on providing relevant information from trustworthy and ranked sources based on the workers request. But, what if the knowledge worker doesn’t ask? A conscious learning corporation considers knowledge an asset and wants the participants in various tasks to actively use the right version of its assets and also actively contribute to the improvement of the asset. This means that the knowledge should have an obvious and well defined presence in the production, and in order to improve the knowledge asset it needs acquisition, assembly with other components, innovation and maintenance. The handling needs a structured ordering of knowledge to provide accurate use.

In support of the industrial approach, the ordering for knowledge in Bluethink methodology follows the idea of production by recipe. Products (buildings) are prepared by a set of activities involving raw material, methods of transformation or assembly, made by personnel with appropriate skills and tools, and based on accurate instructions. Hence, the knowledge management for Integrated Design Solutions needs to encounter as many of such recipe considerations as possible.
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Knowledge elements are therefore managed as separate data entities categorized by a range of category dimensions. Categorization has meaning both for recording in order to understand the reference of the experience or the knowledge content, as well as for retrieval and use in appropriate context. The dimensions used are

- project (location, season, crew, duration)
- phase (design, engineering, site logistics, construction, inspection, use),
- building type (families of repeatable combinations of building solutions)
- building part (apartment, room, internal, external, etc.)
- building element (door, window, shower, curtain wall, etc.)
- discipline (timber, concrete, mechanical, etc.)
- trade (carpenter, plumber, etc.)
- function (insulation, moist protection, etc.)
- issues (leak, moist, cracks, ventilation, etc.)
- means of dissemination (documents, software applications, physical tools)
- area of Application (context, applicable codes and regulations)
- activity
- skill.

All of these dimensions make parts of the information model that makes the skeleton for population of knowledge entities. All entities will be categorized by all applicable dimensions, although entities may have a mix of specific entry point in some of the categories, while having multiple entry points in other categories. Many BIM technology platforms support the Industry Foundation Classes (IFC) building information model defined in the ISO/PAS 16739 standard [3]. Bluethink refers to the same standard in its information model, providing the framework for Integrated Design Solutions by promotion and dissemination of knowledge with relevant referencing in tools supporting the IFC standard.

In order to manage knowledge elements, records include date, recording person, handling agents, discussions on cause, alternatives and effects, historical archive of previous versions of the knowledge element, and promotion method. This allows the organization to handle this as a stock similar to other assets.

### 2.2 Knowledge growth process

Knowledge growth means the accumulation of relevant knowledge elements over time by both structured and unstructured means. However, the conscious
corporate knowledge asset management requires a formal handling procedure of all incoming experience elements and new knowledge (including public codes and regulations). The knowledge Growth Process allocates tasks, responsibilities, roles, authority, and formal process steps to move a knowledge element from recording entry to project dissemination. These steps can be described as

- discovery: the first notion of an experience or new knowledge arrival
- recording: the structured information input to define the element
- exploration: first evaluation of importance, relevance, need for handling, etc.
- elaboration: inclusion of additional information, the evaluation of alternatives, business analysis, preferences and consequences
- decision: selection of use of knowledge element, including activation, de-activation, and means of promotion or activation
- promotion: presentation of knowledge element with relevant reference and content for voluntary use
- activation: publishing knowledge element with relevant reference and content for forced use.

To provide trustworthy and traceable knowledge for all parties involved in Integrated Design Solutions efforts, each of the steps require tooling for information handling, involvement of the right resources, control of completeness of steps, authorizing the forwarding to next step and recording of all relevant information for the handled version of the knowledge element.

2.3 Knowledge dissemination – enhancing organizational skills

Knowledge dissemination may be instrumented in several ways along a path from highly voluntary use, to complete disciplined activation of knowledge directly in a production process step. The means can be of many types, such as: available reference material for lookup; consciously transferred knowledge between colleagues in line or in teams; best practices notes; control system procedures; drawings; 3D models; production recipes; and physical manifestations in for instance prefabricated building elements.
Dissemination of knowledge has historically been achieved by project control procedures and discipline, but is well served by software tools. Bluethink supports three distinct levels of knowledge activation.

**Promotion by Availability**
First, when handling a knowledge element in Bluethink Experience, the categorization will give a lookup to other knowledge relevant by the selected categorization. This will promote the appropriate assembly of experience and new knowledge with relevant consequences, being product quality, process applicability, or human resources.

**Activation by Integrated Design Automation**
Secondly, the Bluethink House Designer uses knowledge based engineering technology to automatically generate design alternatives. It integrates functional intent, material and building element selection, constructability by production method, and compliance considerations, all based on activation of validated knowledge elements. In this context, the designers (collaborative effort by owners, architects and engineers) still explore a fairly open solution space where all knowledge elements’ combinatorial effects can create new designs.

**Activation by Product Configuration**
The third level is supported by Bluethink Supervisor, and leaves only configuration of product options left to the designer. In this situation, all possible outcomes of the use of knowledge is known, similar to how one would order a car by configuration on the internet. The pre-existing integrated data and information include all necessary engineering details, documents and models, and the configuration leads to a selection inside the existing library. The production process is highly predictable and required engineering is reduced to a minimum.

### 2.4 Product lifecycle management – enhanced value delivery

Using a highly enforcing knowledge activation tool, brings the handling of buildings, building information, and construction projects to the similar Product Lifecycle Management (PLM) [4] approach as can be observed in manufacturing industries. The conscious recording of information relevant to products, including division in sub-parts, use of strategic procurement, and sharing information over well defined data transfer protocols, enables a high frequency of innovation and new product releases. The product environment is well documented from inception to operating manuals, and changes are only made when impacts are
understood from the lab through the production facilities, through to operation and use.

The building lifecycle management [5] paradigm is now promoted within the AEC industry, often led by public owners [6] and authorities, but it still focuses on per project collaboration and best effort, along with using BIM for appropriate documentation for operation and maintenance, rather than the overall efficiency in providing the product – the building.

A PLM approach will provide the industry with the industrial predictability. It is still an open question though, if it can handle the market demand for customization.

3. Knowledge activation in integrated design solutions

The NIST report [7] on “The Cost Of Inadequate Interoperability In The U.S. Capital Facilities Industry” is an example of several reports describing how the building industry suffer from inefficiencies due to lack of interoperability. The industry has realized that the inefficiencies are largely due to the conventional linear process, and both professional organizations and public owners are promoting and requesting new collaborative ways of working. The AIA has released their Integrated Project Delivery (IPD) [8] and public owners like US GSA [9], Norwegian Statsbygg [10] and Finnish Senaattii [11] have put out requirements on use of BIM in their projects. One goal is to share as much information as possible through digital information modeling means, but also adopting an integrated, collaborative work style where discussions on solutions and impacts are done as early as possible to avoid the need for iterative re-working cycles and corrective actions later in the project.

3.1 Frontloading the building project

Patrick Macleamy of AIA, in 2004, introduced the “Macleamy Curve” (Figure 2) [8], [12], illustrating the advantages making design decisions earlier in the project when opportunity to influence positive outcomes is maximized and the cost of changes minimized, especially as regards the designer and design consultant roles. This is now well accepted as a driver for sharing information and is commonly used as part of the argumentation for Integrated Design Solutions based on use of BIM.
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Figure 2. Macleamy Curve.

FIATECH [13] is another organization promoting use of digital information technology for improving efficiency in capital project delivery, and in the same manner as the buildingSMART [14] community’s promotion of IFC, looks to data standards as a means to improve collaboration and information flow. FIATECH’s “Vision of an Integrated and Automated Capital Projects Industry” is illustrated in (Figure 3), and shows how “Technical Plan, Target Cost and Schedule” together with “Supplier Designs/Capabilities/Products and Services” can allow for “Automated Design” based on the “Requirements and Conceptual Design” input from the scenarios required from the “Scenario-based Project Planning”.

Bluethink combines the intention of early design decisions in the Macleamy Curve with FIATECH’s vision of automated design by automatically activating integrated design knowledge. As described in 2.3, the automation levels can vary between creating new design as validated combination of known solutions, or by selecting among product configurations. “Frontloading” the building project includes setting up the project for best possible performance with a dramatically improved design processes. Projects starting from product oriented designs rather than emerging one-off designs will require less effort in each project as is illustrated in Figure 4. The benefits are many, but improvements will be found within the design process itself, seeing less need for arbitrating design details, and the construction process and end product will see the advantages of applying solutions and processes that have already been tested.
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Figure 3. FIATECH “Vision of an Integrated and Automated Capital Projects Industry”.

Figure 4. Bluethink’s “Dramatically improved design process”. 
Frontloading of projects is especially attractive to enhance value to owners, operators and contractors who are involved with buildings of typical repetitive use patterns. Examples are

- residential
- public service buildings; schools, kindergartens, nursing homes, court houses
- hotels
- stores
- army facilities.

The participants in these projects typically delivers many similar projects and they often have the benefit of growing knowledge over time about product quality, inefficient logistics, construction processes, documentation inconsistencies, etc. This can all feed into a Product Lifecycle Management information system that allows considerate product innovation and reuse of well established design solutions.

### 3.2 Information flow in integrated design solutions

Information Design Solutions benefits like project efficiency improvements, early design decisions, Building Lifecycle Management and Product Lifecycle Management, are all achievable only if, and when, information can be represented and shared in an efficient way. Digital information systems make it possible to store and retrieve data, but only make a difference in process efficiency when the data can be retrieved and used by other process participants. The CAD drawing-, planning-, procurement-, and other systems applied in the building industry over the last few decades have all led to local productivity gains, but have not solved the issues of lack of interoperability, re-entering of data based on paper prints, and the participant’s need for risk avoidance.

“Frontloading” of a building project with shared integrated design decisions will only pay off when information is represented in a form so it can be well understood by all participating decision makers and available to be directly used in the following project phases. Only then will participants trust the information, continue to elaborate the detailed engineering based on the original data, and collaborate in risk and reward sharing schemas.

The IFC standard now can be used as a schema for data transfer between various software applications, and examples have shown how project phases starting with room programming and schematic designs, carrying on through the detailed engineering, procurement, and 4D (cost) and 5D (time) planning can
reuse the information. The ability of software and organizations to represent data to allow meaningful information to flow is strengthened by the efforts to create handbooks such as the US National Institute of Building Sciences (NIBS) National BIM Standard [15].

However, the IFC standard defines how to transfer data, but not what to transfer. This is now met with the development of standards such as the Information Delivery Manuals (IDM) [16] which map out business processes and exchange requirements for the information content to flow between process steps. IDMs can be used in generic form or as specific agreements in projects. In this way, information content, form, and transferability is assured between phases and participants in a project.

Given proper IDMs, design frontloading of projects create predictable conditions for the following project phases. Furthermore, if the design frontloading is based on product configuration, the IDM in fact constitutes the same information system that makes the PLM system found in other industries.

4. Use cases

The use cases show two Integrated Design Solution examples achieved by frontloading the design process. The first example is a UK construction company targeting the “Affordable Housing” marked in UK, utilizing Knowledge Based Engineering early in the design process to mitigate the risk of not meeting public requirements in a highly regulated market. The second use case is a low cost modular home product delivered by Selvaag. The concept is based on an industrial prefabricated delivery process, where the delivered building is a result of a valid configuration of predefined modules and elements part of a PLM type of a product.

Both use cases will discuss effects and consequences in an Integrated Design Solutions perspective.

4.1 Mass CUSTOMIZATION by knowledge based engineering – affordable housing in UK

Inspace Partnerships, a social and affordable housing developer in the UK (Figure 5), has deployed the Knowledge Based Engineering application Bluethink House Designer to improve their design of affordable housing. The affordable housing market is a highly regulated market with complex codes and regulations. The Inspace challenge is to improve designs and reduce cost by
integrating best practices, standard solutions, public rules and regulations, and constructions methods.

Figure 5. Example affordable housing units from Inspace Partnerships.

The Inspace solution supports and automates the early design phase by enabling use of standard layouts describing the functional intent of the layout instead of the physical solution. The best practices, building methods, and codes and regulations are modeled into the application which activates knowledge as generative functionality automatically creating the design, and validating functionality criticizing the design. The collaborative design team reaches an integrated and validated design at a very early stage.

From a business perspective Inspace is striving for, among others

- avoidance of historical and frequently recurring errors in design through knowledge capture and rule enforcement
- maximum objectivity and reduced subjectivity in: architect design; design co-ordination skills; technical compliance checking
- fewer defects because of more standardisation and more efficiency through rule enforcement on schemes.

4.1.1 Automate knowledge at decision point, frontload the design process!

Automatically applying knowledge early in the design phase, forces the designer to focus on functional intent and not schematic design. Inspace documents their best practices as layouts describing the functional intent. Using Bluethink House Designer the functional intent is described as apartments and buildings with
spaces where the spaces are assigned room types and functionality (Figure 6). Each room type comes with associated rules and reasoning capability. Thus, selecting a specific room type such as “Living Room” for a space automatically activates it all the rules associated with that type in the knowledge base.

To ensure that the correct rules are applied, the user selects the various Rule Sets. In this way the same layout can be the starting point for different resulting designs, allowing focused collaboration among design team members over different integrated design considerations. For Affordable Housing in UK, rule sets concerned with integrated design for Wheelchair, Life Time Homes, Care Homes, etc. will be applied.

Once the functional layout has been defined, a detailed information model is generated. The Preview mode shows detailed floor plan along with the conflict violations detected by checking the model against the active rule sets. For each conflict, rules that are violated are shown, along with recommended solutions to fix the problem, when available. (Figure 7) shows how the doors and windows have been automatically picked and positioned together with switches and some other electric components, all based on the generative rules embedded in the
system. In the right panel, the violations detected are shown. The description also includes reference to the Knowledge Base allowing skills to grow from experience and knowledge directly into new project designs.

Figure 7. Generated layout in showing knowledge reference and rule validation.

When different apartments are integrated into a building with a fixed footprint and elevation, a complete Building Information Model is generated. The model is exported by use of IFC (Figure 8) as a starting point, bootstrapping and frontloading the remaining design process. The process constitutes a frontloaded Integrated Design Solution by which complete new buildings can be created from the validated knowledge within minutes and hours instead of days and weeks.

Figure 8. Example of an IFC export converted into 3D pdf.
4.1.2 Findings and challenges related to Integrated Design Solution

The Inspace system frontloads the design obtaining the Integrated Design Solutions goals of minimizing structural and process inefficiencies by automation, enhancing the value delivered during design, build and operation by providing guaranteed approved affordable housing units, and clearly bringing knowledge across projects by activating best practices. The remaining design process will still include some detailed engineering and creation of construction documentation which will look similar and face most of the same tasks as other projects. However, there are some unique positive effects and new challenges.

Automating information and use of standard components
Since the Knowledge based Design tool select all components used from a library (Equipment, wall types, doors, window etc), the information and component ID will always be aligned with the company standards eliminating designers and engineers “habit” of selecting a better but not standard component. This will lead to a higher percentage of standardized components and thereby better support the estimation and procurement processes. Further down the line, this will also lead to a higher percentage of repeated solutions (Process, material, competency) at building site.

Interactive use of IFC imported models
A frontloaded design from Bluethink House Designer populates its BIM based on known properties in the knowledge base. With today’s available technology, most use of IFC includes the operator of each application to “prepare” the property values included in exported data to match the needs of the receiving application, being energy analysis, estimation, etc. If the export is incomplete or requires an update, the data are typically changed by the operator in the originating application and then re-exported.

To accommodate for the lack of complete information standards, the IFC export from Bluethink House Designer sometimes still require the use of private property sets or other means to prepare its exported BIM for other Integrated Design Solution tools.
4.2 MASS customization by configuration – Low cost modular homes in Norway

The low cost modular homes initiative of Selvaag is aimed at maximizing the industrial potential of residential development. The goal is to deliver quality housing for low income families entering the residential market. The challenge is to allow enough customization to satisfy local municipalities, topographical factors on the site and the end customer. To be able to achieve this without reducing quality and keeping engineering to a minimum for each project, Selvaag has developed a modular product based on repeated use of prefabricated modules (approx. 4m x 12m) (Figure 9). The modules use standardized internal solutions like equipment groups, room clusters and functional associations. Integrated design considerations are all pre-engineered, and information technology is heavily used to control, conduct and automate where appropriate, in learning, engineering, configuration and documentation.

Figure 9. Web based product configuration including illustration and 3D models.
4.2.1 Levels of Product Management

Building type elements and structure
The modular housing product (Product) is divided into building type elements. A typical single element is a repeated element like a set of kitchen equipments, wall elements etc. It is also possible to define more complex elements which combine single elements. Each building type element is logically defined and maintained in Bluethink Supervisor Developer and represented by a linked BIM object in a CAD/BIM tool (Figure 10).

![Supervisor Developer illustrating a product structure with linked BIM objects.](image)

Product model and options
To allow the collaboration between home buyers, project developer, and site engineers, to configure buildings providing the best match to functional and market requirements, and not based on product elements and structure alone, a parallel product model is defined. The product model consists of options with multiple predefined values like number axes, apartment types, façade concepts etc. The Option model is defined and maintained separately, and Supervisor Developer also holds functionality enabling and assuring the developer to obtain a consistent model including both Building Elements and Product Options (Figure 11).
Configurable buildings – a highly efficient design process

Configuration of the buildings is done by selecting the Product option. The Bluethink Supervisor then picks the corresponding Building Type Elements represented in the CAD/BIM library based on configuration rules and assembly rules, and automatically assembles a complete BIM (Figure 12).
Since the BIM is built up by the predefined Building Type Elements the resulting BIM will hold all integrated information to the level the individual BIM objects are modeled. Further use of the BIM is then enabled and dependent on the quality and information level in each BIM object. To achieve an efficient information flow in the project, the BIM objects are modeled according to the Selvaag BIM Manuals and Integrated Design Solutions requirements. This turns into a BIM structure targeted and streamlined for prefabricated module production, providing added value to the contracted builder.

4.2.2 Findings and challenges related to Integrated design solution

Due to the automated configuration and documentation process in each project, the quality of the end product relies on the quality of each Product element. This leads to a situation where the experience and knowledge must reflect the functional perception of the Product in addition to the engineering perspectives of building elements, disciplines, function, etc. Selvaag has experienced that the internal structure in the IFC model exported from the assembled BIM model lack the ability to represent the functional and configuration options perspectives. To allow collaboration between different process participants, the Integrated Design Solution must be able to handle multiple perspectives of the same product.

- Production structure; how the product is modularized and produced.
- Product Option structure; how the product is logically structured, reflecting how the market perceives the product and its options, and how it is partitioned to be flexible enough to meet changes in market demands.
- Building structure; how the end product is documented and defined using IFC.

On the other hand, the Selvaag approach reduces challenges met by most one-off projects when applying Integrated Design Solutions. The design, engineering and documentation process is set up for the Product, not the project. This means that the specific challenges present at each integration point are met one time only, and the process is established and reused across projects.

With Selvaag’s ability to repeat their modular product, they have maximized process efficiency and managed to deliver high quality housing units at low cost. With an Integrated Design Solutions that has project by project variation within predictable
configuration options, they have created a process similar to other industrial PLM processes. Cost of design and engineering in each project is reduced to a minimum.

5. Conclusions

Bluethink has developed tools for automatic, integrated design in building projects. The development of the tools is based on the experience gained from Selvaag, a residential construction company in Norway, in its quest for industrial production of residential buildings. Selvaag has built some 55000 housing units in the Oslo area since the Second World War.

The Bluethink applications discussed add to Integrated Design Solutions with tools for knowledge capture, knowledge management and knowledge dissemination. Knowledge elements are handled as separate data entities which are categorized by a number of industry specific dimensions. Each knowledge entity is managed in a knowledge growth process including the steps of Discovery, Recording, Exploration, Elaboration, Decision and Promotion or Activation. Appropriate personnel with different roles and authority are involved in the process to establish corporate knowledge.

Knowledge dissemination by promotion by availability provides lookup to knowledge relevant to a theme and promotes the appropriate assembly of experience and new knowledge with relevant consequences.

Knowledge dissemination through activation by integrated design automation uses knowledge based engineering technology to automatically generate design alternatives. In this context, the designers still explores a fairly open solution space where all knowledge elements combinatorial effects can create new designs.

Knowledge dissemination through activation by product configuration leaves only configuration of product options left to the designer. All possible outcomes of the use of knowledge is known, similar to how one would order a car by configuration on the internet. The production process is highly predictable and required engineering per project is reduced to a minimum.

Using knowledge activation tool brings the handling of buildings, building information, and construction projects to the similar Product Lifecycle Management (PLM) approach as can be observed in manufacturing industries. Although a building lifecycle management paradigm is now promoted it still focuses on per project collaboration and best effort information use, rather than the overall efficiency in product management. A PLM approach will provide the
Activated knowledge with Bluethink tools facilitates change towards the “Integrated Project Delivery” approach promoted by AIA and the FIATECH’s “Vision of an Integrated and Automated Capital Projects Industry” by “frontloading” the design process with validated designs either by new designs generated automatically from known knowledge elements, or by starting a project from well established configurable products.

Knowledge Based Tools offers enhanced Integrated Design Solutions by frontloading design efforts with automatically created designs using managed knowledge. However, knowledge elements need to be handled with tool support in a formal knowledge growth and dissemination process.

Use cases illustrating knowledge dissemination through activation by design automation and through activation by product configuration show how organizations use Bluethink tools to provide better quality housing at lower cost in two different countries.

Inspace Partnerships apply knowledge of allowed combinations of apartment layouts and public codes and regulations to automate the design of compliant affordable houses. The design process now can focus on functional intent, and it only takes minutes to design valid apartment layouts for buildings in a range of combinations.

The Inspace system frontloads the design obtaining the Integrated Design Solutions goals of minimizing structural and process inefficiencies by automation, enhancing the value delivered during design, build and operation by providing guaranteed approved affordable housing units, and clearly bringing knowledge across projects by activating best practices. The use of the generated building information models in the following process steps still encounters some issues with the IFC based information flow as many tools require “prepared” data to accept the imported IFC model.

Selvaag apply product knowledge in its modular low cost homes. The designs of new buildings are done by configuration of a product option model, and all possible combinations offered have already been engineered. The standard sized modules (4m x 12 m) are produced in factory surroundings and shipped to the building site, where they are merely assembled. This is a highly industrial approach, and the modular product is managed by a PLM approach. However, the IFC information models mainly focuses on physical building elements rather than product capabilities, and the product option model needs to be maintained in a different model.
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With Selvaag’s ability to repeat their modular product, they have maximized process efficiency and managed to deliver high quality housing units at low cost. With an Integrated Design Solutions that has project by project variation within predictable configuration options, they have created a process similar to other industrial PLM processes. Cost of design and engineering in each project is reduced to a minimum.

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