Development strategies for the French construction sector

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Abstract

In 2008, Europe entered a deep recession causing the industrial production to drop by 20%. In an attempt to redress the situation, many strategies were set by industrials to gain market share. The construction sector, however, still struggles to secure a positive margin. Furthermore, this sector is known to be the least efficient in terms of industrialization, process improvements, procedures, and technology application. In other words, waste is generated throughout the construction value chain. All these factors tend to predict a great development potential, estimated at 70% in 2025. This paper presents an overview on the construction field and the applied research conducted in this sector to improve its efficiency and productivity. The paper also investigates the future trends of the construction industry, particularly in the French market.

Keywords: *construction, buildings, France, trends, strategy*

1.   Introduction

While France is known for its industrial performance through the development made thanks to the first and the second industrial revolution, a less recognized prowess are also achieved during the same period of time. For instance reinforced concrete was introduced in the late 20 century by François Hennebique (1841 – 1921). It was, at that time, a technical breakthrough. While concrete has excellent compressive strength, it lacked tensile strength. The latter is essential for many structural like floors and Beams that are more likely to be subjected to flexion generated by the applied constraint. Reinforced concrete solve the problem thanks to the incorporated steel rebars, responsible of taking traction efforts.

During this period of time, French administration was governed by strict regulations. In addition, it wasn't impressed by the introduction of this new material and lacked a clear understanding of

what could bring to its edifices. In 1892, François Hennebique patented the first beams with stirrups.

Another French achievement concerns the invention of pre-cast concrete by Eugène Freyssinet (1928) who saw a key improvement in the use of concrete- steel mixture. He felt that the reinforced concrete could still be improved by subjecting the concrete to a tension during its manufacturing. The concrete is subjected to prior permanent compression stress. Once in service, the concrete will oppose more effectively to traction stress applied to the structure. Many applications are now using pre-cast concrete, especially in bridge construction.

Currently, the construction sector in France generates more than 201 Billion euros in 2013 (source FFB & FNTP). In 2013, 67% of total turnover is realized in the building sector, 33% in civil engineering.

Considered as one of the leading sector in France in terms of worldwide recognition (many construction companies among top 10 world ranking), construction has the lowest productivity among all the existing industries. UK studies indicated that up to 30% of construction is rework, only 40–60% of potential labor efficiency, accidents can account for 3–6% of total costs, and at least 10% of materials are wasted. The cost of rework in Australian construction projects has been reported as being up to 35% of total project costs and contributes as much as 50% of a project's total overrun costs (Aziz & Hafez 2013).

Azambuja M. and V. O'Brien (O'Brien et al. 2008, chap.1) highlighted the differences between manufacturing and construction (Table 1). The gap results in different characteristics: the manufacturing industry relies on mass production, variability of supply reduced, continuous improvement and integration of efficient logistics while construction is limited production (a few projects a year) and highly fragmented (Fulford & Standing 2014): several actors working on the same project which makes managing and precise definition more subtle process. The improved performance has never been the main concern of the construction sector, probably because there was until recently no model (philosophy, methodology, tools) that take into account all the components of the act of building as complex, as spatially and temporally extended. Currently, the construction sector is about to know a decisive period: are introduced rapidly, however, the understanding of the construction as global process (not separate phases) should be in line with the introduction of technical innovations and technologies.

Table 1. Differences between the manufacturing industry and construction (O'Brien et al. 2008)

Characteristics	Manufacturing SCs	Construction SCs
Structure	Highly Consolidated High barriers to entry Fixed locations High interdependency Predominantly global market	Highly fragmented Low barriers to entry Transient locations Low interdependency Predominantly local markets
Information flow	Highly integrated Highly shared Fast SCM tools (factory planning and scheduling, procurement, SC planning)	Recreated several times between trades Lack of sharing across firms Slow Lack of IT tools to support SC (no real data and workflow integration)
Collaboration	Long-term relationships Shared benefits, incentives	Adversarial practices
Product demand	Very uncertain (seasonality, competition, innovation, etc.)	Less uncertain (the amount of material is known somewhat in advance)
Production variability	Highly automated environment (machines, robots), standardization, production routes are defined – lower variability	Labor availability and productivity, tools, open environment (weather), lack of standardization and tolerance management, space availability, material and trade flows are complex – higher variability
Buffering	Inventory models (EOQ, safety inventory, etc...)	No models Inventory on site to reduce risks Use of floats (scheduling)
Capacity planning	Aggregate planning Optimization models	Independent planning Infinite capacity assumptions Reactive approach (respond to unexpected situations, for example, overtime)

The next sections present the major trends of the construction industry in France with the purpose of addressing its substantial faced problems.

2. Emergence of Lean Construction to rationalize construction processes

"Lean (or lean thinking)" is the English name – popularized by MIT researchers (Womack et al. (Womack et al. 2008)) in 1990– to describe the system now known as the Toyota Way inside the company that created it. The original name was Respect for Humanity System. Some called

it The Thinking Way (R. Jadhav et al. 2014). Lean management describes the culture of Toyota, an automobile Japanese company that started to rethink its processes in terms of reducing waste since the 50's: lean takes its principles from Toyota Production System (TPS).

It all started when Kiichiro Toyoda, Taiichi Ohno, and others at Toyota looked at Ford industrial process, based on massive production lines in the 30s. While Ford production system enables massive production, it lacks flexibility and contains many waste throughout the production chains. First, Ford system does not allow the production of different product types: only Ford T model was produced and the whole world had the same vehicle circulating. Second, Ford system was based on a push flow where the production isn't pulled based on the client's demand. As a consequence, a large quantity of stocks is required implying a significant cost. In addition, the system does not right-size machines for the actual volume needed and no control and monitoring so that each process notifies the previous one of its current needs for materials.

Toyota Production System (TPS) tries to create a continuous flow by eliminating of waste (Mudas) throughout the value chain. Waste is defined as every activity that adds no value to the client. Client could be internal (H.R., technical service, financial service, etc.) or external (in the case of outsourcing, another manufacturer or the consumer). The idea is to deliver what the client wants, when he wants it and in the right quality and quantity. In this perspective, seven types of waste are commonly recognized by the lean community (Liker & Meier 2005) :

- Inventory: The idea behind having an inventory is to be sure the production isn't compromised. In a lean point of view, it means lacks continuous flow and process control.
- Transport: unless the value asked by the client is transportation, transport (inward and outward factory flow as well as the flow inside the factory) should be minimized.
- Motion: motion is more related to the flow inside the factory. Moving to grab or check materials could also be considered as a waste if not optimized. This means that the worker should find all the necessary tools in the right place and at the right quantity.
- Waiting: waiting for work to be processed before handling or waiting for a worker to finish the task before taking it to the next phase is a type of waste.
- Over-Processing: when the degree of involvement and time-spend isn't in line with customer demand, one would surely suspect an over-processing waste. This type of waste deals with over-sized equipment for instance or giving a product more sophisticated than required by the client. It also includes over-quality.
- Overproduction: When the quantity required by the client isn't what is produced, a waste is automatically generated. Even if the products will be sold or shipped later, a certain list of tasks is required to manage over-production, considered as a waste.
- Defect (Non quality): the most obvious type of waste is defective products or service. A rework is generated and is considered as a non-value added activity.

While Lean consists of improving performance at the operational level (Pool et al. 2011), it could also drive strategic decisions (Perez et al. 2010). Many research studied Lean implementation issues. In order to be fully grasped, Lean takes many years to be fully grasped and understood.

That is why, a strategic move is needed to take all of its benefits. In addition, Lean management should also be integrated into the company's culture. Thus, an effort to understand how Lean principles could complement the company's practices and way of doing business is critical to for a successful implementation.

Toyota's financial scores raised drastically after maturing their new elaborated system. This achievement was recognized worldwide and lots of companies from different sectors, aeronautics shipping, etc. (Bhamu & Singh Sangwan 2014). For the construction sector, the reflection on how to integrate Lean management principles in construction was initiated by Koskela (Koskela 1992) where he discussed the application of new production philosophy to construction. He stated that information and material flows as well as work flows of design and construction should be identified and measured. In this perspective, he conceptualized the production process using the TFV model: 1) Transformation; (2) Flow; and (3) Value generation; flow is generated based on the value asked by the client through a series of transformation. An illustration of this model could: raw materials are transformed into a products, packed and delivered to the client. In construction, however, things start to get more complex: while manufacturing is a based on a large products quantities, more or less comparable in term of design, construction however, is unique at a certain level and is created in different location (not in a centralized location). In addition, many stakeholders are involved in a construction project and are different from one project to another. All those factors make it difficult to rationalize construction processes throughout project lifecycle.

G. Howell and G Ballard (Howell & Ballard 1994) also contributed to LC genesis by stressing the crucial lack of collaboration. They noted that only half of the planned actions are performed on site per week. A collaborative system called Last Planner System® was then developed by (Ballard 2000) (Ballard 2000) to remedy this problem.

Last Planner system is a collaborative production planning tool designed to improve collaboration among stakeholders in the construction industry. Since construction is a "people" business where different construction actors collaborate to design and construct, the LPS is an efficient way to foster communication in project team. LPS is based on 4 integrated planning elements presented in Figure 3:

- Master schedule: provide an overall overview on project milestones,
- Phase plan: called revers Phase Scheduling. It is based on a pull planning where stakeholders design the project in a reverse chronology.
- Look ahead Planning: It's a six week planning with constraint analysis.

- Weekly Work Plan (WWP): preparation of next week work. WWP helps calculate the Planned Percentage Completed (PPC) which describes the percentage of tasks accomplished in a certain week and track its variance throughout project lifecycle.
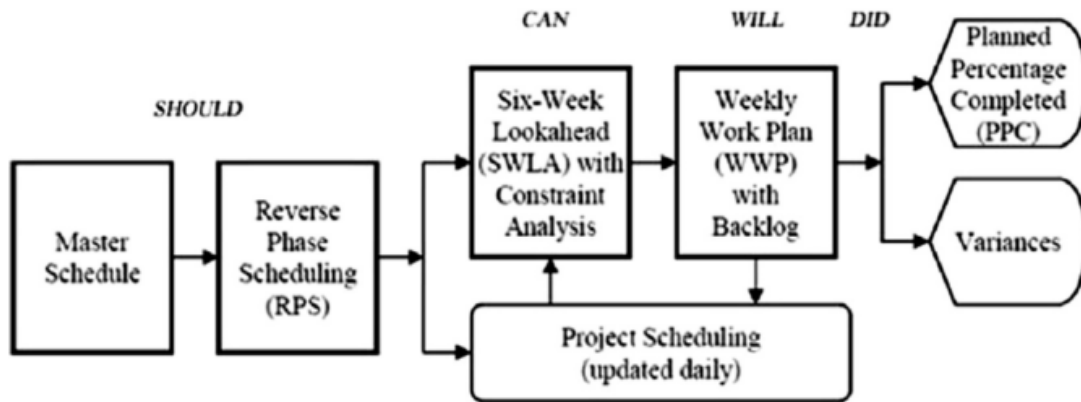

Figure 11 The sequence of last planner process.

Figure 1. Last Planner System functioning (Aziz & Hafez 2013)

In France, the emergence of Lean Construction is still at the beginning. Like any technology, first adopters embraced Lean Construction early in 2008 to try to find ways to improve their margin. Currently in 2015, every known company has experienced Lean in a way or another. Lean Implementation differ from one company to another due to several factors: external consultant competencies, level of understanding of lean theory, the level of implication of top managers, etc. However, it is worth noting that in practice, Lean approach in Construction is different from that of manufacturing. This crucial point isn't yet grasped by construction community and the differences should be well defined, clarified and communicated by the scientific community and by practitioners as well.

3. First attempts to integrate BIM as a new way to for collaboration

Building Image Modeling (BIM) is inscribed in the context of integrating Information Systems (IS) in the construction sector. (Aranda-Mena et al. 2009) stated: "For some, BIM is a software application; for others it is a process for designing and documenting building in- formation; for others it is a whole new approach to practice and advancing the profession which requires the implementation of new policies, contracts and relationships amongst project stakeholders."

One thing is for sure: BIM isn't just a software but a way of collaboration and could even be considered as revolution of the way construction projects are managed. BIM is based on a 3D digital modeling of the construction. A dynamic is created around the model since all the stakeholders add their knowledge and advancement in the 3D model (Figure 4).
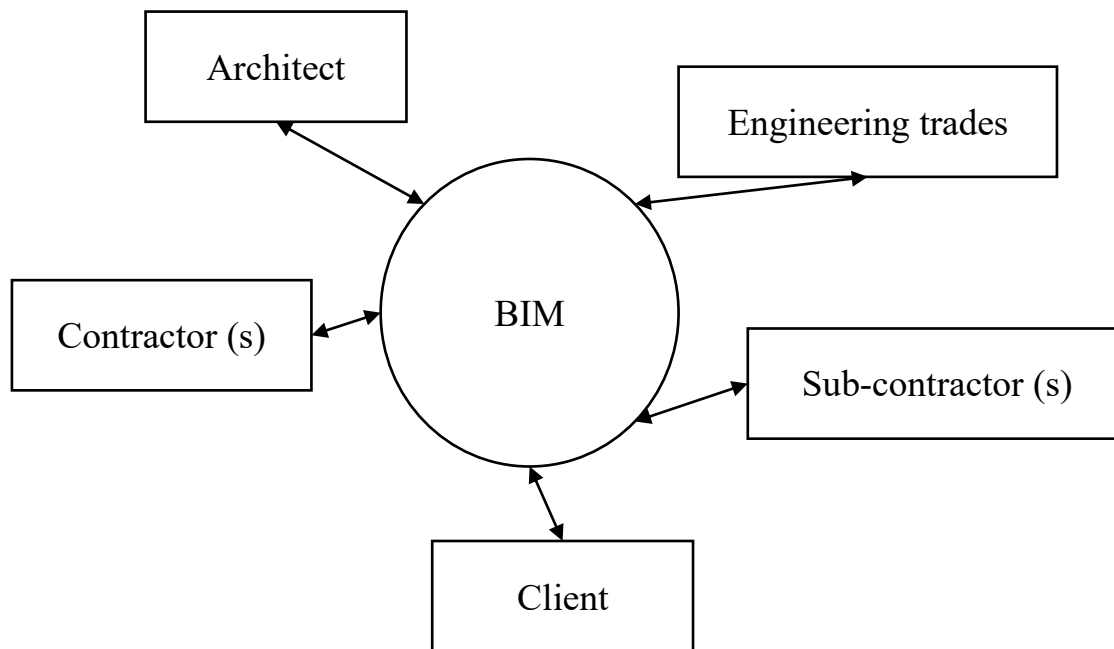
Figure 2. Every stakeholders adds its understanding and knowledge of the project through BIM.

Implementing BIM requires passing by a series of maturity levels. 4 maturity levels are commonly used to describe the maturity of BIM implementation (Figure 5). Level 0 is often referred to as 2D CAO which is an unmanaged and unstructured level. Collaboration is difficult. Projects are not geo-referenced and do not have the same units and models. Everyone is working alone with his own tools and standard. Level 1 adds a 3D model with a structured database containing the necessary information (database). It is in level 2 where one can mention the practice of a real collaboration since every stakeholder manage his work and produces a 3D digital model in his corner (architect, engineers, MEP, etc.) before synchronizing the work with a common server. Level 3 is the optimal way of collaboration and changes in the 3D digital model are instantaneous. Stakeholders work directly in a single model stored on a centralized server, accessible throughout the life of a book via IFC / IFD / IDM. Tracking and monitoring the advancement of the different parts of construction follows is continuous during all project phases (design / construction). Standards and contracts are not available for level 3 BIM this is why most governments aren't yet supporting a full implementation of Level 3. In this perspective, UK is the most developed in terms of lean maturity level (reached level 2). However, France is still in level 1until now. This is mainly due to the politic followed by the two countries: UK invested and financed BIM initiatives for many years and obliged public tenders to use BIM. Overall, an assessment of a 2-year gap exists.
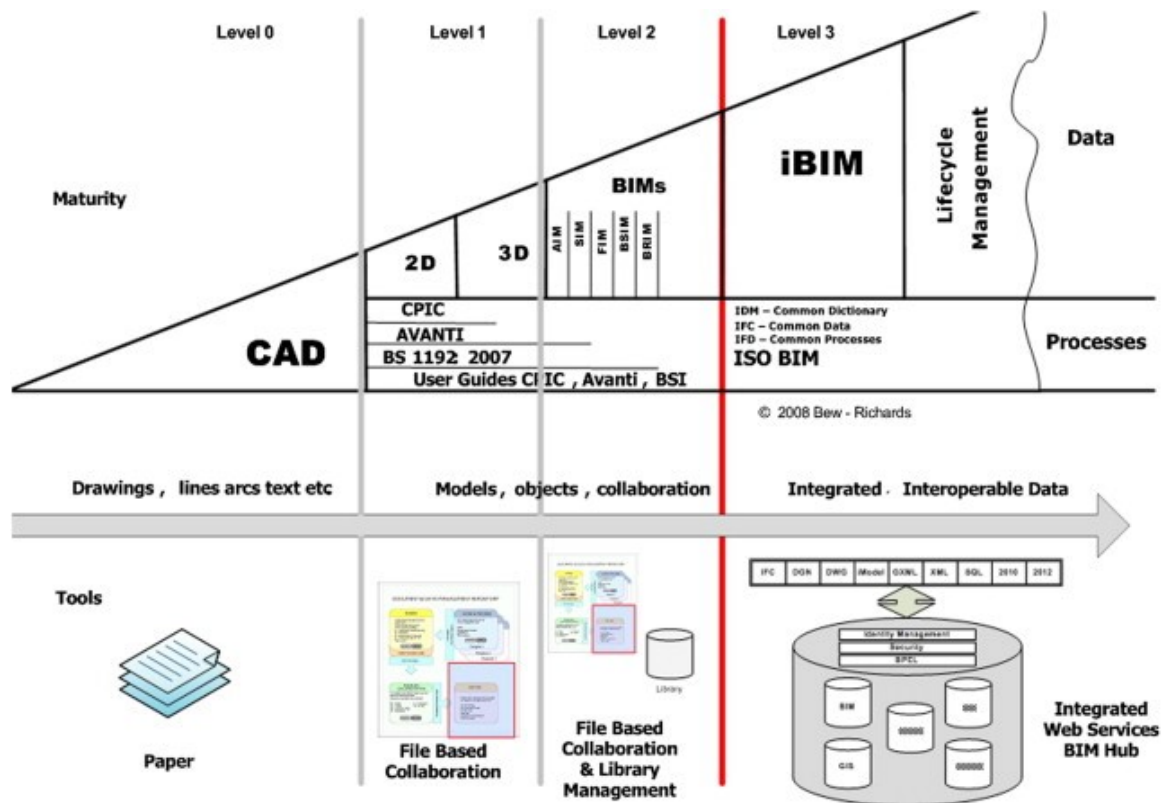
Figure 3. BIM maturity levels (Barlish & Sullivan 2012)

The use of BIM started during the last decade. Many countries embraced BIM early and others were obliged to follow the trend to stay competitive. In general, North America is advanced in BIM implementation compared to Europe (Figure 6). France holds the highest rate of BIM adoption in 2010 among professionals of the construction sector, with 38%. It means that a real interest raises among construction actors to rethink the way construction is conducted. However, the level of BIM maturity is still to be developed compared to other European countries (UK and Scandinavian countries).
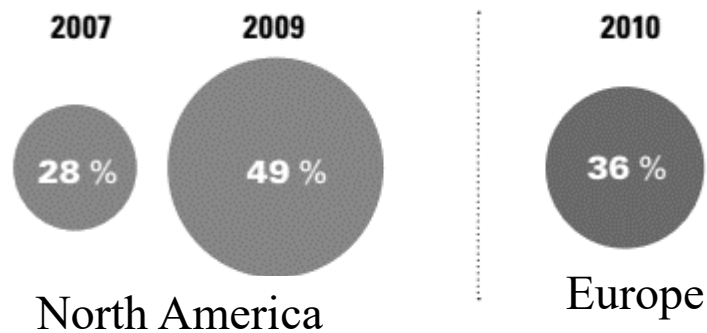
Figure 4. Adoption of BIM in Europe and North America among construction actors (adapted from: Mc Graw Hill Construction 2010)

With the advent of BIM, a rethinking of Construction Company's organization is required. For Human Ressources, a new job is created: "BIM manager". His role is manage workflow and coordination under the BIM platform. For planning department, a shift in responsibility occurs since the focus would be more directed towards gathering models and synthetizing stakeholder's models. BIM definitely affects every corner of the construction business. The real stake is to anticipate those changes and to prepare for the next step most effectively.

4. Future trends and vision of the French construction sector

4.1 Project delivery shift towards more collaborative system

Project delivery system describes the relationship between project stakeholders and the client. According to (Qiang et al. 2015), clients select PDSs to define the roles of project participants, share authority and responsibility, allocate profit and risk, and organize and incentive participants to fulfill the clients' project objectives.

In the French construction industry, several project delivery systems exist. The main ones are:

- Design-Bid-Build (D/B/B): It is the most common delivery system in France. It is characterized by a sequential process. The architect team starts by designing the project. Afterwards, tender is launched in order to select a contractor (builder) using some criteria (price, technical feasibility, sustainability). However, the main criteria of selection usually is the price. This phase is called the bidding phase. The selected contractor can begin the construction with a complete design and clear schedule.

- Construction Management at risk: the client secures the services of a construction manager to work with the design team and the trade contractors as well. However, in this configuration, the risk is now taken by the construction manager. The latter is responsible of the project success according to the design fixed with respect to the schedule and the budget. This way of building has been introduced in France in 1992 by the Federation of the European Construction Industry (FIEC).

- Public Private Partnership: this type of procurement system concerns offers provided by the public sector designated to the private sector. The contractor is in charge of the construction, maintenance and management of the public work. The contractor can receive direct payment from the public partner or he can use the public installation (example: highway) for a certain period of time as a payment method. Public Private Partnership (PPP), born in Anglo-Saxon countries have taken reality in France since the order of 17 June 2004. This type of delivery system is considered by major AEC French companies as possibly having an impact on the future markets. This formula allows private financing of public works and services, associating a private third party to a public project, and beyond the usual duration of public service delegation.

Figure 7 reveals the repartition of delivery systems in the U.S. construction vertical market. The US market is mainly directed by the use of D/B/B configuration. However, an increase of Construction Management at risk is also noticed in the last years. Another important aspect is the introduction of IPD (Integrated Project Delivery) which is associated to Lean Construction Practice. IPD is a project delivery system based on collaboration and partnership from at an early stage of the project. It is also based on a shared gain-loss model for project stakeholders. (Jones 2014) describes IPD as follow: "At a very early stage (project development, pre-draft phase) the entire planning (design) is carried out by a team that involves not only an architect and a structural engineer, but also consultants in the areas of construction management, MEP engineering, energy technology, building physics, acoustics, façade construction and, depending on the type of project, other specialists".
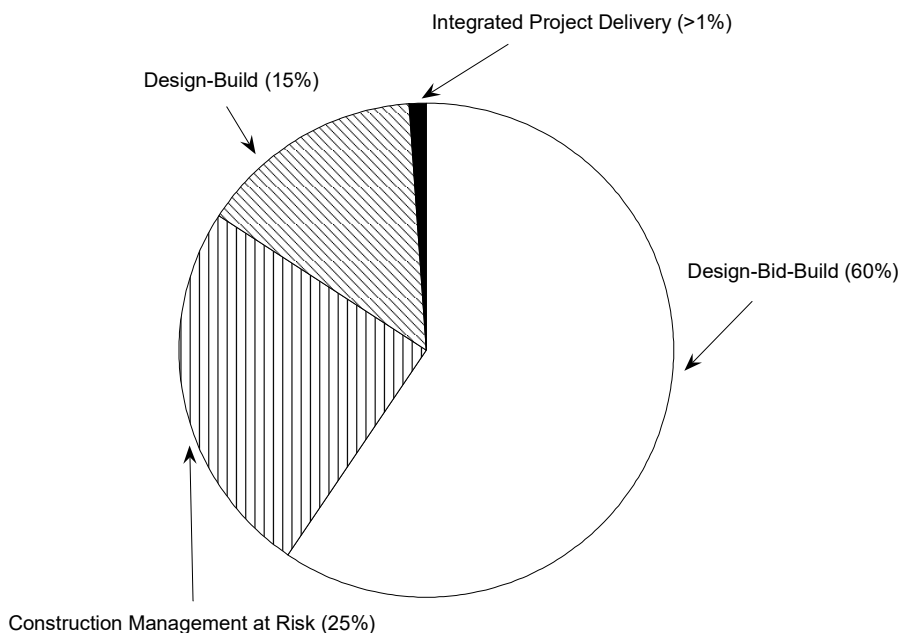

Figure 5. Repartition of delivery systems in the U.S. construction vertical market (adapted from: CMAA 2012)

For France, construction stakeholders (client and construction companies) start to assess the limitations of current project delivery systems and the need to go for a more collaborative project delivery systems from project genesis. More than 70% of building project in France are based on a D-B-B (Rabot Dutilleul 2015). This kind of project fragmentizes the construction project into separate phases in which each phase is realized by a different set of actors. Thus, loss of information and rework is common. Finding performance levers seems out of reach due to the nature of project delivery system.

IPD practice, however, isn't yet introduced and applied in France. In the next decade, rearranged in the favor of more cooperative systems.

4.2 Renovation as a niche market in France

A key feature of the building sector is its excessive energy consumption. In 2007, residential and commercial buildings consumed 67.6 mtoe (adjusted consumption climate effects), or 44% of final energy consumed in France. This consumption is up 42% since 1970 (Ministère de l'écologie du développement durable et de l'énergie 2007).

To remedy this problem, France has set a reduction target of 2% per year in final energy intensity by 2015, and 2.5% per year to 2030 as part of the POPE law (Legifrance 2005). However, the average annual decrease in energy intensity since 2005 stands at 1.3% (ADEME 2012). The reduction of energy consumption implicitly involves the construction sector as it is largely the largest consumer of energy in France.

The building sector (new building construction) in France is saturated. A study conducted by (Insee 2015) among real estate home developers in France reveals that the number of new building constructions is decreasing year after year.
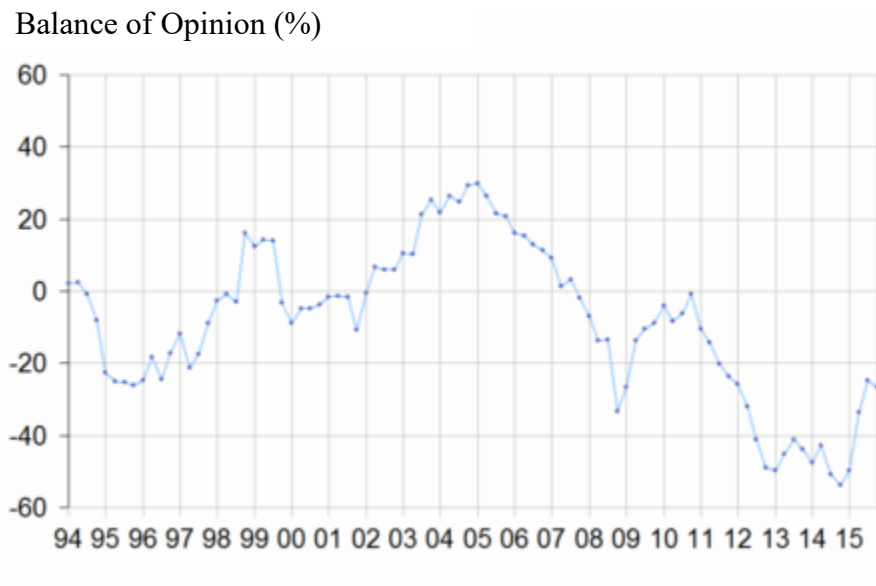
Balance of Opinion (%)

Figure 6: Real estate's developers Balance of opinion for launch of new buildings in France (Insee 2015)

Figure 8 describes the balance of opinion (The balance of opinion is defined as the difference between the proportion of respondents expressed a positive opinion and the proportion of respondents expressed a negative opinion) of new home buildings launch in France. Overall, real estate developers experience a clear decrease of home building launch, related to a demand decrease. There is a slightly decrease for home sale, however, rental homes demand knows an aggresse decrease.

World War II buildings in France needs to be renovated since their life cycle is reached (building lifetime is 50 years on average for Post World War II buildings). The French government is investing in renovation projects and new technologies for renovation as well.

A trend shift in building renovation is noticed by "Fédération Francaise de Bâtiment": a 53% increase in building renovation in 2013 against 51% in 2012. In contrast, new building construction decreased from 43% in 2012 to 41% in 2013.

According to (Direccte 2014), an increase of 60% is expected in the renovation market in France by 2020 and a 75% increase by 2030 based on 2010 index. As a consequence of this new trend, other industry markets are flourishing. For instance, thermal insulation is needed for almost all renovation projects. The insulation market generates an annual turnover of nearly € 1.3 billion in France, with an increase of 174 million from 1 January 2014 (Planetoscope 2014). The insulation market represents nearly 1% of the turnover of the French construction companies.

4.3 Big data in Construction

The construction industry is now connected to seemingly infinite amounts of information that can be accessed in a matter of seconds thanks to BIM and technology introduction (Hardin &

McCool 2015). The current project delivery systems used (mainly D/B/B) impose a fragmented information flow among project stakeholders. The interest in using Information Systems (IS) in the construction sector is more evident than ever. The objective is to create a continuous flow of information throughout all project lifecycle.

Big data is now entering the construction sector in different forms. From augmented reality (Meža et al. 2015) to creating a system evaluation for tender price evaluation (Zhang et al. 2015), the use of Big Data is now more prevalent. The real stake, however, is to assess the return on investment of Big Data integration. This lack of ROI evidence hinders the adoption of Big Data and its integration as a strategic axis.

4.4 Technology integration

France occupies the 21th position in the ranking of innovative countries, according to the "Global Innovation Index". This observation seems no capital importance since the priorities are oriented towards the most critical issues, such as employment, cost cutting and economic performance.

A critical look at the current situation raises the speed of change experienced by the world today. Technological advances are now more than ever flowering. The economy also follows fluctuating and following the most promising market.

While economic indicators such as GDP or the rate of investment in infrastructure and societal as the employment rate and education appear most critical, one-sided view of these indicators will reach the objectives targeted by the forces policies.

Several countries have wagered on other themes to create the activity. For example, Sweden has for decades invested on infrastructure, now collects the fruit of these efforts is the European leader in modular construction and recycling of waste. Sweden was aware of its geographical position, climate factor and consequently has developed solutions adapted to their situation for the good of the people. The example of Germany is also speaking, having invested more than 200 billion euros to the son of time to allow German industry to position in strategic markets. The birth of the "Industry 4.0" in German factories has now become commonplace and these factories are conducting margins contradict those of the traditional competition.

4.5 Introduction of Robotics

A robotic system is an advanced classification of a machine characterized by certain abilities such as programmability, autonomy, flexibility and sensitivity to external conditions. By observing the technological advances of robotics, it is expected that this area will experience a similar development to that of personal computers in the 90s. Experts and governments worldwide (such as South Korea) announced the era of robotics. Currently robots are becoming more user-friendly, cheaper, adaptable to different spots, smaller, widely distributed and integrated into the work process. With this continual evolution in this area, new research and technical skills were explored as modularity, light design, technology mobile robots. Over time, the capacity of robots have evolved to function in unstructured environments similar to those of

working men. This development led to a conclusion; apart from the traditional manufacturing industries, this technology can be introduced and operated in several areas such as aeronautics, medicine, agriculture, the construction industry ... In fact, the new skills of robots will not only expand the areas of their applications but also allow them to operate in environments similar to the manufacturing or construction sites.

The construction sector productivity is unfortunately very slowly for several reasons. (Warszawski & Navon 1998) reports the main problem the construction industry faces. Labor efficiency is low compared to other industries. Work quality and control are insufficient and accident rate at construction sites is high. Robotics offers process automation and reliability. The lack of robotics in civil engineering could be linked to product features and complexity (size, diversity, long project life, and the fixed nature of construction sites vs. in manufacturing ...) and the weak capital budgets in research and development and the reluctance of strategies related to construction automation.

4.6 Genesis of 3D printing in construction

3D printing is a technology that allows printing of objects in three dimensions from various materials according to layer by layer manufacturing technique. To date, the most used for 3D printing materials are plastic and metal, but other objects can be printed using ceramics and organic materials.

The first 3D printer, the SLA-250, dates from 1988 and is the property of 3D Systems Company. It prints objects using a material sensitive to ultraviolet rays. In 1996 with the launch of three printers - the Genisys Stratasys, the Actua 2100 3D Systems and Z Corporation Z402 - starts a new generation rapid prototyping printers. 3D printing in construction is now evolving rapidly. First used by promoters to create 3D model prototypes for marketing purposes, 3D printing currently is tested for a large-scale production of full house printing.

As a consequence of 3D printing introduction in construction, material (used for construction printing) market is expected to elaborate a turnover of over 600 million dollars by 2025 (MarketsandMarkets 2014). In this perspective, the market for 3D construction printing materials may be the one where economic impacts are the greatest.

3D printing is an inherent part of the "Industry 4.0". Indeed, the transformation of industrial production involves customization, personalization and flexibility of production. The era of mass production (introduced by Henry Ford in late 1930s), is no longer adequate to the needs of modern people today. Germany appears to be the leader in the industry 4.0 thanks to the policies taken by its government, dedicating a total of 200 billion euros of investments. The objective is to maximize the use of robots, automation and connection in the internal and external processes of the industrial park.

Meanwhile, France is currently deploying its finances to advance Industry 4.0 concept. The objective is to adopt robotic, industrialization and digitalization for all its industries (construction included). According to (Bpifrance 2010), 1.2 billion euros of research &

Development tax Credit are issued and 730 million euros of capital-investment grants for industrial projects.

Construction advancement in France depends on a broader ambition of the modernization of the production tools in order to assist companies in the transformation of their business models, their organizations, their methods of design and marketing, in a world where digitalization is commonplace.

5. Conclusion

While the construction industry is considered as one of the prominent market in France, it still lacks efficiency in terms of quality and technology integration. The objective of this paper is to present the future trends of the French Construction. The aim of the followed trend is to bring each construction company to take a step towards the modernization of its production facilities and the transformation of its business model by digital technology. Lean construction, Building Image Modeling (BIM), robotics, bid data are identified as the main trend enablers. Regarding French market status, it is dominated by a more divided project delivery system and a more integrated and collaborative system is starting to raise the concern of construction stakeholders. Finally, a shift from new building construction to renovation is introduced slowly in the French market due to the need to reassess Post World War II buildings. The real stake now is to switch toward a more collaboration system and early integration of project stakeholders earlier in the project lifecycle to make a substantial gain in in project performance (quality, cost and time). For this to happen, the major change should be instilled by the government (policies) and the client (prioritize integrated project delivery approaches).

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