BIM & PLM

WORKSHOP

June 4-5, 2014

Report

Transitioning to Building Information Modeling and Product Lifecycle Management in the Quebec Construction Industry:

Challenges, Possible Solutions and Proposed Action Items

October 22, 2014

version 1.1

ÉTS

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OUTLINE

1. Executive Summary

The Pomerleau Industrial Chair held by Professor Daniel Forgues at the École de Technologie Supérieure (ÉTS) in Montreal, Quebec, Canada, in collaboration with Hydro-Québec (HQ) and the Groupe de Recherche en Intégration et Développement Durable en Environnement Bâti (GRIDD), under the leadership of Prof. Louis Rivest, organized the Building Information Modeling (BIM) & Product life-cycle Management (PLM) workshop on the 4th and 5th of June 2014 in Montreal, Quebec, Canada. The principal objective of the workshop was to define the desired state of BIM-PLM deployment and explore possible avenues for optimization of Hydro-Quebec's current project delivery processes. The secondary objectives of the workshop were to:

1. Converge on a vision for the future of BIM-PLM throughout the construction supply chain,
2. Identify the challenges to achieve this vision,
3. Identify solutions to these challenges, and
4. Propose a feasible action plan.

In parallel, HQ wished to find answers to three questions:
(Q1) Engineering processes have evolved to include 3D mock-ups and data; construction processes also need to evolve; what practical experiences from abroad can we learn from to efficiently fuel this evolution?
(Q2) Which contractual relationships models can realistically be implemented between the contractors and HQ to maximize benefits from BIM-PLM?
(Q3) Which organizational changes and what responsibilities must we implement to maximize the benefits from BIM-PLM?

Over the past decades, PLM has shown great potential in positively impacting project outcome in the manufacturing, automotive and aerospace industries. On the other hand, BIM has emerged as a tool, technology and process similarly aimed at improving project outcome in the construction industry. Hydro-Quebec, being a major client in the Quebec construction industry, has been adopting and implementing BIM-PLM since 2003 in an attempt to improve their project delivery process. The BIM-PLM workshop was an opportunity for leaders in the industry, namely from HQ, and prominent members from academia, including Professor Henk Jan Pels from University of Technology, Eindhoven and Professor Julie Jupp from University of Technology, Sydney, to come together and determine a vision for the future of BIM-PLM for the construction industry. A common vision for BIM-PLM was established by unifying the underlying concepts of both approaches : **"the collaborative development and management of a project's data and information throughout its life-cycle. This is achieved through the co-creation and co-development of a parametric digital model containing product data and information situated at both the physical and meta- level to maximize value through total supply chain and life-cycle optimization."**

Once this vision was established, the challenges were identified and solutions were suggested to overcome them. The main challenges which were identified as hindering the transition to BIM-PLM were:

1. The general inertia with regards to change in the construction industry
2. The lack of a clear business case to foster the buy-in from general industry practitioners - i.e. no clear answer to the question: "what's in it for us?"
3. The lack of a conducive procurement and contractual landscape which hinders innovation

4. The absence of clearly defined requirements (modeling and project based) across all domains
5. Issues around technical interoperability and data exchange and reuse
6. A misalignment of processes which hinders value creation

In response to these challenges several action items were proposed across two tiers: first, breaking the industry's inertia and resistance to change and second, sustaining the transition to BIM-PLM. These action items reflected the solution avenues discussed. The main action items that were put forth to break the inertia within Quebec's construction industry were:

1. Learn from international initiatives and innovative practices
2. Foster buy-in from industry by introducing a strong governance from industry leaders
3. Implement change management strategies at the organizational level
4. Adopt relational procurement methods and develop long-term alliances to facilitate knowledge capture and reuse (difficult due to legal landscape in Quebec and necessity to go with the lowest bidder)

The main action items that were put forth to sustain the transition to BIM-PLM within Quebec's construction industry were:

1. Look for incremental change rather than radical change - encourage small steps instead of giant leaps
2. Map processes and work to align them across the supply chain
3. Develop clear rules and requirements for the deployment of BIM-PLM and the development of models
4. Define a better suited contractual framework
5. Implement robust data exchange standards such as IFC
6. Mandate a BIM Project Execution Plan (BIM PxP) and make it part of the contractual framework at the project level
7. Develop and implement a performance measurement and benchmarking strategy by developing and targeting Key Performance Indicators (KPI)
8. Define the appropriate technological environment to allow unhindered use of software

The workshop concluded with a discussion on key take-aways and highlights. The top key take-aways were:

1. There is a clear sense that BIM-PLM is the right way to go both in the industry and in academia.
2. HQ needs to better determine how agile they really are (for procurement, project delivery, etc.) and should look inward to 'reset operational goals'
3. There is a need to set clear priorities and attribute value in the decision making process and address the issues of politics and power
4. There is a need to simplify the picture by making clear what is to be achieved through the transition to BIM-PLM
5. There is a need to involve the supply chain and get feedback from all stakeholders
6. Develop and gain momentum by broadcasting success stories and learn from them, in particular from the vast experience gained by HQ as a leading client.
7. There is a need to empower stakeholders in the transition to BIM-PLM by granting sufficient latitutde and power in the decision making process.

Building Information Modeling (BIM):

A digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.

(NBIMS – National BIM Standard – United States)

Product Lifecycle Management (PLM):

A business model that, using ICT technologies, implements an integrated cooperative and collaborative management of product related data, along the entire product lifecycle.

(Garetti & Terzi, 2004)

Eastmain 1A, Powerstation, Hydro-Quebec, January 2010.

2. Introduction

Under the leadership of Prof. Louis Rivest, the Building Information Modeling (BIM) & Product life-cycle Management (PLM) workshop was held on the 4th and 5th of June 2014 in Montreal, Quebec, Canada. The workshop was mandated by Hydro-Quebec, a principal partner in the Pomerleau Industrial Chair held by Professor Daniel Forgues at the École de Technologie Supérieure (ÉTS) in Montreal, Quebec, Canada. It fulfills part of the Industrial Chair's mandate to (1) map the current situation found within Quebec's construction industry, (2) establish and define a desired state for Quebec's construction industry, and (3) define an action plan to fulfil these objectives. The principal objective of the workshop was to investigate possible avenues to define a desired state to optimize the deployment of BIM-PLM in Hydro-Quebec's current project delivery process.

This report presents the outcomes of the BIM-PLM Workshop. Its objective is to communicate the findings from the workshop, the areas of consensus and the plans for the future of BIM-PLM at HQ and within the Quebec construction industry.

The report begins by presenting HQ's operational context and traces a brief outline of BIM-PLM adoption and implementation within HQ. The overall vision for BIM-PLM agreed upon by the participants is then presented by discussing the similarities and the differences between both concepts. The challenges in transitioning, both within HQ and within the Quebec construction industry, are presented across four interrelated dimensions: technology, organization, process and context. A series of solutions and action items are then developed across two-tiers: overcoming inertia and sustaining the transition to BIM-PLM. Lastly, concluding remarks from the workshop are presented.

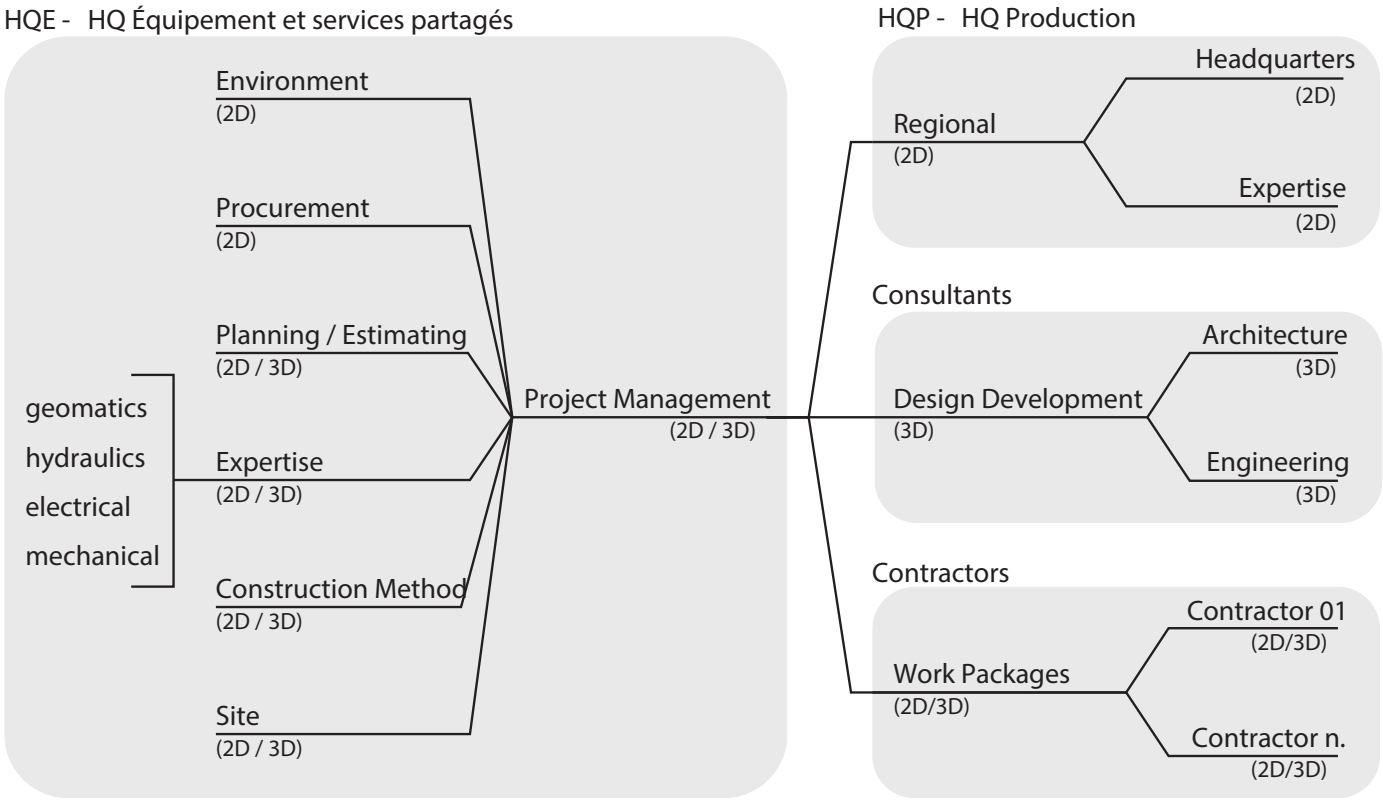


Figure 1 - Organizational-Functional capital project delivery structure

3. Context

The workshop focused on two specific contexts: the larger context defined by Quebec's construction industry and Hydro-Québec's more immediate context embedded into the Quebec construction industry context. Hydro-Québec is a state-controlled 'crown' corporation generating, transmitting and distributing electricity throughout Quebec and to parts of northeastern North-America since 1944. Hydro-Québec is one of Quebec's largest client bodies, with heavy investments in the development, modernization and long-term operability of the power system, as well as a telecommunications network, IT equipment and real estate holdings, which totaled $4.3 billion in 2013. The hydroelectric developments include 61 generating stations and 26 large reservoirs with a combined storage capacity of 175 TWh, as well as 656 dams and 97 control structures. This provides a total installed capacity of 36,068 MW (in 2013). HQ also counts about 20,200 employees at 150 different locations. In 2013, procurement of goods and services from Québec companies totaled $3,370 million, or 95% of a total estimated $3.5 billion in procurement.[1]

The department responsible for delivering these capital projects is Hydro-Québec Équipments et services partagés. Figure 1 illustrates the organizational-functional structure for project delivery by the project management department to his client HQ production for energy generation projects. Projects are procured through traditional design-bid-

"...from Hydro-Quebec's perspective, [...] you have, at least to me, something that could be qualified as a super vision, and your key problem is that [...] you're not able to transmit the vision and have the supply chain buy into it."

Prof. Louis Rivest, ÉTS

[1] http://www.hydroquebec.com/about-hydro-quebec/who-are-we/hydro-quebec-glance.html accessed on June 11, 2014

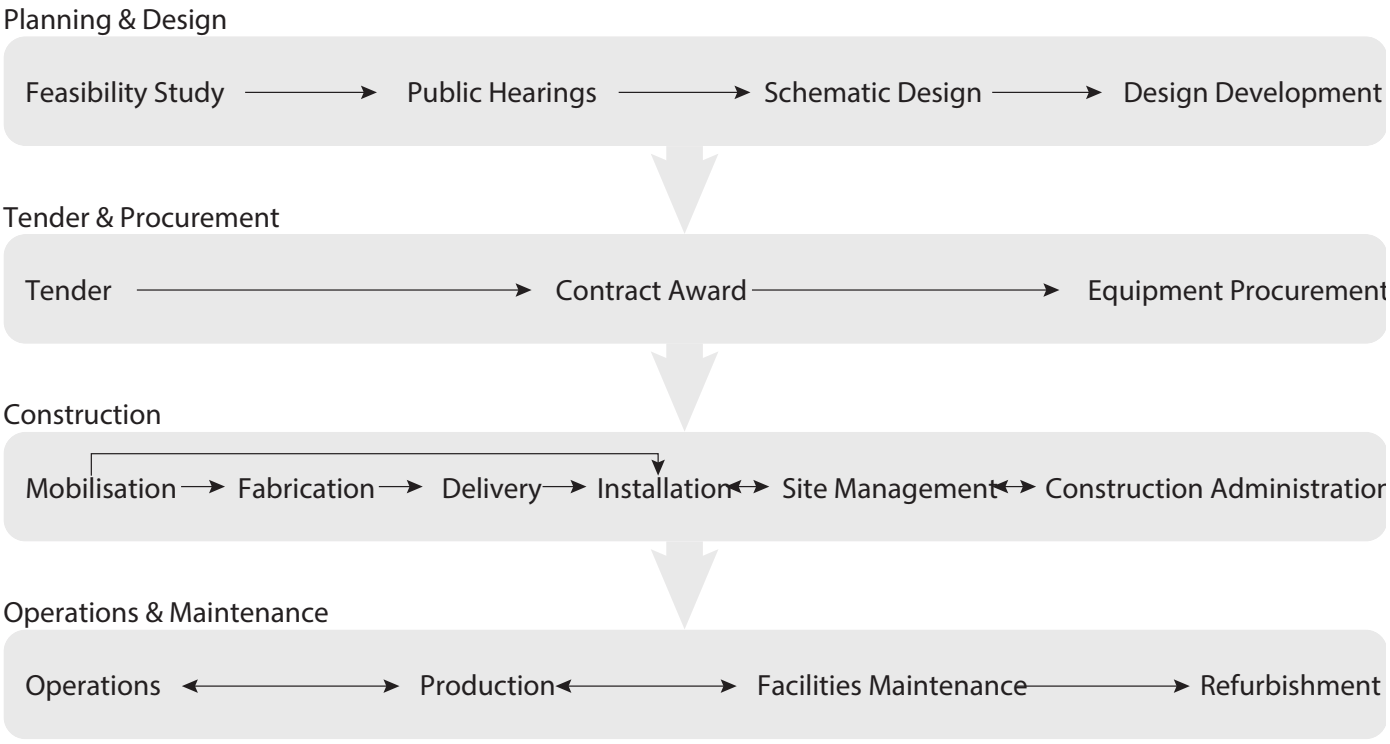


Figure 2 - General project delivery process

build (DBB) contracts with suppliers. As such there are little interactions between the client and the specialty trades although that is beginning to change through the exploration of more integrated procurement modes. However, being a crown corporation, Hydro-Quebec is subject to the general laws concerning procurement of services by public entities, namely the obligation to go with the lowest bidder.
The project delivery is phased in a linear fashion. Figure 2 illustrates the general phases and stages of this process.

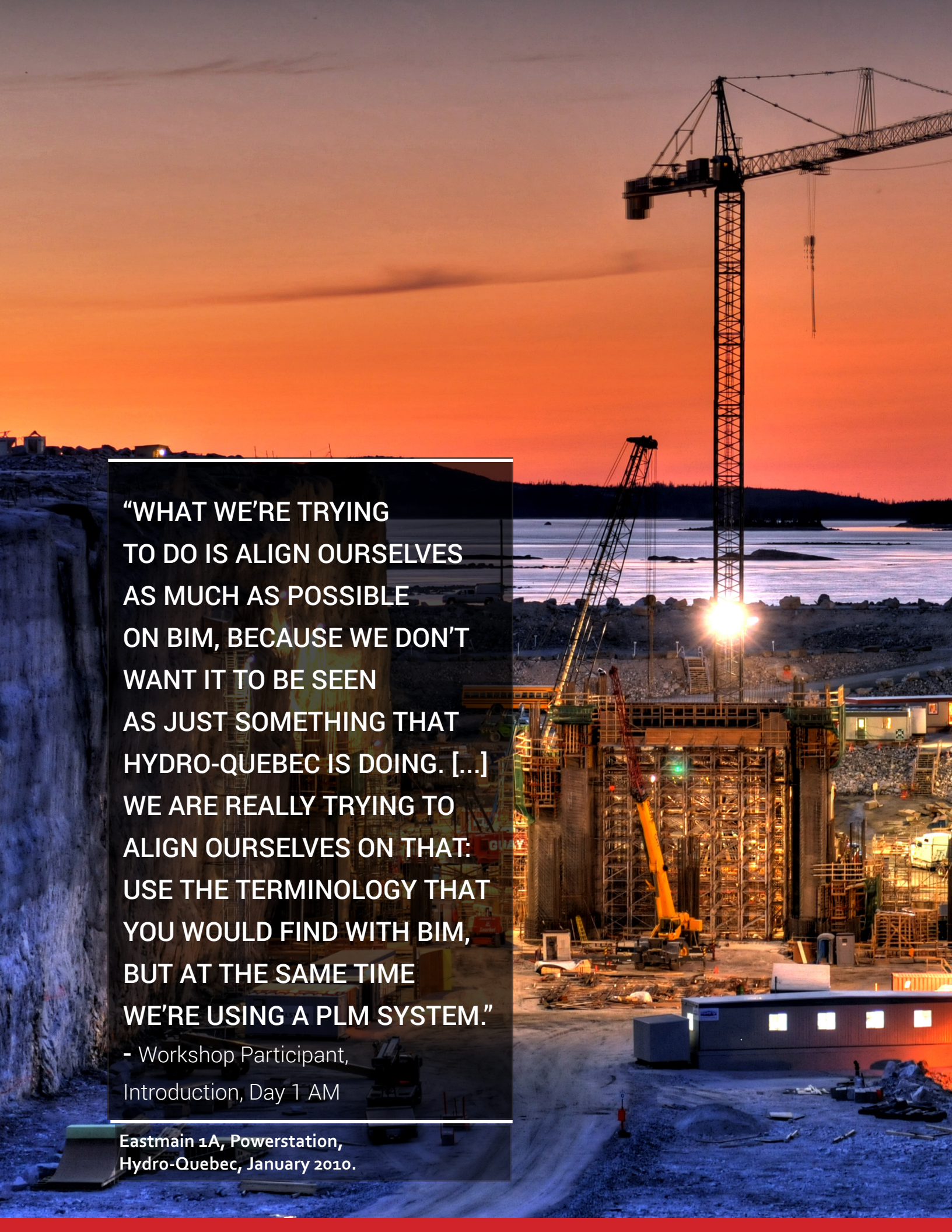
HQ adopted PLM-BIM in 2003 with the aim of optimizing their project delivery process through the development of a fully integrated, parametric model. The reduction of project lead time, the elimination of costly change orders and the reduction of capital costs associated to the construction of their facilities were the main motivating factors behind this move to PLM-BIM. The progressive elimination of 2D drawings would accompany this transformation and oblige a transition to a 3D model based tender and documentation process.

HQ began looking into 3D models to resolve interferences in their projects prior to construction. They initially implemented the Autodesk suite of software products, but have since moved to a PLM system, encompassing CATIA, Smarteam and Delmia, which was seen as better suited to HQ's needs. Despite the transition between systems, HQ has made an effort to align their adoption of PLM within the BIM 'conceptual domain' by adopting its terminology (e.g. "Levels of Development" (LOD)). This was done in an effort to facilitate exchanges with and foster commitment from external stakeholders as well as to develop project specifications based on concepts and a language which is increasingly being adopted within the construction industry.
Over the past 10 years, HQ has developed in-house capabilities with the following BIM-PLM uses:

- Modelling of existing structures
- Site analysis
- Quantity take-offs
- 4D sequencing
- Conceptual design
- Design review
- Numerical analysis
- 3D interdisciplinary coordination
- Construction site planning
- Construction systems design
- Digital fabrication

The next steps for HQ regarding their BIM-PLM implementation is two-tiered:

- **Internally,** to broadcast and propagate the organizational reconfiguration initiated by the transition to BIM-PLM beyond the engineering and project delivery departments, namely to the energy generation department, the principal client body within HQ;
- **Externally,** to revise their contractual documents by integrating rules, requirements and clear processes within their approaches to procurement and project delivery.



"WHAT WE'RE TRYING TO DO IS ALIGN OURSELVES AS MUCH AS POSSIBLE ON BIM, BECAUSE WE DON'T WANT IT TO BE SEEN AS JUST SOMETHING THAT HYDRO-QUEBEC IS DOING. [...] WE ARE REALLY TRYING TO ALIGN OURSELVES ON THAT: USE THE TERMINOLOGY THAT YOU WOULD FIND WITH BIM, BUT AT THE SAME TIME WE'RE USING A PLM SYSTEM."

- Workshop Participant, Introduction, Day 1 AM

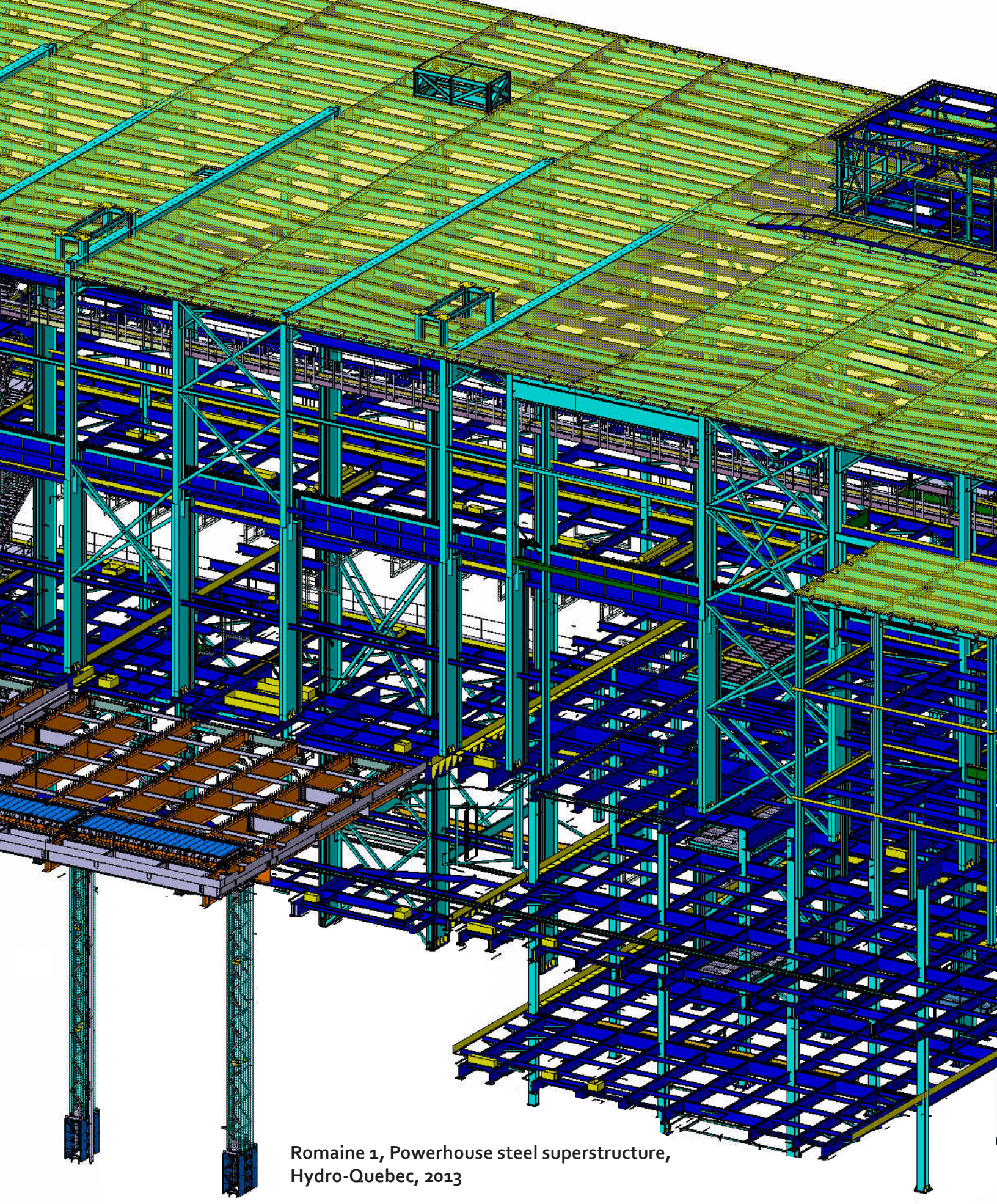
Eastmain 1A, Powerstation, Hydro-Quebec, January 2010.

4. Vision

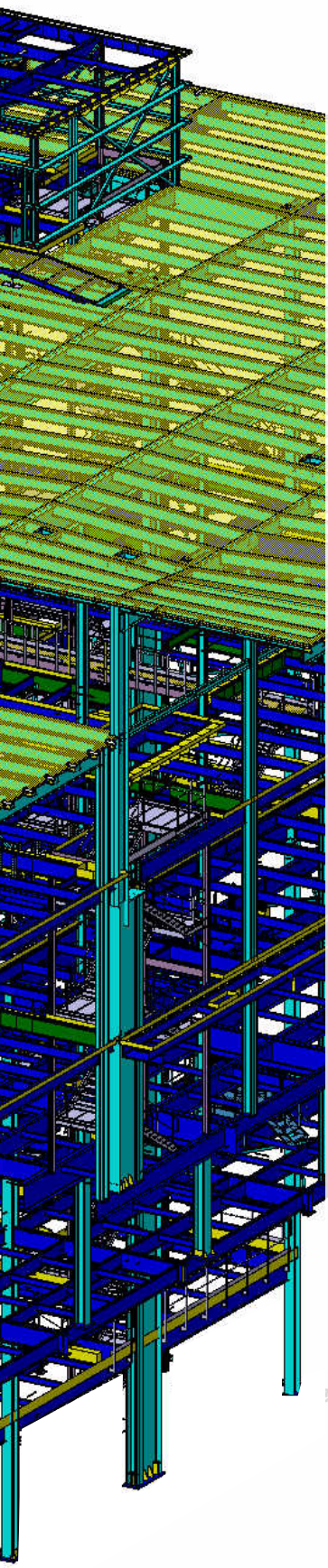
The first part of the workshop was dedicated to gaining an understanding for Hydro-Quebec's approach to project delivery and establishing a vision for PLM and BIM approaches. The objective was to 'converge on a vision of the future for BIM-PLM throughout the construction supply chain.' First, both concepts were defined and presented. Similarities and differences were exposed and the gap between both approaches was identified. Subsequently, the past, current and envisioned BIM-PLM practices at HQ were presented and discussed through a series of individual presentations. Lastly, a plenary discussion was held to foster consensus between workshop participants on a vision for BIM-PLM.

From the initial discussions on PLM and BIM, the two approaches present certain similarities such as the creation, integration (or federation) and reuse of project information, the concept of 'digital mock-up' and project management practices. In essence, both approaches are informed by the same objectives: to increase collaboration, productivity, optimisation, and to deliver better value to the client. However, the differences between PLM and BIM highlight several gaps which limit the scope of both approaches.

The underlying differences between both approaches are found in the context in which they are deployed and in the configuration of work that is inherent to these contexts: the way in which people work is different across domains. Whereas clear sets of rules and requirements traditionally exist within PLM approaches, these rules and requirements have not yet been developed nor established within current BIM approaches. This begs the question as to how to better inform these contexts to bridge the gaps found between BIM and PLM .



Romaine 1, Powerhouse steel superstructure, Hydro-Quebec, 2013

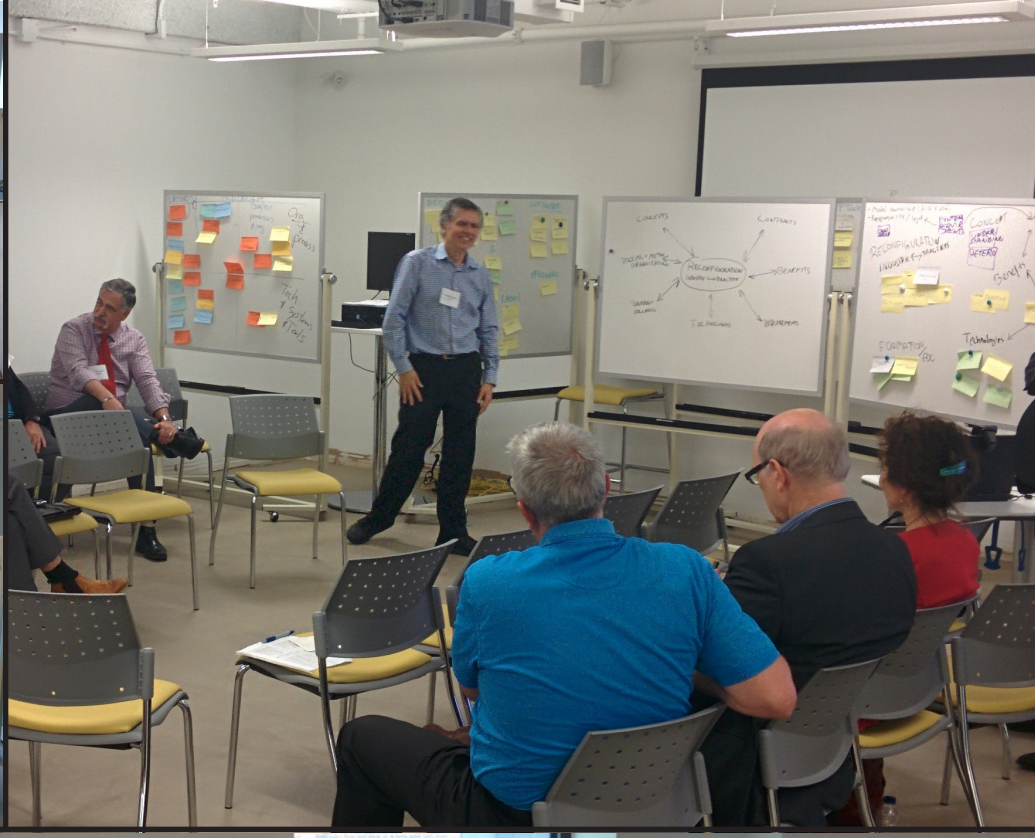


The plenary session gave the participants in the workshop a chance to discuss the concepts underlying BIM and PLM while fostering consensus around a common vision for the integration or unification of both concepts for the construction industry. The underlying concept unifying both approaches was identified as being **the collaborative development and management of a project's data and information throughout its life-cycle. This is achieved through the co-creation and co-development of a parametric digital model containing product data and information situated at both the physical and meta- level to maximize value through total supply chain and life-cycle optimization.**

The mitigating factors of this vision from HQ's perspective discussed in the plenary were: the complexity of the tool and its limited deployment across the supply chain; the complexity of HQ's internal supply chain and project delivery processes; the legal obligations to procure services and products according to a design-bid-build (DBB) procurement mode; and the lack of involvement from industry stakeholders. In extending this to the rest of the industry, the issues grow considerably. For instance, large owners can't clearly identify their requirements nor do they have clear metrics to assess the project delivery process including the development and use of digital models. The industry also is subject to inertia with regards to modifying its practices. Also, the cheapest price often trumps the best quality. Once the transition is initiated, a whole other set of challenges arise, namely interactions within the digital environment, hand-offs, ownership, roles and responsibilities, etc.

In the end, the group identified a number of challenges, possible solutions and action items in transitioning to a BIM-PLM business model within the construction industry. These are developed across two-tiers: first - breaking the industry's inertia and resistance to change and second - sustaining the transition to BIM-PLM. Furthermore, HQ's power and influence within Quebec's construction industry was highlighted: how constrained is HQ by provincial procurement laws and other mitigating factors which hinder their transition to BIM-PLM? What should their role be in promoting this vision? This poses a further question: how involved should all levels of government (federal, provincial and municipal) be in supporting an industry-wide transition to BIM-PLM? Lastly, the tight coupling between tools and processes in the BIM-PLM approach gives rise to questions around which tools should be deployed and how they should be deployed.

Having thus established a vision for BIM-PLM, and inspired by HQ's past experiences and future direction, the workshop participants looked towards identifying the issues and challenges with initiating and maintaining a transition to BIM-PLM in the Quebec construction industry. The results of this portion of the workshop are presented and discussed in the next section.



Brain sketching breakout session
BIM&PLM Workshop 4-5 June 2014

5. Challenges

The challenges were identified through "brain sketching" [2]. The objective of the brain sketching exercise was to 'identify the challenges to achieve the vision of BIM-PLM project delivery within the Quebec construction Industry'. The workshop participants were split into four groups during a break-out session. Each participant was asked to remember 3 or more issues they had encountered with the use and deployment of BIM (BIM-PLM for those who were working in this approach) in their daily activities. They then wrote down key words which related to the issue they had identified on a post-it note and read them out loud to explain each issue. All the issues identified by the participants were then categorized according to themes. These themes were presented to the entire workshop group during a plenary discussion. The challenges presented below were highlighted during the plenary session and are the result of the brain sketching exercise. They are organized across 4 interconnected dimensions: Technology, Organization, Process and Context.

"..the discussion today brought out some things that people don't really want to say, [...] At the present time whether you're a contractor or a consultant, what's in it for me? What am I gaining?" -

Workshop Participant, Discussion, Day 1 PM

[2] http://www.mycoted.com/BrainSketching

5.1 Technology

The technology dimension is related to the deployment of information and communication technologies by encompassing the tools and technologies implemented within an organization or project team. The identified technological challenges were:

- Technological interoperability
- Control over the shared data
- Clarity of data requirements
- Hardware upkeep

Technological Interoperability

The lack of technological interoperability was seen as being one of the core challenges that hindered the efficient exchange of data across different software platforms in the BIM-PLM approach. The fact that HQ is using a software platform which isn't "standard" within the North American construction industry, namely CATIA and Smarteam, nor does it possess the capability to publish data to a common "open" format, the Industry Foundation Class (IFC), limits the extent of the use of this data. While workarounds have been developed, the issue of technological interoperability still poses an important challenge within HQ and is of major concern.

Control over the shared data

Questions of access to data and operations on this data were raised. The ways in which the models and their associated data were exchanged and manipulated through subsequent operations on the model were discussed. The level of detail input into the model, the quantity of data that was produced as well as the extent to which it was developed were issues that were raised as having an impact on the quality of the data, its reliability and ultimately its value.

Clarity of data requirements

At the root of the previous issue is the lack of clarity in the data requirements and the absence of contractual language stipulating what is required and at which moment it is required.

Hardware upkeep

The increasing size and complexity of the models being produced, their increasing level of development, and the way in which they are being produced is requiring better and faster hardware environments which allow fluid manipulation of these models. In addition, the increasing everyday use of the model - its ubiquity, and operations in remote locations, require an ever-expanding infrastructure to support this access. The costs associated to this upkeep are non-negligible, in particular for small or medium enterprises (SMEs).

"This problem of sharing has been around for twenty years and its going to be around for another twenty years [...] it's very difficult but your are never going to get any complete information. It is never going to happen to one hundred percent"

Workshop participant, Presentations, Day 2 AM

"...if you want to have a platform that's going to be used by everybody [...] you're bound to have a period where everything you need for the mechanical people, for the electrical people, for the construction people, will not be in the software. We will need to wildly migrate [the software] to do this and then sometimes he [the software provider] will figure out that there is not enough market, and will stop updating it" -

Workshop participant, Presentations, Day 2 AM

5.2 Process

The process dimension enables an organization or project team through mechanisms and actions. It is related to the generation of data, information and knowledge, its management as well as its exchange across the organization or project network and throughout the project life-cycle. The main identified process challenges were:

- The lack of clarity and 'connectedness' of internal, external and inter-disciplinary processes and workflows
- Piece-meal optimization vs. global optimization
- Lack of the 'life-cycle' view of a project or product
- Lack of measurement strategies to improve processes
- The 'old ways' of working

Clarity and 'connectedness' of internal, external and inter-disciplinary processes and workflows

The overall lack of clarity within and across process, be they within the organization (internal), between organizations (external) and between disciplines (inter-disciplinary) introduces barriers to communication flows and impedes value creation. In a BIM-PLM approach, this results in the inefficient deployment of the technologies which produces waste, such as information loss or overproduction, and sub-optimal solutions.

Piece-meal optimization vs. global optimization

The lack of common objectives, integrated processes and the presence of entrenched organizational realities were indicated as leading to 'piece-meal' optimization of a product or project where each stakeholder seeks to optimize their own portion of work rather than the overall project or product. This is contradictory to the BIM-PLM approach, which seeks to optimize the whole.

Lack of the 'life-cycle' view of a project or product

This difficulty to achieve an overall optimum in the traditional project setting was identified as being partly due to the limited 'life-cycle' approach to project delivery that is adopted by Owners and Clients. The 'lowest possible cost', which was seen as prevalent in the Quebec construction industry by workshop participants, seriously hinders the 'life-cycle' approach which may result in increased capital costs over lower operational and maintenance costs in the longer-term. Again, this 'lowest-cost' approach is contradictory to the BIM-PLM strategic approach.

The 'life-cycle' view in the BIM-PLM strategic approach also considers the 'life-cycle' of the data and information that is contained within the 3D model. For HQ, the challenge lies in optimizing the value of this data and information across the facilities life-cycle through reuse by the operations and facilities management departments of HQ.

Lack of measurement strategies to improve processes and evaluate the returns

A lack of performance measurement and assessment strategies at both the organizational and project level was identified during the workshop as a challenge for the implementation of BIM-PLM strategic approach. A lack of measurement strategies impedes the development of capabilities and additional competencies due to the lack of basis for comparison. It also impedes the quantification of returns (benefits) to justify the investments and makes the case to support the transition to BIM-PLM.

The 'old ways' of working

There is a misunderstanding of what competitive advantages PLM-BIM may offer. The old ways of work and collaboration are seen to bring benefits to certain people who may resist a change towards more integrative, and therefore transparent, ways of working, as proposed by the BIM-PLM approach.

"BIM is for what? BIM is for whom? It's for the owner at the end. [...] It's how the client is going to use our work at the end to maintain their equipment, to modify the model, and to understand when they're ready for refurbishing." -

Workshop participant, Plenary Discussion, Day 1 AM

5.3 Organization

The organization dimension structures the project team and considers the organization itself. It relates to contractual set-ups, hierarchical links created, roles and responsibilities. The main organizational challenges that were identified were:

- The cost associated to the transition
- Contractual and procurement models
- The project and organizational culture
- Data and model ownership
- Roles and responsibilities
- Varying levels of maturity across the supply chain
- Knowledge creation, retention and learning
- Long-term vs. short-term relationships
- People issues

The cost vs. the value of the transition

The capital costs associated with the transition to BIM-PLM were discussed as a barrier. The cost of the technological infrastructure, the training, and the hiring of new personnel may be too much for certain industry stakeholders, especially given that the majority of these stakeholders are SMEs. Profit margins in the construction industry are generally low and that there is little or no investment in Research & Development. Furthermore, the value proposition is not yet clear to all stakeholders. A recurring question that was posed during the workshop was: what's in it for us?

Contractual and procurement models are ill suited to the life-cycle approach

A general theme that was discussed throughout the workshop was the reconfiguration of practices to suit the BIM-PLM strategic approach. This reconfiguration was seen as being greatly hindered by the current contractual practices and public procurement laws governing the Quebec construction industry. It remains though, that the contractual and procurement practices could go a long way in fostering a more conducive environment which could facilitate this transition to BIM-PLM. Lastly, the robustness and flexibility of these contracts was discussed. Questions as to how much and what type of requirements should be included, what to ask for, practical incentives and the amount of transparency required were elements that were deemed pressing points to resolve.

The project and organizational culture

Cultural organisational structures of the construction supply chain vary and depend on many factors such as the size of an organization, the history, its goals, market and operating environment. The challenges identified were to align the participatory and collaborative culture of the different organizations within the project management framework of the BIM-PLM strategic approach.

Data and model ownership

Similarly to the challenges associated to the control over project data identified as a technological challenge, the ownership of the data was highlighted as a major issue in the Quebec construction industry. Whereas in the PLM approach within the aerospace industry, data ownership is clear (i.e. the Client, being the provider of work, owns the model, the data and the information), in the construction industry, no clear ownership boundary exists. For HQ, this becomes an issue when the model starts being shared with external stakeholders and more importantly, when these stakeholders participate in the modelling process (e.g. structural steel supplier creating a detailed model for fabrication and shop drawings). The issue around ownership of data extends to the Operations and Maintenance phase due to the challenge of maintaining and updating the model to 'as-built' conditions during the construction phase, responsibilities around who should be maintaining this model and costs associated to this process. Lastly, there is the question of intellectual property (IP) which must be accounted for in this context.

Roles and responsibilities

The roles and responsibilities are not clearly defined. There is no clear consensus of which actor, if any, should drive the development and adoption of BIM-PLM. The challenge lies in defining the roles and responsibilities of the client body with respects to BIM-PLM, as they are the ones who drive the process. In parallel, the transition to BIM-PLM was seen as a catalyst for the reconfiguration of practice and thus the modification of roles and responsibilities across the supply chain. What these new roles and responsibilities are and how they are developed is an emerging phenomenon as the transition to BIM-PLM gains momentum. There is thus a lot of uncertainty around these roles and responsibilities which increases the risks associated to this transition.

Varying levels of maturity across the supply chain

The varying levels of maturity and capability found throughout the Quebec construction industry pose a serious challenge to the optimal

deployment of BIM-PLM and its efficient use within the project setting. The general maturity of the Quebec construction industry with regards to BIM-PLM is perceived as being relatively low. For HQ, this poses the challenge of finding service providers capable of fulfilling their obligations within the BIM-PLM approach put forth by HQ. This impacts the way in which the data and information are used and leveraged to generate value over the project life-cycle. At the industry level, the fact that there is no 'one size fits all' solution to transitioning to fully integrated models was discussed. As a consequence, different levels of BIM-PLM implementation require different approaches to model-based collaboration. However, it was discussed that organizations in the construction industry focus on project processes, through established project management approaches, and pay little attention to organizational processes. In essence, business analysis is lacking in the construction industry, which hinders the creation of a consistent basis to support the transition to BIM-PLM.

Long-term vs. short-term relationships

A challenge that was identified as a symptom of the current legal landscape is the 'short-termism' which characterizes the Quebec construction industry. This short-term, project based approach hinders the creation of critical elements such as trust, product knowledge and common experience. This impacts the deployment of the BIM-PLM approach due to the relatively high-investment/low-return offered by one-off projects. More considerable benefits appear when long-term, repeat relationships are developed.

Knowledge creation, retention and organizational learning

As noted above, the creation, retention and reuse of knowledge and overall organizational learning is somewhat hindered by the short-term approach to project delivery in the Quebec construction industry. While the construction industry will always remain a project-based industry, certain measures can be implemented to encourage organizational learning between projects which fits into the BIM-PLM strategic approach. Furthermore, there is a need to identify which processes and relationships should be leveraged to support this organizational learning and knowledge transfer.

People issues

At its core, construction is a social process: it is a human-centered industry. As opposed to the manufacturing sector where humans have gradually been phased out of the production line, the construction industry will

continue to be largely dominated by a human presence. As such, alignment of human resources, motivation and organisational development as well as understanding the requirements of the BIM-PLM strategic approach within the existing system is a challenge. In transitioning to BIM-PLM within the construction industry, the fundamental challenge lies in removing people from their comfort zone.

One of the challenges I see here in the Province [of Quebec] is the integration of all these people for Facility Management with the software for energy estimation, energy analysis, simulation, they are not that much integrated in the tools that are commonly used. -

Workshop Participant, Presentations, Day 2 AM

5.4 Context

The contextual dimension defines the environment in which evolves the collaborative project delivery system. It represents anything that is outside the organization or project team. It is concerned with issues such as norms, regulations, policies, markets and cultures, which are unique to each project setting. The main contextual challenges that were identified were:

- The general fragmentation of industry
- The lack of informed Owners and Clients in a position to drive the transition
- An ill-defined frame of reference
- The importance of the geographic and market contexts

The general fragmentation of industry

The fragmentation of the construction industry is a long standing challenge which hinders collaboration, innovation and general value creation within the industry. In the transition to a BIM-PLM project delivery approach, fragmentation exacerbates issues such as technology use and optimization of processes. This challenge relates to the development of an agile business model which suits an ever changing context, defined through continuous learning and adaptation.

The lack of informed Owners and Clients in a position to drive the transition

HQ being the exception, most Owners and Clients lack a clear vision for the processes to be put in place to ensure their projects be successful. The transition to BIM-PLM in the Quebec construction industry goes through an increase of its demand from these Owners and Clients. They have a significant role to play in driving the process. The challenge lies in educating these Client bodies to the benefits they can reap from this transition and how they can use the increase in information to better maintain and operate their buildings. They also must learn to frame their requirements clearly and develop their contracts accordingly. In effect, of all the industry stakeholder to be impacted by the transition to BIM-PLM, it would seem that the Owner/Client is the one who needs to transform the most.

An ill-defined frame of reference

BIM and PLM are both subject to much interpretation; their definitions fluctuate. As such the interpretations of both of these concept vary between countries, organisations and individuals. Currently, there are limited references from which organizations can learn (although this is changing at a rapid pace). The construction industry faces a challenge simply in understanding the core concepts of BIM-PLM, what they intend and then to tailor these concepts to the contextual characteristics of the Quebec construction industry.

The importance of the geographic and market contexts

At the core of the workshop was the importance of the geographic and market contexts on the transition to BIM-PLM. Several issues were identified which implied the structuring nature of this context. The commitment from the Quebec government to create and sustain an environment that is conducive to enable improvements in construction performance and thus to achieve best practices was a recurring theme. The lowest-cost/lowest bid mentality was also identified as an important challenge. The various levels of government involved in the construction process as well as differing regional mentalities were identified as leading challenges. In fact, the geographic and market context was somewhat identified as the root of the Quebec construction industry's inertia in the face of the transition to BIM-PLM.

"...what makes a difference here is that Hydro-Quebec is [...] a very knowledgeable owner and this is something which makes a big difference because in the building construction industry, most owners are not as knowledgeable as them." -

Workshop Participant, Plenary discussion, Day 1 AM

“How do you think you can empower the people you will be working with?

What responsibilities are you willing to take?”

Prof. Sylvie Dore, ÉTS

6. Proposed Action Items

The 2nd day of the workshop was dedicated to finding solutions and proposing action items to initiate and sustain the transition to BIM-PLM within the Quebec construction industry. Through participant presentations, a round-table and plenary discussion, some solutions and action items were identified. The proposed action items are distributed across two tiers: (1) Breaking the Quebec construction industry's general inertia in the face of the emergence of BIM-PLM and (2) sustaining the transition to BIM-PLM.

Panel discussion
Workshop BIM&PLM, 5 June, 2014

6.1 Breaking the Inertia

The first tier of the proposed action items aimed at transitioning to BIM-PLM are concerned with breaking the inertia, which is generally felt within the Quebec construction industry. The following action items have been proposed:

1. Learn from international initiatives and innovative practices
2. Foster buy-in from industry stakeholders and develop momentum by introducing a strong governance from industry leaders
3. Implement change management strategies at the organizational level
4. Adopt relational procurement methods and develop long-term alliances to facilitate knowledge capture and reuse.

Learn from international initiatives and innovative practices

The Quebec construction industry should look outward, towards other government and industry initiatives aimed at transforming the industry. Initiatives, the implementation and the lessons learned, such as those put forth in the United Kingdom and Australia, among others, should be used to orient and inform the Quebec construction industry's transition to BIM-PLM.

Foster buy-in from industry stakeholders and develop momentum by introducing a strong governance from industry leaders

In an attempt to foster buy-in from industry stakeholders and develop momentum, a strong governance from industry leaders is needed. This governance can take the form of broadcasting of success stories, lessons learned, or the development of a "Body of Knowledge" and the creation of discussion forums to broadcast to the industry. Industry leaders, such as HQ and the Société Québécoise des Infrastructures (SQI), were seen as key players in a position to influence the industry and provide impetus to this momentum. However, there is the need to focus this governance around clear objectives and goals. Lastly, the need to publicize and broadcast the transition towards BIM-PLM by major players in the industry was seen as a key factor that could help in fostering a "climate of change"

Implement change management strategies at the organizational level

At the organizational level, change management strategies must be implemented to provide structure throughout the transformation process. These strategies must be adapted to the organizational context. Organizations looking to implement change management strategies should look to hire someone to champion this change process.

Adopt relational procurement methods and develop long-term alliances to facilitate knowledge capture and reuse

The ways in which consulting and construction services are procured should be re-examined to allow for longer-term, more relational approaches to contracting. While this is a considerable challenge within the Quebec public procurement domain, due to the legal landscape informing procurement and the necessity to go with lowest bidder, there was a general sense amongst workshop participants that this landscape had to shift towards more relational approaches. This would allow better synergy between organizations and could lead to innovation, better knowledge generation and knowledge retention as well as could allow for longitudinal benchmarking of performance. In addition, this would allow for co-development and concurrent evolution of BIM-PLM capabilities. To a certain extent, this is already happening between HQ and their consultants with whom they have developed specific capabilities to exchange and develop their 3D models. However this has yet to be extended to contractors.

" I think Hydro-Quebec has always tried to be an innovator and will continue to do so and the effect of trying to bring these new solutions, these new approaches to the industry, it's also to encourage industry in its development and its evolution." -

Workshop Participant, Plenary discussion, Day 1 AM

6.2 Sustaining the Transition

The second tier of the proposed action items aimed at transitioning to BIM-PLM are concerned with sustaining the transition the Quebec construction industry by reconfiguring requirements, processes and the rules which inform and mediate project delivery. The following action items have been proposed:

1. Look for incremental change rather than radical change - encourage small steps instead of giant leaps
2. Map processes and align them across the supply chain
3. Develop clear rules and requirements which leverage the BIM-PLM strategic approach to project delivery
4. Define a better suited contractual and legal framework
5. Hire a BIM-PLM manager to champion the transformation process
6. Mandate a BIM Execution Plan (BIM PxP) and make it part of the contractual framework at the project level
7. Develop and implement a performance measurement and benchmarking strategy by developing and targeting Key Performance Indicators (KPI)
8. Define the appropriate technological environment
9. Implement robust data exchange standards such as IFC

Look for incremental change rather than radical change - encourage small steps instead of giant leaps

In reconfiguring the organizational practices and transitioning to BIM-PLM, organizations must look to take small steps and introduce incremental change. Identify the 'low hanging fruit' and establish clear and measurable short and long term goals.

Map processes and align them across the supply chain

The need to better understand and simplify certain current practices and processes was highlighted during the workshop. Certain actions or tasks were seen to constrain the deployment of BIM-PLM by introducing interoperability issues, amongst others. The mapping of processes would allow the elaboration of protocols and the optimization of these processes. The priority should be given to the processes which are seen to have the most impact on project delivery and on those which can be optimized through the BIM-PLM approach. Issues such as level of detail of the map-

ping, repetition or uniqueness of process and level of understanding of given processes should be accounted for.

Develop clear rules and requirements which leverage the BIM-PLM strategic approach to project delivery

The need to establish clear rules, guidelines and requirements to inform how the deployment and use of BIM-PLM within the project team was identified as a high priority item during the workshop. These rules, guidelines and requirements will be established through a keen understanding of the specific design and construction processes for each stakeholder and life-cycle phase. There is also a need to clearly establish how far to develop the 3D model in light of the possible added value that developing the model provides. This should be clearly stated in the requirements

Define a better suited contractual and legal framework

The aforementioned rules, guidelines and requirements will be found within the contractual framework which is implemented in the project setting. As mentioned, there is a need to look at long-term contractual relationships, even if this is not the norm under public procurement within the Quebec construction industry. While it was indicated that HQ had limited influence on redefining the contractual and legal framework to facilitate transitioning to an optimal BIM-PLM approach certain actions could be taken to foster more commitment to the process such as including a contractually binding BIM Project Execution Plan (BIM PxP, discussed below). Furthermore, within the contractual and legal framework, the concepts associated to BIM-PLM must be clearly defined in order to normalize expectations. Lastly, as another way to foster buy-in from industry stakeholder, transitioning to a 3D model based permitting and tender process will act as a catalysts for change by making it necessary for potential service providers to develop their internal capabilities to bid on certain jobs. In other words, by making the 3D model part of the contractual and legal framework, HQ is provoking the change to a certain extent.

Hire a BIM-PLM manager to champion the transformation process

One of the aforementioned action items in breaking the inertia, the BIM-PLM change management process should be supported by a BIM-PLM manager to champion this process. The BIM-PLM manager would act as the guide for value creation for the owner: translate requirements and needs more efficiently, manage the configuration of production, better describe the processes and the requirements, etc. He would also contribute to the internal dialogue within the organization and help in identifying risks and precise action items in the transition to BIM-PLM.

Mandate a BIM Project Execution Plan (BIM PxP) and make it part of the contractual framework at the project level

As previously mentioned, one of the action items identified as being key in sustaining the transition to a BIM-PLM project delivery approach was the mandating of a BIM Project Execution Plan (BIM PxP) and making it part of the contractual framework. The BIM PxP should highlight the requirements to be fulfilled, the process to be implemented and the roles and responsibilities of all project stakeholders. It should also be adaptable to each project context.

Develop and implement a performance measurement and benchmarking strategy by developing and targeting Key Performance Indicators (KPI)

As indicated by Prof. H.E.Pels during the workshop: "the better the measurement, the better the process". As such, in order to improve and maintain high performance standards and encourage feedback and learning, a clear benchmarking and performance assessment strategy should be implemented at the organizational level. This performance assessment strategy should target Key Performance Indicators (KPI) which are clearly related to the BIM-PLM approach. One strategy that was suggested was to attempt to quantify all inputs and outputs within given processes. In addition, by quantifying the benefits of the BIM-PLM approach, these could be publicized and broadcasted to the industry, which would fall into the first tier of action items. Lastly, another dimension of the benchmarking and performance assessment process is maturity modeling and the evaluation of capabilities. As discussed during the workshop, and corroborated in the literature, the alignment of capabilities is fundamental to the effective deployment of the BIM-PLM approach. The evaluation of these capabilities and maturity is supported by multiple maturity models which have been developed through past research.

Define the appropriate technological environment

The technological environment in which BIM-PLM was deployed was the center of much discussion during the workshop. The choice of software platform and its level of customization were seen as introducing potential issues in the BIM-PLM deployment process. On the other hand, the introduction and development of parallel technological systems which tapped into the BIM-PLM approach (such as laser scanning, mobile tablets, etc.), their deployment to site and their integration into the project environment were seen as key in improving productivity and increase the value of the tools. As such, ensuring that the right technology be deployed and that the right technological infrastructure is in place to ensure the proper use of the software tools is a requisite to sustain the transition to BIM-PLM.

Implement robust data exchange standards such as IFC

As part of the technological environment, the data exchange standards which are adopted will play an important role in facilitating collaboration amongst project stakeholders. The current tools which have been adopted by HQ currently lack the capability to subscribe to the construction industry's standard 'Industry Foundation Class' (IFC), as such this poses several issues in exchanging data with external project stakeholders. It was mentioned that subsequent versions of the software platform adopted by HQ would have IFC capabilities. However, it was agreed that even through IFC, data and information loss would be inevitable. In light of this, it was mentioned that efforts should be made to develop standard exchange protocols which could take into account interoperability issues and counter them. Certain standards exist, such as IFC and the information exchange standards (ie. COBie), which should be deployed, whereas other standards, namely process related, need to be developed in-house. The responsibility for standardization should fall on the BIM manager within the company.

"...we have a different way of understanding the processes, different terminologies [...] We should agree on the same understanding and have a process. Then from there, I think, on top of the process, we can position the tools or the contracts and the legal aspects: how to make the process work."-

Workshop Participant, Panel discussion, Day 2 PM

"Sure it's transformation, but that's what we're trying to do here. It's all about process innovation, we're trying to change practices [...] It's how we do that that is the challenge. It's necessary to consider the level of detail when implementing process change. It's important to understand both business and design processes relative to your supply chain's and their existing ways of working. [...] Because this is where, I think, the big gains of process mapping lie and the added value of BIM-PLM can be leveraged. " -

Assoc. Prof. Julie Jupp, UTS

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7. Questions

Q1 - Engineering processes have evolved to include 3D mock-ups and data; construction processes also need to evolve; what practical experiences from abroad can we learn from to efficiently fuel this evolution?

From the University of Technology Sydney (UTS), in Sydney, Australia, Prof. Julie Jupp's presentation on BIM & PLM in Australia highlighted two important aspects that would help in breaking the inertia: (1) Industry level Governance and (2) the fear of being left behind (as in organizations adopting and implementing BIM to stay competitive). As such, an effort to broadcast the lessons learned and success stories from HQ could go a long way in fueling the evolution to BIM-PLM.

Q2 - Which contractual relationships models can realistically be implemented between the contractors and HQ to maximize benefits from BIM-PLM?

As innovative procurement and project delivery modes are emerging elsewhere, many different opportunities arise for HQ to leverage these novel contractual environments. For example, while the public procurement laws in Quebec are seen as a hindrance for full supply chain integration, therefore making procurement modes such as Integrated Project Delivery (IPD) almost impossible to implement, there are modified versions that have been developed, termed IPD "light" which attempt to harness the benefits of IPD, ie. fostering a more conducive collaborative environment within the project supply chain, within the confines of public procurement laws.

Q3 - Which organizational changes and what responsibilities must we implement to maximize the benefits from BIM-PLM?

One suggestion was that a BIM manager with sufficient power and leeway be hired within HQ to champion the BIM-PLM implementation process. Other mechanisms that were discussed were to look towards process mappings and determining and defining clear requirements which could be translated to contracts with service providers and contractors.

8. Conclusion

The BIM-PLM workshop was an opportunity for leaders from the industry and prominent members from academia to come together and determine a vision for the future of BIM-PLM both within HQ and within the context of Quebec's construction industry. Once this vision was agreed upon, the challenges which hindered its fulfillment were identified and solutions were suggested to overcome them. From these solutions, several action items were proposed across two tiers: first, breaking the industry's inertia and resistance to change and second, sustaining the transition to BIM-PLM.

Three questions were asked at the onset of the workshop by HQ. The two days spent to discuss the vision, issues, challenges, solution avenues and developing action items allowed to formulate an answer to these questions (see opposite page)

Finally, the overall sense from the workshop participants was that BIM-PLM was the right way to go (and has been for the past 10 years for HQ) and that the time had now come to gain momentum and reach critical mass within the Quebec construction industry. By broadcasting the success stories and learning from industry leaders such as HQ, it is believed that a shift in momentum can be provoked and BIM-PLM become part of the contemporary landscape.

9.1 Annexe

Attendees

Hydro-Quebec

Hrair Labajian	HQ
Michael Labelle	HQ
Albert Virgile	HQ
Catherine Côté	HQ
François Chaput	HQ
Victor Gauvin	HQ
Michel Guevremont	HQ
Serge Paradis	HQ
Steven Weyman	HQ
Richard Déziel	HQ
Richard Morissette	HQ
Marc Imbeault	HQ
Benoît Matte	HQ

ETS

Dr. Daniel Forgues	GRIDD - ÉTS
Erik Poirier	GRIDD - ÉTS / U.B-C
Gulnaz Aksenova	GRIDD - ÉTS
Jean-François Côté	GRIDD - ÉTS
Pierre Collot	GRIDD - ÉTS
Sébastien Frenette	GRIDD - ÉTS
Zoubeir Azouz	GRIDD - ÉTS
Dr. Sylvie Doré	GRIDD - ÉTS
Dr. Louis Rivest	ÉTS
Escandon Lorena	ETS

Invited Participants

Jean-François Théberge	EXP
Dr. Ahmad Jrade	U.Ottawa
Dr. Henk Jan Pels	Eindhoven U Tech.
Dr. Ivanka Iordanova	Pomerleau
Dr. Julie Jupp	U Tech. Sydney
Dr. Thomas Froese	U.B-C
Dr. Zhenhua Zhu	U.Concordia
Guy Paquin	SQI
Jean Thibodeau	Canam
Mohamed Ali El Hani	Impararia
Mohammad Nahangi	U.Waterloo
Sylvie Robichaud	AECOM

9.2 Annexe

Future Research Opportunities

Several opportunities for future research arose from the workshop, all helping to further define a desired state of BIM-PLM deployment in public owner organisation and continue efforts in the optimisation of project delivery processes. Three themes emerged from discussions with workshop participants, including a focus on the understanding and development of: (1) IPD-based procurement methods for large infrastructure projects delivered by public entities, (2) IT resources for increased organisation agility in public entities, and (3) the transfer of best practice from PLM-enabled manufacturing industries into construction based organisations. These could be conducted in collaboration between workshop participants.

The first area for future research concerns the further understanding and development of existing procurement methods. Since public work projects, such as those in HQ, are constrained by procurement legislature and cannot fully apply IPD principles, an effective platform for the procurement of public projects that can provide the many benefits of IPD is required if BIM-PLM deployment is to achieve further optimisation within HQ's organisation. Fixed and intractable procurement legislature must be identified and assessed relative to those areas that provide flexibility and capacity for absorbing IPD principles. Areas of opportunity within existing procurement processes and typical contractual forms should be identified so as to examine where the 'value-add' lies and how effective process-oriented gains can be achieved via new contractual arrangements. Related research initiatives, existing industry case studies and innovative public procurement systems should be identified and analysed in relation to Quebec's current public procurement legislature and the specifics of HQ's organisational and project context. The following areas may therefore provide valuable insights relative to the 'where' and the 'how' of the practical and realisable changes to HQ's present procurement processes lie, namely the nature of its product and supply chain, existing and forecast BIM-PLM capabilities, and IPD ambitions relative to: tender processes, procurement phasing, partnering frameworks, pre-qualification processes, risk, responsibilities, intellectual property, legal liability, and technical requirements.

The second potential avenue for further research concerns building a greater understanding of the use of BIM-PLM relative to a public entity's organisational agility. This research theme is based on the premise that public organisations delivering

and maintaining large infrastructure projects need to develop superior firm-wide BIM-PLM capability to not only successfully deliver individual one-off projects, but also to manage IT resources and realise organisational agility across a portfolio of projects. IT is generally considered an enabler of an organisation's agility. BIM-PLM capabilities are increasingly focusing on connecting project level data with corporate metrics, highlighting the role that business intelligence systems may increasingly play as BIM-PLM capabilities mature within the construction industry. IT investment will therefore likely continue to increase. The typical premise that greater IT investment enables a firm and its projects to be more agile is not a given in this context. Previous research in other industries shows that it is not uncommon that IT can also hinder and sometimes even impede organisational agility. This frequently observed but understudied IT-agility contradiction – by which IT may enable or impede (project and/or firm level) agility – requires further investigation relative to the deployment of BIM-PLM in a construction context. One approach to exploring this contradiction would be to conduct field work to empirically examine the nature of a public entity's IT capability and agility. The study would provide initial empirical evidence to build a better understanding of essential BIM-PLM IT capabilities and define their relationship with organisational agility, illustrating the useful implications for managerial practices at both the project and corporal level.

A third promising area of research that may lead to further gains and optimisation of HQ project delivery processes concerns the transfer of best practice from the manufacturing industries to construction. This area of research concerns a cross sector comparison where a greater understanding of best, or at least good, practice in the manufacturing industries' deployment of PLM will be explored from the perspective of how the BOM (Bill of Materials), processes and tools influence project delivery and how these constructs look between PLM in the manufacturing sector, on the one hand and BIM in the construction industry, on the one hand. This cross sector comparison would therefore aim to highlight the similitudes and differences of PLM and BIM deployment relative to these characteristics. It is perceived that the deployment of PLM in manufacturing is widely product-centric and BOM-based, while the use of BIM in construction is a more process-centric and technology-led approach. It is not clear today how true these perceptions are. A promising approach to investigating these ideas would be to compare in a detailed manner how similar undertakings – such as shipbuilding, as a 'PLM/Manufacturing' project, and stadium building, as a BIM/Construction project' – compare in terms of BOM usage, processes and tools. Such an investigation would shed new light on the similitudes and differences between both universes and help transfer best practices from one to the other.

9.3 Annexe

Schedule

JUNE 4th, 2014

BIM/PLM: where we stand as of now, where we are heading

AM	Start Time
	8:30 Welcome
	8:45 Brief participants introduction
	9:15 Prof.D.Forgues (ETS): Comparing PLM & BIM
	9:30 PLM/BIM at HQ Introduction
	9:35 PLM/BIM - Excavation and backfill design
	9:50 Coffee break
	10:10 PLM/BIM - Structural design and construction
	10:25 PLM/BIM - Mechanical design P&ID
	10:40 PLM/BIM - Estimation 3D to 4D
	10:55 PLM/BIM - Refurbishment design
	11:10 PLM/BIM - Engineering authentication
	11:25 Plenary discussion on vision; do we converge?
	12:15 Lunch, on site

Organizational challenges to BIM/PLM benefits

PM	Start Time
	13:15 Prof.H.JPels (EUT): BIM and PLM for CAE - the potential - the challenge
	14:15 Break-out - 4 teams
	14:20 Challenges and issues for BIM
	15:15 Coffee break
	15:35 Plenary discussion on challenges and issues
	16:30 Takeaway of the day as per HQ
	16:40 Conclusion
	16:45 End

9.3 Annexe

Schedule

JUNE 5th, 2014

Experience from abroad: learning and transposing

AM **Start Time**

8:30	Welcome
8:35	Prof.J.Jupp (UTS): AUSTRALIAN BIM & PLM EXPERIENCES
9:35	Plenary discussion on cultural & contractual issues
10:25	Coffee break
10:45	S.Robichaud (AECOM): Perspective from the supply chain: Engineering firm
11:05	J-F.Théberge (EXP): BIMchallenges from the supply chain perspective : Engineering & Construction
11:25	Plenary discussion on experience from abroad vs. Local
12:15	Lunch, on site

Items for an action plan to reconfigure the supply chain

PM **Start Time**

13:15	Panel : Items for an action plan to maximize BIM/PLM through the supply chain
14:15	Break-out - 4 teams
14:20	Identify items for an action plan
15:15	Coffee break
15:35	Plenary discussion on the items for an action plan
16:35	Takeaway of the day and workshop as per HQ
16:50	Conclusion
17:00	End