leanWOOD

Buch 4 – Teil A
Prozess

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1. Prozess

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Federation of the Finnish Woodworking Industries (Finnland)
KINNO Kouvola Innovation Oy (Finnland)
SK Finnish Real Estate Federation (Finnland)
LECO Construction, XJ Développement (Frankreich)

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KTI Kommission für Technologie und Innovation (Schweiz)
BMEL Bundesministerium für Ernährung und Landwirtschaft unter der Projektträgerschaft der FNR Fachagentur Nachwachsende Rohstoffe e.V. (Deutschland)
TEKES The Finnish Funding Agency for Innovation (Finnland)
MAAF Ministry of Agriculture, Fisheries and Forestry Resources (Frankreich)
ADEME French Environment and Energy Management Agency (Frankreich)

FP7 Seventh Framework Programme European Union
WoodWisdom-Net

Aus Gründen der besseren Lesbarkeit wird auf die gleichzeitige Verwendung männlicher und weiblicher Sprachformen verzichtet. Sämtliche Personenbezeichnungen gelten gleichwohl für beiderlei Geschlecht.

INHALT

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Internetreferenzen

www.dataholz.com

Abbildungen

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1 Einleitung

1.1 Zielsetzungen

Der derzeit im Hochbau angewendete Planungsprozess, der auf den Gesetzmäßigkeiten des konventionellen Bauens basiert, ist nicht optimiert für die speziellen Herausforderungen des vorgefertigten Bauens. Ziel von leanWOOD ist es, für das vorgefertigte Bauen mit Holz geeignete Planungsabläufe zu entwickeln, die auf die relevanten Planungs- und Vergabemodelle zugeschnittenen sind. Dabei soll eine Festlegung der Aufgaben und Verantwortlichkeiten der einzelnen Mitglieder des Planungsteams sowie die Definition der Schnittstellen erfolgen.

1.2 Methodik und Vorgehensweise

Die Erkenntnisse in diesem Beitrag sind das Ergebnis der Forschungskooperation «leanWOOD» in der Zusammenarbeit der TU München mit der HS Luzern bezogen auf die Besonderheit der Planungskultur im deutschsprachigen Raum durch die Trennung von Planung und Ausführung.

In Interviews und Expertengesprächen wurde häufig das Problem des späten Inputs der Holzbaukompetenz in den Planungsprozess und der damit verbundenen redundanten Planung nach Erstellen der Ausführungsplanung des Architekten bis hin zu einer fertigungstauglichen Werk- und Montageplanung des Holzbauunternehmers als Erschwernis für den vorgefertigten Holzbau ausgemacht und mit den Beteiligten diskutiert. Dies ließ den Schluss zu, den Gedanken und dessen Auswirkungen zu untersuchen, holzbaurelevante Entscheidungen, im Sinn einer integralen Planung, in eine frühe Planungsphase zu verlegen.
Im Folgenden wurden Erfahrungswerte aus der Praxis analysiert und in einen holzbaugerechten Projektablauf übertragen. Es wird dargestellt, welcher Einfluss des Holzbaus zu welcher Planungsphase erforderlich ist. Weitere den Planungsprozess begünstigende Maßnahmen, wie Standardisierung oder die BIM-Methode wurden untersucht. Ein Seitenblick in andere hochentwickelte Industriesparten brachte keinen überzeugenden Beitrag.

2 Der Planungsprozess

2.1 Holzbaugerechter Planungsprozess

Die Planung jeden Bauvorhabens weist eigene Spezifika und Dynamiken auf. Die Ursache für verschiedenste Probleme im Prozess liegt jedoch oft in der Nichteinhaltung von einigen Grundvoraussetzungen.
Zum Teil betrifft dies Punkte, die auch außerhalb des Holzbaus Gültigkeit besitzen: Bereits in der Phase der Projektentwicklung sollten die Anforderungen und Ziele mit dem Auftraggeber so weit als möglich definiert werden. Budget und Terminrahmen, funktionale Anforderungen und persönliche Vorstellungen bilden wichtige Planungsgrundlagen. Der projektspezifische Bedarf an Fachplanung sollte im Sinne eines integralen Planungsansatzes sehr früh bestimmt, das Planungsteam frühzeitig zusammengestellt und beauftragt werden. Das Spezialwissen der Fachplaner sollte bereits in die ersten Planungsüberlegungen integriert werden.

Die Ressourcenplanung aller Planer sollte auf der Grundlage eines realistischen und verlässlichen Planungsterminplans stattfinden. Eine gute Kommunikationsstruktur mit regelmäßigen physischen Besprechungen ist dafür Voraussetzung. Es bedarf klarer Vereinbarungen zu Planläufen und zum Änderungsmanagement zwischen allen Beteiligten. Für einen erfolgreichen Prozess ist ein vollständiger Abschluss der Leistungsphasen in Abstimmung mit allen Planungsbeteiligten hilfreich. Die regelmäßige Ergebniskontrolle mit dem Bauherrn sollte zum Ziel haben, dass Korrekturen nur innerhalb der Leistungsphasen, nicht aber phasenübergreifend stattfinden und die definierten Planungsleistungen aller Beteiligten abgestimmt vorliegen. Das Verständnis für die Erfordernisse und Perspektive der jeweilig anderen Disziplinen erleichtert die Zusammenarbeit.

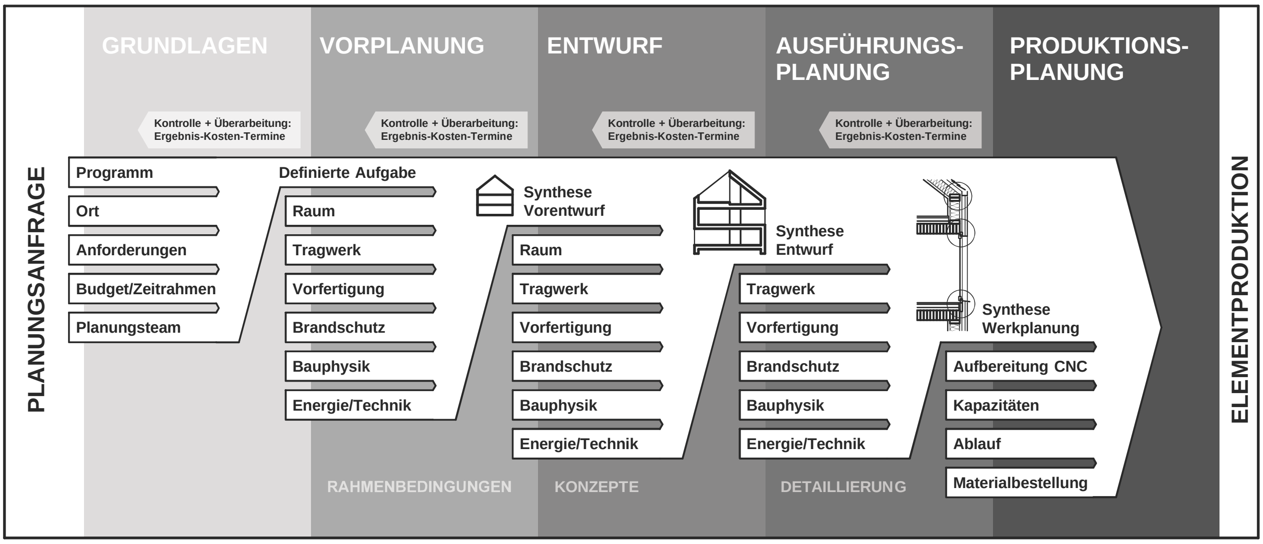

Abbildung 5: Planungsphasen von der Anfrage bis zur Elementproduktion mit ihren zentralen Themen. Der Abschluss der Vorphase bildet jeweils die Grundlage für die Folgephase

Insbesondere im Holzbau ist eine Planungszeit, die der Komplexität der Aufgabe angemessen ist, von großer Bedeutung. Der Zeitersparnis in der Bauphase steht in aller Regel ein verlängerter Planungsprozess gegenüber. Kompetenz und Erfahrung im Holzbau ist im Idealfall nicht nur bei den Disziplinen Architektur, Tragwerksplanung, Brandschutz und Bauphysik vorhanden, sondern auch bei der Planung der technischen Gebäudeausrüstung. Hier ist eine klare

Schnittstellendefinition besonders wichtig. Kritische Punkte an den Schnittstellen von Baukonstruktion, Brandschutz und technischer Gebäudeausrüstung sollten frühzeitig lokalisiert werden. Klar definierte Qualitäten der zu liefernden Planungsleistungen in den jeweiligen Phasen sollten vereinbart werden.

Im Holzbau müssen aufgrund der Vorfertigung wesentliche Entscheidungen zu einem früheren Zeitpunkt getroffen werden als beim konventionellen Bauen. Daher bietet es sich an, projektprägende Festlegungen den einzelnen Leistungsphasen zuzuordnen:

- In der Vorentwurfsphase sollte die Definition der wesentlichen Anforderungen aller Disziplinen (Brandschutz, Schallschutz, Energie, Tragwerk, Vorfertigung) erfolgen und diese in die Entwicklung des Raumkonzeptes integriert werden.

- In der Entwurfsphase sollten alle grundlegenden Konzepte entwickelt werden: Tragwerk, Holzbausystem, Schichtenaufbauten, Fügung, Oberflächen, Schnittstellen-Definition, Vorfertigungsgrad und Elementgrößen werden im Grundsatz geklärt.

- In der Ausführungsplanung der Architekten und Fachplaner erfolgt die detaillierte Ausarbeitung der im Entwurf festgelegten Konzepte. Montageablauf, Elementstöße, Fugen und Verbindungen werden durchdacht.

- In der Werk- und Montageplanung der ausführenden Firma steht das Zusammenführen der Ausführungsplanung des Architekten mit der Ausführungsplanung des Tragwerkplaners und der Integration der Belange aus der Fachplanung der technischen Gebäudeausrüstung in einen kongruenten Planstand im Vordergrund. Ein weiteres Ziel dieser Phase ist die Umsetzung der planerischen Vorgaben in konkrete, für den jeweiligen Zweck bauaufsichtlich zugelassene Bauprodukte.

Eine Einbindung des Holzbau-Knowhows in den vorgelagerten Planungsphasen trägt dazu bei, die inhaltlich-technischen Fragen in diesem Stadium schon weitestgehend gelöst zu haben. Das erlaubt die Konzentration auf organisatorische Aspekte der Produktion und Montage (Arbeitsvorbereitung mit Kapazitäten-Planung, Ablaufplanung, Materialbestellung).

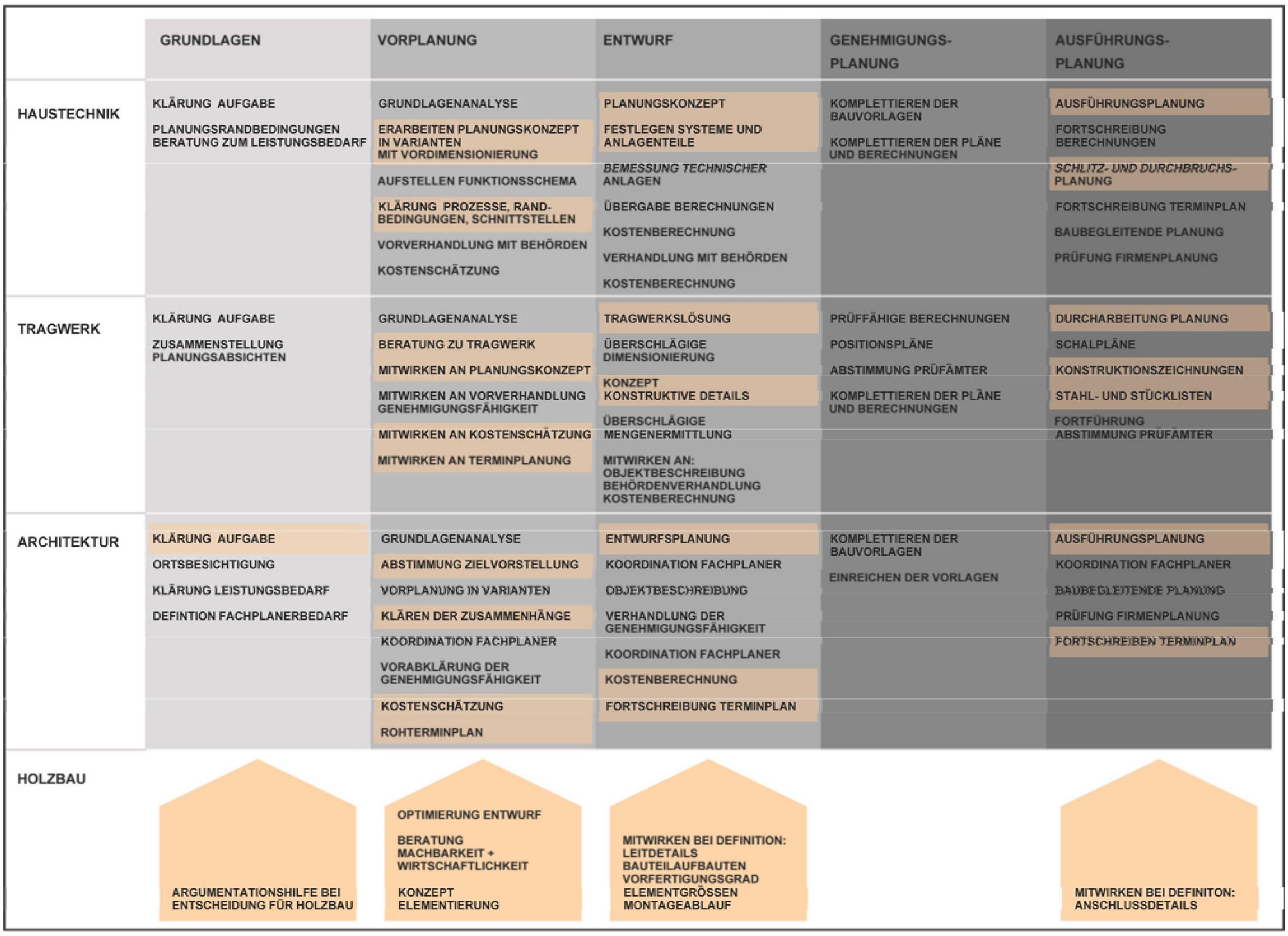

Abbildung 6: Leistungsbilder gemäß HOAI 2013 mit Input Holzbau

2.2 Lernen aus der Industrie

Der Begriff «lean» in leanWOOD zielt auf die «schlanke» Abwicklung von Prozessen und die effiziente wie effektive Koordination der am Prozess Beteiligten. Dies stellt das entscheidende Potenzial für Produktivitätssteigerungen im industrialisierten Holzbau dar. Auf der Grundlage der Erforschung und Analyse von Arbeitsmethoden anderer hoch entwickelter Industriesektoren zieht leanWOOD Parallelen für optimierte Prozesse und Zielsetzungen. Diese Ergebnisse werden in Part D des Buchs 4 durch den französischen Partner FCBA beschrieben. Die Diskussion um die Vergleichbarkeit des Planungsprozesses beim vorgefertigten Bauen mit Holz zu hochtechnologisierten Branchen, wie dem Automobil- oder Schiffsbau, führt stets zu kontroversen Ergebnissen. Letztlich stellt sich immer die Frage, ob die Herstellung eines seriellen Produkts mit der eines Unikats überhaupt vergleichbar ist.

Zwischen dem anerkannten Forscher der ETH Zürich und Architekten Odilo Schoch und dem Holzbauingenieur Stefan Zöllig kam es bei der Swiss Bau 2016 zu kontroversen Ansichten bei der Nutzung von ein und derselben Datenplattform, wie es in Automobilindustrie üblich ist. Zöllig favorisiert eine durchdachte Software Lösung: *„wo alle an einem Datenhaufen arbeiten"*. Odilo Schoch ist der Meinung: *„Das kommt nie, aber es muss eine gleiche Semantik existieren. D. h. wenn jemand einen Holzbalken als Datensatz exportiert, wird die Geometrie und der Datenhaufen geschickt, aber alle Software soll wissen, das ist wirklich der Holzbalken."*

Zöllig: *„Was wir wollen ist, dass alle gleichzeitig im gleichen Datenmodell zusammenarbeiten, weil dann reden wir nicht mehr von Änderungen, sondern von* *einem gemeinsamen Grobkonzept wo man gemeinsam auf ein Ziel zusteuert. Es sollten alle Planer und an der Planung beteiligten auf einer Plattform vereinigt werden und wir haben so etwas gefunden und zwar in der Automobilindustrie. Da sollte man sich orientieren. Wir haben letztens Leute von 3DS getroffen und die sagen, dass 3D an Bedeutung verliert. Viel wichtiger seien die Prozesse und dass man genau zurückverfolgen kann wer was dabei gemacht hat und die Dokumentation möglich ist. Aber das ist mit den gegenwärtigen Programmen nicht möglich."*

Bei der Vergleichbarkeit der Prozesse gibt auch Alexander Kodisch von der Lürssen Werft zu bedenken, dass „bei einem Schiff wesentlich weniger Anforderungen an den Bauteilaufbau gestellt werden. In der Regel ist die Außenwand ein Stahlblech, das konstruktiv zusammengefügt wird. Im Holzbau scheint mir der Aufbau wesentlich komplizierter." Und „auch im Schiffsbau ist die Redundanz in der Planung vom ersten Grobmodell bis zur finalen Planung häufig gegeben, da fertiggestellte Schiffe eben als Unikate zu sehen sind."[1]
Zwar wird auf einer gemeinsamen Datenplattform mit gleicher Software geplant, aber dahingehend steht die Holzbaubranche in nichts nach. In der Fertighausbranche ist eine durchgängige digitale Kette basierend auf einer Software-Familie (s. 3.1.1) bereits Standard. Solange aber Daten-Schnittstellen unterschiedlicher Softwareanbieter nicht die erforderliche Qualität liefern, lässt sich eine vergleichbare Prozessstruktur mit einer Vielzahl, von an der Ausführung Beteiligten, nicht umsetzen.

2.3 Standardisierung am Beispiel dataholz.com

Der Markt bietet eine fast überdifferenzierte Auswahl an Materialien mit entsprechend vielen Konstruktionsmöglichkeiten. Bauaufsichtliche Zulassungen sind oft an einzelne Produkte gebunden und für vermeintlich identische Konkurrenzerzeugnisse nicht gültig. Diesbezüglich gibt es derzeit noch keine übergreifende Standardisierung im Holzbau. Jedes Holzbauunternehmen bevorzugt – je nach Produktionsmöglichkeiten, Zuliefernetzwerk und Erfahrungsschatz – eigene Aufbauten und Details, was eine firmenunabhängige Planung erschwert. Die Branche hat die Möglichkeiten der Standardisierung aufgenommen und ist um Lösungen bemüht. Doch aktuell sind viele Aspekte der Planung noch von Spezifika der Holzbauunternehmen abhängig.
Die Standardisierung im Holzbau steht derzeit im Anfangsstadium. Das laufende Forschungsvorhaben dataholz.de der TUM zur Übersetzung der österreichischen Holzbau-Datenplattform dataholz.com auf deutsche Rahmenbedingungen lässt auf Verbesserung hoffen.
Zur Gewährleistung der notwendigen Planungs- und Genehmigungssicherheit ist es wichtig für die Vielzahl von Varianten auch die baurechtliche Verwendbarkeit sicher zu stellen, um alle Anforderungen aus der Bauphysik, dem Brandschutz und der Tragwerksplanung gem. rechtlichen Anforderungen nachweislich zu gewährleisten. Dazu ist die Beachtung einer hohen Anzahl von Produktregelungen auf der Basis nationaler und europäischer Normen und Zulassungen erforderlich, häufig gepaart mit zusätzlichen nationalen Besonderheiten in der Nachweisführung.

[1] Interview mit Alexander Kodisch 02.06.2017

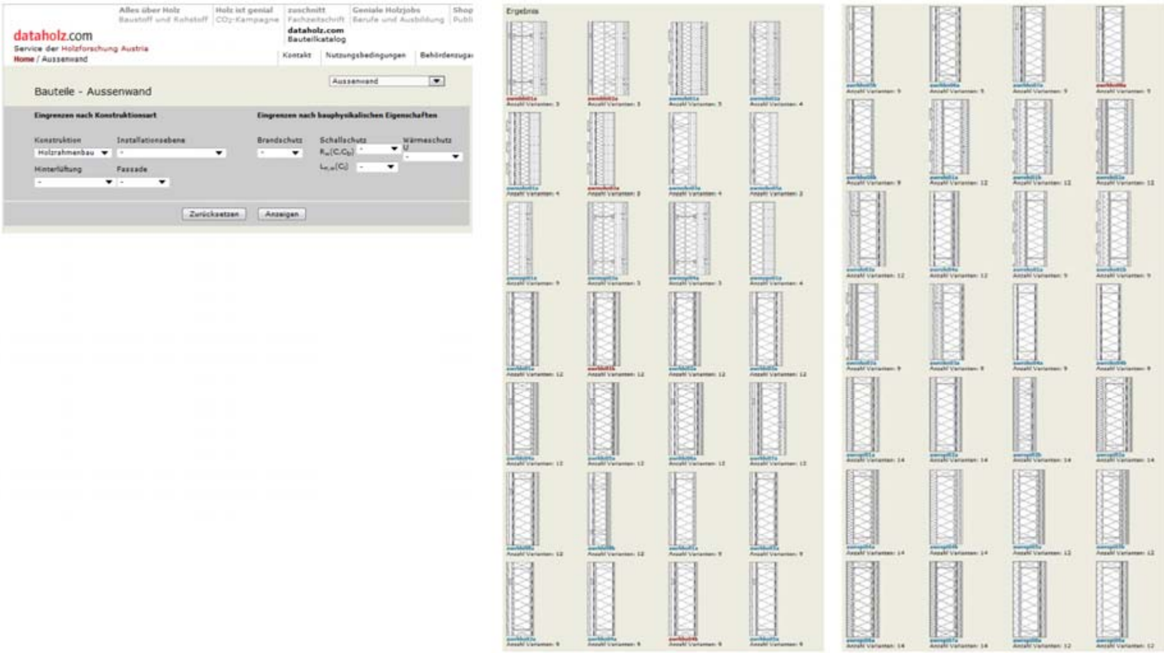

Abbildung 7: exemplarische Bauteilauswahl über die Datenplattform dataholz.com

Vor diesem Hintergrund hat die Holzforschung Austria 2004 eine Online-Plattform mit für Österreich geprüften Konstruktionsaufbauten ins Leben gerufen. Damit wurden Architekten, Ingenieure, Behörden und Ausführende in die Lage versetzt mit fast 1.500 geprüften Konstruktionen und Bauteilanschlüssen in bauphysikalischer und ökologischer Hinsicht verlässlich zu arbeiten. Verwendungsnachweise sind als pdf hinterlegt. Aufwändige Prüfverfahren für den Nachweis von Brand-, Wärme- oder Schallschutz werden dadurch erheblich vereinfacht oder können entfallen.
Der Inhalt der Online-Seite wird fortwährend aktualisiert und erweitert. Obwohl die Plattform prinzipiell nur für den österreichischen Markt angewendet werden kann, informieren sich bereits derzeit ca. 15% der Anwender aus Deutschland. In Deutschland ist derzeit keine vergleichbare Information erhältlich. Mit Abschluss des Forschungsprojekts dataholz.de soll diese Lücke geschlossen werden. Durch die Realisierung des Vorhabens wird von einer höheren Akzeptanz des Holzbaus ausgegangen. Die Ziele im Forschungsantrag für dataholz.de wurden so formuliert:

- Direkte baurechtliche Verwendbarkeit der aktuell im Holz-Geschossbau nachgefragten und angewendeten Wand-, Decken- und Dachkonstruktionen. Die sehr große Vielfalt der österreichischen Konstruktionen soll auf eine wesentliche Auswahl reduziert werden, um mit dem Planungsinstrument ‚dataholz.de' auch eine
- gewisse, produktunabhängige Marktsteuerung zu betreiben. Es wird erwartet, dass
- durch die Konzentration und daraus folgernde, vermehrte Nachfrage bestimmter
- Konstruktionen auch eine Verbesserung der Kostensituation eintritt.
- Kostenlose und jederzeit abrufbare Bereitstellung aller für die direkte Anwendung erforderlichen Bauteilnachweise und -daten (Brand-, Wärme-, Feuchte-, Holzschutz, Ökodaten) zu Baustoffen, Bauweisen und Konstruktionsarten auf dem neuesten Stand des Holzbaus (2016).
- Akzeptanz von ‚dataholz.de' durch alle Genehmigungsbehörden in Deutschland ohne zusätzliche Nachweise und einzureichende Unterlagen
- Hersteller- und Produktneutralität

- Unabhängige Bereitstellung der Informationen durch anerkannte Forschungseinrichtungen und akkreditierte Prüfstellen
- Praxisorientiertes Informationsangebot mit Konstruktionsdetails und Bauteilaufbauten durch einfache Navigation und individuell einstellbaren Ausgangsdaten für Bauteilsuchen, Verknüpfung der Datenbank mit Beispielprojekten
- Geschlossene Darstellung des Holzbaus nach außen, Informationsbündelung und Erleichterung der Planung

Für den Planungsprozess in Deutschland würde die Einführung eine wesentlich verbesserte Planbarkeit von Holzbaukonstruktionen bereits in den Leistungsphasen LP 2 und LP 3 bedeuten, da Sicherheit besteht, dass die geprüften Konstruktionen problemlos baurechtlich anwendbar sind.
In die Zukunft blickend könnte dataholz.com zur Standardisierung der Bauteil-Bibliotheken bei der BIM-Anwendung beitragen. Allerdings wäre dafür eine Weiterentwicklung als 3D-Komponente erforderlich.

2.4 Integrated Project Delivery (IPD)

“Integrated Project Delivery (IPD) ist ein Projektlablaufansatz, der Menschen, Systeme, Geschäftsstrukturen und Praktiken in einen Prozess integriert, der gemeinsam die Talente und Erkenntnisse aller Teilnehmer zur Optimierung von Projektergebnissen einsetzt, den Wert steigert, den Abfall reduziert und die Effizienz durch alle Phasen der Planung, Fertigung und Konstruktion maximiert.
IPD-Prinzipien können auf eine Vielzahl von vertraglichen Vereinbarungen angewendet werden und IPD-Teams können Partner weit über die Trias von Eigentümer, Architekt und Auftragnehmer hinaus beinhalten. In allen Fällen zeichnen sich die integrativen Projekte durch eine sehr effektive Zusammenarbeit zwischen dem Besitzer, dem hauptverantwortlichen Planer und dem hauptverantwortlichen Ausführenden aus, beginnend von der frühen Planung bis zur Projektübergabe.” (Vorwort des IPD-Guides der AIA)[2]

IPD ist also eine Projektmanagementmethode aus den USA, die mit dem o. g. Leitfaden des AIA, dem Berufsverband der Amerikanischen Architekten, erläutert und verbreitet wird.
Die Kernüberlegung bei IPD ist die Verschiebung von Entscheidungen in eine frühere Phase der Planung und das kollaborative Zusammenarbeiten der wichtigsten an der Planung Beteiligten zu einem frühen Zeitpunkt der Planung – in der Vorplanung. Obwohl in den USA eher ein Generalunternehmermodell nach der Genehmigung der Planung üblich ist, hat sich diese Methode als effizient erwiesen um Änderungen zu einem späten Zeitpunkt im Bauablauf und damit Kostensteigerungen zu vermeiden. Für die damit verbundene Verschiebung des Leistungsbildes der Planer empfiehlt der AIA neue Beschreibungen für das Leistungsbild in der jeweiligen Phase und reagiert somit auf die Verschiebung des Arbeitsaufwandes. Der Leitfaden beschreibt auch verschiedene Formen der Zusammenarbeit und gibt Antworten zu rechtlichen Fragen.

Wie auch die BIM Bewegung bedient sich die AIA bei der Visualisierung Ihres Prozessablaufs der Methode und Grafik von Partrick MacLeamy, die er mit mehreren Kurven darstellt, um zunehmende Baukosten durch Änderungen zu einem späten Zeitpunkt im Projektablauf zu veranschaulichen. Auch er plädiert für die

[2] AIA, Integrate Project Delivery – A Guide 2007

Verschiebung von Entscheidungen in eine frühe Planungsphase, weil zu diesem Zeitpunkt die Möglichkeit die Kosten und Funktionen, ohne gravierende Auswirkung auf das Ergebnis, zu verändern am größten ist. Dabei wird der vorgezogene Planungsprozess dem traditionellen Planungsprozess in einer Aufwandskurve gegenübergestellt.

Für leanWOOD bedeutet der Vergleich zu IPD, ähnlich wie zur BIM-Methode, eine Bestätigung der Annahme Planungsentscheidungen im Prozess nach vorne zu verlagern um effizienter zu werden. Auch für den Planungsprozess beim vorgefertigten Holzbau lässt sich die MacLeamy Curve zur Veranschaulichung einsetzen

Integrative Planungsansätze basieren eben auf dem Prinzip der Einbeziehung aller erforderlichen Fachdisziplinen zu einem frühen Zeitpunkt, um vorhandenes Optimierungspotenzial zu nutzen. Das ist für die erfolgreiche Bewältigung komplexer und großmaßstäblicher Bauaufgaben in Holz nur durch produkt- und fertigungsneutrale Planung zu erzielen. Die fertigungsgerechte Planung könnte von qualifizierten Holzbau-Unternehmen selbst oder auch von speziell ausgebildeten Fachingenieuren erbracht werden. Ein höheres Maß an Standardisierung auch in der Produktion würde diesen firmenunabhängigen Weg begünstigen.

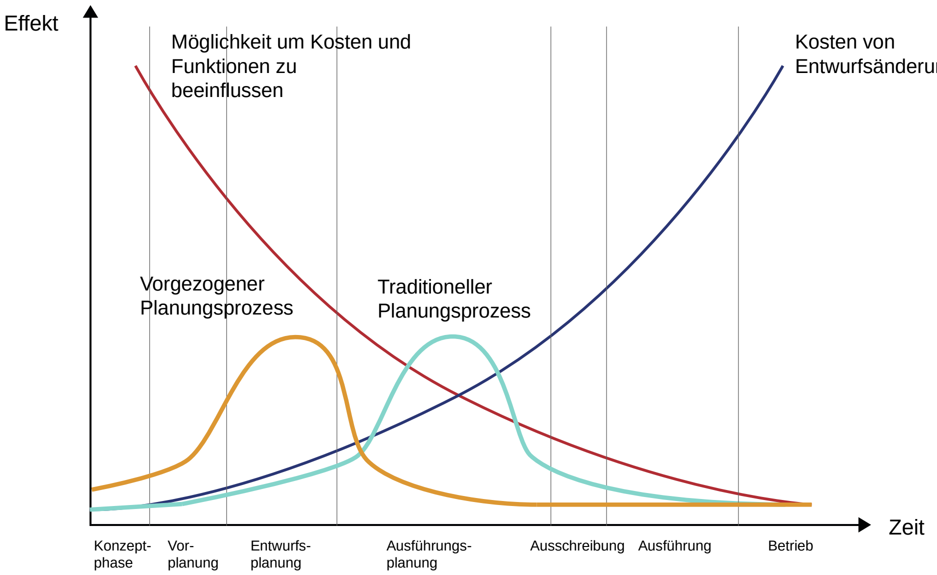

Abbildung 8: Vorgezogener und traditioneller Planungsprozess im Holzbau – Aufwandsverlagerung und Einfluss auf Kostenentwicklung (nach MacLeamy,2004)

3 BIM im Holzbau

3.1 BIM im Holzbau

Der digitale Prozessablauf im Holzbau als „digitale Kette“ basiert auf einer durchgängigen Organisation von Daten beginnend beim Entwurf des Architekten, vertieft in Konstruktion und Berechnung mit Fachplanern sowie anschließenden Optimierungsprozessen und endend bei der finalen Fertigung im Holzbauunternehmen. Mit der Übernahme von 2D / 3D CAD-Daten (Computer Aided Design) der Architektenplanung in die CAM-Fertigungsplanung (Computer Aided Manufacturing) des Unternehmens ist eine Anpassung der Planung an die Besonderheiten der Fertigungsprozesse des Unternehmens verbunden. Die CAM-Daten basieren in der Regel auf einem 3D-Modell und sind die Grundlage für die Maschinenansteuerung und Werkzeugauswahl. Fertigungsrelevante Aspekte wie Verschnitt, Materialverbrauch, statische Dimensionierungen, Elementteilungen usw. werden zu diesem Zeitpunkt bewertet und optimiert. Ab diesem Zeitpunkt sind Änderungen in der Planung mit hohem Aufwand in der Ausführung verbunden. Der Prozess der Vorfertigung im Holzbau erfordert daher frühere Festlegungen in der Planung als im konventionellen Planungsablauf und führt zur Vorverlagerung von Planungsentscheidungen in die Vor- bzw. Entwurfsplanung.

Diese Notwendigkeit verbindet den modernen Holzbau mit der BIM (Building Information Modelling) Methode, die einen optimierten Prozess von Planung, Ausführung und Bewirtschaftung von Gebäuden mit Hilfe einer 3D-Software beschreibt. Dabei werden alle relevanten Gebäudedaten digital erfasst, vernetzt und im Idealfall in einer gemeinsamen Daten-Plattform gespeichert. Zudem wird das Gebäude als virtuelles 3D-Gebäudemodell geometrisch veranschaulicht.

Konventionelle 2D-Darstellungen in Grundriss und Schnitt beschreiben das Bauwerk nur zum Teil und bringen daher einen höheren Abstraktionsgrad mit sich. Durch die 3D-Darstellung werden mehr Informationen konkret dargestellt und verwaltet. Dadurch bedarf es bei der BIM Methode, wie bei der Vorfertigung im Holzbau, einer Vorverlagerung des Planungsprozesses in frühe Planungsphasen (s. Abb.), um eine frühzeitige Grundlage für Planungsentscheidungen zu schaffen. Kollisionen in der Planung unterschiedlicher fachlich Beteiligter können rechtzeitig erkannt und vermieden werden. Ein baubegleitender Planungsprozess während der Ausführung, wie beim konventionellen Bauen, wird damit vermieden. Der höhere Informationsgehalt lässt genauere Betrachtungen hinsichtlich Kosten, Wirtschaftlichkeit, Energieeffizienz, usw. zu.

3.1.1 Closed oder Lonely BIM

Übereinstimmungen in der Philosophie des modernen Holzbaus und der BIM-Methode sind Integrative Planungsprozesse und das zentrale digitale 3D-Modell als Informationsträger. Bei den derzeit meistverbreiteten Anwendungsformen von BIM in der Holzbauvorfertigung handelt es sich um ein sog. „Closed oder Lonely BIM-Modell“ im eigenen Unternehmen des Holzbauers. Die Entwurfsplanung wird mit systemkonformer Software in die Fertigungssoftware übernommen und als 3D-Modell entsprechend der internen Prozesse beschrieben. Das 3D-Modell wird mit möglichst vielen Informationen angereichert. Über das Zeichnen der Planung hinaus werden Kosten und Massen ermittelt, Stücklisten, Angebote und Abrechnungen erstellt sowie die Baustellenlogistik organisiert. Im Beispiel der Fa. Baufritz wird die

Software hsbcad eingesetzt. Bei der Umsetzung von BIM wird die interne Prozesskette von CAD zu CAM bereits durchgehend eingesetzt, d. h. Planer und Betrieb verwenden die gleiche Software-Familie. Die Planung basiert auf einer zentralen 3D-Datei, die alle benötigten Information trägt. Die anhängenden Informationen werden für in den jeweiligen Ausführungsschritten bei Bedarf mitverarbeitet. Im Grunde genommen wird intern ein Level 2 oder auch „Closed BIM“ Standard nach den BIM Kategorien angewandt.

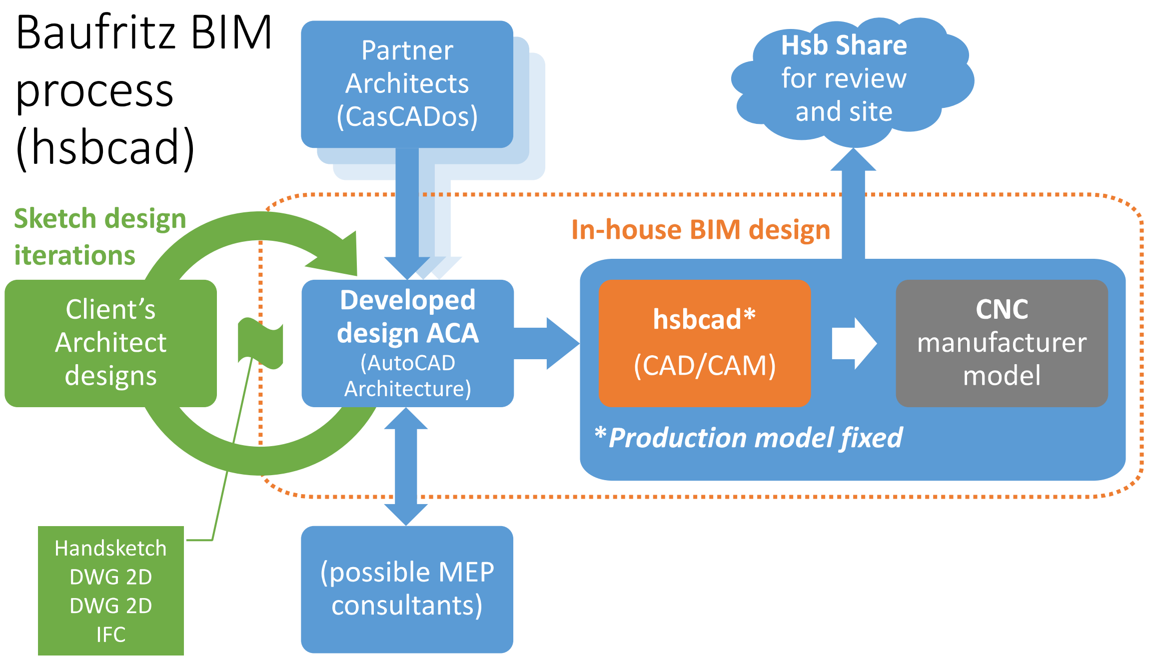

Abbildung 9: Closed BIM Process, Example Baufritz, Graphic by Simon le Roux

3.1.2 Open BIM

Für einen umfassenden integrativen Planungsprozess, bei dem die Daten aller an der Planung und Ausführung Beteiligten zu einem frühen Stadium der Planung zusammengeführt und auf den Produktionsprozess abgestimmt werden, sind weitere Schritte erforderlich. Architekten, Fachplaner und zuliefernde Firmen liefern entsprechend einer vorherigen Vereinbarung bezüglich des Detaillierungsgrades, auch LOD (Level of Detail oder Development) genannt, Ihre Daten in einem 3D-Modell, die mittels eines Datenaustauschformates, z. B. IFC, in einem gemeinsamen 3D-Modell auf einer Datenplattform zusammengeführt und im Idealfall mit den Daten des 3D-Modells der Fertigung verknüpft werden. Vorfertigung und BIM würden so effizient genutzt werden. Dieses Modell mit weitgehend einer gemeinsamen Datenplattform, entspricht dem „Open BIM Modell“.
Für die Integration der CAM-Dateien in ein gemeinsames Datenmodell steht derzeit jedoch keine geeignete Software zur Verfügung. Auch Bauteilbibliotheken mit einheitlichen Standards sind nicht ausreichend entwickelt und die Schnittstellen zum Datenaustausch noch weitgehend umständlich. Die Informationen, die mit dem Austauschformat transportiert werden, kommen nicht in gleicher Weise beim Empfänger an, wie sie vom Adressaten aufgegeben wurden. Viele der Informationen die der Datei anhängen sind mit unterschiedlicher Software oft nicht lesbar.

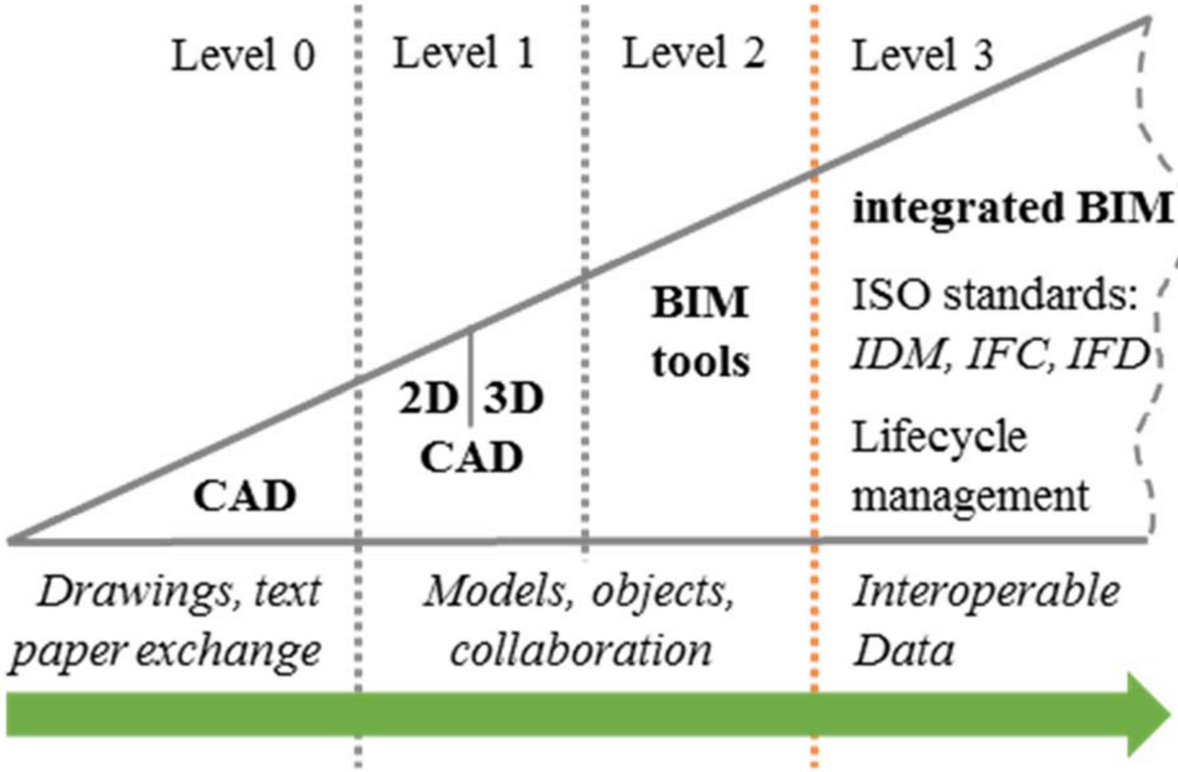

Abbildung 10: BIM Levels in Bew-Richards BIM Maturity Model (Bew, M., and Richards, M. 2008) Graphic by Simon le Roux

3.1.3 Schnittmengen Holzbauplanung - BIM

Das 3D-Modell des Holzbauunternehmens mit festgelegten Zeichenstandards und eigenem Bauteilkatalog, abgestimmt auf die Fertigungsprozesse entspricht im Wesentlichen den Strukturen des 3D-Modells der BIM-Methode. Der hohe Vorfertigungsgrad und die Automatisierung in der Produktion decken sich mit der BIM-Idee. Um die Potentiale der BIM-Methode optimal zu nutzen und das 3D-Planungsmodell mit dem 3D-Produktionsmodell des modernen Holzbaus ohne Schnittstellen in Einklang zu bringen sind Entwicklungen bei der Software notwendig. Derzeit sind die Schnittstellen zum Datenaustausch noch sehr umständlich. Es gibt bisher keine überzeugend funktionierende Verknüpfung zwischen der Software des BIM-Modells und den CAD-Programmen der Holzbauunternehmen.

3.1.4 Standardisierung der Informationsmodelle

In der Studie des Fraunhofer IAO wurde ermittelt, dass mehr als jedes zweite Unternehmen eigene Bauteil-Bibliotheken erstellt. Auf Bibliotheken der Hersteller und Zuliefererindustrie greifen 38% zurück. Lediglich 11% nutzen überwiegend Internetplattformen, wie beispielsweise BIMobject als Bauteil-Bibliothek.
In Bezug auf die Standardisierung der Bauteil-Bibliotheken könnte die Weiterentwicklung der Österreichischen Bauteil-Plattform dataholz.at mit geprüften Bauteilschichten für den deutschen Markt beitragen. Zahlreiche Prüfverfahren sind aber vorher erforderlich um die deutschen Normen und Brandschutzanforderungen zu erfüllen. Am Ende könnte eine 3D-Bibliothek stehen, die die Grundlage einer zertifizierten Anwendung darstellt.

3.2 Verbreitung von BIM

In den deutschsprachigen Ländern wurde, anders als in angelsächsischen und nordischen Ländern, eine verpflichtende Anwendung von BIM bisher nicht eingeführt. Die Verbreitung bei Architekten beschränkt sich daher auf größere Bürostrukturen, die größere Auftragsvolumen bearbeiten und Ihre Aufträge meist im Ausland generieren. Für kleine Bürostrukturen, die in Deutschland 90% der Architekturbüros ausmachen, ist die Einführung von BIM mit hohen Investitionen und Mehraufwand bei der Projektbearbeitung (Fachkompetenz für BIM-Management) verbunden. 60% der BIM-Anwender nutzen die Daten nur intern für ein 3D-Modell wegen Problemen mit dem Datenaustausch. Es gibt bisher keine überzeugend funktionierende Verknüpfung zwischen der Software des BIM-Modells und dem CAD-Programm der Holzbaubetriebe.
Eine Studie des Fraunhofer IAO mittels Online-Umfrage unter 400 Befragten aus Planern, Fachplanern und Ausführenden, ermittelte im August 2015 den Stand und die Potentiale digitaler Planungs- und Fertigungsmethoden.

Die Kernaussagen der Studie in Kürze:

- Jeder fünfte Befragte kennt die Planungsmethode BIM nicht
- Jeder zweite befragte Planer (Generalplaner, Architekt, Fachplaner) arbeitet immer anhand von 2D-Zeichnungen, egal ob analog oder digital
- In 29 Prozent der Aufträge zur Fertigung von Bauteilen dienen 2D/3D-Planungsdaten immer oder häufig als Grundlage für ein eigenes Modell

Jedes dritte Unternehmen mit Projektvolumen von über 25 Millionen € arbeitet bereits nach der BIM-Methode

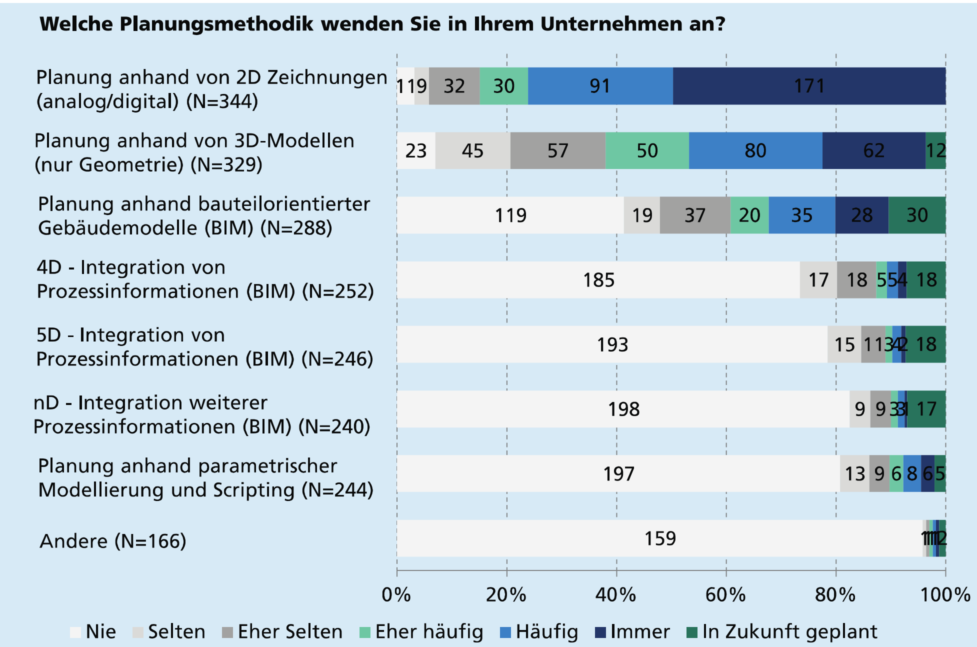

Abbildung 11: BIM Studie Fraunhofer IAO, 2015

Die durchgängige digitale Prozesskette von der Planung bis zur Vorfertigung ist also in der Praxis noch nicht erreicht. 31% der Befragten geben an, dass die BIM Methode erst ab einer größeren Mitarbeiterzahl oder einem größeren Projektvolumen rentabel ist. Die Investitionskosten für Anschaffung von Software und notwendigen Schulungen für das Büro ist zu hoch.

59% der Befragten erklären, dass die Schnittstellenprobleme zwischen den Beteiligten der Planung, Fertigung und Ausführung wegen der unterschiedlichen Software und den Problemen beim Datenaustausch nicht gelöst seien und zu erheblichem wirtschaftlichen Mehraufwand führen.
7% bestätigen, dass die Planungssoftware keine Schnittstelle für die Fertigung enthält.
Betrachtet man die einzelnen Teilnehmergruppen wieder isoliert, so beklagen fast 86% der an der Studie beteiligten Zulieferbetriebe, dass es aufgrund unterschiedlicher Software und fehlender Austauschformate zu Schnittstellenproblemen zwischen den beteiligten Partnern gibt.
Bei den befragten Bauhandwerkern sind es sogar 100%. Bei der Gruppe der Investoren, Bauträger und Projekt-, Objektentwickler sind es 79%, bei den Bauunternehmen und der öffentlichen Hand je 65%. Die Fallzahlen in diesen Gruppen sind aufgrund der hohen Teilnehmerzahl der Planer von 72% jedoch gering.

Die Informationen, die mit dem Austauschformat transportiert werden, kommen nicht in gleicher Weise beim Empfänger an, wie sie vom Adressaten aufgegeben wurden. Viele der Informationen die der Datei anhängen sind mit unterschiedlicher Software oft nicht lesbar.

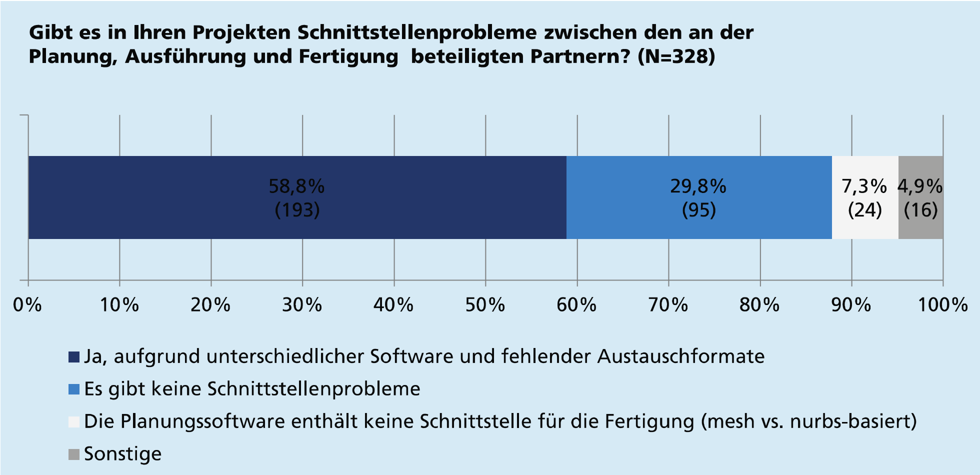

Abbildung 12: BIM Studie Fraunhofer IAO, 2015

Neben den Kosten sind also Software und Schnittstelle die größten Hemmnisse bei der weiteren Verbreitung der BIM Anwendung. Im Holzbau funktioniert die Umsetzung von BIM insofern gut, weil die interne Prozesskette von CAD zu CAM von vielen Betrieben bereits eingesetzt wird.

Das Ziel der Entwicklung ist, das kollaborative Arbeiten mit einer von Beginn des Prozesses an festgelegten Struktur und der Begleitung durch einen BIM-Koordinator zu einem integrativen Planungs- und Fertigungsprozess vom Entwurf bis zur Maschinenansteuerung zu erreichen. Voraussetzung für einen durchgängigen Planungs- und Produktionsprozess ist die Bereitschaft der fachlich Beteiligten zur interdisziplinären Kommunikation.

3.3 Fazit

Die Hypothese ist, dass die Holzindustrie in Open-Source-BIM Anleitungen für Designer investieren muss und an gemeinsamen Pilotprojekten zusammen mit BIM-Entwickler und Lean Construction Praktiker experimentieren sollte, um Software-Plattformen zu testen und aus der praktischen Erfahrung zu lernen. Das Risiko besteht darin, dass die Software-Plattformen und BIM Anforderungen angenommen werden und mit der Weiterentwicklung der Holzbauindustrie unvereinbar sind. Die Entwicklung von "ready-made" Objektbibliotheken für bearbeitete Holz Komponenten erfordert ein tiefes Verständnis für die Datenanforderungen und für die Modell Interoperabilität und Kompatibilität, Leitlinien für die Zusammenarbeit in der Konstruktion, spezifische Objektattribute und Toleranzen für CNC-Holzherstellung und Sensibilisierung für die rechtlichen Verpflichtungen, die mit der Spezifikation der geschützten Objektbibliotheken in Verbindung gebracht werden. Die Entwicklung von BIM-Plattformen schreitet unabhängig von der Holzindustrie voran, aber die Risiken der Industrie werden zurückgelassen. Anstatt Holzbaukonstruktionen einzuschränken, sollte es eine verbesserte Datenkonsistenz in BIM Spezifikationen, eine größere Auswahl an generischen BIM-Objekten und intelligente parametrische Steuerung für das Holzdesign geben.[3]

Ein Weg dorthin könnte der Gedanke eines virtuellen Unternehmens sein - übertragen auf ein Bauprojekt. Das setzt voraus, dass der gemeinschaftliche Sinn aller an der Planung und Ausführung Beteiligten ein Bauwerk zu erstellen im Vordergrund steht. Die autistische profitorientierte Haltung des Einzelunternehmens verschwindet zugunsten eines integrativen Planungs- und Fertigungsprozesses. Dafür wird eine Person benötigt, die den Prozess und überblickt. Architekten und Holzbauingenieure könnten dafür ausgebildet werden, da sie den gesamten Prozessablauf aus Planung und Produktion im Blick haben. Für die Entwicklung der Software wäre der Blick in die Automobilindustrie ein Anknüpfpunkt, weil dort die Erfahrungen mit der Planung an einem Datenmodell am größten sind und Regelstandards am weitesten entwickelt sind. Die Arbeit mit der BIM Methode wird sicher Arbeitsabläufe und Tätigkeitsprofile verändern, aber der Holzbau sollte diese Chance begreifen um größere und komplexere Aufgaben wirtschaftlich erfüllen zu können.

---

[3] Simon le Roux, WCTE 2016 proceeding; Investigating the Interaction of Building Information Modeling and Lean Construction in the Timber Industry

leanWOOD

Book 4 – part B
process

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1. Manufacturing process

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Project Partners

Research

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Kompetenzzentrum Typologie & Planung in Architektur (CCTP)
(Koord. Schweizer Konsortium)
TUM Technische Universität München, Professur für Entwerfen und Holzbau, Germany (Koord. Int. Konsortium)
Aalto University, Chair of Wood Construction, Finland
VTT Technical Research Centre of Finland, Finland
FCBA Institut Technologique, France

SME Partners / other funding

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Timbatec Holzbauingenieure AG, Thun, Bern, Zurich (Switzerland)
Kämpfen für Architektur AG, Zürich (Switzerland)
Lignatur AG, Waldstatt (Switzerland)
Gumpp&Maier. Lösungen aus Holz (Germany)
lattkearchitekten, Arch. Frank Lattke (Germany)
Rakennusliike Reponen Oy (Finland)
Federation of the Finnish Woodworking Industries (Finland)
KINNO Kouvola Innovation Oy (Finland)
SK Finnish Real Estate Federation (Finland)
Federation of the Finnish woodworking industries (Finland)
LECO Construction, XJ Développement (France)

Funding

KTI Kommission für Technologie und Innovation (Switzerland)
BMEL Bundesministerium für Ernährung und Landwirtschaft unter der Projektträgerschaft der FNR Fachagentur Nachwachsende Rohstoffe e.V. (Germany)
TEKES The Finnish Funding Agency for Innovation (Finland)
Ministry of Agriculture, Fisheries and Forestry Resources, MAAF (France)
French Environment and Energy Management Agency, ADEME, (France)
FP7 Seventh Framework Programme European Union
WoodWisdomNet+

Insofar as the masculine form is used in the contents of this report solely for reasons of better readability it is assumed that this refers to both genders on equal terms.

CONTENT

Literature

Ballard, G., & Arbulu, R. (2004). Making prefabrication lean. Paper presented at 12th Annual conference of the International group for Lean Construction. Elsinore, Denmark

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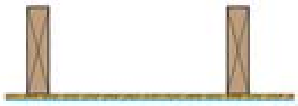
Tatum, B. (1986). Constructability improving using prefabrication, pre-assembly and modularization, Technical report no. 297, Stanford University, California, U.S.A

1 Prefabrication and Lean

1.1 Definition of prefabrication in literature

There is no official definition of prefabrication but we can retain the followings from the literature. Tatum et al. (1986)[1] presented prefabrication as "a manufacturing



process, generally taking place at a specialized facility, in which various materials are joined to form a component part of the final installation" and "pre-assembly as a process by which various materials, prefabricated components, and/or equipment are joined together at a remote location for subsequent installation as a sub-unit." Gibb[2] encompasses these terms in the expression « offsite fabrication » but it implies that this phase takes place on the final construction site. Ballard & al. (2004)[3] suggested to definite prefabrication as "the fabrication all or part of an object in some place other than its final position".

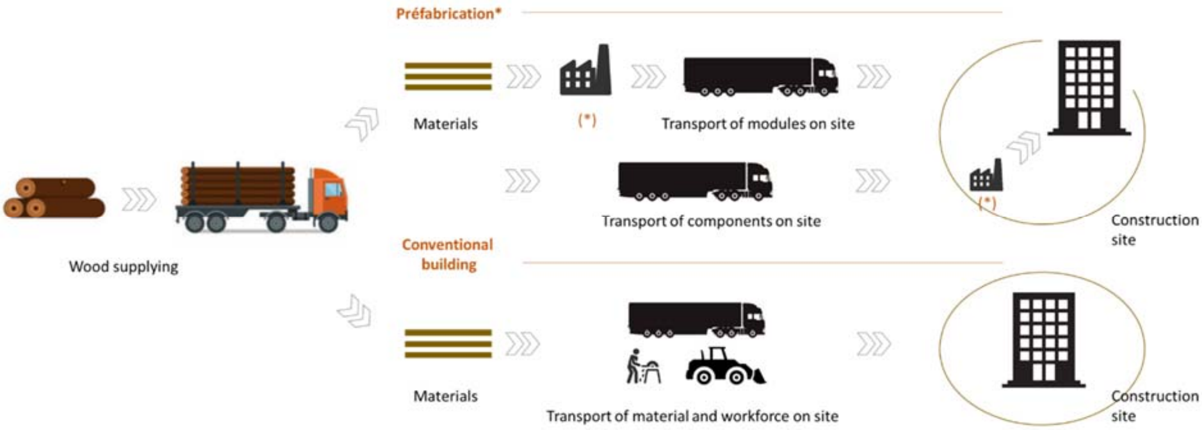


Figure 1: Conventional and prefabrication processes (source: FCBA)

1.2 Levels of prefabrication

There are three main kinds of building systems that can be prefabricated in timber construction: wooden framework, cross laminated timber (CLT) and 3D modules.

1.2.1 Framework

In the Catalogue Construction Bois[4], three levels of prefabrication for wooden framework walls and decks were defined: structure, structure& envelope, structure & envelope & exterior wooden cladding.

Structure:
Studs, wall sheathings and lintels are put together in the factory. Depending on their size, they can be lifted with or without a crane or lightweight hoist.

---

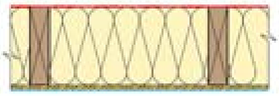
[1] Tatum, B. (1986). Constructability improving using prefabrication, pre-assembly and modularization, Technical report no. 297, Stanford University, California, U.S.A

[2] Gibb, A.G.F., Offsite fabrication - pre-assembly, prefabrication & modularisation, Whittles Publishing Services, 1999, 262 pp.

[3] Ballard, G., & Arbulu, R. (2004). Making prefabrication lean. Paper presented at 12th Annual conference of the International group for Lean Construction. Elsinore, Denmark

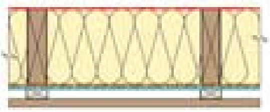
[4] www.catalogue-construction-bois.fr

structure& envelope:



The second level of prefabrication includes the implementation of the insulation and vapor barrier in the factory.

structure & envelope & exterior wooden cladding:



Besides the structure, the thermal insulation and the vapor barrier, the exterior wooden cladding is added in the factory. The windows and doors can also be assembled in the factory.

1.2.2 Cross Laminated Timber (CLT)

The CLT panels are prepared in the factory (cut to size, holes for the fluids and windows ,...), assembled on site and finally insulated and cladded.

1.2.3 3D Modules

The 2D panels (structure, envelope and cladding) are put together in the factory and delivered on site with or without the equipment (bathroom ,...)

1.3 Economic impacts

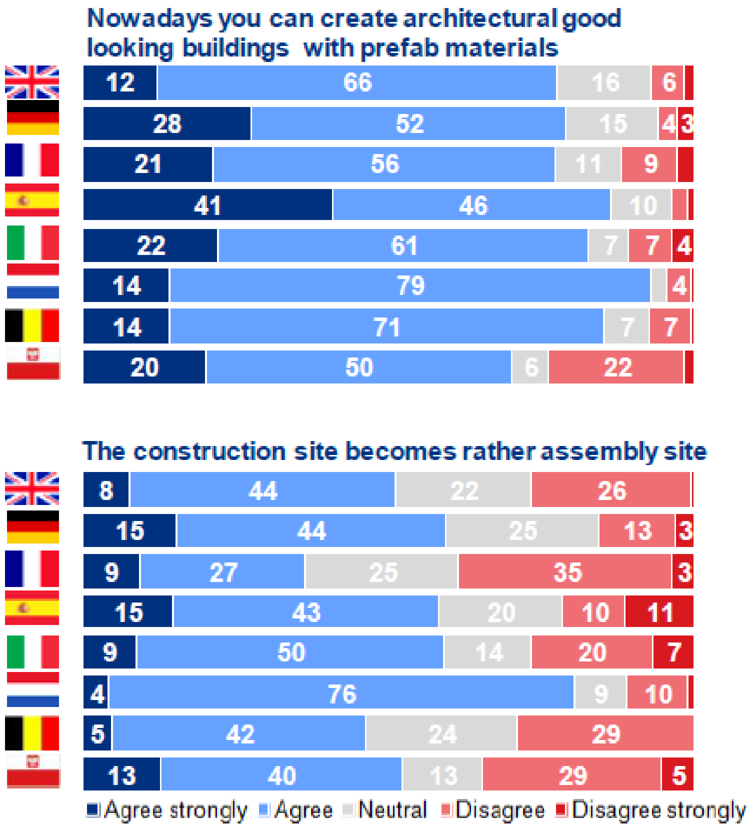
1.3.1 Importance of prefabrication in construction

According to LuxResearch, prefabrication accounts for 20% to 30% of new construction in Europe, the U.S. and Australia[5]. But this percentage can vary a lot according to the countries and materials used. For example, about 84% of detached houses in Sweden integrate prefabricated timber elements while in UK no more than 5% of permanent houses use prefabrication.[6]

While prefabrication has long been perceived as temporary and “poor quality” housing, it is now more and more accepted by users and professional of the construction sector. Between 70% and more than 90% of architects in European countries have a positive perception of prefabricated materials in order to design “architectural good looking” buildings (see graph below).

5 See: http://quarterly.luxresearchinc.com/quarterly/?p=861

6 See: http://www.globalconstructionreview.com/trends/why-sweden-beats-world-h8an0ds-4d2own0-6p4r2e0f8ab/



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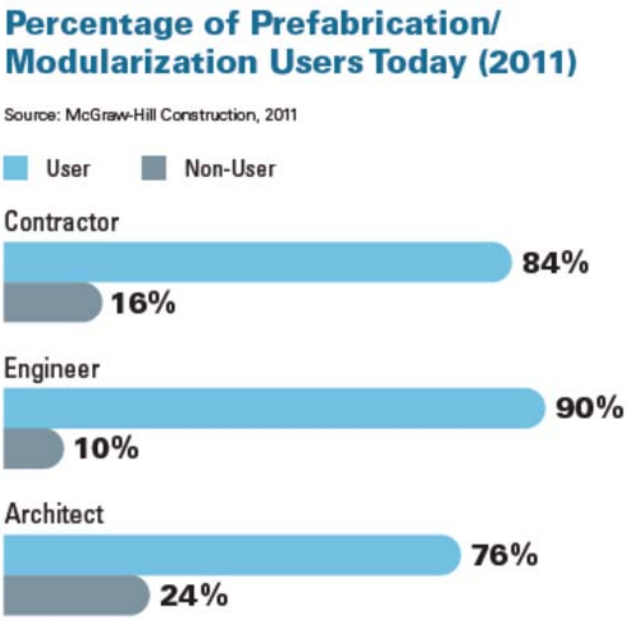
A study conducted by McGraw-Hill Construction[7] underlines that prefabrication and modular building processes are now largely used by construction professionals (see graph below).



Source: McGraw-Hill Construction, 2011

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[7] McGraw-Hill Construction (2011), *Prefabrication and Modularization: Increasing Productivity in the Construction Industry*, Smart Market Report.

1.3.2 Comparative analysis between prefabrication and traditional construction

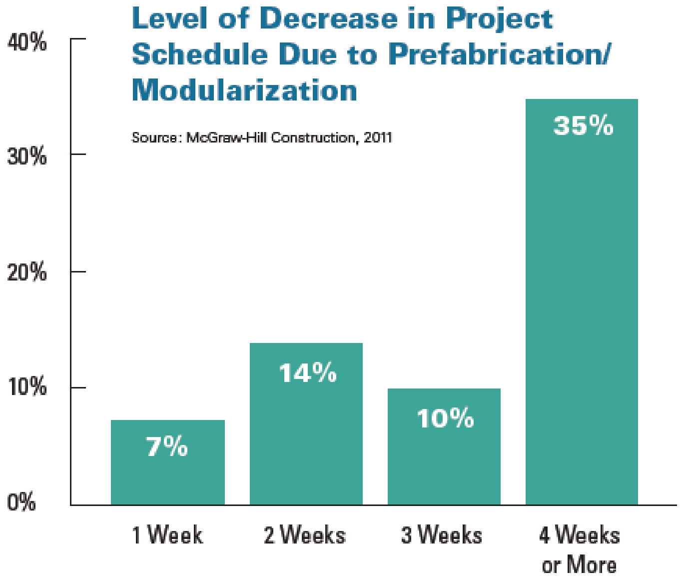
The development of prefabrication is driven by several advantages compared to traditional construction. Firstly, it is highlighted that prefabrication allows to enhance the productivity of a building operation. In particular, a shorter construction cycle time is commonly observed when prefabrication is used. This is due to the ability to build in the factory several housing components simultaneously rather than sequentially when done on-site. Moreover, the progress of building is less dependent on weather conditions which can reduce construction time. Secondly, prefabrication can reduce on-site costs, mainly labor costs, equipment costs, energy and water costs. On-site labor costs are replaced by manufacturing costs (in the factory) which can generate economies of scale. Nevertheless, these economies of scale highly depend on the production volumes and standardization. Moreover, a factory requires higher fixed costs (capital, machines) than a traditional on-site construction operation (see table below).

Advantages	Issues
• Better productivity / positive impact on project schedule / shorter construction cycle time • Potential economies of scale • Reduces building costs (labour costs, material costs) • Reduced waste (= lower waste management costs) • Reduces the post-delivery defect risk (due to quality control in the factory) • Budgets are more predictable and economic outcomes more secure	• Higher fixed costs (requires a factory) • Requires a strong coordination between supply chain and project operations • Requires a longer planification phase • Economies of scale are an important requirement of efficient prefabricated construction. They are depending on the production volumes and standardization.

In the literature, several studies have conducted comparative analysis in order to measure the gap between prefabrication and traditional construction processes in terms of productivity, costs of the projects.

1.3.3 Productivity

Productivity can be defined as the ratio of output to the resources (labor, capital, raw materials) used to produce this output. Generally, the literature shows that prefabrication can enhance the productivity and reduce the project schedule. In the survey conducted by McGraw-Hill Construction, two-third of firms have registered a reduced project schedule by using prefabrication or modularization. And 35% of them have experienced a decrease of 4 weeks or more.



In New Zealand, a case study shows that different degrees of prefabrication (transportable, panelised, hybrid) take less time to construct a 120 m2 house than a traditional on-site process.

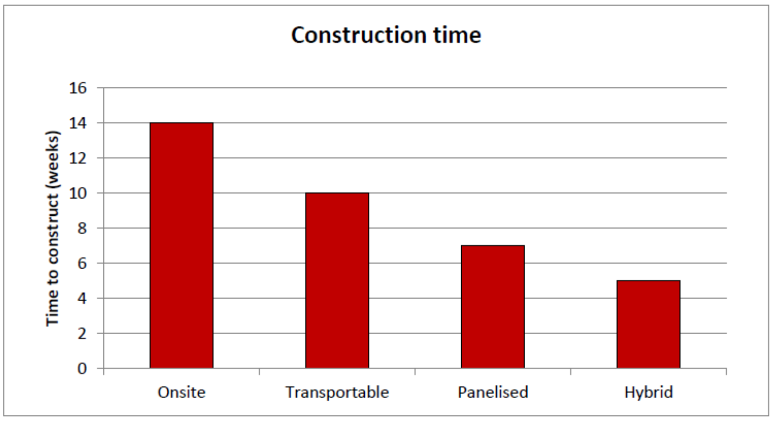


Figure 12: Time to prefabricate a 120 m² case study house compared to traditional onsite construction

Source: Burgess et al. (2013)

1.3.4 Cost savings

Prefabrication generates costs savings, mainly on-site labor costs and material costs as underlined in the graphs below.

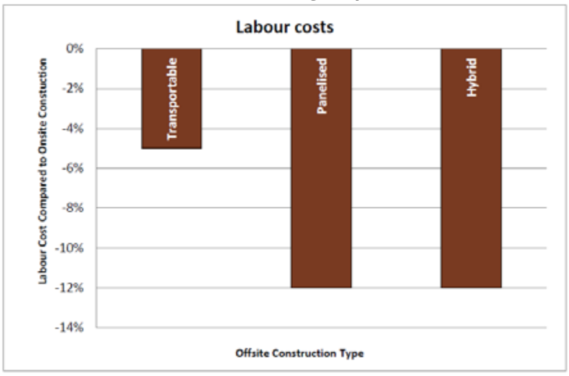


Figure 13: Labour costs for the 120 m² case study house when compared to onsite construction

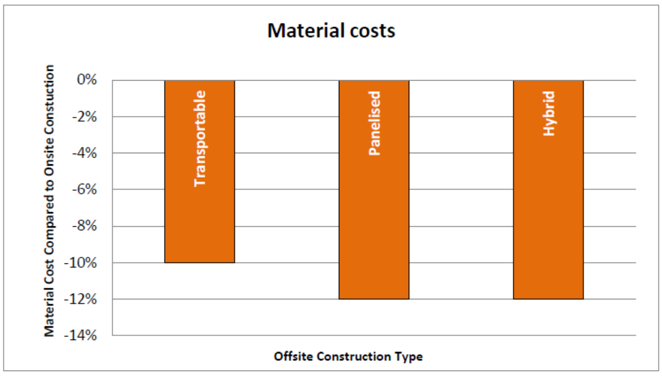
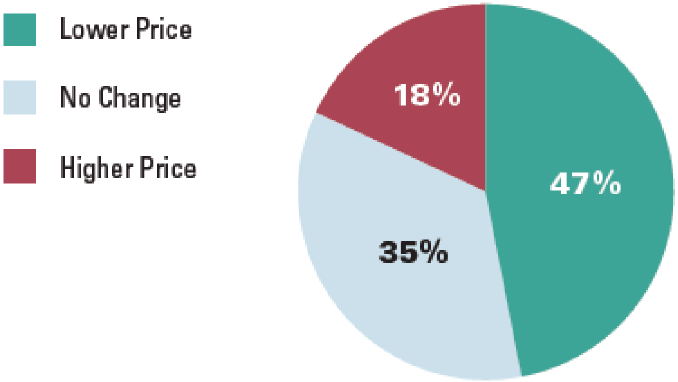


Figure 14: Material costs for the 120 m² case study house when compared to onsite construction

Source: Burgess et al. (2013)

Impact of Prefabrication/Modularization on Purchase and Installation Prices for Materials

Source: McGraw-Hill Construction, 2011



2 Case study: POBI, La Charité sur Loire (France)

2.1 Methodology of the case study

A visit and an interview was carried out and an oral presentation was followed to procure additional information.

2.2 Presentation of POBI

POBI is a timber frame company since 2003 based in La Charité sur Loire in the center of France. In 2015, POBI produced 54 000m² which represent about 2 houses per day. They fabricate walls, floors, windows and carpentry. Since 2014, they have added a joinery. Today, they are 73 employees.

2.3 POBI and Lean

Its dynamic prefabrication process is similar to the one used in the automotive industry.
The implementation of lean in the factory is clearly visible since everything is well organized, labelled and they are no wastes. Rolling conveyers bring the products from workstation to workstation, adding to the quality of the end product.



POBI implemented lean for different reasons:

- limit wastes,
- produce exactly what the client require, no more, no less
- the delivery cadence is agreed with the client and must be respected by both sides to avoid storage
- continuous improvements

Thanks to the implementation of lean POBI went from one house a day to two. The goal is to get to 10 houses per day and saved around 10 to 15% on production costs.

The first step in the introduction of lean was the definition of standard models in accordance with regulations and market trends. The production facility was then built to fit those requirements. The production speed is adapted to the takt time, rhythm of production, to achieve just in time fabrication. Moreover the production schedule is defined to alternate the complexity of the components to avoid jam on the line (windows,…).

A few steps of the process were adapted to fit the requirements of lean such as the drawings following the wall. In the future the drawing will be on dematerialized media. Continuous improvement indicate that the product is in the market mainstream. In order to reach the highest quality of production there is a no defect rule: never accept a non quality object, never transmit a non quality object.

3 Case study: Construction of a college in Loire-Atlantique in Clisson (France)

3.1 Methodology of the case study

First a bibliography was carried out to learn most information about the project. Afterwards, one interview was carried out and one oral presentation was followed to have a more complete overview of the projet and specific information about the wood aspects of the project.

Source: LECO

Stakeholders:

Client: **Conseil Général de Loire-Atlantique**
Architect: **Rocheteau Saillard**
Mission CETRAC: **Technical assistance to the Project Manager**
General contractor: **Quille Construction (subsidiary of Bouygues Construction)**

General data: Calendar: delivery on september 2015 (12 months of work)

Surface: 5 767 m^2

Works budget : 15,5 M€ HT

12 M€ (excluding studies), including 3,5 M€ for modular constructop,, 1 M€ for framework, 1 M€ for green areas and earthworks, 1 M€ for technical equipment,1 M€ for wood and metal frame et 4,5 M€ for secondary trades

Accommodation capacity: 500 pupils

Delay: 2 years between the notification of the contract and the delivery, of which **1 year of works**

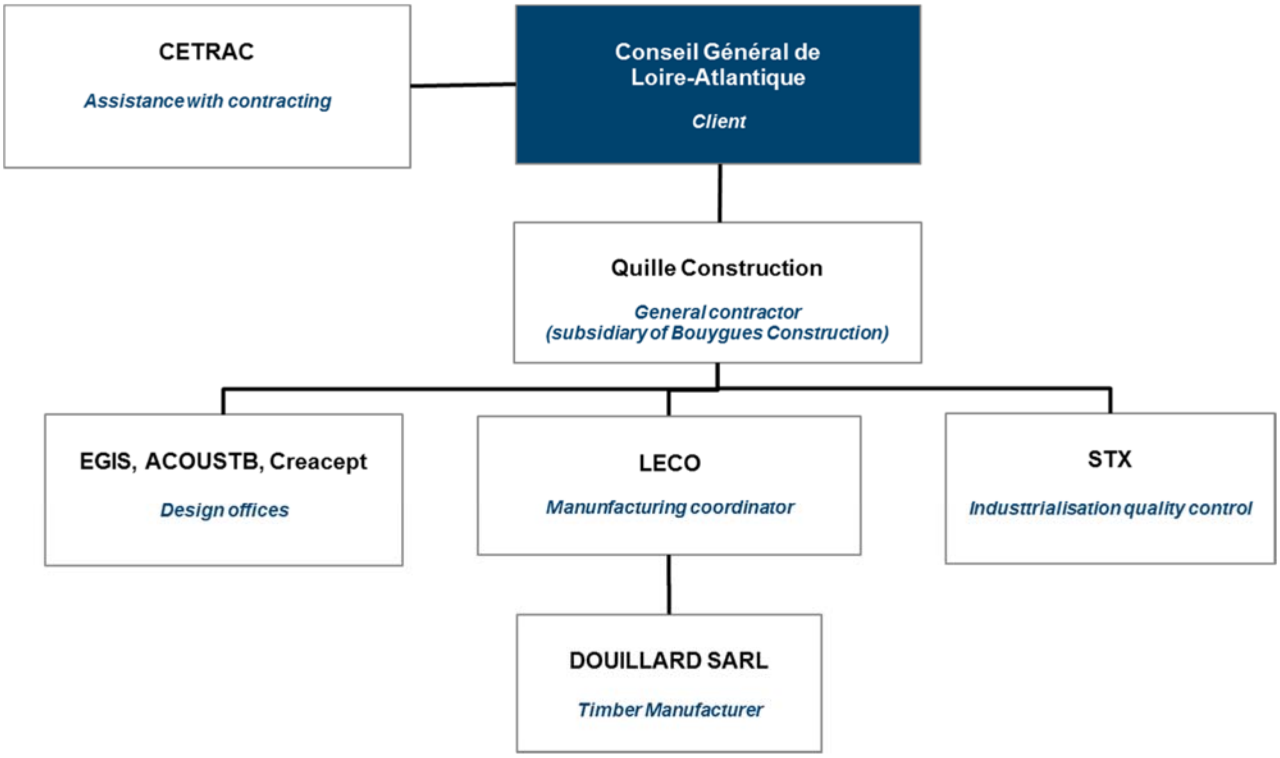


Figure 2 : Organization between stakeholders of the project

3.2 Description of the project

This project is a first in France since for the first time, a public establishment was designed with 98 industrial wooden modules, a technique hitherto reserved for housing. This public college was realized in design-realization to accommodate 600 students divided into 24 classes.
This project had a high environmental quality approach, with among other things, the management of water retention, the development of outdoor spaces, accessibility to the structure or low consumption.
This project who used an innovative process made it possible to carry out the work of the college in one year and to reach construction costs 15% lower than a traditional constructive solution

The LEAN method is used in the workshop to organize sequentially the different tasks of the companies and optimize the construction schedule.
Manufactured in accordance with the Dhomino® licensed construction system (www.dhomino.fr), the modules are assembled in pairs to form a classroom, then nested together, guaranteeing the waterproofness of the assembly. Two modules per day are finished in the factory and about 4 to 6 can be installed on the building site.

3.3 Wood construction system

Dhomino wood modules are a fully-fledged construction system. If the wooden modules designed by the Dhomino design office are similar to wood-frame construction, they differ from the basic structure by rectangular frames, assembled according to the technique of the industrial frameworks and on the other hand, the vertical uprights take up the loads entirely and do not rest on a low rail.
For this project the modules are up to 16 meters long and can incorporate a half-classroom and an adjoining corridor. The modules are thus assembled in pairs in order to form a classroom and then nested together, guaranteeing the tightness of the tailor-made assembly since on the 98 modules, since 80 different models coexist.

Figure 3 : Système construction Dhomino (source : Dhomino)

3.4 Method deployed to carry out this project

This project was made possible by the choice of an innovative construction process, under Dhomino license, by assembling wooden modules, and by the industrial organization of the site. The objective of the Lean method was to reduce as much as possible the "hazards" that waste time, energy and money and inflate the invoice. The solution implemented in Clisson was therefore based on 3 points:

1. Industrialization of the construction process

In order to optimize the construction costs, a detailed breakdown of the elements constituting the module was carried out in order to obtain an inventory. An assembly order was established with the aim of simplicity and speed. The construction of the module was thus the result of two stages: the first was the manufacturing by subcontractors of prefabricated components, the second, on site, was the assembly of the elements by the carcassing work companies and the secondary trades. On site, the organization of the space and the tools, even if they were limited, were taken into account. All the interventions were timed, not to put pressure on the operators but to optimize the organization of each one. This upstream planning involved not only production tasks but also purchasing.

This method reduced the errors on site and optimized the journey time of companions on actual work.

2. The use of local resources

The subcontracting companies and the companions in charge of the assembly were recruited locally, to limit the time of transport, and facilitate the daily work on the site. The distance between the assembly site of the modules and the construction site was also reduced to the maximum. In Clisson, a former logistics hangar of 15,000 m² was leased for 4 months, located 3 kms from the site.

3. Initial training

Before the beginning of the project, LECO organized a training session in which the entire project team was involved: project owner, architect, design office, companions of all the lots involved in the modular construction, control office ... This team had a day to build a site bungalow, each contributing to the title of its profession. The trainer observed, identified the problems, lead everyone to identify the actions that would avoid delays or errors ... The objective was double: to learn to work together and to learn self-control. Everyone was responsible for the quality of their work and was part of a chain of realization where each link depends on the previous one.

3.5 Feedback of a company: SARL Douillard

The company Douillard made a feedback during the seminar “Les rencontres construction bois” in September 2016 in Angers (France).

The project concretely for the company started in April 2014 with the signature of the contract.

In May 2014 Douillard carried out 4 prototypes to validate the solution with the client and the reception took place in July 2015.

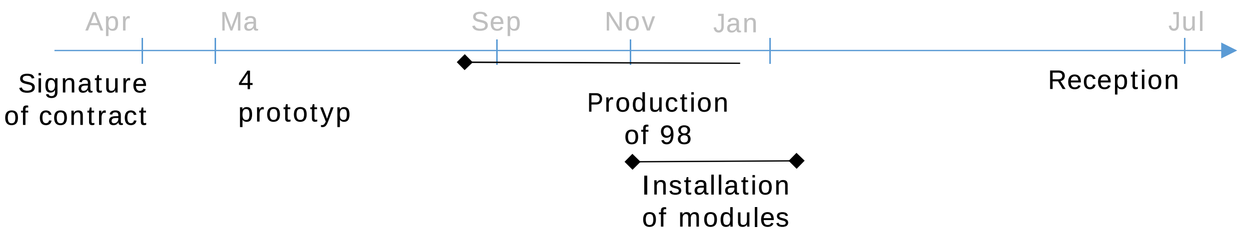


Figure 4 : Schedule

For the company here are a few key figures:
9500 hours of work over 4 months
600 hours of studies
1,8 modules produced per day

LEAN experience for Douillard
The Lean was set up in 2 stages. First, an assessment was made at the end of the prototyping phase by comparing what had been done, the time needed and what had been sold to the client. At that time the company realized that it had to find with this companions 40% of saving time if not the very survival of the company was threatened. So a first reflection of half a day made it possible to find solutions easy and applicable immediately: number of pistols, trolley, necessity of a nacelle, etc. Finally, actions were very basic and very effective.
Before the actual manufacture of the modules, a Lean training was mandatory and imposed by the LECO agent. At first the companions did not want to go but the obligatory nature of the market and the obligation to find sources of productivity made them change their opinion. The training lasted 3 days with theoretical training in the morning, and practical training filmed and video analysis in the afternoon.
The challenge then was to put into practice the lessons of training in our everyday profession. And it was very complicated to apply these rules when you have companions who have 15 or 20 of professional experience and a boss with no industrial experience. And as long as a person is not convinced that she will save time, that person will return to the method mastered.
The construction of a module was divided into 4 stages, and therefore 4 team leaders were appointed with each stage, each morning, evening and evening. These points were used to discuss what had been seen in training and Of what could be applied to the practical case

The LEAN experiment was positive on two points:
- The project in terms of production hours was respected
- Humanely it was a very nice experience. Initially when the program was presented to the company, only one person volunteered to participate. And finally the companions who had not participated in the production were a little jealous of the group atmosphere and the speed of production on this site.

On the other hand for the company Douillard there is a limit to the Lean: it is a participative and collaborative method and if a person does not play the game, the Lean can’t work. Douillard had plans on this site. The plumber also had validated plans but the two companies had different plans (position of a trapdoor). This led to many discussions and wasted time to finally realize that the synthesis with all the state bodies had not been well done.
Today what is left of the Lean experience?
The lean must be driven by the entrepreneur but it really has to be explained to the employees to train everyone. Douillard took advantage of this experience on the pre-fabrication phase but not on the construction phase because the company did not take the time to look at the work done. On the other hand today in the workshop the companions have acquired good reflexes. But you must always be vigilant and carry out reminder stings so as not to fall back into old ways.

leanWOOD

Book 4 – part C process

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1. Increasing efficiency of planning processes by pre-designed detailing

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VTT Technical Research Centre of Finland, Finland
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Federation of the Finnish Woodworking Industries (Finland)
KINNO Kouvola Innovation Oy (Finland)
SK Finnish Real Estate Federation (Finland)
Federation of the Finnish woodworking industries (Finland)
LECO Construction, XJ Développement (France)

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FP7 Seventh Framework Programme European Union
WoodWisdomNet+

Insofar as the masculine form is used in the contents of this report solely for reasons of better readability it is assumed that this refers to both genders on equal terms.

CONTENT

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1 Introduction

Detailing is one element of improving the building practice. It is usual that for example joints and structures are first designed by the architect, redrawn by the structural engineer, redrafted by a sub-contractor and revised on site before finishing the building. This type of redundancy is a waste of work and resources in the building design process.

2 Lean construction and design

Research into lean production and manufacturing started with the *Toyota Production System* (TPS) (Womack et al. 1990). The further development of the construction industry based on lean methodology has gained speed in the 21st century.

Howell (1999) defined *Lean construction* in saying that "Essential features of lean construction include a clear set of objectives for the delivery process, aimed at maximizing performance for the customer at the project level, concurrent design of product and process, and the application of production control throughout the life of the product from design to delivery". Lessing et al. (2005) and Bildsten (2011) identified *Industrialized construction processes* as the planning and control of processes, developed technical systems, off-site manufacturing of building components, long-term relations between parties, integrated supply chain management, customer focus, the use of information and communication technology, systematic performance measuring and the reuse of experiences.

According to Bildsten (2011), Lessing et al. (2005), and Rich (2012) systematization and industrialized construction do not equate with mass-production. The aim should be for high customer satisfaction and a bespoke building as an end result - expressed in other terms as "/…/ a custom product exactly fit for purpose /…/" (Aziz and Hafez 2013).

The application of standardized components serves improving the efficiency of the production. (Aapaoja and Haapasalo 2014). They identify a track record, increased productivity, decreased waste, replicable processes, shorter lead-in times, and a higher quality as benefits of standardized components. Bildsten (2011) and Rich (2012) see the use of standardized components as a means to achieve a continuous improvement of processes.

Aapaoja and Haapasalo (2014) conclude, "Current design processes do not support using the standard products and components". Rich (2012) reports on waste of resources in the design process caused by an ambition to design beyond the limits of expertise. He sees potential in pre-developed detail design and earlier collaboration with suppliers.

From the early 1900s to the reconstruction era after World War II, the aim was to lower the costs of housing production by an industrial approach and mass-production. Álvaro Siza was an early forerunner of user-driven design by developing mass-customized building production. (Benros and Duarte 2008)

Current development suggests module-based solutions. Powell et al. (2014) see modularization as the future for producers of engineer-to-order products with small volume but high variety similar to "*Modular design of one-off projects*" introduced by Mohamad et al. in 2013. The strategy builds on the modularization of the building and the standardization of modules. Benros and Duarte (2009) propose a framework integrating architectural design with building construction. Key attributes are combination of flexible design, digital communication (Computer Aided Design-application, CAD), and industrialized building processes. Jensen et al. (2012) propose similar thinking with building system-based design automation to promote the use of modular standard objects in architectural design. Pasquire and Connolly (2003), developers of the "*design for manufacture and assembly (DFMA)*"-model, support decreasing unnecessary work and emphasize the value for the client over detailed design.

The research on lean construction has identified re-design and unnecessary detail work as wasted resources in the building design process. This article examines the availability of pre-designed details and assesses the usability of them as standardized components in order to achieve more efficient design and production of timber buildings.

3 Pre-designed standardized details for timber buildings

Six detail catalogues for timber construction are published in Austria, Finland, France, Germany, and Switzerland. The earliest publication is from 1999 and Holzforschung Austria was the first to publish online in 2003. In all cases, the material is freely available and has solutions both for wooden frame and for massive wood structures. The contents of these publications are compared regarding availability, format, structures and solutions. The usability in practice and added value of other materials is also assessed.

Table 1 presents selected collections.

Collection / Country of origin	RunkoPES 2.0 Finland	Dataholz Austria	Lignum Bauteil-katalog Switzerland	GHG4 Germany	Baubook Austria	CCB France
Aim	To create a basis for the commissioning, design and execution of timber buildings in which: 1) a building can be designed without knowing who	General construction details to serve as a start for conceptual, initial and detailed design and execution of residential timber buildings	To support the design of ceilings fulfilling impact sound criteria	To create a catalogue with thoroughly designed details and structures for timber building in accordance with the German building regulation code *Musterbauordnu*	To offer details for the design and support for the ecological evaluation of passive houses	To aid the design of timber buildings in accordance with RT 2012 (Réglementation Thermique 2012, design for energy efficiency) and requirements set in NF DTU 31.2

	will execute building works or whose solutions are used, 2) suppliers of different solutions are able to make an offer coherently and cost efficiently, 3) and different manufacturers´ solutions are interchangeable in the design and on site			*ng 2002* and the guideline for fire-resistant timber structures from 2004		(Eurocode compatible timber frames)
Structures	external walls internal walls intermediate floors wet spaces ceilings roofs balconies	wood, wood composites insulation, ligning materials and other external walls internal walls intermediate floors ceilings roofs windows doors other connections and joints	Floors	external walls internal walls intermediate floors selected joints including joints between timber and massive wall structures (e.g. concrete or brick) window detailing	external walls internal walls intermediate floors windows roofs	external walls internal walls intermediate floors roofs ductwork integration
Construction types	massive wood framed structures	massive wood framed structures	massive wood framed structures	massive wood framed structures	massive wood framed structures	massive wood framed structures
Other material	Overview catalogue, example designs for a model multi-storey apartment building including HVAC designs, model building permit drawings	NA	NA	extensive guide book on the design for timber construction	Construction calculator (also available in English), Eco2soft calculation tool	General guidelines for the design of timber structure and separately for single family homes and multi-storey housing
Formats	Pdf-documents, objects in ArchiCAD 17, ArchiCAD 16, Revit 2014, and IFC 2x3	Pdf-documents	Pdf-documents	Pdf-book, available as CAD-objects for Dietrichs CAD/CAM	Pdf-documents, book published by Springer (in German and English)	Pdf and MS Word-documents, dxf-objects
Languages	Finnish	German, English, Spanish, Italian	German	German	German, online version only partly in English	French
Availability	Free of charge	Free of charge	Free of charge	Free of charge	Free of charge	Free of charge
Website	www.puuinfo.fi/suunnitteluohjeet/runkopes-20	www.dataholz.com/	bauteilkatalog.lignum.ch/?lang=de&page=home	www.irbnet.de/daten/rswb/14109008377.pdf	www.baubook.at/phbtk/index.php?SW=19	catalogue-construction-bois.fr/

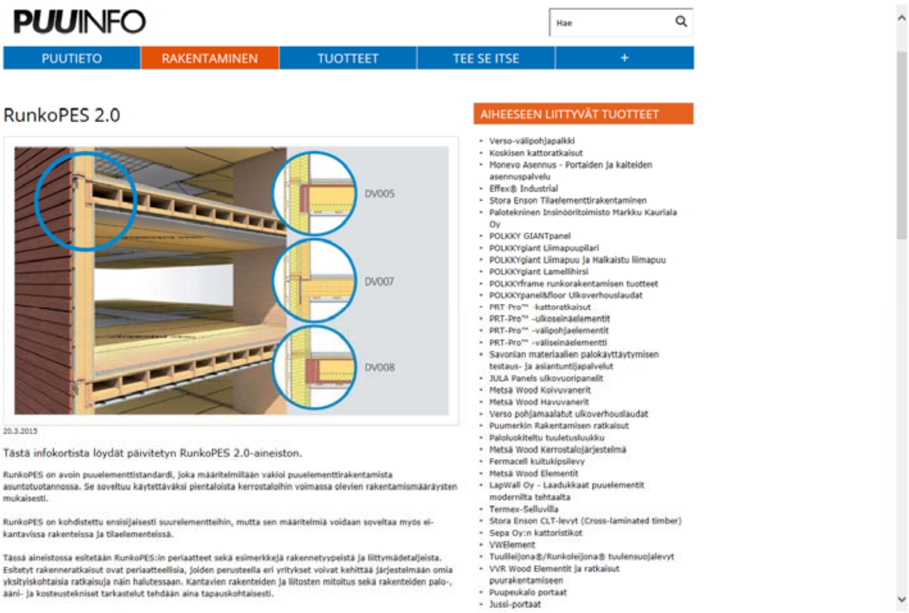
Table 1: Online collections of pre-designed timber building details evaluated in this research.

3.1 Detail catalogues: Availability and Offered Formats

Finnish RunkoPES 2.0 was published in 2013. It is an open timber-element -standard for residential housing production conforming to the Finnish National Building Code. It gives guidelines for designing multi-storey houses of fire classification P2 and large-scale element production. It can be applied to non-load-bearing structures and spatial modules. Detail designs show the principles and are to be further developed by, for example, element manufacturers.

3.1.1 RunkoPES 2.0.

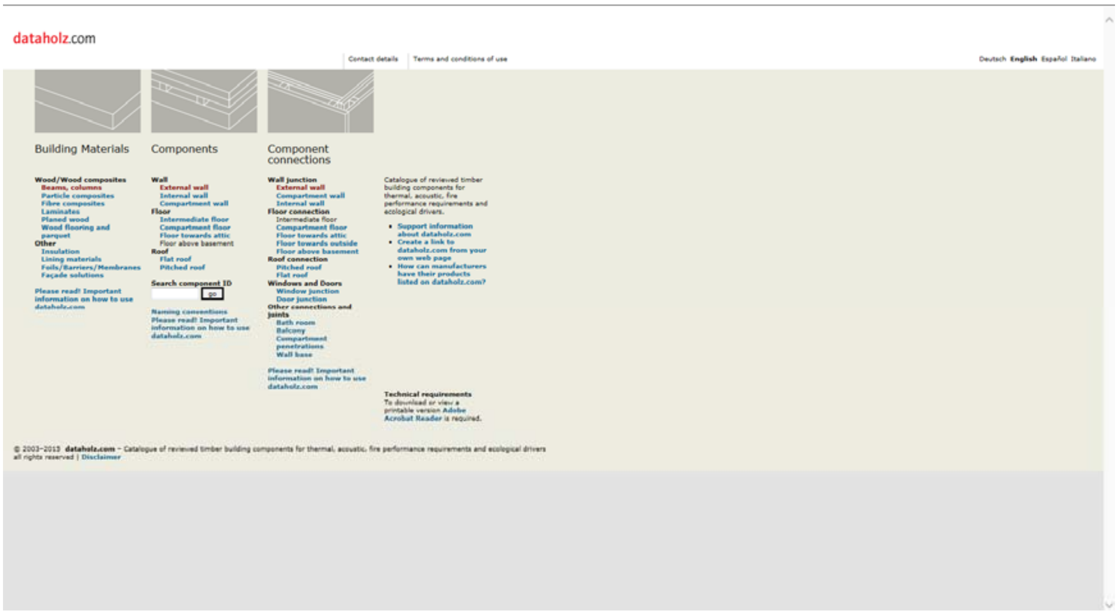
Structural solutions are collected into an overview in pdf-format and joint details in a separate document. The material can be printed but is copy protected. Additional materials consist of exemplary designs for a model multi-storey apartment building including HVAC design and building permit documents. The CAD-objects are available in formats ArchiCAD 17, ArchiCAD 16, Revit 2014, and IFC 2x3. Final structures are to be verified by a structural engineer for each building project.



Picture 1 RunkoPES 2.0 homepage. Published by Puuinfo Oy.
www.puuinfo.fi/suunnitteluohjeet/runkopes-20

3.1.2 Dataholz

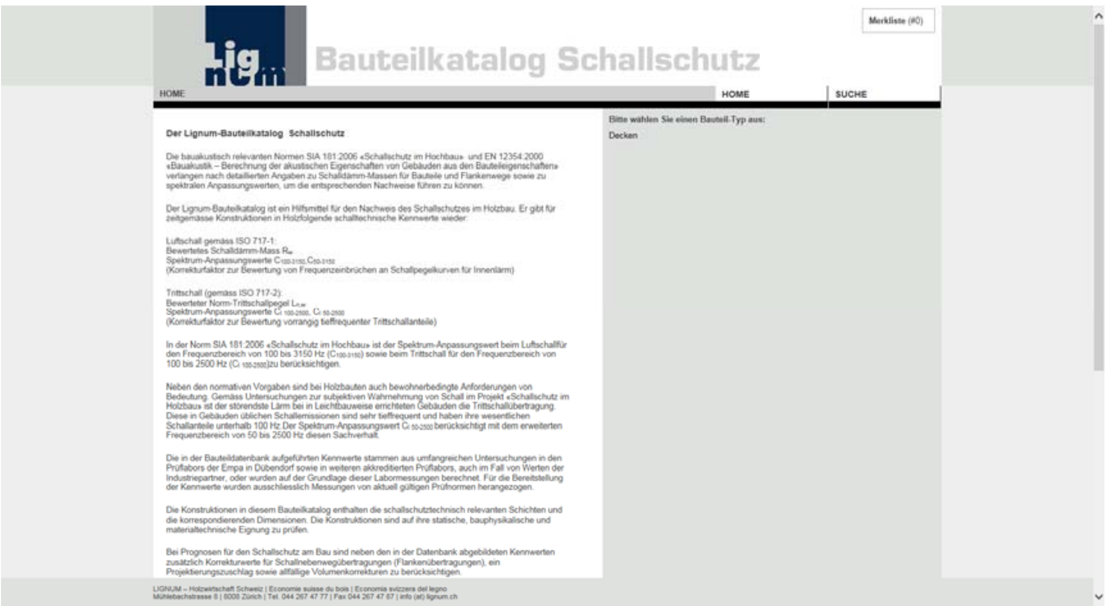
The *Catalogue of reviewed timber building components for thermal, acoustic, fire performance requirements and ecological drivers* (Dataholz) was published in 2003. It includes construction details for residential buildings. The material consists of fact sheets and drawings in pdf-format. All can be both copied and printed. Language options include German, English, Spanish and Italian. The material is offered as suitable proof of compliance with Austrian building regulations. However, no liability is accepted.



Picture 2 Dataholz.com homepage.
dataholz.com/en/

3.1.3 Lignum Bauteilkatalog

Swiss timber construction details, *Lignum Bauteilkatalog Schallschutz* (Lignum Bauteilkatalog), were published in 2014. It is a collection of intermediate floor structures only for acoustic design according to standards SIA 181:2006, EN 12354:2000, ISO 717-1, and ISO 717-2 and to reduce low-frequent impact sound (below 100Hz). The material consists of structural detail fact sheets and drawings in pdf-format. Documents can be printed and the information can be copied.



Picture 3 Swiss Lignum Bauteilkatalog Schallschutz homepage.
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3.1.4 Erarbeitung weiterführender Konstruktionsregeln / -details für mehrgeschossige Gebäude in Holzbauweise der Gebäudeklasse 4

The Erarbeitung weiterführender Konstruktionsregeln/-details für mehrgeschossige Gebäude in Holzbauweise der Gebäudeklasse 4 (GHG4) was published in 2014 (Gräfe et al. 2014). It promotes the design of multi-storey timber buildings in Germany up to 13 m height of upper floor level (Gebäudeklasse 4). The material contains background and general information, structural and detail-solutions. Content can be copied and printed.

Picture 4 Frontpage oft he publication "Erarbeitung weiterführender Konstruktionsregeln/-details für mehrgeschossige Gebäude in Holzbauweise der Gebäudeklasse 4" (Gräfe et.al. 2014)

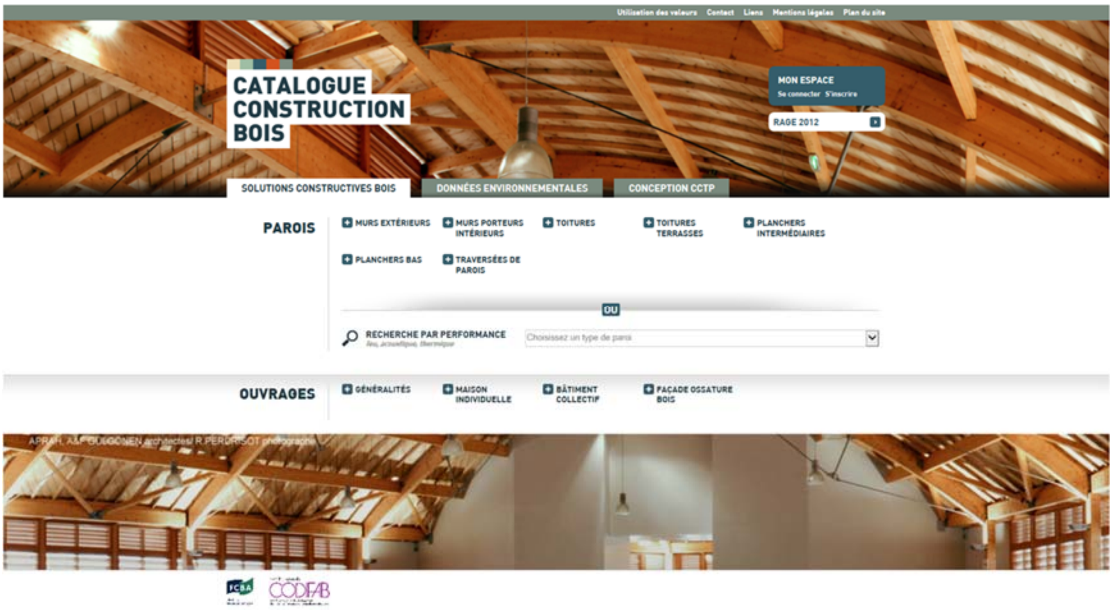
3.1.5. Passivhaus Bauteilkatalog (Baubook)

The Austrian *IBO Passivhaus Bauteilkatalog* (Baubook) Collection consists of 68 pre-designed structures for passive house design. They include the solutions in a standard and an ecologically optimized version. The fact sheets are available as separate pdf-documents and structures can be examined as 2D or 3D-images. All material can be copied or exported to pdf-documents. It is available in German only, with some parts translated to English. Materials and structures listed need no separate verification: they are accepted by the authorities and funding institutions. The online-version bases on the Passivhaus-Bauteilkatalog – Ökologisch bewertete Konstruktionen first published in 1999 (Passivhaus-Bauteilkatalog 2009). The latest publication from 2009 includes full text in both German and English and can be purchased through the Baubook-website.

Picture 5 IBO Passivhaus Bauteilkatalog homepage.
www.baubook.at/phbtk/index.php?SW=19

3.1.5 Catalogue Construction Bois (CCB)

The French *Catalogue Construction Bois* (CCB), published in 2013 and 2014 includes structural and joint details, and guidelines for fire-safety design. It consists of structural solutions for single-family homes and multi-storey apartment buildings. All material is available in pdf-format, partly in MS Word-format. It can be both copied and printed. Details are available as pdf-documents and in dxf-format (CAD).



Picture 6 Catalogue Construction Bois homepage.
catalogue-construction-bois.fr

3.2 Comparison of the Structural solutions: Case Intermediate Floor

Structures for intermediate floors are compared here, since this is the only structural type available in all the catalogues. The reference structure is the intermediate floor type VP801KRL from Finnish cataloque RunkoPES 2.0.

3.2.1 RunkoPES 2.0: VP801KRL

RunkoPES 2.0 presents structural details in one pdf-document including guidelines for their use. The publication includes ten different types of intermediate floors and eight solutions for bathrooms. Single details are shown on separate fact sheets with drawings in scale 1:10. A table explains structural layers and their task, like ensuring fire performance or sound absorption, material type and thickness of the layer. Performance data of the structure as a whole is also listed. Weight is excluded. To compare different collections, intermediate floor type VP801KRL is selected as a benchmark. It is dimensioned for a span of maximum 6 meters.
Structural layers are listed in Table 2 and illustrated in Figure 1.

Thickness	Layer
15 mm	floor surface, parquet
75 mm	concrete casting
	polypropylene sheet
18 mm	timber board
12 mm	sound absorption
360 mm	timber beam, including 100 mm thermal insulation (load bearing structure)
20 mm	gypsum board 2 x 10mm
500 mm	total structural thickness, weight not listed

Table 2: Structural layers of intermediate floor type VP801KRL, RunkoPES 2.0.
Performance characteristics: REI 60, $R_w \geq 55$ dB, $L_{n,w} \leq 53$ dB, U-value not listed.
(Finnish Wood Research 2013b, p 146)

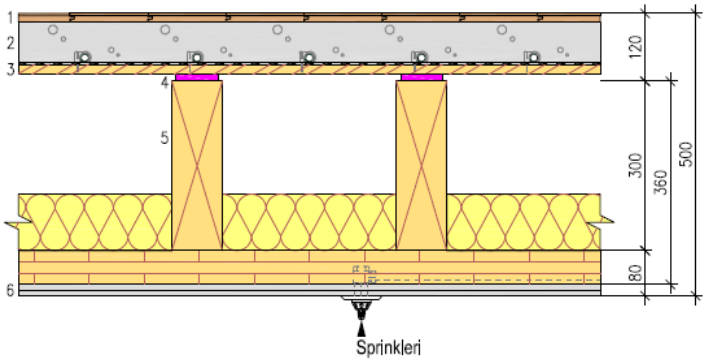


Figure 1: Build-up of intermediate floor type VP801KRL, RunkoPES 2.0.
Authors note: The structural detail drawing includes a sprinkler. According to the National Building Code of Finland sprinklers are mandatory in timber framed buildings from two stories upwards.
(Finnish Wood Research 2013b)

3.2.2 Dataholz: gdrnxn04b-08

The *Dataholz* shows a list of structural types and details on first page. After selecting intermediate floors, a new page opens up with the possibility to select and organize solutions according to fire safely, acoustic and thermal performance. Construction, floor assembly and type can also be selected. Detailed descriptions are examined directly on the website or as separate pdf-documents.

Additional data include an extensive overview of sustainability impacts with calculated values for the Global Warming Potential (GWP, Equivalent kg CO_2), Acidification Potential (AP, Equivalent kg SO_2), primary non-renewable energy content (PEI ne, MJ), primary renewable energy content (PEI e, MJ), the Euthropication Potential (EP, Equivalent kg PO_4), and Photo-oxidants (POCP, Equivalent kg C_2H_4).

Similar to RunkoPES 2.0 intermediate floor VP801KRL, two alternative structural types are suggested. Type gdrnxn04b is similar to type VP801KRL. After selecting this type, the site lists in this case ten different alternatives with small variations. Intermediate floor type gdrnxn04b-08 is closest to the benchmark. It is dimensioned for a maximum span of 5 meters.
The structure is presented in Table 3*.*

Thickness	Layer
50 mm	cement or anhydrite screed
	plastic separation layer
30 mm	impact sound absorbing subflooring MW-T
19 mm	particle board
220 mm	timber, including 100mm rock/or mineral-wool thermal insulation (online: glass-wool) (load bearing structure)
24 mm	cladding, spruce
25mm	gypsum plasterboards with improved properties at high temperatures (fire), 2x12,5 mm) or 25 mm gypsum fibre board 2x12.5mm
368 mm	total structural thickness, weight 161.8 kg/m^2

Table 3: Structural layers of intermediate floor type gdrnxn04b-08, Dataholz. Performance characteristics: REI 60, R_w = 55 dB, $L_{n,w}$ = 66 dB, U-value 0.28 W/m^{2}K. (Holzforschung Austria 2003). Authors note: The online-version lists glass-wool as thermal insulation throughout the layers (both German and English version). However, glass-wool is generally not used in Austria in this type of structure due to fire precaution.

3.2.3 Lignum Bauteilkatalog: A.2.01-01a-10-00a-01-110a-aa

Intermediate floor structures of the *Lignum Bauteilkatalog* total 323 alternatives. Selection criteria for structures consist of acoustic performance, load bearing structure, filling finish, floor surface for dry or wet installation, fastening system of ceiling (intermediate floor), total mass, and building part identification number. Information of each item comprises a drawing of the detail itself, basic data of acoustic performance, thickness of the structure in millimeters and weight in kilograms per square meter.

Single structural layers are described in a table including the suggested material, thickness of the layer, weight, the manufacturer for components and possible other specifications. Fire performance is not listed. Of each structure, a fact sheet in pdf-format can be generated. The intermediate floor type closest to type VP801KRL of RunkoPES 2.0 is type number A.2.01-01a-10-00a-01-110a-aa, identification number 298. Maximum span for the structure is not.
Structural layers are listed in Table 4.

Thickness	Layer
80 mm	cement screed (not the final surface)
30 mm	impact sound absorbing subflooring (impact sound insulation board)
27 mm	paneling/ planking with three-ply panels
240 mm	timber beam, including 160 mm thermal insulation (load bearing structure)
27 mm	paneling/ planking with three-ply panels
15 mm	gypsum board filled
419 mm	total structural thickness, weight 247 kg/m^2

Table 4: Structural layers of intermediate floor type 298, Lignum Bauteilkatalog. Performance characteristics: Fire performance not listed, R_w = 62 dB, $L_{n,w}$ = 53 dB, U-value not listed. (Lignum 2014)

3.2.4 Erarbeitung weiterführender Konstruktionsregeln/-details für mehrgeschossige Gebäude in Holzbauweise der Gebäudeklasse

The *Erarbeitung weiterführender Konstruktionsregeln/-details für mehrgeschossige Gebäude in Holzbauweise der Gebäudeklasse 4* (GHG4) detail catalogue is an all-inclusive publication. The amount of details is limited to three types of structures for intermediate floors, showing principles and layer types only. Two intermediate floor types use solid wood as a load bearing structure, whereas the basic type TD1 is similar to type VP801KRL of RunkoPES 2.0. Maximum span for the structure is not specified.
Structural layers are presented in Table 5.

Thickness	Layer
	floor surface
≥ 30 mm	cement screed or anhydrite screed
≥ 20 mm	impact sound absorbing subflooring
≥ 19 mm	timber
	timber, including thermal insulation (load bearing structure)
	air-tight layer if required
	Timber
36 mm	gypsum or gypsum fibre board 2x18mm
	total structural thickness, weight not listed

Table 5: Structural layers of intermediate floor type TD1, GHG4.
Performance characteristics: REI60, R_w = 60 dB, $L_{n,w}$ = 48 dB, U-value not listed. (Gräfe et al. 2014, p 155)

3.2.5 Baubook

The *Baubook*-website introduces the collection on the first page and structural groups on the next. After selecting floor structures, a new page opens with a list of solutions. Detail information includes the thickness of structural layers, information of thermal insulation capacity and performance, weight, primary renewable energy content (PEI e) and reference values for GWP (kgCO_2/m^2) and AP (kgSO_2/m^2). Fire or acoustic performance is not listed. Of the six available intermediate floors type GDl 01, version a, is closest to the benchmark VP801KRL of RunkoPES 2.0. Maximum span is not specified.
Structural layers are listed in Table 6.

Thickness	Layer
10 mm	floor surface, parquet
50 mm	cement screed or anhydrite screed
0.2 mm	polyethylene (PE)
30 mm	impact sound absorbing subflooring, rock-wool or mineral-wool (online: glass-wool)
50 mm	bonded chippings
0.2 mm	polyethylene foil (PE)
22 mm	OSB-board
220 mm	timber, including 80mm thermal insulation and air-tight layer (load bearing structure)
22 mm	OSB-board
50 mm	rock/or mineral-wool 40 mm + air gap 10 mm (online: glass-wool)
30 mm	gypsum or gypsum fibre board 2x15mm
484.4 mm	total structural thickness, weight 266.6 kg/m^2

Table 6: Structural layers of intermediate floor type GDl 01a, Baubook. Performance characteristics: Fire performance or acoustic properties not listed, U-value 0.232 W/m^{2}K. (IBO 2009) Authors note: The online-version lists glass-wool as thermal insulation throughout the layers. However, glass-wool is generally not used in Austria in this type of structure due to fire precaution.

3.2.6 CCB: Intermediate floor type 1

The *CCB* website allows for selecting the type of structure on the front page. After selecting intermediate floors, available types are listed on the following page. Four types of intermediate floors are included: 1) timber frame, 2) prefabricated element-structure, 3) double timber frame and 4) solid timber frame. For type 1 the following page shows several alternatives with joint details. One is similar to type VP801KRL of RunkoPES 2.0. Maximum span is not listed.

The structure is presented in Table 7 and illustrated in Figure 2.

Thickness	Layer
14 mm	surface layer, parquet
50 mm	concrete casting on polyethylene
18 mm	timber board
	timber, including thermal insulation (load bearing structure)
	impact sound absorbents
36 mm	gypsum board 2 x 18 mm
	total structural thickness or weight not listed

Table 7: Structural layers of intermediate floor type 1 with two layers of gypsum board, CCB. Performance characteristics: REI60, R_w = 63 dB, $L_{n,w}$ = 49 dB, U-value not listed. The structural principle is shown in the detail-document and dimensions listed separately. Structural layer descriptions refer to separate standard documents. (FCBA 2013)

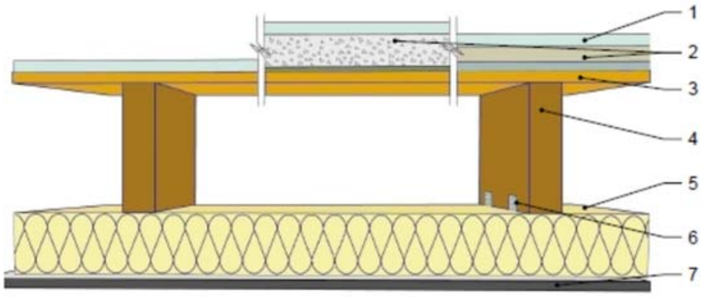


Figure 2: Build-up of intermediate floor type 1, CCB. (FCBA 2013)

3.3 Supporting Material

In addition to pre-designed solutions, four of the catalogues offer additional material, such as general guidelines for timber design. Dataholz and Lignum Bauteilkatalog offer fact sheets only. This chapter presents supporting material with information relevant for the application of intermediate floor structures discussed in the previous chapter.

3.3.1 RunkoPES 2.0.

RunkoPES 2.0. Catalogue consists of a short introduction, tables with basic data of all structures and separate fact sheets for each. The table offers an overview enabling comparison of structures according to fire safety and acoustic performance, maximum span, U-value and thickness. CAD-objects are downloadable.

Software for the dimensioning of intermediate floors is found on the website. Fire-safety design solutions for integrating e.g. ventilation ducts are shown in separate documents. Other joint details are collected into a separate publication. Exemplary building permit drawings illustrate the design of a complete building.

3.3.2 Erarbeitung weiterführender Konstruktionsregeln / -details für mehrgeschossige Gebäude in Holzbauweise der Gebäudeklasse 4

The *GHG4* consists of a comprehensive publication including an overview of building regulations, and solutions for e.g. integrating building technology. Fire performance, testing and recommendations are discussed in their own chapter. About one third of the publication is dedicated to suggested structures and details which are listed in overview tables according to type, description and index number. Separate fact sheets for each structure include a detail drawing, list of layers, and values on fire and acoustic performance. No additional software, calculation tool or material is included.

3.3.3 Baubook

In addition to timber building details, the *BauBook* online-collection includes a complementary software, Eco2soft, which is available to aid in calculating the environmental footprint of a whole building. Attributes include U-values, GWP 100, PEI and AP. The Bauteilrechner offers an opportunity to compare, edit and save selected structures after a separate login (free of charge).

3.3.4 CCB

Supplementary information of the *CCB*-website includes information on design and dimensioning principles for attributes like thermal insulation, acoustic and fire performance, load bearing capacity, accessibility and durability. Documents on regulations, norms, and environmental impacts are available. The link to Eurocodes is highlighted. Principle designs for a multi-storey residential building and single-family homes are shown, including structural dimensions.

4 Usability in practice

European catalogues of standard details support the use of building systems in architectural design. However, the comparison of available material and the benchmarking of the intermediate floor structure revealed both barriers and opportunities for the usability in practice.

Language is one of the obstacles. Only Dataholz is available in several languages and the online-version of Baubook has some material in English. The other four publish material in native language only. Different language options would lower the barrier for implementation.

User interfaces and the path to find a specific detail vary. Dataholz and Lignum Bauteilkatalog proved practical because of the limited options of attributes like fire performance. The smaller amount of details in the four other collections made the task simple as well. However, to find a detail or structure with matching requirements was difficult.

The comprehensiveness of material presented in each catalogue varies. For example, Dataholz lists a vast variety of alternatives for each separate structural type, whereas GHG4 only contains a few principle solutions. The only catalogue clearly focused on large multi-storey buildings is RunkoPES 2.0, whereas the other versions mainly introduce structures with smaller load bearing capacity, shorter spans, and very few alternatives developed for prefabrication. Then again, RunkoPES 2.0 contains solutions and principles for multi-storey housing only.

Some catalogues emphasize the aspect of general advice. For example, GHG4 contains advice for multi-storey timber housing and CCB works as an introduction to timber building with an informative overview of selected structures and details for single-family homes and multi-storey residential buildings. RunkoPES 2.0 includes the largest variety of material from general guidelines to principles of detailing, exemplary building permit documents and CAD-objects. Dataholz and Lignum Bauteilkatalog do not contain any guidelines, but the variety and amount of details and structures is significant. RunkoPES 2.0 and the webpage of the Finnish Timber Council offer additional support for the dimensioning of structures and large amounts of information. Only Baubook publishes a comprehensive ecological calculation tool. All catalogues implement identification numbers. The numbering acts as an internal indexing system. Usability could be improved by referring to external sources like building regulations.

The vision of this study is that use of pre-designed standard details help the architectural design processes and reduces unnecessary work and re-design. For pre-designed details to be used it would require a complete, compatible, and established set of standard structural and joint drawings. In terms of extent among discussed catalogues, Dataholz responds best to this requirement, whereas RunkoPES 2.0 offers the most comprehensive approach.

Another characteristic of lean culture is the use of information and communication technology to enhance efficiency and CAD-software is an essential tool component of this aim. However, only a few of the catalogues offer CAD-objects. The most versatile catalogue in this respect is RunkoPES 2.0.

The selected catalogues have been developed by the wood-based product and timber-building industry in collaboration with various research institutes. The aim is to help the design process and promote building with timber, however, this study revealed a vast amount of incoherent material. Efficient use would require more established solutions and more easily navigable interfaces.

However, the comparison shows that suggested structures for building with timber are similar throughout Europe. Fire safety and acoustic performance are solved similarly. For example, fire performance is mainly ensured by structural encapsulation with gypsum boards. Due to the dimensioning for different spans, beam heights of structures vary and the only clearly different structure, which is designed for passive houses, is presented in the Baubook. These findings are significant as they illustrate a common basis for standardized timber building-design.

5 Conclusions

Research on lean construction has identified unnecessary re-design and one-off detailing as a waste of resources in the building-design process. Timber-building could be optimized by using pre-designed details, thus supporting reduced work and leaner processes.

To assess this option, six European free online catalogues of standard timber-building details were examined. The usability in practice was explored by identifying and comparing similar intermediate floor structures and supporting material in all catalogues. Identified barriers include limited language options, impractical user interfaces, variety and quantity of structural types in the published material and difficulty in following identification systems. CAD-objects are absent in most catalogues, failing to effectively support the use of computer aided processes. Some collections serve more as an introduction to timber construction and others as a design tool.

For a practicing architect the collections offer an overview of timber-solutions and a means to verify the compatibility of designs with local building regulations. The discussed exercise also illustrates relatively minimal variation. Similar structures can be found in all collections. This finding supports the idea of limiting building-specific detailing in the design process.

The similarity of structures is an opportunity for the construction industry in European wide competition. Based on this study, timber buildings in Austria, Finland, France, Germany and Switzerland could be designed and constructed in principle with similar structural solutions.

leanWOOD

Book 4 – part D
process

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1. Big picture of lean construction

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Insofar as the masculine form is used in the contents of this report solely for reasons of better readability it is assumed that this refers to both genders on equal terms.

CONTENT

1 Big picture of lean Construction

1.1 What is lean?

Lean is a system involving a continuing transformation of waste into value from the customer's perspective. It focuses on two linked steps:
- The continuous elimination of waste
- And the creation and flow of value with minimum waste without interruption.

Lean construction is improving the construction process to profitably deliver all the customer needs. There are 8 types of waste in construction that lean eliminates.
1. **Stock / Inventory:** supply in excess of what is required. Inventory includes raw materials, work in-process and finished goods. Excess inventory can quickly build up entire money waist and resources due to the additional handling and space needed
2. **Transport:** unnecessary movement of materials or products that is not directly support immediate production it should be minimized as much as possible as it is not value added activity and the material would be exposed to handling damage
3. **Defects**: products materiel or services that do not meet expectation or conform to specifications, corrections and defects or anything not done correctly the first time and must be repaired, sorted, remade or redone as well as materials which are cracked due to defects.
4. **Waiting**: waiting refers to the periods of inactivity that occur because the proceeding activity tends deliver on time or finish completely weaving waste increases the cycle time during which no value added activity is performed
5. **Non use of good ideas**
6. **Useless operations or Over processing**: unnecessary steps in operations such as re-processing, double handling, additions of unnecessary procedures, added communication and double checking which adds no value over processing.
7. **Motion** the extra steps taken by people to accommodate the inefficient process lay out defects, reprocess and over production or excess inventory ; to move and add value is called work to move and not add value is called motion
8. **Over production** is producing more than is needed, faster than is needed or before it is needing. This results in excess inventory carrying cost

The benefits of lean Construction reach the customer, business, management and staff.

The **customer** gets a more consistent service, improves flexibility, responsiveness, construction time and product quality and a lower cost

Business as a better cash flow and productivity reduce stock holding, improve asset utilization, environmental benefits, increase profit and improve customer relationship

Management gains by better collaboration between design, general contractor and sub-contractor, more reliability processes, less crisis management, improve staff flexibility and delegation of the responsibilities

Staff receive improved safety and job satisfaction, greater ownership of work area, more pleasant work environment, less stress and immediate feedback of their performance

2 Lean Construction Basics

2.1 Definition of Lean Construction

Lean Construction is first of all a concept, It shall not be reduced to a tool assembly, as someone's makes too quickly the shortcut, by simply adding the semantics of Construction to the word Lean that they know from the industry. The definition of Lean is still under evolution especially as research support this concept. Greg Howell and Glenn Balard (the co-founders of the Lean Construction Institute, LCI) consider the Lean Construction as a new way of organizing the Construction projects management. The aim, principles and techniques of Lean Construction considered all together, form the basis of a new system. Lean Construction lays the foundations of a simple system based on the building site operations for a new apprehension of the project management. The Lean Construction takes its origin in the Toyota Production System (TPS) and allows significant improvements result of any project.

The Construction Industry Institute (CII) defined the Lean Construction as "a continuous process of waste elimination which reach or exceed all the client's needs, focusing on the whole chain that creates value and looking for perfection in carrying out a construction project".
Lauri Koskela (2002)[1] describes the Lean Construction as a way of conceiving the production system that minimizes the wasting of material, time and efforts, in order to generate the greatest possible value.

The most recent and current definition of Lean Construction, elaborated upon the previous ones and completing them is: "***Philosophy which aims to create value for the client by elimination of wasting, supported by collaborative tools of project management and which falls within an automatic and systematic approach of continuous improvement"***

"Philosophy", more than a set of tools, the Lean Construction is first of all an intellectual approach brought to university level by Berkeley University in California (PS2L Laboratory) and companies such as DPR, Turner, Veidekke which apply it to their overall operations.

"Creating value", the value for the client is actually what he agreed on paying for. Recent investigations of Glenn Ballard (2008)[2] have shown that only 15 to 20 % of building operations create some value for the client (what he pays for).

"Waste elimination", to create value one must eliminate waste. For example, waiting for concrete drying of a slab cast in place is a typical example of waste, therefore not creating value for the client. The client pays for the use of a concrete surface and not for a drying time during which all work is made impossible because of the floor formwork towers.

"*Supported by collaborative tools of project management",* the Last Planner System, key tool of the Lean Construction process forces collaboration between the different operators and stakeholders of the project.

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[1] *Foundations of Lean Construction*, Elsevier Ed.

[2] *The Lean Project Delivery System : An update, Lean Construction Journal editions*

"An automatic and thorough approach", the results come from the involvement in the recurrence and of the rigour of the approach.

"Ongoing improvement", "Lean is a journey, not a destination": emblematic sentence of the Lean design which illustrates the infinite nature of the approach. We can do our best for perfection, but never reach it.

2.2 Author's definitions of lean

For Manrodt, Lean is a systematic approach to enhancing value to the customer by identifying and eliminating waste (of time, effort and materials) through continuous improvement, by flowing the product at the pull of the customer, in pursuit of perfection.

For Ballard, Lean is – a fundamental business philosophy – one that is most effective when shared throughout the value stream.

For the Lean Construction Institute (LCI), Lean construction is a production management-based project delivery system emphasizing the reliable and speedy delivery of value.

For Radnoret, Lean is a philosophy that uses tools and techniques to create a change of organizational culture in order to implement the good practice of process/operations improvement that allows the reduction of waste, improvement of flow, more focus on the needs of customers and which takes a process view'

For the Construction Industry Institute (CII), Lean is the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and pursuing perfection in the execution of a constructed project.

For Shad and Ward, Lean is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability.

2.3 Roots of lean in car industry

In order to understand how Lean Construction techniques work in the construction field, we first have to understand how they work in manufacturing, where they come from. Lean in English means "fat free". It's this idea of removing the superfluity (which weakens performance) which is at the root of the concept. Lean manufacturing uses less of everything compared with mass production. Womack et al. (1990), in their book "Le système qui va changer le monde"[3], the authors described the genesis of Lean in manufacturing. They explain how a Lean production use half of the resources that are usually consumed: workforce in the factory, space in the plant to perform the activity, investments in machinery, materials… In a few words, we can say, a Lean system produces what is required, at the requested amount and time.

[3] *Le système qui va changer le monde, James P. Womack, Daniel T. Jones et Daniel Roos, Rawson Associates, 1990 and Dunod Ed., 1994*

2.3.1 Henry Ford

Henry Ford was the first major industrial to try setting up a continuous flow in its production plants, but he focused on the mass production in order to supply the huge demand that emerged after the Second World War.
In his time, Henry Ford has established several practices that are found today in the Lean conception. The Ford standards, in the first half of 20th century, were showing among others, the followings items, which are still up-to-date:

- The working environments should be and remain clean,
- The captains of industry should seek to serve their communities and society in every sense
- The production techniques should not be taken for granted but enter into a continuous improvement scheme
- The manufacturers have to assist their suppliers to produce better and faster
- The managers should not stay in their office but go into the factory and be able to do the job themselves
- The workers must be trained and have the opportunity to improve and enhance the products.

2.3.2 Toyota, Shingo, Ohno and the wastes at Toyota

At the end of the Second World War, the Japan's situation was very tense economically and industrially, compared with the United-States. Therefore, the Emperor of Japan decided that improving productivity was to be considered as a national cause. A young engineer named Taichii Ohno was appointed to get trained in the Ford and General Motors (GM) automotive manufacturing plants, viewed at that time to be at the cutting edge of efficiency. Taichii Ohno returned really trained, having learned what not to do! He was disconcerted by the numerous sources of waste that he could detect in the American plants. A few years earlier, William E. Deming – statistician at that time but now considered as the father of Quality – had worked on the development of a new management system based on eliminating waste through collaboration, participation and employees empowerment.

2.4 Origins of Lean construction

Franck Gilbreth[4] had already in the 1890's, identified the potential of the building sector improvement while applying some approaches of the manufacturing industry, especially on the speed of execution and the efficiency of the manpower. Gilbreth is seen as the father of industrial engineering for having worked on the Taylor's principles. Gilbreth was first interested in the brickwork; and noted that many displacements and gestures were purely useless because they didn't contribute in any way to erecting the wall. The worker used to seek each brick, to turn and turn over it to place it then on the wall and plaster it. Gilbreth made several recommendations; including that of locating the pile of bricks on the scaffolding at shoulder-high; supplied by less qualified (and less paid) handlers which allowed the trained masons to focus on their best added value. Gilbreth developed a series of best practices that reduced the number of movements and displacements from 18 to 4, minimizing thus the tiredness and maximizing productivity.

Gilbreth set up a series of testing in order to find the optimal load a worker can carry in a wheelbarrow every day safe. He developed labor standards to increase the predictability of work. Gilbreth started his own construction company and was part of the most profitable and respected companies of the early 20th century. With the help

[4] Entrepreneur, member of the American Society of Mechanical Ennngineers ASME

of his wife Lillian, he developed a corpus of knowledge that become industrial engineering. During the 20th century, the building productivity improved but still slower than in manufacturing. The Cavallo's study carried out in the United States showed that over the period 1967-2007, the productivity increased annually of 1,8% in the industrial sectors (excluding industrial operations), but at the same time, only of 0.6% in construction.

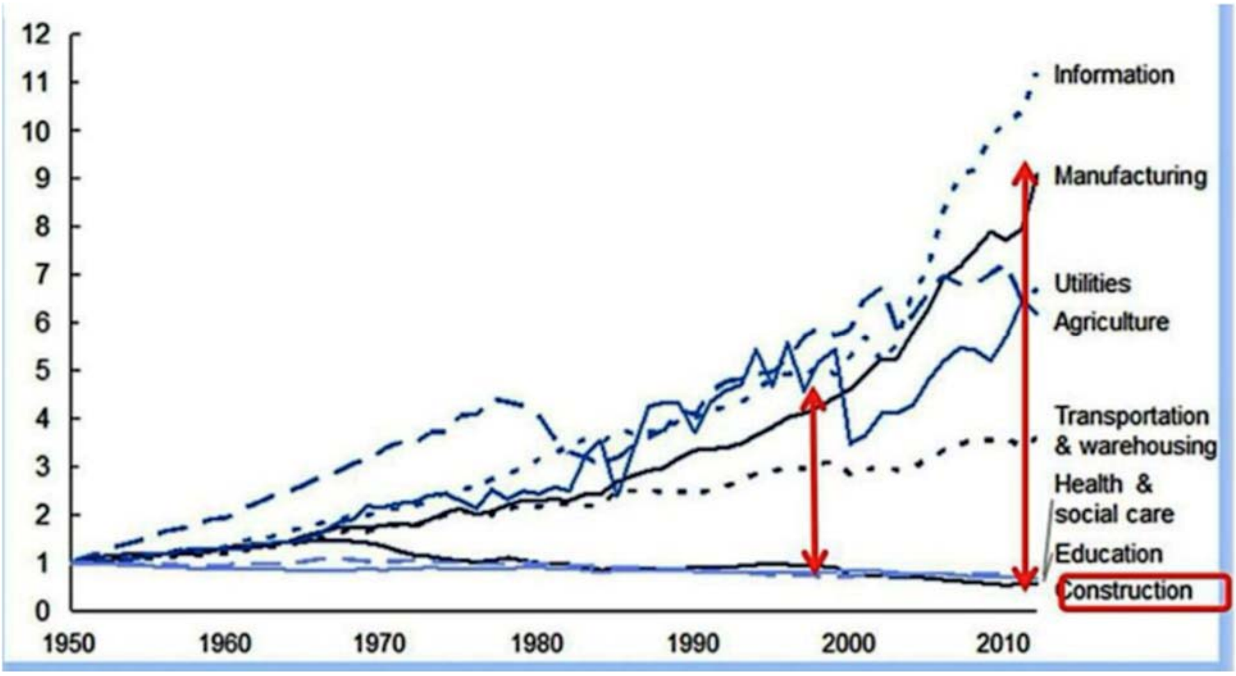

Figure 1 : Productivity (added value per employee, 1950 index=1), in different industries, in USA Adapted with www.delta-pertners.eu and Pr. Paul Teicholz, Stanford University

Building sector didn't grow in productivity compared to all other sectors on the same period of time.

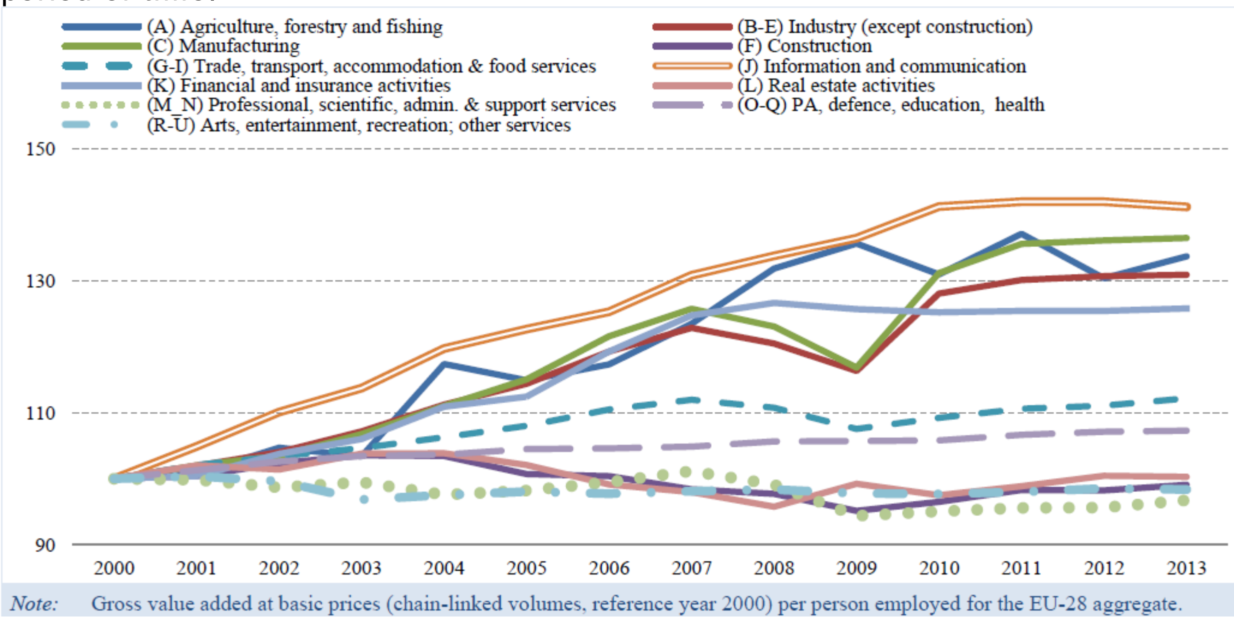

Figure 2 : ***Evolution of labour productivity for the EU-28 (2000=100) (****Source:European Commission, EU Structural Change 2015, DG GROW[5])*

5 http://eur-lex.europa.eu/legal-content/SV/TXT/?uri=CELEX%3A52015SC0203

At a European level, the evolution of labour productivity between 2000 and 2013 show a decrease for the construction industry

A relatively small proportion of total hours spent on a construction site is really productive. The 1990 report of Michael Pappas[6] noted that in steel construction, only 11.4% of the hours observed on site were creating added value. Hammarlund and Ryden in 1989[7], then Nielsen and Kristensen in 2001[8] observed that the added value operations accounted for only 30% of time spent on site all employments taken together. Lauri Koskela in 1992[9] examined the application of industrial technologies in building. Koskela spent a year at Stanford University as a visiting professor and led the well-known study: “Applying the new production philosophy to construction”. He highlighted the parallels between these two sectors by characterizing the building as a form of production. Koskela modelled this new production philosophy from TPS whose effectiveness is no longer questioned. While it’s true some researchers had proposed before him solutions bases on the same principles (prefabrication and modularization) to address the underperformance of the construction sector, Koskela proposed a new approach but based on the principles of the production philosophy which has three stages:

1. Implementation of tools such as “Kanban”
2. Implementation manufacturing methods
3. Application of a different management approach (Lean Manufacturing, Just In Time (JIT), Total Quality Control…)

Koskela, referring to numerous studies conducted in the United States and Europe in the manufacturing plants, showed that the most effective production management methods are based upon JIT (Just In Time) philosophy. Before him, Schönberger studies in 1986[10], then Harmond and Peterson’s in 1990[11] were leading to the same kind of findings. In a typical production pattern, the material is conveyed from one work station to the other, passing through very distinct stages: inspected and moved to the next station or placed in storage awaiting to start again its progress. Control and waiting times are considered an integral part of the manufacturing process as a “flow”. The transformer stations are considered bringing value while "flow” position are not. Koskela considers the Lean applied to construction, Lean Construction as a flow process combined with transformation activities. This vision was the foundation of what became the TVF (Transformation Value Flow) theory. Improving productivity may go through eliminating or reducing “flow” activities, whilst working on processing activities to make them more effective.

Koskela attributed the prevalence of non-value added activities to three basic causes: design, ignorance and the very nature of production (construction). According to him, poor design would be the fact of tasks division (fragmentation) since each sub-task inherently increases the overall level of control, inspection, waiting and displacements.

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[6] Evaluating Innovative Construction Management Methods through the Assessment of intermediate Impacts. University of Austin Texas

[7] Effectivity in the plumbing Industry – the use of the working hours, Svenska Byggbranchens urvecklingsfond, Sweden.

[8] Time study of the erection of concrete walls on the NOVI Park 6 Project, Svenska Byggbranchens urvecklingsfond, Sweden

[9] Application of the new production philosophy to construction, CIFRE

[10] World class manufacturing. The lesson of simplicity applied, Free Press

[11] Reinventing the Factory: Productivity Breakthroughs in manufacturing today, Free Press

Koskela has listed the following investigative principles:

1. Reduce the share of non-value added activity
2. Increase the value of the finished product by the systematic consideration of client needs
3. Reduce variability
4. Reduce cycle time
5. Simplify by minimizing the number of steps, equipment and materials as well as links between them
6. Increase flexibility in the finished product
7. Increase transparency of process
8. Focus control over the whole process
9. Balance improved flows with dialog improvements
10. Benchmark.

It should be noted, in connection with these experimental principles, that:

1. non-value added activities may be limited by their identification, measurement and modification (redesign of the activity)
2. the finished product value may be increased by identifying each stage of its manufacturing process and by clarifying the client's needs
3. the high variability of production time in construction increases the volume of non- value added activity
4. The process control requires measurements as well as an authority assigned to this control which can be interdisciplinary and self-managed regardless of production constraints. Team spirit and cooperation with suppliers (and subcontractors) are important sources of global optimization of the workflow in the case of an organization involving several firms as it is often the case in construction.

Glenn Ballard and Lauri Koskela met at Berkeley University in California, began to compare their visions and aspirations and studied a contribution to a concrete change in the near future of construction. This collaboration gave birth in 1993 to the first conference on Lean Construction in Helsinki. It was the beginning of more than twenty years of annual conferences, bringing together researchers and professionals from around the world within the IGLC (International Group for Lean Construction). It was during this very first conference in Helsinki that the name "Lean Construction" was selected. Subsequently, Ballard and Howell co-founded the LCI[12] (Lean Construction Institute) in 1997, which quickly expanded national branches in Chile, Denmark and England. Then Ballard invented in 1992, a method of collaborative planning which would become the flagship tool of Lean Construction: LPS (Last Planner* System). The LPS is based on the reduction of hierarchical levels and transfers part of the planning authority to the site managers in order to best allocate the available resources in a weekly forecast. Ballard will complete his system in 1998 by adding the rolling six weeks period and determining collaboratively the planning schedule at the beginning of the operation. These changes aimed to permanently set the flow at the system center: reduce the variability compared to the forecasts and use buffer margins to limit the impact of residual flow variabilities.

Lean Construction was born

[12] www.leanconstruction.org

2.5 Problems of the current system

Traditional construction is mainly based on craftsmanship. So it inherently induces a lower work rate (but a higher cost) than in mass production which has been using Lean for nearly half a century. These crafted goods are performed by a multitude of specialized companies (electricians, plumbers, plasterers, tilers…) whose work is very interdependent, often gathered under the control of a central general contractor.

2.6 Characteristics of Lean construction

Adopting the Lean philosophy means first leaving the traditional methods and changing one's behavior. Cultural change is the biggest challenge to be faced by any person or organization which would like to start deploying a Lean methodology. We cannot force people to change. They have to accept to be pulled to join, and later, they will be themselves promoters of the methodology. Relationship with others has to evolve. In a Lean pattern, manpower has to be considered and treated as the most important capital of the company, workers will be even more reactive, reliable and motivated.

2.6.1 Lean principles

The five principles of Lean as described by Womack *et al.* in 1994[13] apply to any organization:

1. Creating value: it is essential to identify the value actually carried by the client and provide it. Resist the temptation to convince the client that what he wants is what is easiest to provide by the company.
2. Knowing its value chain: mapping the value chain for each product or service helps to identify waste and their elimination by forcing collaborations between stakeholders
3. Sustaining the flow: it is necessary to contemplate its operations as an ideal flow through successive steps, each creating value
4. Pulling (rather than pushing): much of the efforts to be performed involves maintaining the flow pulled by the finished product requested by the client
5. Seeking perfection: even if it was never to be reached, developing working directions, procedures and creating quality controls always involving those who do the job.

2.6.2 Value

Value-added activities transform materials and information into products and services requested by a client. Therefore the value is not necessarily only economical. Wandahl and Bejder (2003)[14] make the difference between "product value" and "process value". The product value relates to the tangible aspects: composition, price, compliance with standards… Whereas the process value relates to the different stages of construction in their own environment: time limit, communication, teams.

Non-value added activities consume resources but do not participate in the product transformation as requested by the client. In order to illustrate these concepts of

[13] Le système qui va changer le monde, J.P. Wormack, D.T. Jones and D. Roos, Rawson Associates 1990, and Dunod Ed. 1994

[14] Value-based management in the supply chain of construction projects, 11th Annual Conference on Lean Construction, Lean Construction Journal

added and non-added value activities, let's take the example of fixing an electric plug in its box beforehand sealed in concrete:

- Electrical cable hangs from the recessed box
- The electrician looks for (and finds) his tools
- He holds the cable in one hand and the cutter (or cable clamp) in the other to adjust the cable sheath for making the connection
- He cuts the cable to an approximate length and uncovers each cable before connecting it and tightening the clamp washers
- He then pre loop the remaining cables so that they fit in the recessed box properly, before attaching the socket to the wall by means of the cap screws
- The electrician fetches then le next plug box in the stock to move on to the next one.

The required stages to connect and attach the socket to the wall take about 1 minute, which represents the sum of value added steps. The fixing times observed on site are rather about 3 to 4 minutes; this difference is due to the waiting time searching for the tools and materials.

2.6.3 Five main ideas

Lichtig in 2005[15] extrapolated five principles by applying them to the site of Sutter Health Hospital in California and summarized them as follows:

1. *Collaborate, truly collaborate*

It is through collaboration that the stakeholders will be able to make the most of the actions. The understanding and expectations of the ones with respect to the architectural or technical design mostly differ from that of the others. A close collaboration between the main actors allows to take decisions in full knowledge, to compromise and therefore to secure the overall and individual performance. At design, a highly iterative process, the end product determines the required resources and the available resources. A high level of collaboration from the design phase maximizes the opportunities of positive interactions and therefor the success of the site both for the client and for the company.

2. *Increase the relationships between all participants of the project*

Each stakeholder of a project acts at the beginning like a stranger. The introduction of innovative actions that promote open-mindedness, the development of human and respectful working relationships will help establish trust, basis of the project effectiveness.

3. *The projects are commitment networks*

The projects are not only processes. The role of the project manager is to create a networking of commitments, in which each stakeholder will have the opportunity to express his creativity and reliability through innovation and honoring his commitments; the aim being to insure the most continuous flow, in real time. This is a significant and fundamental difference compared to the projects carried out more classically, in which the reliability of forecasts is limited by the order/control scheme and a one-way leadership.

4. *Optimize the whole project, not only pieces*

In a conventional pattern of project management, the resources are "pushed" inside the construction site in order to increase the production speed and reduce the delays. "Pushing" some tasks may have, the effect of increasing productivity; this is

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[15] Sutter Health Developing a contracting model to support Lean Project Delivery, Lean Construction Journal

a local performance. The performance of the following tasks will not be improved so far, the level of stress to achieve them will have even significantly increased.

In a Lean pattern, the tasks will often be decompressed by adding a buffer margin. The project performance will then come from the capacity of the team to find and implement solutions that will satisfy the whole project. The personal interests have in that case to be set aside and the earnings have to be considered over the medium term. The security level is increased by 50% in a collaborative decisions scheme.

5. *Closely pair up action and apprenticeship*

Once the conditions of collaboration are set up, continuous improvement will go through systematic and periodic observations and measures. It will be possible then to deploy corrective and/or innovation actions which will limit variations and secure the earnings.

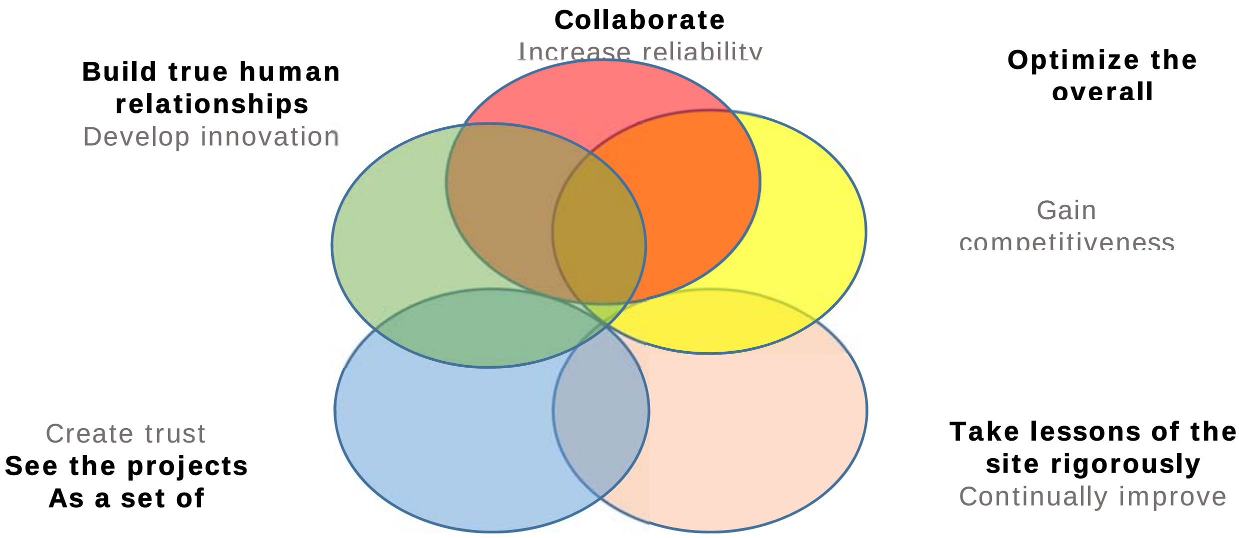


Figure 3 : Collaborate, truly collaborate

3 Procedures for the award of contracts in France

Once the construction of one or several buildings has been decided, the contracting authority has to define the building program. The type of procedure used to award the works' or service's contracts depends on the kind and cost of the project. Usually, the contract of service for the architect is separated from the contracts of works signed with the different building trades. However, it is sometimes possible to have only one contract, called design-execution, for both the planning and the construction. In that case, the project managers and the companies are brought together from the start. For projects with several similar constructions spread on several years, a framework contract can be used.

For the private sector, mutual agreement contracts are the most common. For projects done for public entities (government, local authorities,…), the procedures and selection criteria are defined by the French law n°85-704 of 12th of July 1985 called "loi MOP".

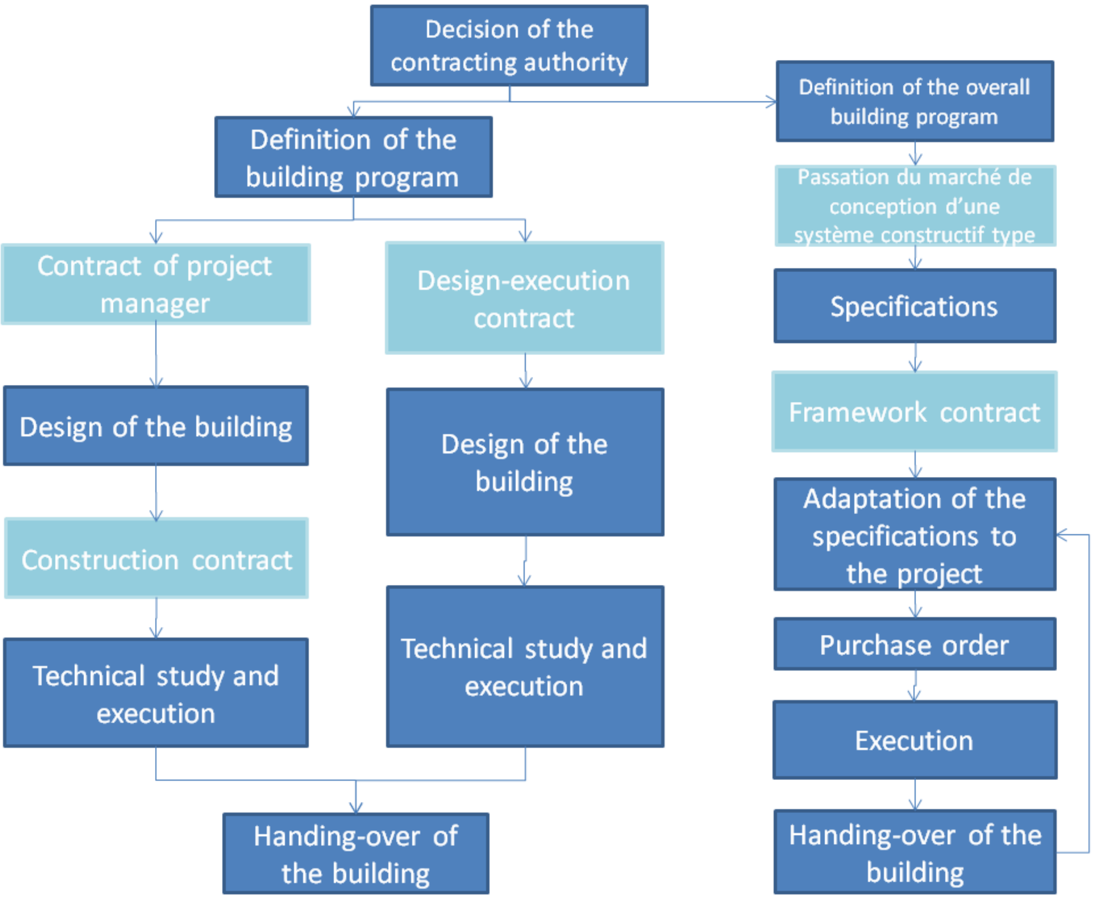


Figure 4: Different types of contracts awarding for building programs in France

3.1 Different kind of contracts

3.1.1 Contract with the project manager

The contract with the project manager deals with the selection of the team that will take care of the design, planning and eventually the worksite management. This team can consist of the architect (authorized representative), economist of the construction and technical design offices (structure, thermic, acoustics,...)
The award of this type of contract is usually done through an architectural competition but also after an adapted procedure or negotiated procedure.

3.1.2 Construction contract

The goal of construction contracts is the execution of the works to build the building. Part of the design process can be included in those contracts. They are either signed with a general contractor or separately with each building trade. The selection is done through an invitation de tender except when the cost is under 5.186m€ excluding tax. In that case it is possible to use an adapted procedure. In some cases, it is also possible to use a negotiated procedure, competitive-dialogue procedure or a competition.
In that case, it seems more efficient to use macro-works packages to reduce the interfaces between the building trades.

3.1.3 Design-execution contract

In that case, the project managers (architect, design offices,...) and the general contractor (or separate building trade) bid together to the tender. This solution is only available for projects needing a high level of technical expertise or aiming at improving the energy performances of an existing building. The same thresholds as for the construction contracts are used to know which procedure should be used. This way, only one procedure is needed for both the design and construction aspects of the construction. Since the stakeholders are all brought together from the start, the link between the architectural and technical designs is a lot closer making it possible to reduce the cost of the project. Moreover, they have to commit to the price of the project from the start.

3.1.4 Framework contract

Framework contracts are agreements with suppliers (building trades) about the terms and conditions that would apply to any order placed during its life (maximum of 4 years). In this case, a contract is made only when the order is placed and each order is a separate contract. The beneficiaries of the framework contract are the only suppliers that can be used until its expiration date.
The procedure used for the award of the contract depends on the cost of the overall project.
Framework contracts are a good way to optimize the planning and production period and therefore reduce the cost of similar projects built over a few years (school, houses, social housing,…).

3.1.5 Public-private partnership PPP

A public-private partnership allows a private company to pay and take care of the design and construction of a project in the stead of the public entity in exchange for a rent.
During the last few years, the resort to this kind of partnership has increased but it is criticized because it does not allow the SMEs to bid and the overall cost of the project is usually higher for the public entity.

3.2 Different kinds of procedures for the award of a contract

For the private sector, mutual agreement contracts are the most common but the other procedures can also be used.
For projects done for public entities (government, local authorities,…), the procedures and selection criteria are defined by the French law n°85-704 of 12th of July 1985 called “loi MOP”.
The contracts signed by a public entity have to comply with those principles:

- The procedure used has to guarantee an equal access for all the companies (building trades)
- The transparency of the procedures and equality of treatment between the bidders

Adapted procedure	Invitation to tender	Negotiated procedure	Competitive-dialogue
Adapted communication (contract < 90k€): format of the notice chosen by contracting authority and spread via newspaper, the internet or billposting **Notice for call to tender:** notice according to the decree of the 28th of August 2006 and published in the Official Bulletin of Public Procurement (BOAMP) or Legal announcement Newspaper (JAL) The contracting authority choose the methods of the procedure: documents required, schedule, selection criteria,…	**Notice for call to tender :** notice according to CE n°1564/2005 of the 7th of September 2005 published in the OJ EU or the BOAMP **Open invitation to tender**: every bidder is allowed to answer within 52 days (or more) **Restricted invitation to tender**: bidders have 37 days to apply and 40 days to make an offer once they are selected **Bargaining:** not allowed	Possible only if the invitation to tender was unsuccessful or if only one supplier is able to answer **Bargaining:** possible with some or every bidders (price, delivery schedule, technical solutions ,…)	The awarding authority selects a few bidders to develop one or several technical solutions meeting their requirements before launching a proper invitation to tender.

Mutual agreement
It is possible to resort to mutual agreement when the contracting authority is private or for contracts under 20k€ excluding tax. In that case, there is no call for competition.

Adapted procedure
Adapted procedure represents 80% of the public procurements as it is used for contract over 20k€ excepting tax and under the threshold of the invitation to tender.

Invitation to tender / competition
This kind of procedure is compulsory for works contracts over 5.186m€ excepting tax or service contracts over 207k€ excepting tax (threshold at 134k€ excepting tax for State).

Negotiated procedure
Possible only if the invitation to tender was unsuccessful or unpredictable and urgent circumstances.

Competitive dialogue
Competitive dialogue is restricted to projects with technical, legal or financial complexities.

3.3 Missions of the project manager

The decree n° 93-1268 of the 29th of November 1993 defines the missions that can be entrusted to the project manager (usually the architect) for new buildings or retrofitting.

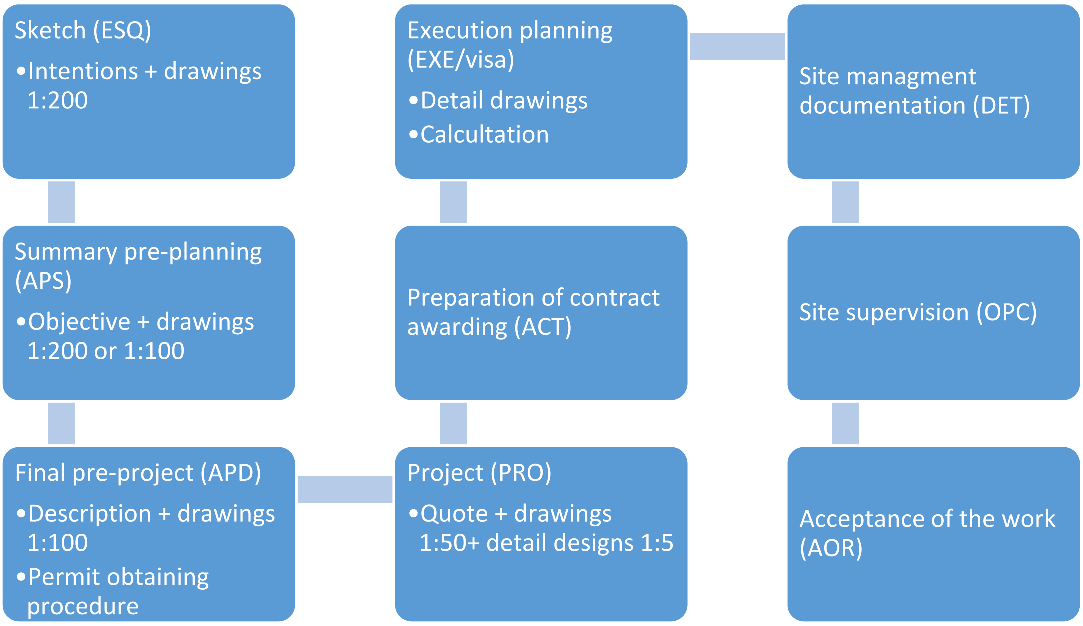
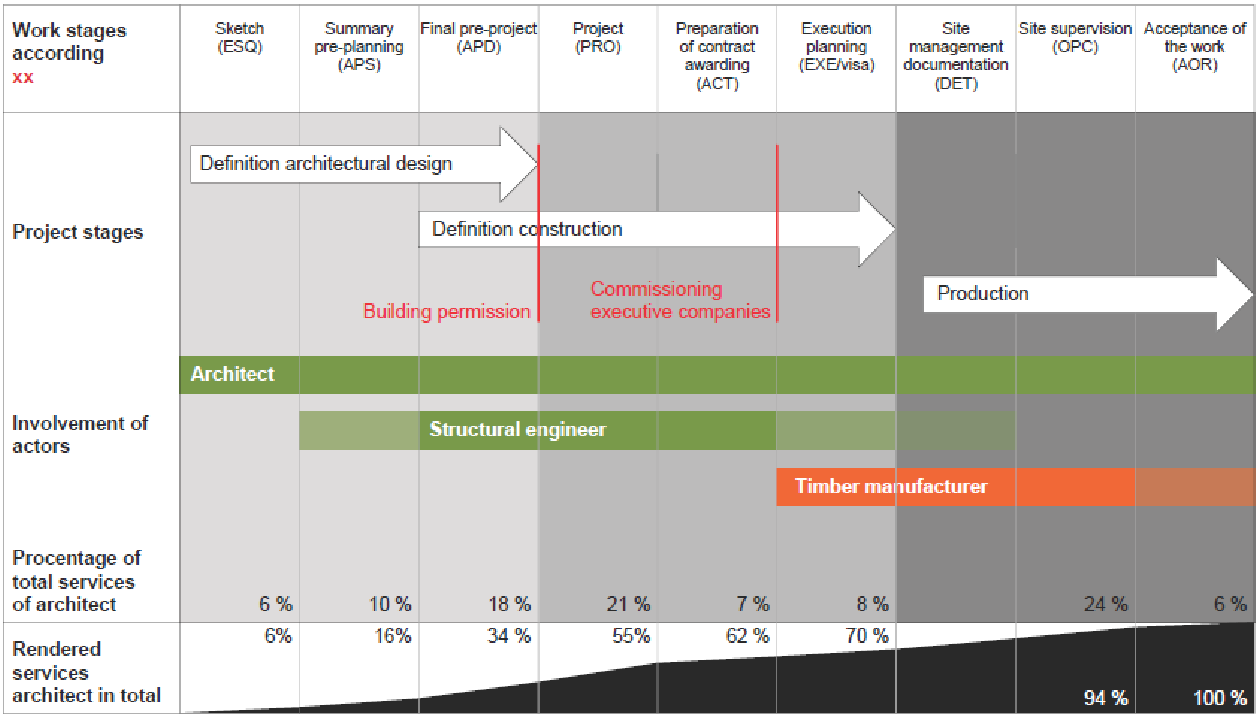


Figure 5 : The nine work stages of a building project in France

3.4 Planning and production process according to French regulation "Loi MOP"



4 Lean Construction, for who?

4.1 Contracting authority: IPD, Integrated Project Delivery

The public and private contracting authorities certainly are the most important stakeholders in the success of the present change of paradigm. Even if it remains true that, in every country of the world where the Lean could develop sustainably, the first Lean initiatives are launched by companies. Nevertheless it remains that, in a contractual context increasingly abundant and with market conditions more and more tense, promotion by the "contractors" of Lean Construction is guarantee of sustainable change. The contracting authorities may indeed fully benefit from the application of lean in their operations, either in the design, the implementation or the construction phase, through the substantial increase of the share of the added value generated by their operation. The application of collaborative methods of design and construction such as Integrated Project Delivery, through a process of advanced consultation, enables a fine definition, well in advance, of the project, in connection with the technological, technical and construction capacities of the companies who have to perform work.

In the "traditional" system, the architect is appointed by the contracting authority at initiation of the project, to develop the project outline and translate the customer needs into a tangible work. Once the project outline is carried out, the technical design offices (structure, fluid, thermal, acoustic...) joint the project team to insert their constraints in the production and continue the definition of the work. Many back and forth information is required in this process of transition from the preliminary to the detailed design. The contracting authority, the architect and the design team are often not in the same geographic area, this leading to a period particularly long and difficult. The difficulty of communicating effectively is then seriously needed. The level of understanding (or detail) of the project increases slowly but remains low.

Once the APD (final pre-project) file is established, a specialized office is then able to be responsible for gathering all of this information to constitute the DCE (project), Business Consultation File. A pre-synthesis is then performed to take into account the technical constraints. The file is sent to the companies that answer by producing a detailed synthesis, each of one also checking the quantities and the potential errors.

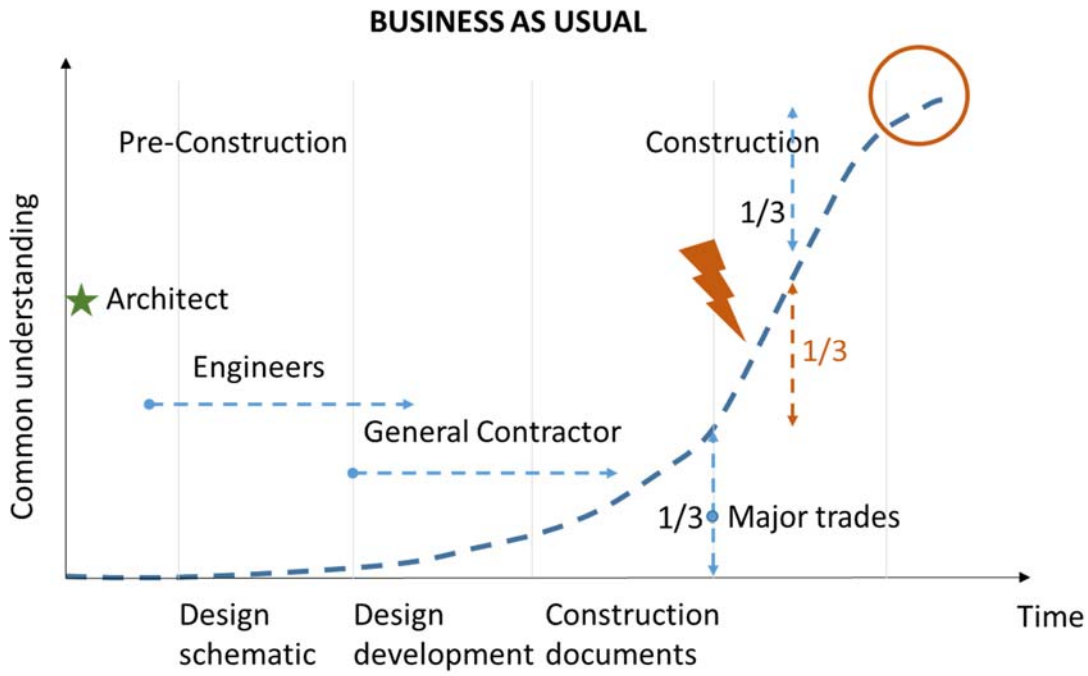
Their return, through the analysis they provided, helps eliminate many problems and further increase the level of understanding (detail) of the project. The companies' implementation plans are then performed on the basis of information provided by the DCE, amended according to the company expertise.

Despite all these efforts, Ann Edminster, recognized architect and specialist in integrated project delivery (IPD), estimates that only a third of the total project is defined when work begins. Many plans, details, choice, validation are left “for later” in “postponement”. Actually, emergencies to be addressed have already appeared facilitated by the complexity and the numerous losses of information of the process. Consequently, even though the construction site has begun and the “real” catches up the “virtual”, the project team has to deploy an immense power to settle the critical points gradually appearing during the execution.

The “virtual”, drawing up plans and construction documents supply the “real”, the construction progress. The virtual can be changed inexpensively as long as the real has not caught it. Rapidly, the plans need to be detailed enough to be immediately exploited by the construction
site. This definition of the second third of the overall project should be done in rush, especially considering the time taken by the previous third.

It is at this point that relations deteriorate between all the project stakeholders, some blaming the others for errors in design and lateness in construction and vice versa. More or less deep and with serious consequences, this crisis that usually occurs in mid-late of the structural work helps to strengthen each party in its position, preparing its response instead of focusing to solve the problems.

Ann Edminster argues that when the construction is completed, the level of understanding (detail) of the work has not reached 100%, this value being actually achieved only after the final completion period and therefore with the first uses of the work and post-reception modifications.



IPD	Validation	Concept	Design	Implementation	Preparation	Construction
Trad.	Draft	APS	DCE	Consultations		Construction

According to Patrick Dupin, Delta Partners; adapted from the "MacLeamy Curve", 2004
Figure 6 : Evolution of the level of understanding relating to a construction project in the traditional delivery approach

This work of defining the construction to supply the workflow on site, made necessary in the traditional scheme, is source of tensions. It is time consuming and prevents optimal productivity, both in the design and the execution phases. Applying a process such as IPD which aims to bring forward the constitution of the entire project team in the first phase may be decided by the client at the project initiation.

The Integrated Project Delivery (IPD) is a project management method that incorporates the stakeholders and their structures, the management systems and the best practices, in a single collaborative approach to leverage the strengths and ideas of each of these stakeholder in order to optimize the final result. The IPD can be regarded as a facilitator of coordination between the processes of designing and those of building; it maximizes the value created for the client by eliminating waste and improving efficiency through all phases, from design to realization.

The principles constituting the IPD are flexible and can be applied to a wide variety of projects, whatever their contractual frames. The IPD team is formed at inception of the project by the developer, the architect and the general contractor (or all the companies) and can be extended to other actors in charge of the design or the execution, depending on the needs and constraints of the project. It is mainly the high level of collaboration between these three parties that distinguishes the IPD approach of a more conventional scheme; implemented at inception of the project, it will grow throughout it until the acceptance of work.

Effectively structured, a collaboration based on trust promotes each party to focus on the end result of the project as a whole, rather than to pursue individual goals.

The interactions between the stakeholders are no longer only based on the risk transfer, but on a sharing of risk and rewards. On a construction project in a conventional approach, the stakeholders generally develop their relationship in an antagonist and selfish scheme. Through a boomerang effect, they endanger their own productivity, until self-limiting the overall effectiveness of the project.

The IPD approach by sharing information and ideas, enables substantial gains throughout the project, for each stakeholder. Without this transparency, each party must include hidden margins and contractual clauses to protect itself from the risks and uncertainties of the project. It should be noted that with the use of BIM the problems can be better identified, more easily and even earlier.

In a process like IPD, the general contractor is appointed along with the architect, forming an effective tandem to ensure a high level of constructability and keep the final cost of the project at its initial level or even below. The first step for this tandem is to validate the owner building project, the architect being even more able to adjust his action that the general contractor ensures the constructive aspect.

This preliminary phase of intense discussions at the beginning between the world of design and the world of realization, allows to identify and solve the constraints and problems linked to the customer’s needs through rapid iterations. In doing so, the level of overall understanding of the project grows quickly from this first stage of construction validation. Once the construction is validated, the concept is achieved, often in three dimensions by inserting the main constructional constraints. The project team works more easily when the communication is natural, each party having taken part to the development of the work.

In the “design” phase, second level of planning details will be confirmed. The most important difficulties of technical synthesis and constructive constraints having been explored in the previous phases, the phase confirms the selection and helps producing the drawings in three dimensions. The phases design and planning constitute the pre-construction. At that stage the project team has all drawings, considerations of possible negotiations and early definitions between the client, the architect and the general contractor; the necessary documents for construction can thus be compiled, it is the implementation phase.

The company has been freed from the validation phase, at a early stage of the project. It can dimension the resources allocated to the project, prepare the logistics with its suppliers and launch consultations of subcontractors, so that they are also involved in the project as early as possible. In that configuration the construction can truly accelerate, each party being able to focus on its added value without polluting others.

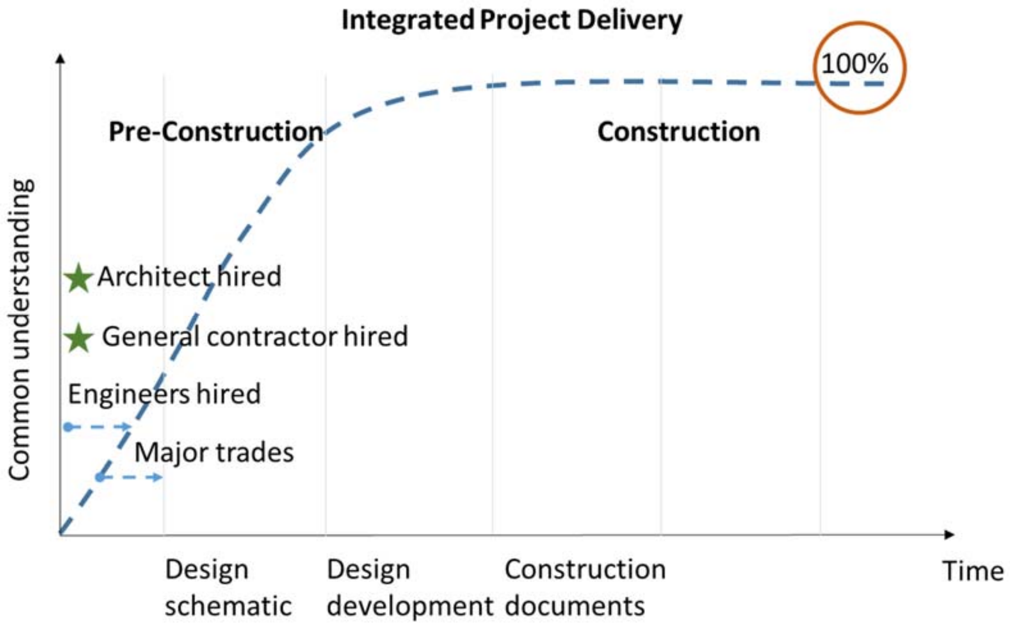


Figure 7 : Evolution of the level of understanding of a construction project in the Integrated Project delivery (IPD) (Source: Ann Edminster & Will Lichtig)

This IPD method has proved its efficiency on numerous private and public construction sites in the USA where it is widely used; the most emblematic exemple is the Cathedral Hill Hospital for Sutter Health in San Francisco, California ; this project costs over a billion dollars for the construction of a 555 beds hospital, completed previous to the date and on budget. The IPD is also used in the Scandinavian countries since the mid-2000s (real estate of the Ministry of Defense in Norway and Senate in Finland for example) and the first IPD construction sites have recently emerged in Germany (Hochtief tertiary projects).

Table 1 : Comparison between both traditional and IPD approaches

Traditional approach		**IPD**
Divided, composed on the basis of “just enough” or “minimum necessary”, strongly hierarchical within a “commend/control” scheme	**Teams**	Integrated team, entirely composed from the start of the project, of the essential stakeholders for a good project execution, in a scheme of open discussions of problems resolution for collaborative and iterative concerns
Linear, distinct, information and understanding, collected “just enough”, and gather creation of information and expertise silos	**Process**	Several contributing levels: provision of knowledge and expertise very early, openly shared information, respect and trust from each stakeholder.
Individual, minimizing the effort to maximize individual profit	**Salary/Involvement**	The team success is linked to the project one ; based on value creation
Individually managed, transferred as much as possible to other parts of the project by preparing action files (claims) in protection approach	**Risk**	Collectively managed, equitably shared
Mainly paper, two dimensions, analogical	**Communication and technology**	Digital model, BIM
Unilateral work, no (or little) sharing in solving problems	**Compromise - agreements**	Collaboration and sharing multilateral issues favored, encouraged to increase the efficiency of the team as a whole.

According to *“a Guide”, Launch of Integrated Projects Delivery,* AIA California Council, United-States, 2007.

In the case of a project conducted by IPD, the final cost of the project is generally below the market, below the client's budget and delivered earlier than expected; the design in this case being an iterative and participatory process to ensure the highest possible level of constructability.

The implementation of plans in three dimensions, as a digital model, has become the norm in the United States, imposed by the public client as part of the consultation regulation since 2008.Therefore, the clients have a central role to play, from the initiation of the project, so that it gets out of the usual context and leads to a different result.

Achieving the benefits available from this new approach requires a change of mindset and accept the following principles:

- Mutual respect and trust

Insofar as the client, the architect, the engineering consultant, the general contractor, his subcontractors and supplies depend on collaboration and teamwork for their productivity in the interest of the project, all have to work in the greatest respect and the greatest trust possible.

- Mutual benefit

The contractual framework of the fees payment (architects, engineering consultants, consultants…) and of works situations (general contractor) has to consider and reward an early commitment in the pursuit of efficiency for the entire project.
The building owner must provide a bonus system for a behavior and solutions found on the basis of "what is best for the PROJECT", in opposition to the traditional "what is the best for me."

- Collaborative innovation

Innovation and collaborative decision making are possible when ideas are freely exchanged between all participants of the act of building. In an integrated project, an idea or a proposal has to be judged on its merit / impact for the purpose of creating value for the project, and not according to the person who behind it.

- Early involvement of stakeholders

The key stakeholders must be engaged and involved as soon as possible to improve the process of decision making. Their various and complementary knowledge, skills and know-how may enter all the greater, not only the effectiveness of the project for the customer, but also the productivity of the achievement for the other stakeholders, than they have been early appointed.

- Early definition of objectives

The project objectives should be developed and defined early to be accepted and respected throughout the project by all participants.

- Even more planning

Special attention to planning increases productivity by reducing waste while reducing unit runtime.

- Open and honest communication

The performance of the team is largely based on the effectiveness of communication. It must be open, direct and honest among all project participants. Lean attitude is to avoid blaming another partner to make him responsible of the situation (and therefore, escape his own responsibility), allow identifying and solve quickly the issues. Partners must focus on the solution rather than seeking responsibilities.

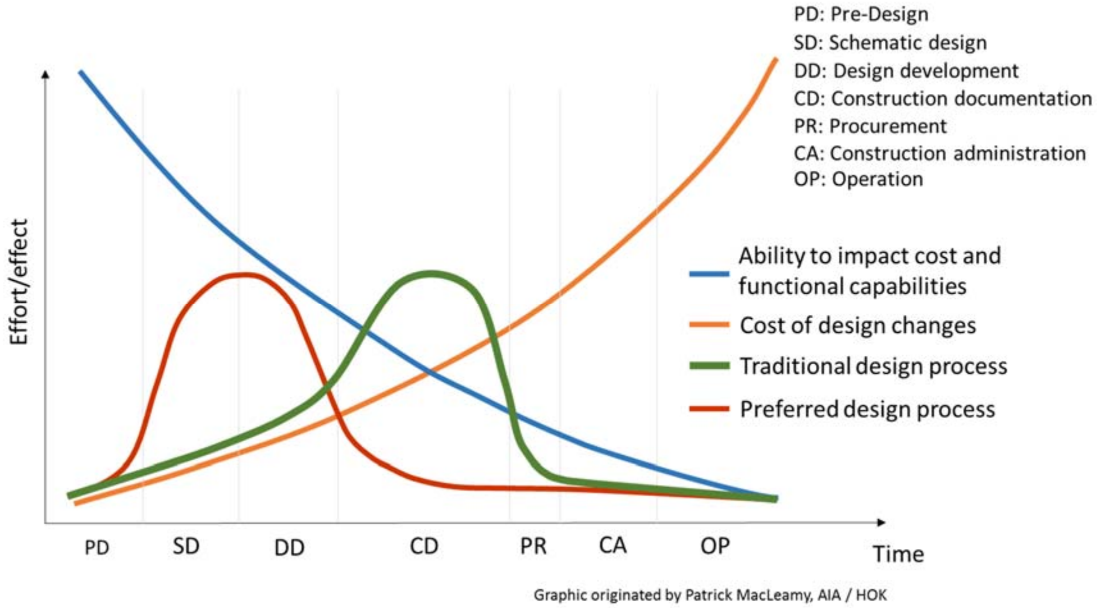
- Appropriate technology

The technology to be used must be specified at the beginning of the project. It is important to maximize the capabilities to develop and find the interdependencies and bridges with systems already used, in order to ensure total and complete compatibility. Open exchange in the database, and a transparent structure, are essential to facilitate communication and thus performance.

- Organization and Leadership

The project team is an organization itself, in which each participant is committed to the goal of the project, its values and its duration. The project management should be entrusted to the most capable members, even if it means create a multi-party or a multicultural project management. Here again, ego and individual goals should be set aside; the individual award is the result of the success of the project. All roles should be well defined from the beginning, reach consensus and be accepted by everyone in order to avoid creating artificial barriers that would inhibit communication and risk taking.

Patrick MacLeamy, architect and managing director of the HOK Group, analyzed the two systems (traditional and IPD) in the different steps and deduced a curve that now bears his name, "*MacLeany Curve*". This outline clarifies the direct impact of a high effort from the beginning of operation: high capacity to restrain the costs for change is cheap. As the project evolves, the cost of change rises rapidly, while the ability to control the budget has already fallen severely. The relevance of IPD scheme is perfectly illustrated here explaining consequently frequent slippages recorded in the budgets construction due to a lack of efforts in the early stages of the project. Moving the curve of effort to the left, is getting out of the outline based on postponement, adapt the draft and make most changes early at lower cost and thus maximize created value for the customer.



According to Patrick Dupin, Delta Partners; adapted from the "MacLeamy Curve", 2004

Figure 8: MacLeamy curve, abilities progression to control the costs and the cost of change in the traditional and IPD approaches

4.2 Architects – technical design offices: BIM

"*Architecture is at the heart of the conflict between the concrete and the theoretical*", was recalling Tadao Ando, a famous Japanese architect (1987)[16]. There is a need of a bridge ensuring the passageway of the intellectual to the concrete, when the real catches up the virtual with the risk of encountering strong disappointments, as much temporal as financial and human, when performing the work.

It is with this imperative that the Lean Construction is inspired to smooth the production on site, but also anticipate the process of defining and understanding of work, as presented in the previous paragraph on the IPD for the clients. The architects and technical design offices can also implement the Lean Construction process and benefit from its contributions. The transition from realizing paper drawings to computer shots allows to "load" the virtual building with a considerable amount of information. The systems (fluids, automation, mechanics...) contained in the technical description becoming increasingly complex, the digital model (Building Information Modeling or Building Information Management) helps the designer to visualize the finished work, by the three-dimensional modeling.

Eastman (2011)[17] defines BIM as a technology and related processes to produce, communicate and analyze building models. Collaborative and participatory work is therefore also strongly represented, fundamental basis of all the tools and all the Lean approaches. In the traditional pattern, a significant amount of information is lost between the various stages of the project, due to the silo structure: different actors using different tools, with different languages at different levels of detail. In a BIM scheme, everyone will collaborate around the same tool initiated by the architect.

Lean is also avoiding (or eliminating) waste. In a classical scheme, the same information for a building is entered on average seven times for the own needs of the electrician, the plumber, the heating, the technical design office... All these redundant inputs are sources of errors, omissions, inconsistencies and delays in delivery to the next lot; thus significantly increase the final cost of the work. It is estimated to more than 10 Giga € the annual cost of inconsistencies in building sector in France.

In a BIM approach, the information loaded into the central system are capitalized at each stage of the process. Thus, the result of each stage (energy calculations, dimensioning heating, cooling, equipment locations, alarms and security, maintenance, etc.) consolidates design in a collaborative and participatory approach of identification and management of conflicts of pre–construction.

The same information system centralizes all the data of the different actors who have thus direct access to all project information, in the same language with immediately compatible software. The design thus becomes a true iterative, collaborative and participative process.

See in chapter 7 the analysis of lean/BIM capacity for the building sector.

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16 *What the land tells us*, interview with Tadao Ando, Françoise Laboc and Serge Salat, Architecture d'Aujourd'hui Ed.

17 *BIM Handbook: a Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors,* John Wiley & Sons Ltd, Hoboken, New Jersey, United States

4.3 SMEs - Companies: 5S and LPS

LPS and 5S applied to the construction site are simple tools that can be implemented simultaneously; the first one synchronizing and thinning the workflow, and the second one creating appropriate performance conditions (safety and quality).

When the project owner has initiated the process by its commitment to implement Lean on the operation, and when the architect has implemented BIM for design, the company "has only to" carry out its work according to the plans drawn up, the 5S and LPS will significantly facilitate his task.

Current silo-based structure that do not communicate provides only poor results in the design phase. Such a structure will not provide better results on site. Planning is carried out on the basis of project information and project objectives, resulting in a temporal state of what "should" be done.

To perform work, add the resources (labor, materials, equipment) and push the cart. The solution is to add resources, always more resources, without really taking into account the intrinsic reality of companies or the reality of the work site. Mainly, the organizational power is centralized, a single entity dictating to the others "what to do" and "when to do". More optimized sequences might have been found by those performing the work, but in a conventional commend / control scheme, this occasion happens rarely.

The interfaces between companies being complex and difficult to plan carefully, the supervisor of the site works very hard, updates schedules, monitors companies, threatens with penalties for unfulfilled deadlines. This ends up, always, with a delay time. He needs this time to digest and analyze the huge amount of information coming up from the site and achieve his coordination.

The Last Planner* System is a tool for communication, considering the constraints of each stakeholder and the reality of the construction. Attention is collectively drawn to the amount of resources that the site absorb. This intrinsic capacity of the site is challenged with the entire schedule in order to check that the site is progressing in the right rhythm, at the right time, as planned.

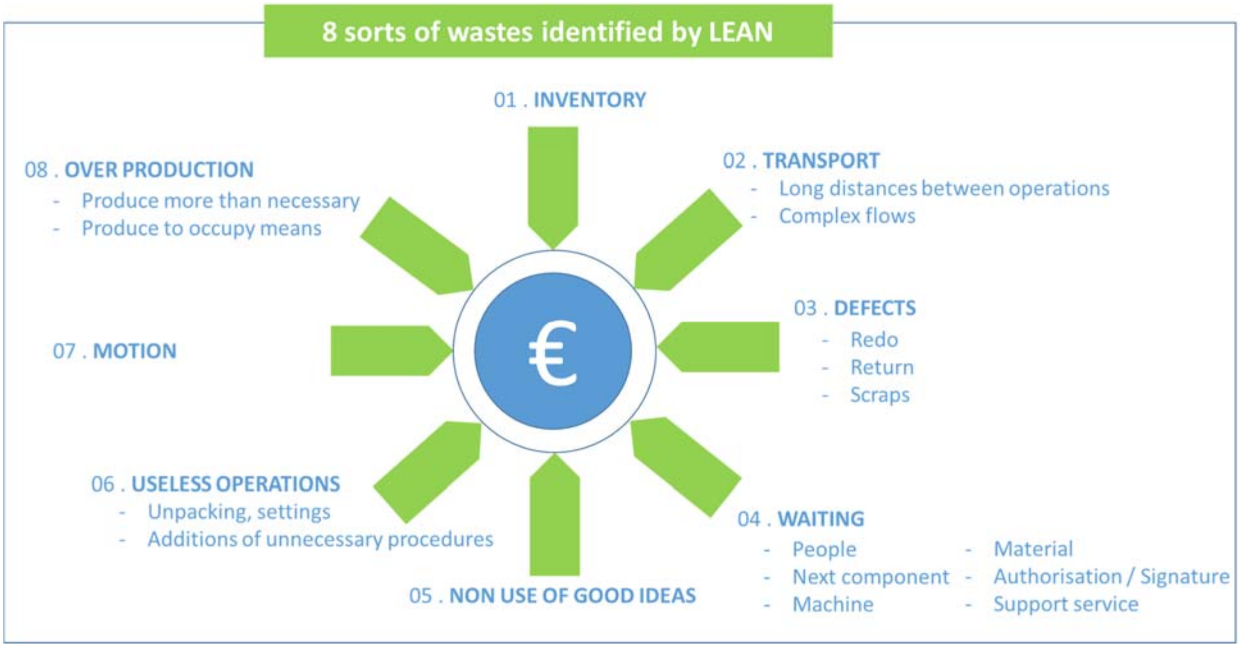
Each company may then get involved on what “will be” done within a week. This involvement is also made with a set of promises to the other companies. A dedicated promise tracking system provides a framework for detecting and addressing the problems as early as possible. It feeds the wheel of continuous improvement, which is constantly running. The LPS is thus also a tool of research of the performance by iteration, similarly to most tools of Lean Construction.

The result of the application of LPS on a general work site is a significant reduction of stress on the work team (both workers and supervisors), a better anticipation of problems and therefore a higher productivity. In the context of a pull flow the orders are made according to the needs of the site, using the Kanban cards.

5 The 7 (+1) sources of waste

In a more and more competitive market, which practices always lower prices and urges companies to reduce their margins at maximum, an almost immediate source of productivity is eliminating waste. As productivity can be defined by the ration of outputs to inputs, decreasing inputs de facto increases productivity.

Toyota identified seven sources of waste: overproduction, waiting, transports, over-quality, storage, movements, non-quality.



5.1 Stock / Inventory

Supply in excess of what is required. Inventory includes raw materials, work in-process and finished goods. Excess inventory can quickly build up entire money waist and resources due to the additional handling and space needed

The quantity of storages on a construction site is a good indicator of the wastage level. This is the sign directly visible of a high flow scheme.

5.2 Transports (logistics)

Unnecessary movement of materials or products that is not directly support immediate production should be minimized as much as possible as it is not value added activity and the material would be exposed to handling damage

The success of the construction of the T5 airport terminal at Heathrow is largely due to the ability of the project team to organize its logistics flows (delivery / removal of equipment and materials). The delivery in a “just in time” flow allows substantial direct and indirect savings. Materials and equipment are not ordered in excess, thereby reducing significant storage costs and optimizing cash flow.

On the other hand, it is commonly accepted that one of the main factors determining the daily production of a construction site is the crane. The number of workers under a crane is limited by the ability of this later to deliver the materials and equipment they need.

This voluntary limitation, acquired for most companies and contractors, is valid in a high flow scheme. For example, the installation of a pre-slab with safety elements and tools, four crane operations (at least) are necessary for proper positioning and lifting of materials:

1) The lorry is positioned next to the site, the pre-slab is lifted by the crane and brought to the storage area to be stocked with the others
2) When it is time to implement this pre-slab, it is generally under another one (at least) which has to be removed through a second crane operation
3) The pre-slab being available, a third crane operation places it at its place
4) When the lorry that brings material arrives, a fourth crane operation is necessary to place it on the pre-slab.

In a pull flow, the orders are made according to the needs of the site, using Kanban cards. The lorry is placed next to the site, the highest pre-slab loaded with materials and equipment is lifted by the crane and directly implemented at its final place. A single crane operation is sufficient to unload the pre-slab, install it. Also, the storage area is reduced.

5.3 Defects

products materiel or services that do not meet expectation or conform to specifications, corrections and defects or anything not done correctly the first time and must be repaired, sorted, remade or redone as well as materials which are cracked due to defects.

5.4 Waiting:

Waiting refers to the periods of inactivity that occur because the proceeding activity tends deliver on time or finish completely weaving waste increases the cycle time during which no value added activity is performed

The most obvious waiting is not being able to carry out immediately an action because of a shortage (equipment, material, labor, information and validation). An automatic preparing of the necessary elements (and sufficient to avoid overproduction) overcomes rather efficiently this wastage. If the execution of a process is blocked while awaiting an element (work, information, material or equipment) that is not necessary to the realization of this process, then it is a real wastage. The most widespread scheme currently consists in an commend / control aimed to avoid any latitude to the subordinates, constitutes a very fertile ground for producing waiting. In a well-in-place commend / control system, the worker will perform his task only in accordance with the orders of the site manager, who himself receives them from the site supervisor. The on-site workflow is very often interrupted by a lack of information and equipment which the site supervisor could not deal with. The worker will therefore wait for these materials and information to continue his work.

The development of responsibility at every level of the site hierarchy (through training), by promoting the presentations of "open-minded" initiatives and creativity, is a quick and effective solution to address the main sources of waiting.

Then the implementation of Kanban cards on site will improve reliability and lock the elimination of waiting. The principle is simple but requires commitment form the workers and foreman to be effective over time.

According to the size of the construction site, the involvement of the workers and foremen regarding the organization of their own work and the level of their own training, it will be possible to carry out weekly or even daily the following steps relating to the organization of material management in Kanban flow.

1) Each worker or foreman owns a Kanban card on which will be pre-printed le name of the site, the name of the person responsible, the date of use of the main materials to order, with their nomenclature (name and enterprise identifier).
2) These Kanban cards are filled in as the work progresses, at regular intervals; it will mention the materials used and to quantity to recommend.
3) The direct manager (site manager or foreman) consolidates the information contained in all these cards. The company will have to implement a system allowing the computerized and systematized processing of this data, Kanban cards being dematerialized on a touchpad. The cost of the lost or stolen touchpads remains negligible compared to the savings generated by their use.
4) The direct manager (site manager or foreman) performs a quick check of the site stock and modulates the consolidated quantities.
5) The order request is made directly to the supplier, with copies to the support services (invoicing, management) and to the site supervisor who has in real time the needs of the site and therefore a display showing advancement.
6) The order is delivered on site, the materials are distributed according to the demands of the workers or foremen, thus limiting the stocks on site.
   In a Kanban system, the materials orders are made according to the real needs of the site and not according to forecasting which is false by definition.
   In this case, the Kanban card is also an educational tool of accountability and involvement that affects the whole hierarchical levels. The management of the site has to accept to give up some of its “power” to the benefit of its subordinates. The site supervisor will then be able to focus on the critical tasks and maintain a high level of anticipation.

5.5 Nonuse of good ideas:

Work collectively and accept and use all good ideas coming from the team regardless who and what is his level in hierarchy. Lean is a bottom up methodology, often good ideas are coming from the production team that actually is doing the work.

5.6 Useless operations or Over processing or Over-quality

Unnecessary steps in operations such as re-processing, double handling, additions of unnecessary procedures, added communication and double checking which adds no value over processing.

Trends well known since the early 2000s in construction, the over-quality is reached when the cost and the energy spent in a Quality system systematically exceed the risk that the Quality method aims to eliminate.

What is the cost of control compared to trust and accountability? More and more standards, regulations and controls can be the source of severe waste. Not that we should ignore these tools whose primary purpose is to increase productivity, but wisely and in a process integrating Quality in a corporate vision. Quality will help in reduction of duplicates, fluidity of operations, absence of non-quality etc. Those concepts are very close of Lean. In fact, Quality and Lean are two complementary approaches, both of which can be carried out in parallel for a better result.

Otherwise, the cost of setting up and running a "blind" quality approach is considerable. It is estimated that it can represent (directly and indirectly) close to 5% of an organization's turnover. The direct costs are the salaries, expenses and costs related to the Quality Unit itself (management, offices, vehicle, production of documents, audits ...) and the indirect costs are those induced by Quality (seminars, forms to fill, demobilization, exploitation of data in very complex tables).

It is therefore necessary, within the framework of a Lean approach, to clearly identify the level of ambition of the Quality approach to be implemented, to ensure that each of its steps brings value.

1.Motion
the extra steps taken by people to accommodate the inefficient process lay out defects, reprocess and over production or excess inventory ; to move and add value is called work to move and not add value is called motion

2.Overproduction
Overproduction is producing more than is needed, faster than is needed or before it is needing. This results in excess inventory carrying costs.

Overproducing may be conceived as the production of a work that will not be used, and will be destined to be destroyed, without it has been appreciated by the customer (or the final user). Overproduction is also using more materials than necessary, more resources than necessary and/or an oversized material for the task to be performed.

The JIT (Just In Time) principle is precisely to reduce overproduction until total elimination. The push flow encourageme to produce more than necessary with oversized material, in order to overcome the lack of internal processes. Reducing overproduction requires the “accurate” constructive definition of the work to be carried out (in three dimensions if possible) and a systematic reflection about the equipment, material and labor needed to produce it, “just in time”.

6 bibliographical surveil

6.1 Number of scientific communication on lean construction

During leanWOOD project we made different bibliographical reviews with generic keywords: ‘lean management’ ‘lean construction’, ‘lean + wood’, ‘lean + prefab’, ‘lean construction + methodology’, ‘lean construction + sociology’, etc. source of articles are:

- Web of Science (12 000 scientific journals and 150 000 congress proceedings in 15 databases),

- Google Scholar
- Internet.

Also we specifically made a review of articles written by the LCI (Lean Construction Institute) members:

- Glenn Ballard,
- Lauri Koskela,
- Ryan E. Smith,
- Rafael Sacks,
- Gregory A. Howell,
- Carlos T. Formoso,
- Per-Erik Josephson,
- Panagiotis Mitropoulos,
- Sven Bertelsen,
- Tariq Abdelhamid.

First of all, it seemed interesting to know the trend of the number of scientific publications in the field of lean construction in order to realize the importance of this topic in the world of the research.

Based on two bibliographic databases (Scopus and World of Science), we have identified 302 scientific articles since 2007. We can notice a significant increase over the last 10 years (and in particular in 2015 and 2016 with 42 and 54 publications respectively):

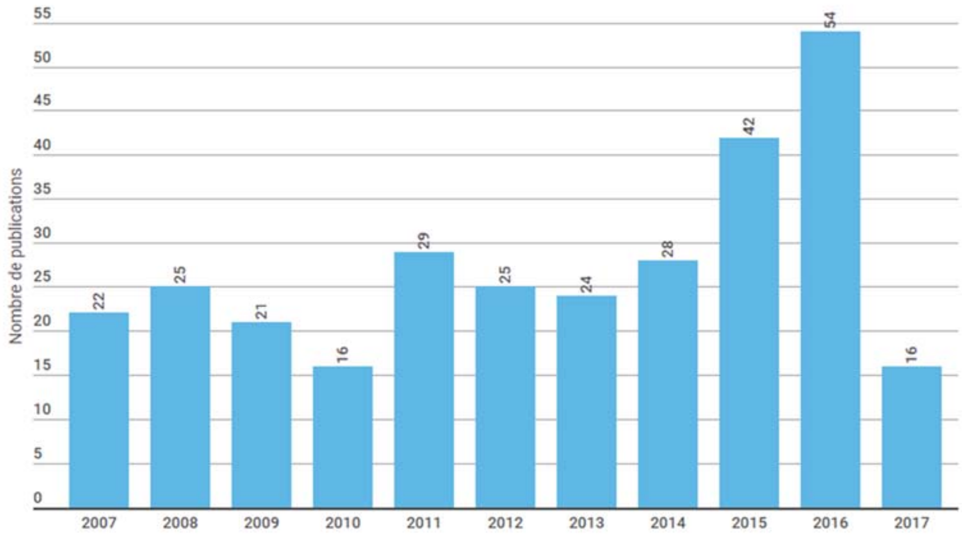


Figure 9 : Number of scientific publications in the field of lean construction per year

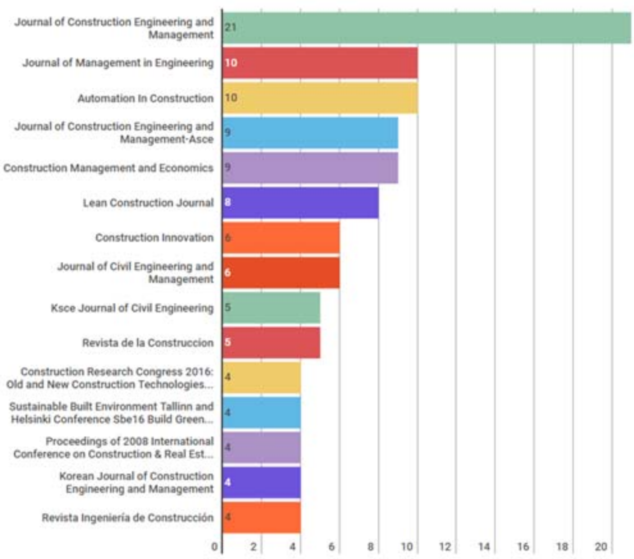
6.2 Keywords and developed subjects

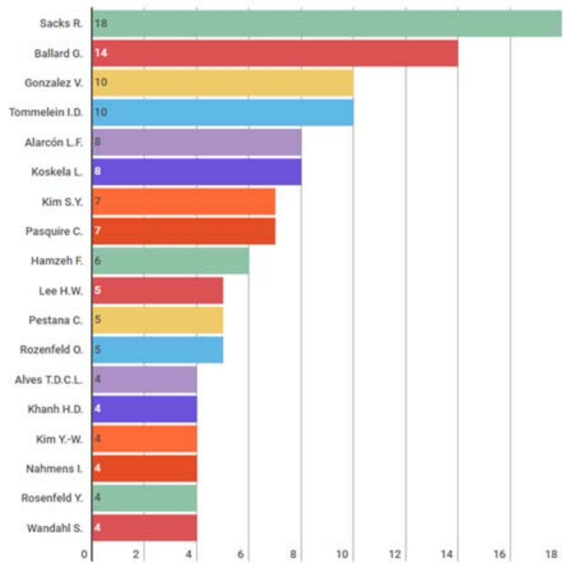
We then focused on most frequent expressions encountered among the keywords cited by the authors. This allowed us to build the word cloud below:

Figure 10 : Word Cloud of the keywords cited in publications.

For more clarity, we have eliminated the term "lean construction", which, being quoted in almost all the articles, did not make it possible to apprehend the list of the other words identified.
We can then see that the most frequent expressions associated with "lean construction" are:
- construction management,
- construction industry,
- lean production,
- project management,
- building information modelling,
- last planner system,
- etc.

Scientific journals as well as researchers producing the most articles in this field can also be seen in the figures below:





The top 3 journals are:

- Journal of Construction Engineering and Management
- Journal of Management in Engineering
- Automation in Construction

The top 3 researchers are:

- Sacks R.
- Ballard G.
- Gonzalez V.
- Tommelein I.D.

If we then focus in co-publication communities and the interactions between them, we can distinguish 4 main groups:

- a group around G. Ballard (the purple one),
- a group around R. Sachs (the blue one),
- a group around F. Hamzeh (the pink one) and
- a group around V. Gonzalez (the green one).

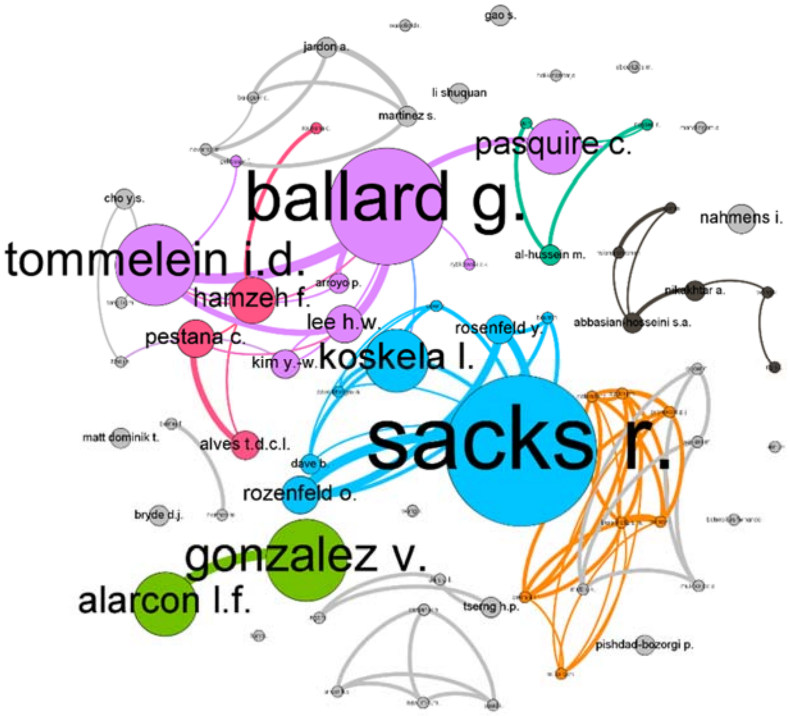


Figure 11 : Interactions between author communities for publication on lean construction

7 What is Building Information Model (BIM) and how did it came to be?

According to the BIM Handbook (Eastman et al. 2008), BIM is defined as" a verb or adjective phrase to describe tools, processes and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later its operation."

The US National Building Information Model Standard Project Committee has the very similar following definition: "Building Information Modeling (BIM) is 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."

From a practical point of view and according to its different kind of users, BIM is both a software, a database, a collaborative process and a management method.

The concept of BIM has existed since the 1970s.[18] But the acronym BIM really began to get popular about 10 years ago.

In his paper Augmenting Human Intellect, Douglas C. Englebart explains what the work of an architect will be like thanks to the use of computers. *"the architect next begins to enter a series of specifications and data–a six-inch slab floor, twelve-inch concrete walls eight feet high within the excavation, and so on. When he has finished, the revised scene appears on the screen. A structure is taking shape. He examines it, adjusts it... These lists grow into an evermore-detailed, interlinked structure, which represents the maturing thought behind the actual design."*

He wrote this in 1962 when computing was only starting but his vision is rather close to what BIM can be. The development of modelling programs and building description databases over the next decades enabled virtual designing to take over the architect's drawing board. Nowadays, the building industry leans toward collaborative designing and the development of software and platforms supporting this trend linked to Building Information Modelling.

7.1 Definition of the levels of BIM

The UK Government has set up a special BIM Task Group to help develop a roadmap for implementation of BIM in the UK. To help with a gradual adoption they have specified 4 levels of BIM that will have to be adopted by construction projects (from the Government Construction Client Group, 2011):

[18] Eastman, Charles; Fisher, David; Lafue, Gilles; Lividini, Joseph; Stoker, Douglas; Yessios, Christos (September 1974). *An Outline of the Building Descripiton System*. Institute of Physical Planning, Carnegie-Mellon University.

Eastman, C., P. Teicholz, et al. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*. Hoboken, New Jersey, Wiley

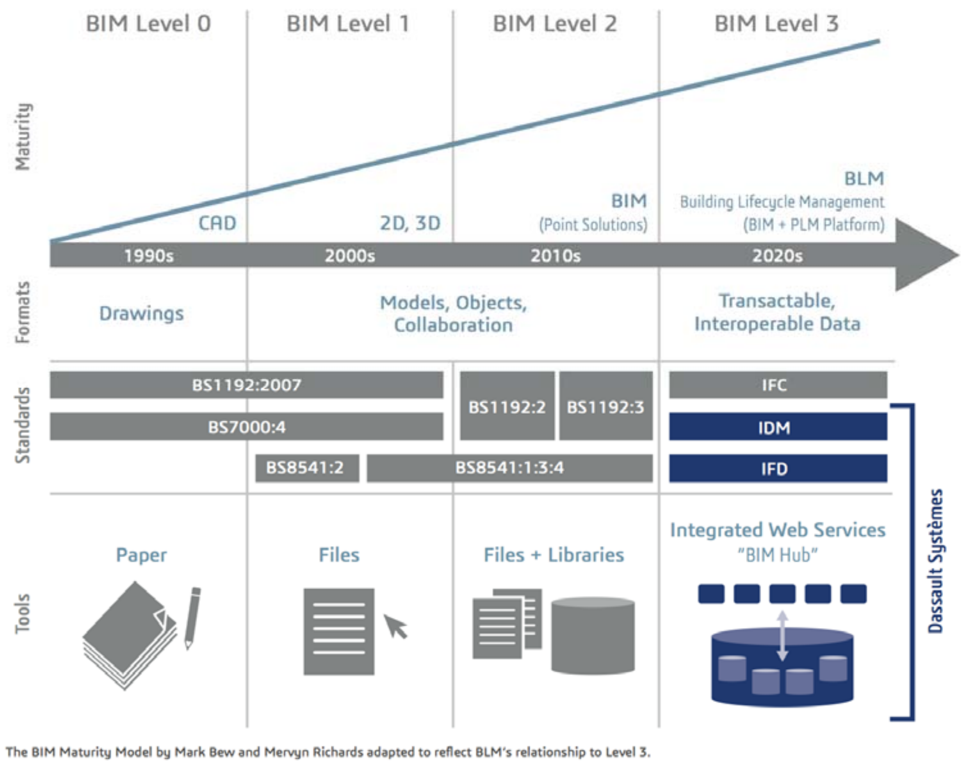


Figure 12: Levels of BIM defined in the UK (Source: http://perspectives.3ds.com/architecture-engineering-construction/what-is-bim-level-3/)

- Level 0: information is exchanged as text or 2D drawings on paper (or as electronic documents), the CAD is unmanaged.
- Level 1: corresponds to digital modelling and one-way exchanges at time t. This work provides a common data environment and possible standard data structures and formats.
- Level 2: co-ordinated 3D BIM environment. Separate discipline models consisting of objects with attached data. Commercial data managed by an ERP (enterprise resource planning) system. Level 2 may use 4D scheduling data and 5D cost elements. This is the current typical, advanced use of BIM and also the level that UK Governments' Construction Strategy requires as the minimum by 2016.
- Level 3: fully open process and data integration enabled by open standards and managed by a collaborative model server. Can be regarded as iBIM (integrated BIM) and potentially employ concurrent engineering processes. Difficult to achieve with the current technologies.

According to the definition giving by Bertrand Delcambre (report "Mission numérique Bâtiment", 2014) BIM is a 3D modelling integrating the geometric characteristics (plans, cross-sections,...) and information about all the components (composition, physical characteristics, acoustics and thermic performances,...). BIM also includes collaborative work since all the stakeholders will be working on the same modelling and enrich it throughout the project. B. Delcambre defines several level of BIM in his report:

- Level 1: modeling of a 3D representation and one-way swapping of information at a given time.
- Level 2: collaborative work based on the 3D modelling with two-way swapping of information between the architects, the design offices and building companies. The stakeholders import the 3D modelling and enrich it throughout the project (Cross- sections of the structures, composition of the walls, kind of cladding,

localization of HVAC...). In this level, it is not necessary for all the stakeholders to share their information on the modelling.

- Level 3: All the stakeholders have access to the 3D modelling and import their information into it. A BIM Manager is then needed to make sure that the modelling is always up-to-date.

7.2 Regulatory framework of BIM around the world

Scandinavia is one of the forerunners for the implementation of BIM in the world. It is compulsory for every public founded projects since 2007 in Denmark and since 2011 in Norway. Senate properties, a state-owned enterprise in Finland, has made the use of BIM compulsory since 2007. Sweden launched the OpenBIM organization in 2009 to establish BIM standards.

In the Netherland, BIM is compulsory for the design, management and maintenance of big public projects since 2012. In the United Kingdom, the use of full collaborative BIM (level 2) is compulsory for all the public sector projects since April 2016. In France, the use of BIM should be mandatory for the public sector starting in 2017. In January 2015, Germany founded the Germany's Digital Building Platform whose goal is to develop guidelines and standards for the use of BIM especially in the public sector. BIM should become mandatory for public projects starting in 2020.

BIM is widely used in the USA but with many different software programs. The arguments are less about the worth of BIM and more about how to standardize the use of this method. BIM is compulsory for projects done for the General Services Administration.

7.3 Examples of BIM projects in France

7.3.1 Labs for Schneider Electric, FR-Grenoble

Schneider Electric is building two new labs in an upcoming and "smart-city" area of Grenoble from now to 2018. They have required the use of BIM for their two projects in order to offer a virtual tour of the buildings showcasing their knowhow and improve the energy management and monitoring of the upkeep. They also want to implement a new workspace organization and will use the modelling to monitor the occupancy.

In order to succeed in this endeavor and with little prior experience and knowledge, they hired a contractor assistant specialized in BIM to help them write the specifications for BIM and choose the companies.

7.3.2 Cité des Civilisations du Vin (Center of Wine Civilizations), FR-Bordeaux

The Cité des Civilisations du Vin designed by X-TU Architectes will open in 2016 in Bordeaux. The structure is mainly made out of concrete, wood and glass. The use of BIM was a requirement of the procurement to better visualized the project but it also made it easier to design the different part of the curved building.

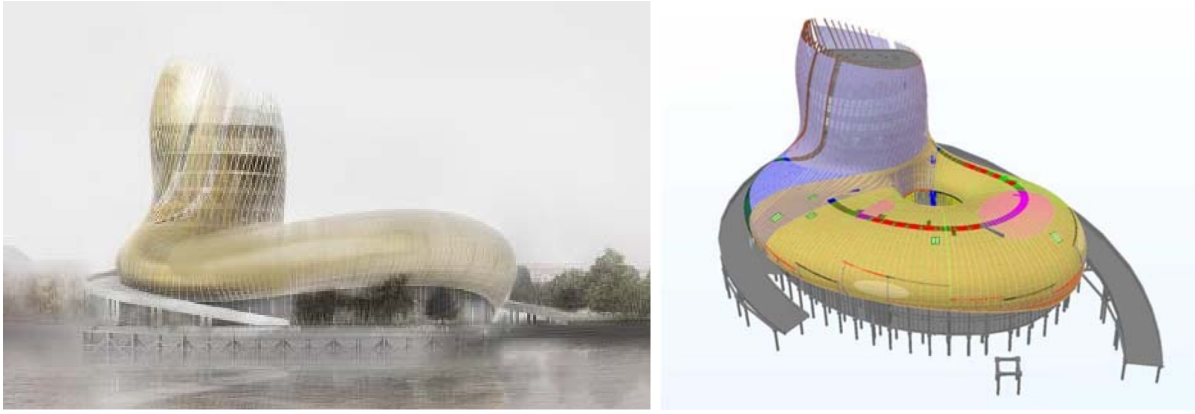


Figure 13: Cité des Civilisations du Vin - 3D model (teklabimsight.com)

The companies in charge of the shell and core construction created and updated a 3D model to monitor the interfaces between the different stakeholders. It was also used to number each glulam arch as they are all different. It was easier for the wood company to create its 3D model as they are used to it contrary to the companies in charge of the roofing and masonry more used to 2D planning.

This model was share with the other actors working on the project but not completed by all of them. It seems unlikely that the 3D model will be used afterwards by the owner since it does not contain all the construction work packages.

7.3.3 Fondation Louis Vuitton, FR-Paris

The Fondation Louis Vuitton unveiled on October 20, 2014 is an art facility including a museum and an event venue stretched over 11 600sqm. It was designed using Digital Project, a software program based on Catia and developed by Gehry Technologies. This program enabling the work on a common 3D model was used to ensure the close collaboration between the different teams that was required to create the intricate shapes drawn by Frank Gehry. From designing to engineering and construction it represents a global team of over 200 people dealing with several materials (curved glass panels, wood glulam beams, steel and concrete).

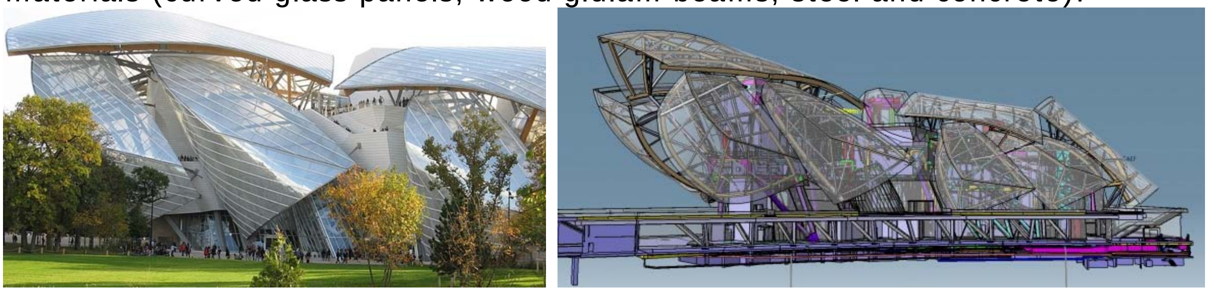


Figure 14: Fondation Louis Vuitton - 3D Modeling (Moniteur,16th november 2012)

The model contributed to the reduction of wasted time and errors during the designing thanks to continuous updates and contractual obligation to developed technical studies within the 3D model. Moreover, the tools allowing the calculations of each glass panel and control of the joints were developed through Digital Project to enable the use of a CNC cylindrical glass bending machine thus avoiding the use of molds and therefore minimized the cost of fabrication. The model was also used construction quality controls thanks to on-site laser equipment and round-tripping back into the model. This way the BIM was always up-to-date and the new pieces could be adapted to the dimensions of the real building.

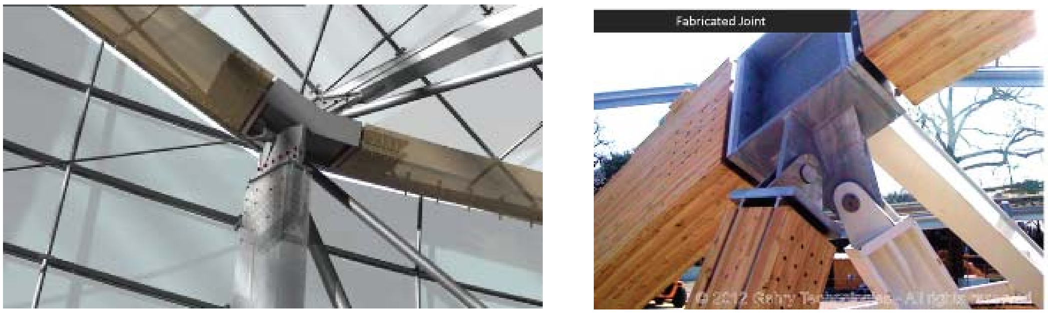


Figure 15: Joint - 3D modelling and fabricated (Gehry Technologies)

This project has received the BIM (Business Information Model) Award for Excellence conferred by the American Institute of Architects.

8 Catalogue Construction Bois

The "Catalogue Construction Bois": the wood construction robust details, was first published in 2013. The collection includes structural descriptions and joint details, with guidelines for fire, thermic and acoustic regulations, as well as assistance templates for architect technical specifications drafting.

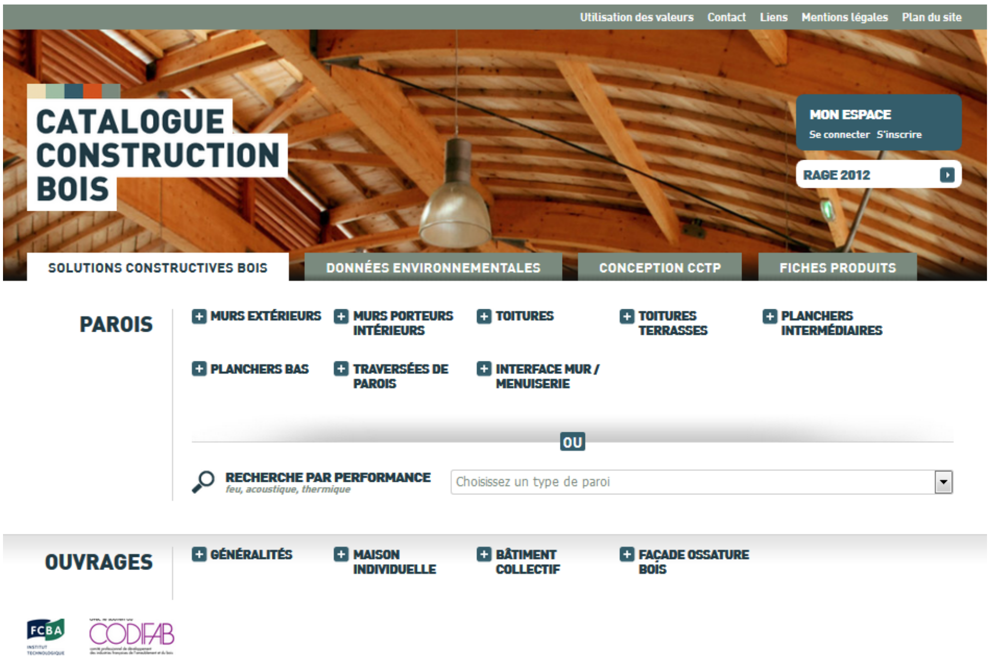


Figure 16 : Frot page of « Catalogue Construction Bois » web site

It contains structural solutions for timber framed constructions and massive timber. It is dedicated for residential single family homes and multi-storey apartment buildings. The material is open source, publicly available and possible to download at the catalogue-construction-bois website. All material is available in *.PDF format, and partly in MS Word format.

It can be both copied and printed. Details are available as pdf-documents and in dxf-format. The website content is published in French Only.

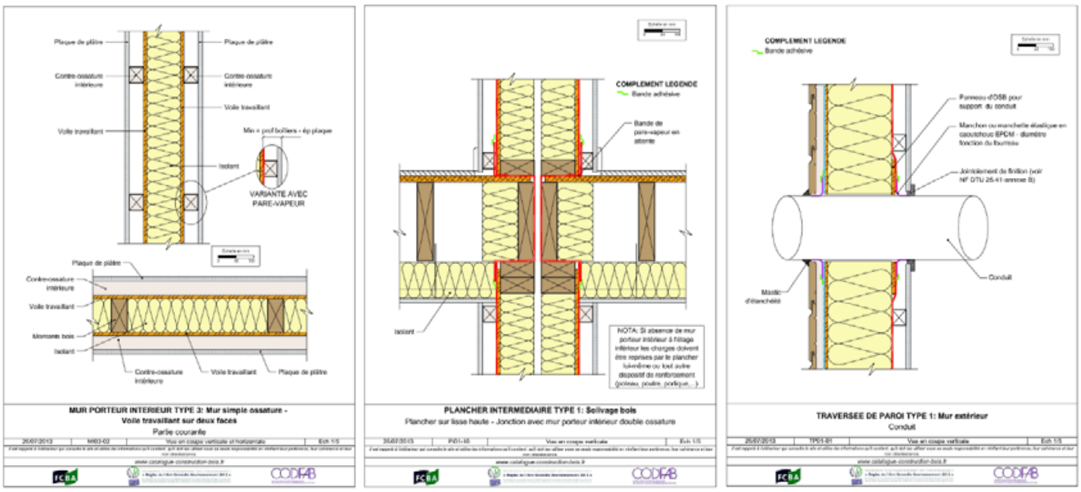


Figure 17: Examples of details available on Catalogue Construction Bois

An update of the website is foreseen in 2017, it will be extended to details and guidelines for retrofitting of building using timber build-ups.

9 Workshop Lean & Timber construction organized by FCBA in 2016 in Bordeaux

FCBA, together with LECO Construction, organized 2 workshops on lean construction implementation and training. The first organized in March 2016 and the second in June 2016.
We invited several actors of the building sector with the promise of being trained to lean:

- Understanding the Impacts of Lean Management on companies effectiveness,
- Experiencing lean in a roleplay building a model of an actual case study,
- Training on Lean fundamentals
- Identify source of waist in building process
- Experience learnings on a model construction

The goal of the workshop was to experience the benefits of Lean Construction though exercises on the reduced scale model of a real project (“Cabane Tachnquée n°53”). Xavier Jaffray, one of the partners of the project LeanWood, and expert of lean in the timber industry monitored the day. A few professionals, took part in the workshop: architect, builder, carpenter, engineer and researcher.

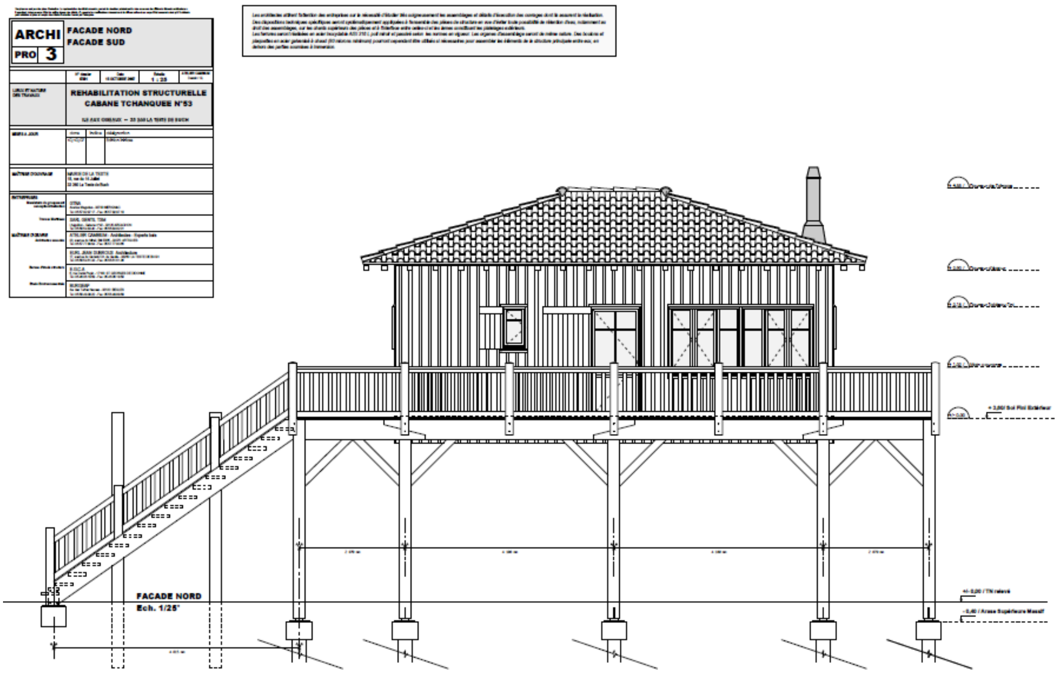


Figure 18: Plan of the North façade

The day was split into several steps. At the start, the organizer gave information, drawings, and complete description about the building project. He lunched the construction with all trainee taking a role: Supplier, building company, implementation team. The trainees could organize themselves like they wanted. Before starting, they had to estimate what they would deliver at the end of a given time. Each trainee was acting in his given role.

Figure 19: implementation of storage area "off-site"

When time run out, they were far from the expected results and some waste of material were listed. After analysis of the morning experience, and a debriefing by the trainer, the trainees changed their organization. All given roles were cancelled and all trainees were organized spontaneously to better perform productivity. Lean management was implemented in organizing teams, communication, coordination, flexibility, cancelling waist, quality production, etc.

The second part of the day was much more productive. An example of the changes, was the implementation of zones “off-site” to facilitate the delivery “on site”.

Figure 20: jig to speed up the fabrication process

A jig was developed to speed up the fabrication process of the frame walls. It could have been a solution, however in this case prefabrication was not the way to go since the access to the site (on water) was complicated.

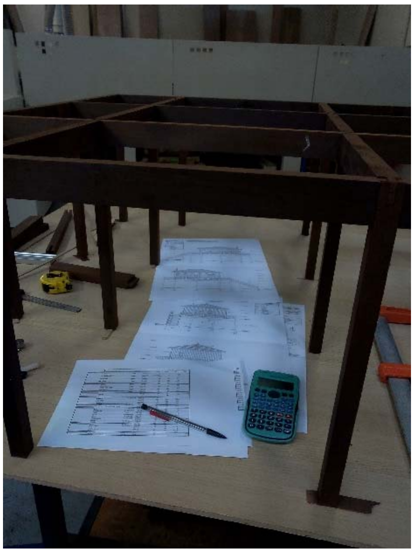


Figure 21: fabrication process

With this live experience, we filmed the whole day of training, and we derived a short video. We organized the scenes chronologically, including analysis periods, briefing periods, and collective brainstorming.

leanWOOD

Book 4 – part E
process

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1. BIM and multi story design

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Federation of the Finnish Woodworking Industries (Finland)
KINNO Kouvola Innovation Oy (Finland)
SK Finnish Real Estate Federation (Finland)
Federation of the Finnish woodworking industries (Finland)
LECO Construction, XJ Développement (France)

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FP7 Seventh Framework Programme European Union
WoodWisdomNet+

Insofar as the masculine form is used in the contents of this report solely for reasons of better readability it is assumed that this refers to both genders on equal terms.

CONTENT

Literature

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Proofreading

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1 BIM and multi storey design

1.1 Need for a change

The construction of wooden multi-story buildings was boosted by changes in building regulations in 2011, and the amended regulations allow the use of wood in 8-story buildings. So far about 50 wooden multi-story buildings have been built in Finland since the mid-1990s. The public sector has an important role in promoting wood-based multi-story building. Despite intensive development, the experiences in wood-based multi-story building in Finland are still limited. Building processes may still suffer from some lack in efficiency in terms of process management and use of resources. It may be possible to address different kinds of issues which would be able to make the process more effective and lean.

The minor project stock is explained partly by the fact that the wood structure systems have not been established, and the projects tend to be individual experiments including a large amount of uncertainty. However, the development of the systems will not actualize if there is no demand. This demand, is restricted for its part by the fact that the project delivery methods mostly used are not suitable for the realisation of projects containing unestablished systems. A process that is suitable, jointly accepted and widely used would intensify operation, minimize the uncertainty, facilitate the arrangement of competitions and increase the willingness to participate in these competitions. By creating such a procurement process, necessary conditions for the development would be provided for the sector.
It is common that the owner of the project employs the designer to draw up the plans of the building, after which their realisation is entrusted to the contractor on the basis of competitive tendering. Such traditional design-bid-build project delivery methods have generally been the most used approach in owner-initiated new construction. However, the independent designer employed by the owner cannot yet have sufficient cost and constructability information to determine an optimal solution when established solutions do not exist.

The know-how of suppliers and contractors of wood structures must be brought to the planning of the building at a stage which is early enough so that the success of projects and the development of the structural systems more generally can be promoted. The different know-how can be best integrated by using the design-build or project alliance delivery methods. Moreover, the precondition for a more common use of wood structure systems is that projects can be procured by means of a competitive process.

1.2 Alternative delivery processes

Design-build (DB) is a project delivery method in which the owner contracts, with a single design-build entity, to perform both design and construction under a single agreement, thus offering the owner a single point of responsibility for design and construction services. Project alliance, on the other hand, is a method based on a joint contract between the key actors of a project, in which the parties assume joint responsibility for the design and construction of the project to be implemented through a joint organisation, and in which the actors share risks related to the project and observe the principles of information accessibility in pursuing collaboration.

Processes of these project delivery systems, especially in the case of alliancing, can benefit from the co-creation of the owner and service providers. In this way the laboriousness of the actual competition stage also remains moderate on the one hand, and integration of the know-how results in a better project solution on the other: at best the interactive development of ideas leads to a positive development trend, benefitting the project considerably. Other parties' immediate feedback directs operations and in addition to the improved solutions, the process also becomes streamlined.

1.3 Use of alternative processes

DB is usually the most appropriate option for customary projects. If the owner's needs and requirements for the project can be specified relatively unambiguously, and the negotiations at the competition stage are sufficient for securing the compatibility of demand and supply, the use of the usual DB method leaning on the competition procedure is reasonable. This is the case, for example, in the building of wooden blocks of flats when there are no special risks other than those related to the structure system and how it functions and can be executed as a part of the project; these risks, again, are the reasons to utilise the suppliers' know-how. Along with the wider use of the procedure, the objectives of a competitive, standardised process which utilises the bidders' know-how would be fulfilled.

If the determination of the project merely with the methods of the market sounding in the competition stage is inadequate, and succeeds only by binding the future users or other interest groups to the design of the project, then the role of the joint development phase needs to be emphasized instead of a relatively quick competition stage. Special requirements and objectives for new types of solutions can also support the deviation from the competitive process described above. In these cases the DB method can be adapted by the way in which two DB teams are selected to an agreement-based development phase on the basis of a capability-oriented competition, and the implementer is only chosen after the development stage. This kind of a process enables the co-creation of the project slightly better.

If the realisation of a challenging wood structure system takes place in a project that is also exceptional in other respects, the risks increase essentially. If the risks are of such nature that they can be mitigated best by means of cooperation of the key parties of the project, the alliance may be the right delivery method for the project. In practice, this requires stronger involvement of the owner in the realisation, while he should also have such know-how which produces added value to the realisation of the project. Alliance projects are typically very large. For these reasons the alliance is not a primary method, which can be adapted widely, but it offers an alternative when it is a question of exceptionally challenging wood construction projects.
For the part of alliancing, a joint development phase carried out with one team only is reasonable when open collaboration is the aim. This also makes phased progress possible in the formation of the alliance team: critical know-how is brought along first and by utilising this view, other actors of the team are chosen in which case the designer, contractor and system supplier can come along separately. On the other hand, the development work done with two teams side by side concretizes the existence of competition, and can act to the advantage of the project by offering the owner an opportunity for a more enlightened decision-making, since the choice of the final project solution and partner(s) is in this way deferred. For example, the development of two different types of wood structure systems could justify the use

of the procedure by enabling to see their development potential as a whole before the final decision is made.

1.4 Needs for development of building information modelling (BIM)

The project delivery method chosen for a construction project sets preconditions for efficient implementation. The project delivery method also has an influence on a building information model (BIM) based design process. In Finland, the same BIM programs are used for the design and engineering of wooden multi-story buildings as are used for other multi-story housing planning. The problem in the wooden multi-story building has been the lack of suitable smart planning components and related add-in programs. Furthermore, the variety of structure systems and on-going development of details hinders the development of more efficient BIM tools. The greatest benefits of BIM-based design are obtained in an industrial building process which is based on regular components and details which are only configured per project.

In Finland the BIM utilization is guided by the Common BIM requirements, COBIM2012, which have been determined by the branch together. The set of requirements contains 14 parts divided according to the actors of a project and some other use cases. The COBIM2012 requirements can be referred to, e.g. in design contracts when BIM-related tasks are specified. COBIM2012 specifies the general demands for information modelling, but the descriptions are independent of e.g. the modelling programs to be used. In addition to them, the parties of some sub-branches of the industry have developed more exact instructions and requirement specifications. For example, the precast concrete industry has prepared the modelling instructions of concrete elements and these instructions also contain application-specific definitions. The concrete industry has also organized common development activities and created planning components for the Tekla Structures program which supports the open precast construction system.

An open wooden multi-story building concept RunkoPES, based on the use of prefabricated elements, has also been created in Finland. The concept specification includes suggested structure types, and modelling libraries have been created for architectural design for Revit and ArchiCAD software. These library components are adequate for managing measures in architectural design but they do not meet the requirements of structural modelling. Detailed modelling of structures would provide a possibility to develop details virtually, which would promote constructability analysis and therefore also improve productivity.

Some structural engineering consultants have developed basic detailing tools for their own use, but there is also an opinion that company-specific tool development will not give a competitive edge and that some branch level common planning tools are preferred. In the short term, the branch could gather joint financing for further development of existing component libraries and share the achieved results in cooperation with software vendors to maximize the penetration. Tools must also be maintained continually, because proprietary modelling software is updated regularly and modifications may have an impact on the functioning of library components. The planning tools will be developed in accordance with the development and utilization of wooden structure systems and prefabricated building elements. At the present production volume of wooden multi-story houses, most of the active development of the building information modelling takes place in actual building projects. Even in such a case, the best practices of modelling in construction projects should be collected and shared openly on some common platform at branch level. Even the clients of building projects could support this, by setting a demand for more open information sharing.

The most essential act, however, is to realize new wooden building projects so that structure systems and tools will be worth developing. In the current market there exist competing structure systems and, at a project level, providers of different systems should be able to participate in tendering. In practice, in comparison to traditional design-bid-build competition, this also requires comparison of design work in the tendering phase. However, this design effort can be reduced for the tender by using efficient modelling, but it should also be determined what is the adequate format and level of detail to be expressed in the tender design. The main tender design representation should be the building information models and most traditional 2D drawings should be replaced by views of the tender models.