leanWOOD

Book 7 – part A resources

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1. LCC, Resource-efficiency – cost-optimal building production

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KINNO Kouvola Innovation Oy (Finland)
SK Finnish Real Estate Federation (Finland)
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CONTENT

Literature

Ruuska, A. & Häkkinen, T. 2016. Efficiency in the delivery of multi-story timber buildings. SBE16 Tallinn and Helsinki Conference, Build Green and Renovate Deep 2016, 5–7 October 2016, Tallinn, Estonia. Energy Procedia. Elsevier Ltd. Vol. 96 (2016), 190–201 Energia doi: 10.1016/j.egypro.2016.09.120 SBE 16 LeanWood - haastattelututkimus.

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Vares S., Häkkinen T. “Resource efficiency in Multi-storey buildings”
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Proofreading

Semantix Oy

1 Resource efficiency, LCC and cost optimal production

1.1 Resource efficiency in multi storey buildings

The study clarifies understanding about material use and efficiency in wooden buildings. It discusses the meaning of building design solution, identifies the magnitudes of raw material consumptions, highlights the material waste generation and shows the building GHG impacts.
Results are presented with the help of wooden multi-storey residential building cases. Technologies used for case buildings were prefabricated elements: large wooden elements, wooden space elements (box-modules) and for comparison building with concrete elements. All the wooden buildings that were under consideration also contained concrete structures; one has a concrete garage, while other has a storage floor made of concrete.

1.1.1 Method and Indicators

Life cycle assessment method (LCA) is used for the assessment of resource use and consequent impacts. EN 15978[1] is the standard for life cycle assessment of buildings. According to the standard building life cycles phases for material production are: raw-material acquisition (A1), transportation (A2) and production (A3) and for construction phase: raw material transportation (A4) and construction (A5).These phases are taken into account also in building resource use assessment.
Direct indicators for efficient resource use could be renewable and non-renewable material resources, renewable and non-renewable primary energy, use of secondary raw materials, abiotic resource depletion, depletion of fossil resources, water consumption etc. In addition, also all potential environmental impact categories indicating indirectly resource use. Ruuska and Häkkinen[2] have been suggested to simplify assessment by using greenhouse gases as an indicator also for resource use. This is a simple and versatile indicator, based on the life cycle assessment, taking into account material and energy raw materials, including also waste materials and impact. Alongside with the use of materials and waste generation GHGs is chosen for the resource use indicator also in this study. GHGs values used in assessments based on VTT Ilmari database.

1.1.2 Building structures

Using wood products in different building structures the natural raw material consumption and carbon footprint could be very different.
Normally wooden materials have a lighter weight and less carbon footprint than heavy concrete. The big difference in resource use and impacts depends on the intensity of using wood and other materials.

Building structures should fulfill different performances (load bearing, heat- and sound insulation, fire protection etc) and depending on that, the material use intensity is different. In the case of column and beam structure the external wall should bear just itself and thus could be made as a lightweight structure, in space element case, the whole space element is a unit for load bearing.

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[1] EN 15978

[2] Ruuska, A. & Häkkinen, T. 2014. Material Efficiency of Building Construction. In: Buildings 2014, 4, pp. 266–294.

In case of wooden frame building the partition floors have a higher resource use in case of floor heating system because heating system should be bedded on the concrete layer. In assessed cases, wooden partition floors consumes materials 86 – 253 kg/m2 when in case of 375mm hollow core slab it was a twice higher (538 kg/m2). Higher resource use leads correspondingly also to the higher GHG value. Previous research made for Finnish Puuinfo Oy[3] shows that the use of natural resources in case of external walls are as high as 60 – 293 kg/m2, greenhouse gases 8 – 68 kg/m2 and embodied carbon 30 – 89 kg/m2. On the basis of case result, CLT wall structure consumes almost twice as much material resource than the wall structure with large wooden elements. However, different building geometries between the case buildings and excessive use of concrete in one of the buildings results in different wood use intensities in total. A considerable difference between CLT structure and concrete panel was observed in weight. An external concrete wall element consumes 5 times more resources and causes 2 times more GHGs.

In general, optimization of building structures according to the resource use and GHGs is beneficial in building design phase but as the structure influences also to detailing and thus to the whole building, the final optimization and assessment should be based also on the whole building. Design could help save resources by designing dismountable building structures for the reuse after their first lives in less demanding cases.

1.1.3 Building shape

It is known that building shape has an influence on the size of the building envelope, but it also has an impact on the amount of building materials used. This could be expressed as a compactness (shape) index: the smaller the relation of the building surface area to the building volume, the more compact a building is. This index is a useful parameter when comparing the resource use intensity or carbon footprints of buildings with different shapes and volumes. A simplified example shows that the amount of external wall-m^2 would increase 44% just because of unfavorable building geometry. In our case, building with large wooden elements leads to less exterior wall-m2 than other wooden buildings, but shows higher resource consumption and GHG emissions as a higher amount of concrete element is used.

The result shows that resource consumption in a 7-storey wooden CLT-based building is less than 600 kg/gross-m^2 when concrete structures are used for piling, foundations, basement and base floor. When the design solution was based on a high amount of heavy concrete, the resource intensity from wooden frame building was unfavorable and even higher than in concrete element building.

1.1.4 Construction Waste

The main material type in modular box production was CLT, which also causes the main share of emissions. Off-site element production generates a small amount of waste, a substantial part of which is utilized in energy or material production. According to the study, the use of building materials in building construction would increase because of the waste generation by 10–12%, with less prefabrication and especially if waste materials are not utilized. Prefabrication of wooden elements shifts waste generation from the building site to the controlled manufacturing

[3] Ruuska, A., Häkkinen, T., Vares, S. (2012). Puurakenteiden ympäristövaikutukset - laskentatuloksia valittujen rakenteiden osalta http://www.puuin fo.fi/sites/default/files/content/info/rakennetyyppikirjastot/puurakenteid en-ymparistovaikutukset.pdf VTT (2012), 32 s. (in finnish)

process, where waste utilization is easier. Ease of material utilization depends on the material purity level. Both the studied pre-fabrication technologies utilized the wooden materials residues (cuts) by using them for energy production and utilization within the production process, and this was also seen in lower GHG values. However, it is notable that a relatively high amount of waste is generated from gypsum board, which is not suitable for energy recovery.

1.1.5 Building construction

Energy consumption in building construction assessed with the help of three wooden multi-storey element building and four concrete element buildings. The assessment included electricity, district heat and fuel oil consumption from building construction and it is based on the purchased energy bills. Assessment covers buildings with different size where smallest volume was 4700 m3 and highest app. 60 000 m3. According to the result energy content for building construction show small difference between buildings but averagely all was in the same range. Building construction represents the amount of energy which would be needed for the one year operation. The variation would be bigger when extreme prefabrication levels would have been included (100% of on-site production / space element production).

1.1.6 Conclusion

When the GHG is the indicator for resource efficiency, it is important for material producers to improve their production processes in a way that enables the use of wastes or secondary resources. This must be planned carefully, considering any possible effects on service life.

At the end of a building's life, wooden structures and materials might be utilized for less demanding products or for energy production. Material utilization depends highly on the designed solution and construction technology. Moving towards industrialized processes and pre-fabrication of building structures also enables design for dismantling with better possibilities for utilization.
The use of building materials in building construction would increase, because of the waste generation, by 10–12%, with less prefabrication and especially if cuts and waste materials are not utilized.

The study shows that building construction uses averagely energy raw materials in the same amount as building during the one year operation. The result represents element building types but in case of extreme opposites, 100 % on-site construction and highly prefabricated space element, the variation between buildings would have been higher.

Life cycle-based material flow accounting shows that the lightweight nature of wooden structures embodies efficiency in resource use. However, it also depends on building shape, compactness and the type of designed solutions. When the use of other materials is high enough and the building design is not favorable, the final GHG result for the wooden frame building can be on the same level as for concrete buildings.

1.2 Effect of LEAN on energy-efficient multi-storey building construction productivity and cost

The energy Performance of Buildings Directive requires all new buildings to be near zero energy buildings by the end of 2020 (in the public sector by the end of 2018). The national regulations are based on cost optimization within a calculation period of 30 years in the case of apartment buildings. Lean construction is a client-driven process in which the client sets the target-values. Lean construction is a primary way to prevent large amounts of information losses at the interface of planning, factory production and construction. Compared to traditional on-site construction, prefabricated timber solutions require a higher effort for planning and decision making in early project stages; this is also a precondition for successful nZEB construction.

The project process of nZEB in wooden residential building is based on integrated and lean production

- Design (design concepts, process design, product design, detailed engineering)
- factory production (fabrication and logistics)
- construction
- operations and maintenance.

1.2.1 Case

An example of target setting for nZEB and verifications is investigated using:

- Minimum requirements based on the Finnish regulations
- Design targets of nZEB based on target information compiled by the builder and construction company
- Targets of Lean nZEB based on the original design targets and labour productivity improvements as seen potential for lean production
- Construction Lean nZEB values based on realized nZEB solutions with corresponding energy efficiency values
- Phase values based on energy consumption measurements and a user survey.

1.2.2 Conclusions

Lean construction is a collaborative working method and an innovative way to achieve nZEB targets and a good indoor environment. The project process and technological solutions used in both case A and case B were shown to achieve the national nZEB targets.
A target-setting matrix makes it easy to apply individual economical and energy efficiency targets to a project, in order to steer design towards targets and to control energy efficiency in use.

Lean production of cost optimal wooden nZEB causes relatively low additional investment costs compared to construction which only fulfils the minimum requirements set by the regulations. Savings in energy cost are almost 10 €/m²,a and in the annual life cycle cost about 5 €/m²,a as a present value for a calculation period of 30 years. Resale value and user value are also slightly higher compared to the corresponding values of a traditional building. The importance of lean

construction for total investment costs is relatively low, because the share of the labour cost is rather low.
Wooden nZEBs also mean very efficient use of natural materials and non-renewable energy.
It can be stated that the design target of excellent user satisfaction (Thermal comfort, indoor environment, acoustics) is achieved in the Kivistö case.

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Book 7 – part B
resources

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1. LCC on case studies

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CONTENT

1 FCBA Headquarters case study

1.1 Part 1 – General information on the project

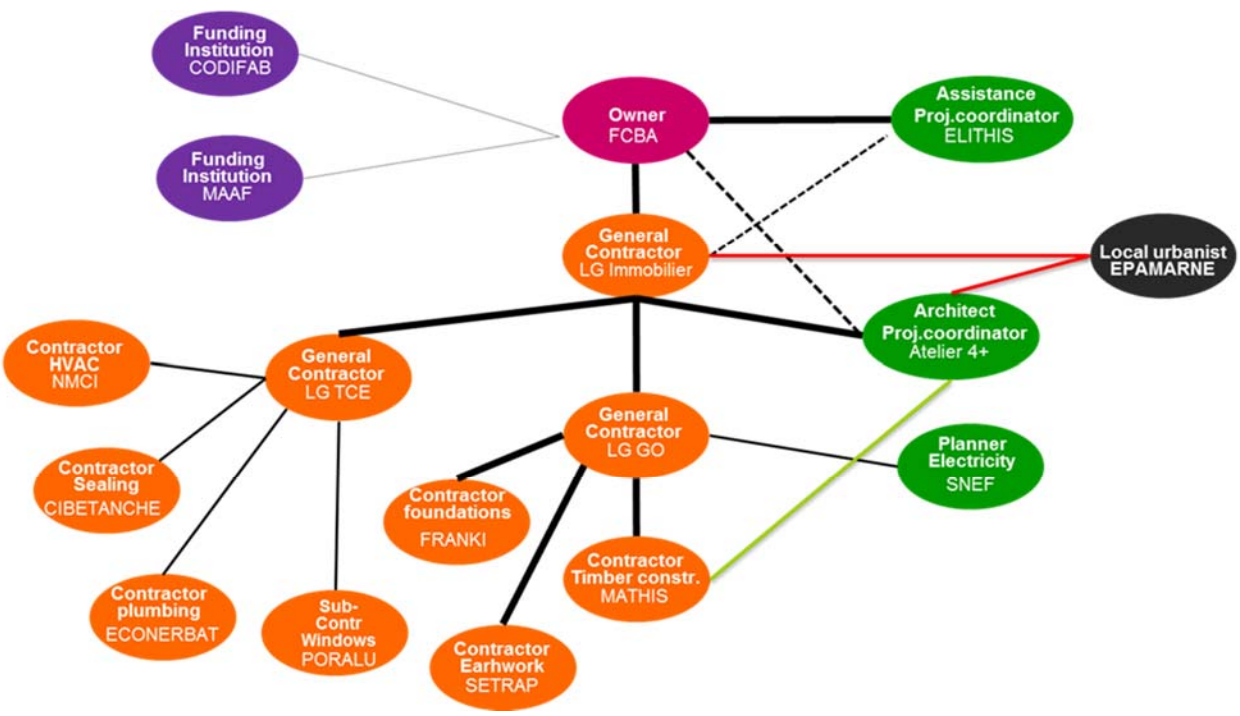
Version 03.03.2015

Project Name	*FCBA Champs-sur-Marne headquarters*
Location	*10 rue Galilée 77420 Champs-sur-Marne France*
Measurement	*New building*
Use of the building	*Office and laboratories*
Gross floor area	*14 000 m² SHOB*
Rentable net floor area	*10 600 m² SHON : 4000 m² of offices and 6 600 m² of laboratories*
Gross Volume	*/*
Height of building	*5 storeys*

1.2 Project participants

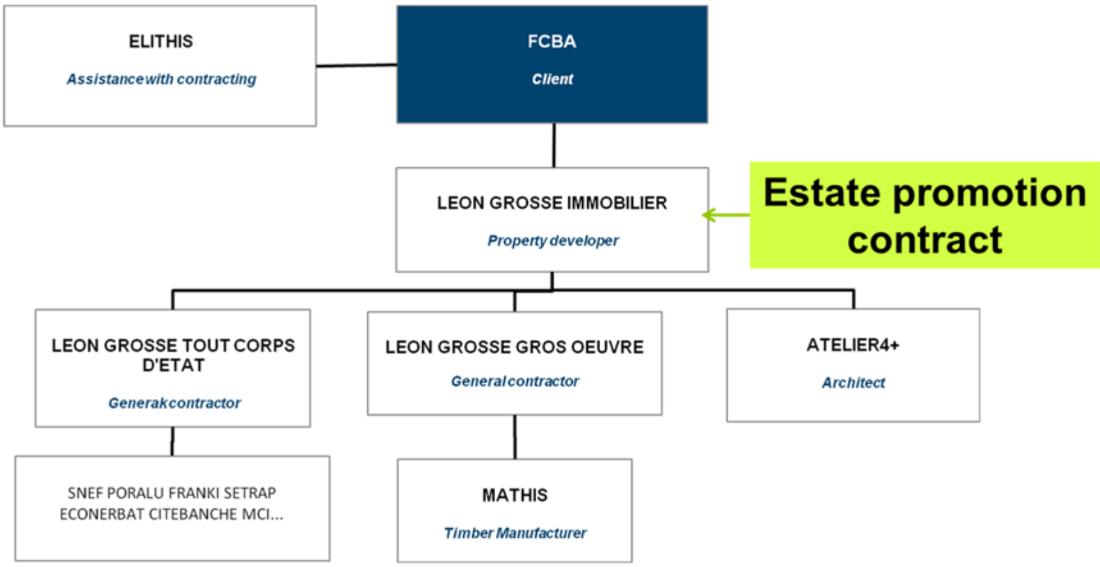
Rôle dans le projet	Nom entreprise	Ville	Site internet	Contact
Client	*FCBA*	*Champs-sur-Marne*	*www.fcba.fr*	*Bruno.piens@fcba.fr*
Entreprise générale / gestionnaire de la construction	LEON GROSSE IMMOBILIER	Versailles	http://www.leongrosse.fr	/
Architecte	ATELER 4+	Lyon	*www.atelier4plus.fr*	/
Ingénieur civil et structurel	LEON GROSSE TRAVAUX	Versailles	http://www.leongrosse.fr	/
Ingénieur bois-construction	MATHIS	Muttersholtz	*www.mathis.eu*	/
Ingénieur des services de construction	/			/
Fabricant bois	MATHIS	Muttersholtz	*www.mathis.eu*	/

1.3 Handling of timber building process



To work on this case study, different interviews were carried out with several actors of the project

- ELITHIS: assistance with contracting
- FCBA: client
- LEON GROSS GROS OEUVRE: general contractor
- ATELIER 4+ : Architect
- MATHIS : timber manufacturer



1.4 Diagram of main actors of the project

Task	Experience
Decision for the project	*It was decided in 2010 to move FCBA's headquarters because even in FCBA owned its headquarters buildings, the land belonged to the French government who needed to get the land back.* *A preplanning process was defined with the general contractor.* *As FCBA is the Technological Institute in France for wood, it was compulsory to use wood in the structure of the building.*
Preplanning / Concept design	*FCBA launched a tender with requirements about the use of wood. The general promoter answered the tender in collaboration with the architectural firm who did not have advanced skills in wood construction. The architect in charge of the answer asked from the beginning to work with a timber manufacturer to answer the tender.*
Planning / Developed design	*The architect and the general contractor worked on the planning and developed design in relation with the requirements of the tender. The timber manufacturer was solicited when needed to confirm options suggested by the architect.*
Detailed Planning / Technical design	*Collaboration architect/engineers/timber manufacturer challenges/good experiences/interfaces*

	The collaboration between the architect and the timber manufacturer enabled the architect to design the building with approval of the general contractor. Once some technical discussion occurred between the architect and the timber manufacturer who disagreed on a technical solution.
Manufacturing	*One contractor (Leon Grossse Gros oeuvre) with subcontractors, in particular for the timber structure and cladding (Mathis)*
Prefabrication	*Timber frame walls were prefabricated*
On site project management	*The project was managed by Leon Gross Gros Oeuvre without specific experience with wood building. Considering the size of the project one person managing the project was not enough (managing both technical and administrative aspects).*
Costing	*The contract with FCBA was a sale before completion transaction (VEFA in French) so the budget was based on the initial program. The final budget is therefore very close to the initial estimation.*
Tender	*The tender specifications mixed both functional and detailed requirements because the building had to house laboratory activities and offices. The use of wood was compulsory so all the answers without specific experience in wood could not be accepted.*
Procurement + Contract model	*The procurement was a sale before completion transaction. There was no Public-Private Partnering but FCBA benefited from public financial support. The estate promotion contractor had 3 main subcontractors, 2 of them being subsidiaries and the third one the architect.*

1.5 Further questions

1.5.1 Forecast planning

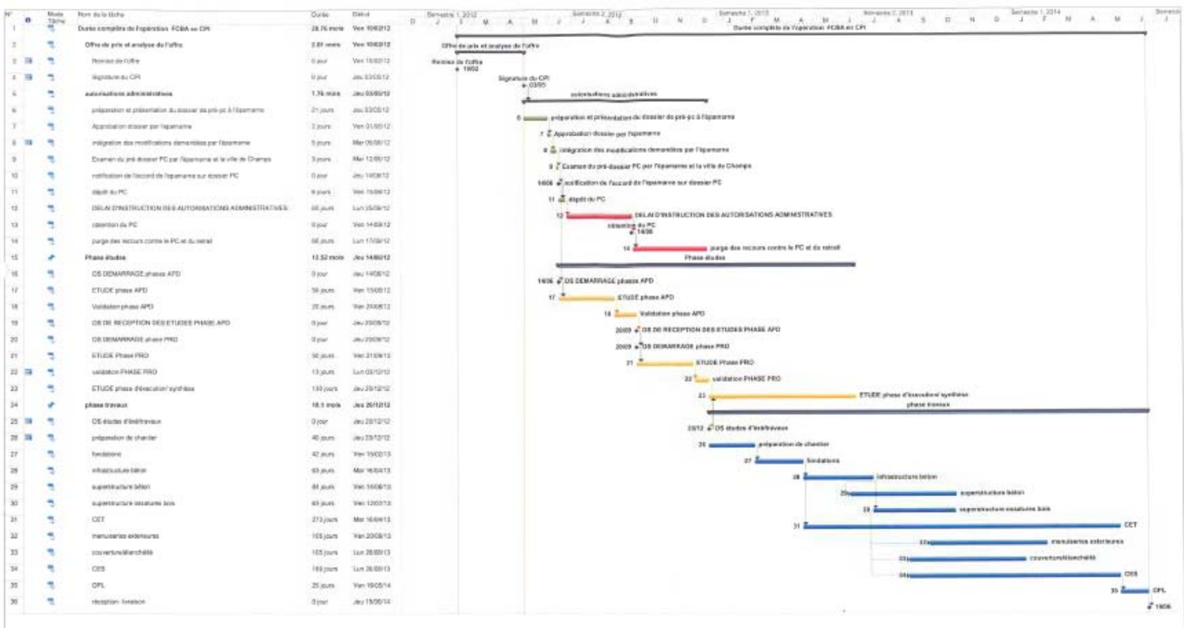


Figure 1 : Forecast planning

1.5.2 According the forecast planning, 2 main delays were identified:

- Regarding foundations: a natural pollution due to green clay was found and resulted in a delay of 5 weeks
- A short delay of 20 – 22 days occurred dur to severe weather

1.5.3 Minor delays

- Drying problem with choice of lasure of cladding
- French larch instaed of Russian larch → necessity to fond sawmills → choice: larch + douglas
- Organizational problem with timber structure company → inadequation between needs and workers (confirmation needed)

1.5.4 Planning - reservations

Lifting of reservations: More than 1000 reservations
On the upstream phases of design, the architect remained in its estimations, despite significant changes in the draft planning. On the tracking of the worksite, however, times were multiplied by 2 or even 3. In the draft planning all the technical parts of the process were not taken into account. The technical rooms were under-dimensioned (underestimation of the density of the networks) and it was necessary to revise upwards everything concerning the network of fluids. The design office of the general contarctor underestimated this part although the specifications were clear enough (machines and power listed). In the end it was necessary to double the dimensions for the technical rooms, to raise certain roofs and to recreate floors. The architect devoted 50% more time to what it was initially estimated on the whole project.

1.6 Feedback regarding the use of wood

- Use of local wood: the client wanted local wood. The difficulty of supplying French larch pushed the general contractor to choose douglas above the 1st floor, with characteristics less interesting than those of the larch. FCBA got involved in the technical choices which raises the question of the client's responsibility in relation with this choices. For Mathis, it was necessary to reword the sections because of the change of essence for douglas-fir is a gnarled wood and more nervous than larch. Moreover, Mathis had to refuse deliveries for quality defects and the quantity of waste was significant. This led to a delay that was all the more difficult to manage because the amendment was requested in a late phase.
- When assembling the wood frame, it seems that MATHIS did not implement the means necessary to respect the calendar and encountered problems for the supply of glued laminated beams. The general contractor had difficulty putting pressure on them because, contrary to other companies, MATHIS was a co-contractor for the general contractor and not a subcontractor.
- 15 French windows needed to be changed after less than 1 year of use of the building. Intermediate crosspieces were necessary but it seems that the architect did not want that solution.

- The specification of the client did not provide a requirement for homogeneous aging of wood in outdoor areas. The architect wanted to show that wood could age properly outside and therefore took this parameter into account from the beginning. Typical facade elements were installed to perform finishing tests. Moreover, efforts were made to protect the wood correctly (metal flap, crowning ...). On the most exposed facade to the west the wood was not used.
- The use of laminated flooring was a real discovery in this project for the architect. MATHIS had enough experience in using this constructive system to reassure the architect firm. They now know how to size the frames and now try to propose this constructive system in other projects. Before wood was mainly used in industrial projects but it is possible to propose laminate in the housing and the tertiary. It has an interesting sound quality which can be enhanced in noble buildings.
- Realization of plans
    - Top floor: On the top floor, as the structural elements are outside, MATHIS feared that the wood would not be adapted to the risks of bad weather and / or infiltration. So MATHIS proposed to the architect to replace the diagonal beams with metal and to retrace these lattice beams. This had the effect of modifying the original design, which the architect refused and the estate promotor feared that FCBA would refuse the substitution of the wood for another material. The compromise found was to replace the wood with metal while remaining the initial design of the architect. These discussions led to successive modifications of plans to achieve the best aesthetic / functional relationship. In the end, when FCBA was actually questionned about that point during the case study, he didn't have any problems with changing material.

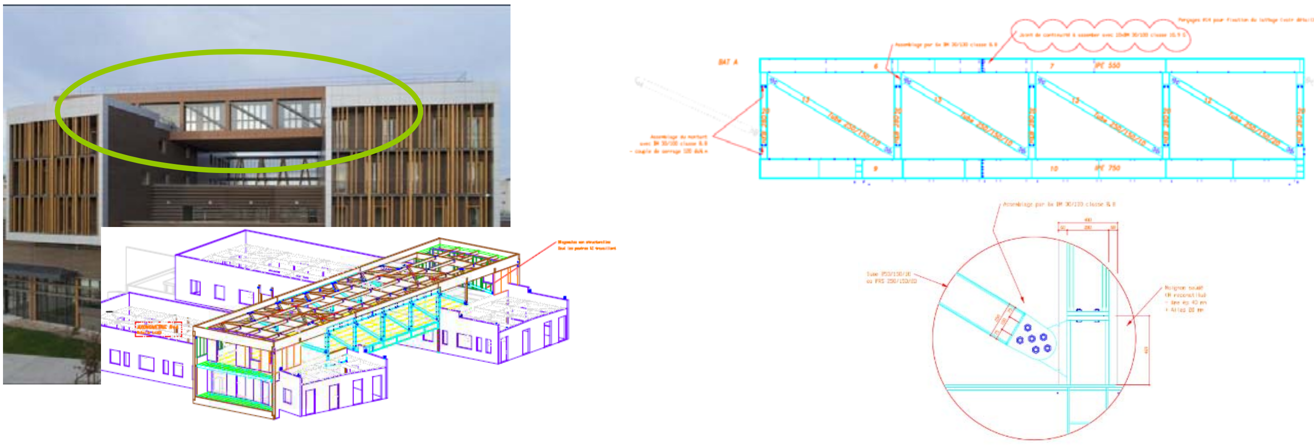


Figure 2: Modifications oft he top floor

- Networks: In the storeys, Mathis had to synthesize the technical batches and the structure batch to allow the networks to pass through the beams. For reasons that MATHIS does not explain, many modifications were requested, in particular for heating / ventilation, and with each new request MATHIS had to redo its plans and take again the justifications for the mechanical strength of the beams after drilling

1.6.1 Relation between actors and planning

In France, companies share the responsabilities of the works done with the project manager. The detailed planning are realized by the companies which can result in modifying the architect's plans.
For the projects, there was no main unconformity between the draft and execution planning. MATHIS and the architect collaborated together directly without exchanging through the general contractor because they already knew each other. But all the subcontractors exchanged with the general contractor who transmitted any useful information to MATHIS.

1.6.2 Checklist of collected documents

Document	Provided	Comment
planning + construction schedule	*Yes*	*Confidential*
Building permit application planning	*Yes*	*Confidential*
Implementation planning architect (floor plans, 1-2 sections, 1-2 elevations, a few details 1:20-1:1)	*Yes*	*Confidential*
Implementation planning structural engineer (floor plans, 1-2 sections, 1-2 elevations, a few details 1:20-1:1)	*No*	
Implementation planning HVAC engineer (floor plans, 1-2 sections, 1-2 elevations, a few details 1:20-1:1)	*No*	
Implementation planning timber manufacturer (floor plans, 1-2 sections, 1-2 elevations, a few details 1:20-1:1)	*No*	
Tender documents timber construction	*No*	
Relevant contracts	*Yes*	
Calculated planning hours architect	*No*	
Real planning hours architect	*Yes*	
Calculated planning hours structural engineer	*No*	
Real planning hours structural engineer	*No*	

Calculated planning, prefabrication + construction hours timber manufacturer	*No*
Real planning, prefabrication + construction hours timber manufacturer	*No*
Images (always deliver images with ready prepared information about copyright, photographer, year etc.)	*Yes*
List of project participants (complete including all companies…)	*No*
Site plan / organization/logistics	*No*

2 LCC

2.1 Introduction

LeanWood LCC –tool is a calculation framework to be utilized in
- Economical comparison of high level of energy efficiency (nZEB) in relation to building regulations
- Economical comparison of lean wooden nZEB in relation to wooden apartment building produced by ordinary ways

It may also be utilized in research purposes but also by companies with the help of their own unit cost information. LeanWoodLCC covers new urban timber buildings in any countries. The tool is based on standard-based LCC methods and tools formulated for comparison purposes.

2.2 Principles of Life Cycle Costing

The Life Cycle costs cover capital cost, maintenance cost and energy costs. The life cycle calculations are done for 30 year period in the case of residential buildings. The following issues are taken into account in the calculations [ISO 15686-5:2008 Buildings and constructed assets. Life-cycle costing]:

• Planning and investment cost covers the design and construction costs being based on either unit cost information given by the user or estimated total cost of whole construction project.
• Financial cost is based on real financial needs given by the user.
• Residual value is directly calculated by LeanWood LCC -tool
• Capital cost (= investment cost + financial cost – residual value) is directly calculated by LeanWood LCC –tool.
• Maintenance cost are based on unit cost information given by the user [National real estate management Files]
• Heating energy cost (€/kWh) based on calculated demands or monitored results, local average tariffs and local average basic fees. The energy source and unit costs are given by the user of LeanWood LCC-tool [EN 15459:2007. Energy performance of buildings. Economic evaluation procedure for energy systems in building].
• Electrical energy cost is based on the local prices (€/kWh). The energy source and unit costs are given by the user of LeanWood LCC-tool [EN 15459:2007].

2.3 Calculation results

2.3.1 Case study: Helsinki

The building (heated area 7 700 m²) was designed and built in 2013 – 2015 by wooden prefabricated apartment modules being located in the city of Helsinki. The client was a public procurer. The delivery method was design-build method, in which the owner provides requirements for the specified project and awards a contract to a company who will both design and build the project. The contractor under contract to the client is responsible for the project's design and implementation as an entity.
nZEB technologies applied in the case study are as follows

- protection towards sun shine
- structures with low thermal transfer and good air-tightness
- effective heat recovery of mechanical ventilation
- energy efficient and smart lightning system

LeanWood Life cycle cost

Definition:
The assessment covers costs because of planning and building, contractor's general cost, VAT (when relevant), financing, maintenance and renewal during calculation period, energy, and residual value

The calculation method for life cycle cost is based on the following standards:
- ISO 15686-5:2008 Buildings and constructed assets. Life-cycle costing
- EN 15459:2007. Energy performance of buildings. Economic evaluation procedure for energy systems in buildings
- FprEN 16627. Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods. 2014
- Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements
- LCC as a contribution to sustainable construction, a common methodology. Davis Langdon Co 2007

Residential building	Unit	Quantity						Guidelines
Inflation factor	Factor	1,02						According to typical national annual inflation rate (100 + inflation rate %)/100
Cost level								
Calculation period	y	30						Typical calculation period in case of residential buildings, also other can be chosen
VAT	%/100	0,24						National VAT %
VOLUMES								
Net floor area	m²	7700						Net floor area of the building
ENERGY EFFICIENCY	Unit	Quantity						
Heating energy	kWh/m2,a	57						As input from energy performance calculation
Cooling energy	kWh/m2,a	0						As input from energy performance calculation
Electric energy	kWh/m2,a	37						As input from energy performance calculation
Price of heating energy	€/kWh	0,075						Local unit cost
Price of cooling energy	€/kWh	0,095						Local unit cost
Price of electric energy	€/kWh	0,095						Local unit cost
COSTING €, €/m²	Unit	Quantity	Unit cost	Total cost	Maintenance period	Maintenance Unit cost	Maintenance cost	
Planning cost	m²	7 700	€/m² or €/m					Estimated total planning cost
Investment cost:								Quantity information from bill of quantities. Unit cost information from local relevant sources.
Contractor's general cost	m²							Maintenance periods: EN16627, EN149:2007, Local standards.
Basement	m²				50			Maintenance unit cost from local information sources
Columns	column-m				Life time			
Beams	Beam-m				Life time			
Internal walls	wall-m²				Life time			
Exterior walls								
Concrete	wall-m²				15		-	
Wood	wall-m²				15		-	
Windows	win-m²				10		-	
Upper floors	floor-m2				15		-	
Heating system								
Connection/Transmitter	m2				Life time			
Distribution	m2				10		-	
Storage	m2				10		-	
Heat pumps	m2				1		-	
Ventilation system								
Air transfer	m2				10		-	
Distribution	m2				1		-	
Water supply system								
Generation of warm water	m2				15		-	
Distribution	m2				10		-	
Water storage	m2				Life time			
Planning and investment cost	€			0				
Alternatively: Planning and investment cost and maintenance as TOTAL value				29 000 000			5 800 000	
VAT	€			6 960 000				
Total investment cost	€			35 960 000				
Financing cost	€			3 500 000				Realistic summarized financing costs with the help of an interest rate calculator
Residual value	€			-10 788 000				The future cost value of facility
Capital cost	€			28 672 000				
Capital cost	€/m²			3 724				
Maintenance cost	€			5 800 000			-	Summary of maintenance cost
Maintenance cost	€/m²			753				
Maintenance cost	€/m²,a			25				
Energy cost								
Basic fees	m2	7700	11	84 700				Local unit costs
Heating energy	m2	7700	128	987 525				
Cooling energy	m2	7700	0	0				
Elecric energy	m2	7700	105	811 965				
Total energy cost	€			1 884 190				
Total Life Cycle Cost	€			36 356 190				
Total Life Cycle Cost	€/m2			4 722				
Total Life Cycle Cost	€/m²,a			157				
Total Life Cycle Cost €/occupant,a	occupant	300	€/occupant,a	4 040				

Table 1 shows the results of LeanWood –LCC –tool for the case Eskolantie calculated for two alternatives as follows: Energy efficiency in accordance with the Finnish building regulations and nZEB.
Table 1. Example of comparison of Life cycle costs based on LeanWood LCC –tool.

Wooden apartment building Calculation period: 30 y Cost level: 6/2015	Unit	Basic	Eskolantie Energy efficient
Net area	m2	7700	7700
ENERGY EFFICIENCY			
Heating energy	kWh/m2,a	80	57
Electric energy	kWh/m2,a	42	37
Price of heating energy	€/kWh	0,075	0,075
Price of electric energy	€/kWh	0,105	0,105
E-value	kWh/m2,a	129	101
Energy class		C	C
COSTING			
Investment cost	€/m2	4 600	4 670
Financing cost		447	454
Residual value	€/m2	1 380	1 400
Capital cost	**€/m2**	**3 667**	**3 724**
Basic energy fees	**€/m2**	12	11
Heating energy	€/m2	180	128
Electricity energy	€/m2	119	105
Total energy cost	**€/m2**	**311**	**244**
Total maintenance cost	**€/m2**	**780**	**753**
Total Life Cycle Cost	**€/m2**	**4 758**	**4 722**
Total Life Cycle Cost	**€/m²,a**	**158**	**157**
Energy class		**C**	**C**

According to the calculations cost optimal wooden nZEB causes only about 70 €/m² additional investment cost compared to the construction alternative that only fulfils the minimum requirements by regulations. Savings in energy cost are about 2.3 €/m²a, and in annual life cycle cost about 1.1 €/m²a as present value for calculation period of 30 years. Also the resale value and user-value (aesthetic value, thermal comfort, high quality of inner climate and good adjustable lightning) are little higher compared to the traditional building. The economic efficiency of energy efficient wooden apartments is improved compared to the basic case calculations (as required by the regulations) in two cases: when energy costs rise and/or the investment costs decrease. The difference between lean production and traditional production is relatively low as the importance of labour costs is minor.

2.3.2 Case study: FCBA Headquarters

The Headquarters of wood technical center FCBA was delivered in October 2014 and is located in Cité Descartes – Champs sur Marne (Paris region – France). The building area is around 10 600 m2 and includes 4 000 m2 of office space and 6 600 m2 of laboratories. 950 m3 of wood were used both for the building structure and the secondary construction (windows, claddings…).
A Life Cycle Cost (LCC) analysis was conducted on 2015 data. The LCC perimeter includes design and construction, operating and maintenance costs. No assumption was made on the residual value at the end period.

Other assumptions on calculations are the following:

- calculation period: 40 years
- discount rate: 4%
- inflation rate (energy/water): 4%

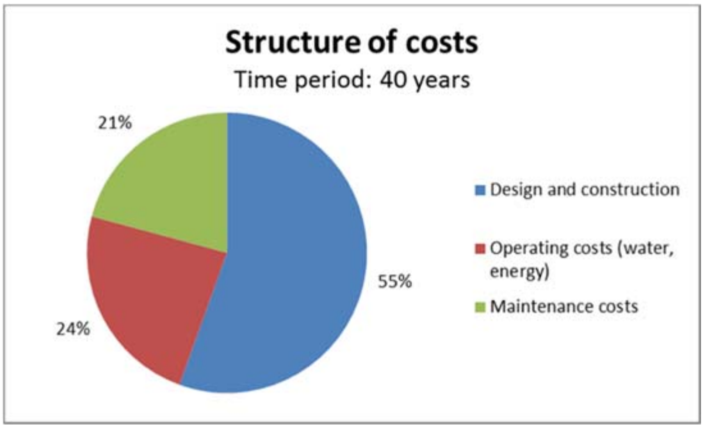
The results are presented in the table below:

LeanWood Life cycle cost

Definition:
The assessment covers costs because of planning and building, contractor's general cost, VAT (when relevant), financing, maintenance and renewal during calculation period, energy, and residual value

The calculation method for life cycle cost is based on the following standards:
- ISO 15686-5:2008 Buildings and constructed assets. Life-cycle costing
- EN 15459:2007. Energy performance of buildings. Economic evaluation procedure for energy systems in buildings
- FprEN 16627. Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods. 2014
- Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements
- LCC as a contribution to sustainable construction, a common methodology. Davis Langdon Co 2007

Residential building	Unit	Quantity						Guidelines
Inflation factor	Factor	4						According to typical national annual inflation rate (100 + inflation rate %)/100
Cost level								
Calculation period	y	40						Typical calculation period in case of residential buildings, also other can be chosen
VAT	%/100	0,196						National VAT %
VOLUMES								
Net floor area	m²	10600						Net floor area of the building
ENERGY EFFICIENCY	**Unit**	**Quantity**						
Heating energy	kWh/m2,a							As input from energy performance calculation
Cooling energy	kWh/m2,a							As input from energy performance calculation
Electric energy	kWh/m2,a							As input from energy performance calculation
Price of heating energy	€/kWh							Local unit cost
Price of cooling energy	€/kWh							Local unit cost
Price of electric energy	€/kWh							Local unit cost
COSTING €, €/m²	**Unit**	**Quantity**	**Unit cost**	**Total cost**	**Maintenance period**	**Maintenance Unit cost**	**Maintenance cost**	
Planning cost	m²							Estimated total planning cost
Investment cost:								Quantity information from bill of quantities. Unit cost information from local relevant sources.
Contractor's general cost	m²		€/m² or €/m					Maintenance periods: EN16627, EN149:2007, Local standards. LT = Life Time (usually 0 years)
Basement	m²			0	50			Maintenance unit cost from local information sources
Columns	column-m			0	Life time			
Beams	Beam-m			0	Life time			
Internal walls	wall-m²			0	Life time			
Exterior walls								
Concrete	wall-m²			0	15		-	
Wood	wall-m²			0	15		-	
Windows	win-m²			0	10		-	
Upper floors	floor-m2			0	15		-	
Heating system								
Connection/Transmitter	m2			0	Life time			
Distribution	m2			0	10		-	
Storage	m2			0	10		-	
Heat pumps	m2			0	1		-	
Ventilation system								
Air transfer	m2			0	10		-	
Distribution	m2			0	1		-	
Water supply system								
Generation of warm water	m2			0	15		-	
Distribution	m2			0	10		-	
Water storage	m2			0	Life time			
Planning and Investment cost	€			0				
Alternatively: Planning and investment and maintenance cost as TOTAL value								
VAT	€			0				
Total investment cost	€			0				
Financing cost	€							Realistic summarized financing costs with the help of an interest rate calculator
Residual value	€			0				The future cost value of facility
Capital cost	€			25 338 000				
Capital cost	€/m²			2 390				
Maintenance cost (alternative as total cost H46)	€			9 501 000			-	Summary of maintenance cost
Maintenance cost	€/m²			896				
Maintenance cost	€/m²,a			22				
Energy cost								
Basic fees	m2			0				Local unit costs
Heating energy	m2			0				
Cooling energy	m2			0				
Elecric energy	m2			0				
Total energy cost	€			10 800 000				
Total Life Cycle Cost	€			45 639 000				
Total Life Cycle Cost	€/m²			4 306				
Total Life Cycle Cost	€/m²,a			108				
Total Life Cycle Cost €/occupant,a	occupant	150	€/occupant,a	7 607				



leanWOOD

Book 7 – part C resources

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1. Lean method – making the value chain more efficient

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Federation of the Finnish woodworking industries (Finland)
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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 What is Lean?

1.1 Lean philosophy

Lean manufacturing or lean production, often simply called "lean", is a systematic method for the elimination of waste within a manufacturing system. In that context, waste is assumed not to participate in the client's satisfaction, not creating any "value" a customer would be willing to pay for.
In other terms, lean is centered on making obvious what adds value by reducing everything else. Lean manufacturing is a management philosophy which roots are very old.

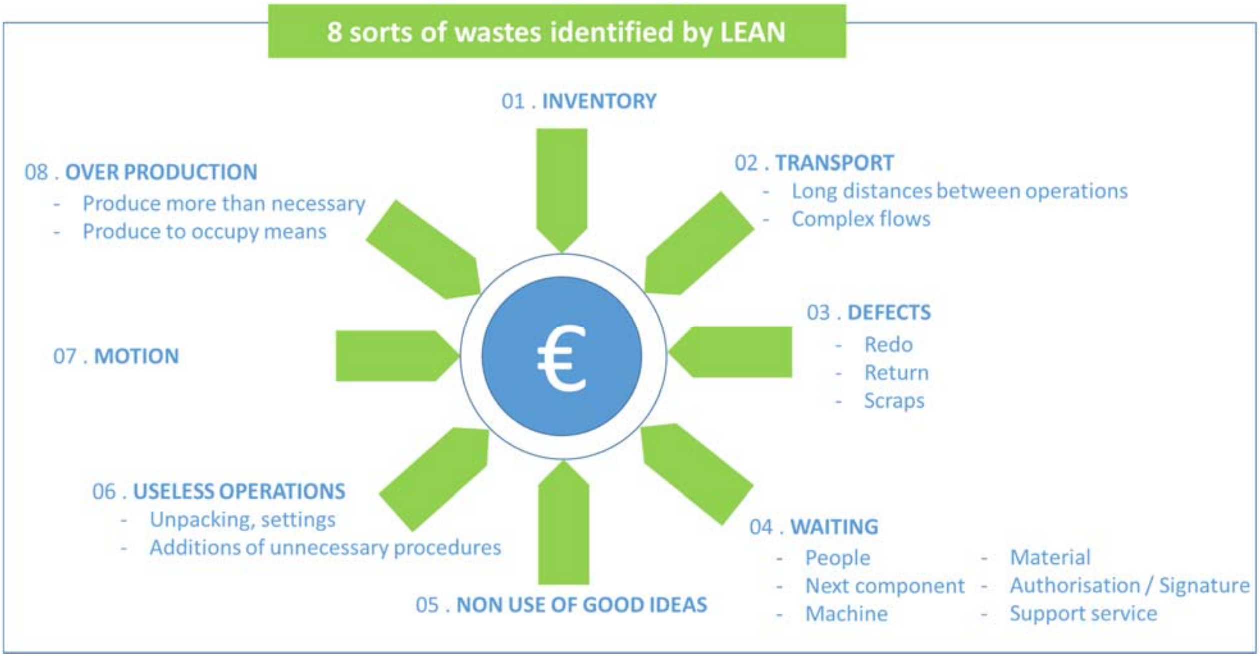


Figure 1 : Sorts of wastes (source: FCBA)

In 1574 King Henry III observes boatbuilding in the arsenal of Venice where boats are assembled in one hour thanks to a continuous flow.

1.2 History of Lean

1.2.1 Henry Ford

Henry Ford in the early 1910's was the first major industrial to try setting up a continuous flow in its production plants, focusing on mass production in order to supply the huge demand of cars that emerged after the Second World War.
In his time, Henry Ford has established several practices that are found today in the Lean philosophy. The Ford standards, in the first half of 20th century, were showing among others, the followings items, which are still relevant nowadays:

- 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.

1.2.2 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, mainly 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 regarded at that time to be at the cutting edge of efficiency. It occurred to him among others that a series of simple innovations might make it more possible to provide both continuity in process flow and a wide variety in product offerings. He therefore revisited Ford's original thinking, and invented the Toyota Production System. In the same period, William E. Deming – statistician at the time but now considered as the father of Quality – worked on the development of a new management system based on eliminating waste through collaboration, participation and employees empowerment…

2 Why Lean in construction?

Franck Gilbreth had already in the 1890s, identified the potential of the building sector improvement if he was 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 paid less) handlers which allowed the trained masons to focus on their added value. Gilbreth developed a series of best practices that reduced the number of movements and displacements from 18 to 4, minimizing thus the fatigue 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 of his wife Lillian, he developed a corpus of knowledge that was to 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 (and published in 2009) 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.
A relatively small proportion of total hours spent on a construction site is really productive. The 1990 report of Michael Pappas noted that in steel construction, only 11.4% of the hours observed on site were creating added value. Hammarlund and Ryden in 1989, then Nielsen and Kristensen in 2001 observed in their turn that the added value operations accounted for only 30% of time spent on site all trades taken together. Lauri Koskela in 1992 examined the application of industrial technologies in

building. Koskela spent a year à Stanford University as a visiting professor and led a now famous 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 makes doubt. 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 cards
2. Implementation manufacturing methods
3. Application of a different management approach (Lean Manufacturing, 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, then Harmond and Peterson’s in 1990 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 resume 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.
Koskela has listed the following heuristic 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 conversation improvements
10. Benchmark.

It should be noted, in connection with these heuristic 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 meeting then 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 term "Lean Construction" was selected, as reminded by Glenn Ballard. Subsequently, Ballard and Howell co-founded the LCI (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.

Efficiency of construction
Lean benefits and drivers
Lean in the construction process

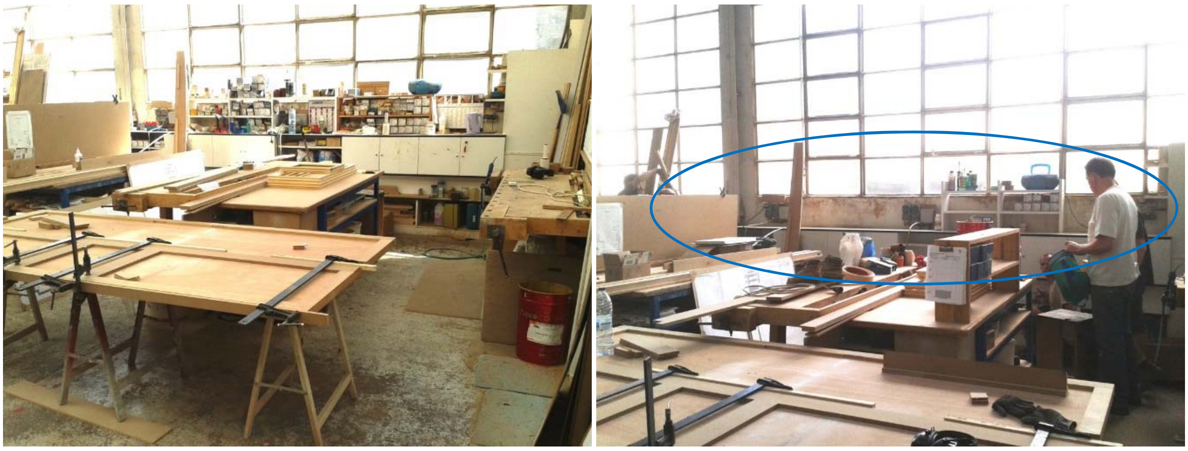
3 Examples of Lean tools

3.1 5S

Among the best practices recognized and put into practice by companies, the "5S" occupies a place of choice. This sign designates both an approach, a method, and the 5 fundamental actions to be carried out. This applies to both industry and service companies. In the construction sector, the 5S can be set up on the site as well as for prefabrication and even design development.

Figure 2 : 5S in five stages

The 5S includes 5 steps and 5 key words which start with an "S" in Japanese:
Sorting (Seiri) – sort out the necessary from the unnecessary.
Simplifying (Seiton) – put everything (that we determined necessary in Sorting) in a designated place and mark it so it can easily be seen.
Sweeping (Seiso) – physically clean up the work area; deliberately pick up all parts and materials that are out of place and return each to its assigned place.
Standardizing (Seiketsu) – create standard ways to keep the work areas organized, clean and orderly, and standard ways to do the 5S's.
Self-Discipline (Shitsuke) – follow through with the 5S's agreements.



Before After

Figure 3 :Example of 5S applied in a furniture company

3.2 Kaizen

Kaizen is a strategy where employees work together proactively to achieve regular, incremental improvements in the manufacturing process. It combines the collective talents of a company to create an engine for continually eliminating waste from manufacturing processes.
Kaizen began its life shortly after world war 2 when the US sent a number of advisers to help the Japanese rebuild their economy; one of these advisers Dr. Deming is often credited with the ideas behind Kaizen stating;" Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs."

What is Kaizen?

- A team to solve problems to the root
- A method to apply the Leann philosophy
- Meaning in Japanese "change for the better"
- Before everything else, a state of mind involving all stakeholders

Main principles

- Team work
- Not to remain in a blocking situation
- Not to freeze on an idea but to accept criticism
- Do not paralyze one seeking a perfect solution
- Explore several solutions (not only the first idea)
- Strong involvement of people (employees)
- Immediate application of patches
- Systematic test after each correction

Important factors

- Clear mandate at the outset and achievable over time
- Management support
- Involvement of key persons
- Quick help for units in need
- Take into account favorable periods
- Big room to meet close of the workplace
- Coordinator mastering the subject
- Actions need to be made during the Kaizen, not after
- Continuous communication between teams, management and affected staffs

To avoid

- Start without the involvement and support of the management staff
- Seek to resolve non-jurisdictional problems
- Misleading or vague terms of reference that may give rise to confusion
- Rush to implement the solution

Starting a Kaizen – Main steps

- Meeting the management (check that everything is under control of that management, otherwise involve other staffs)
- Suggest the Kaizen approach
- Observe on the ground
- Prioritization of action

- Validation of mandate
- Launching and brainstorming

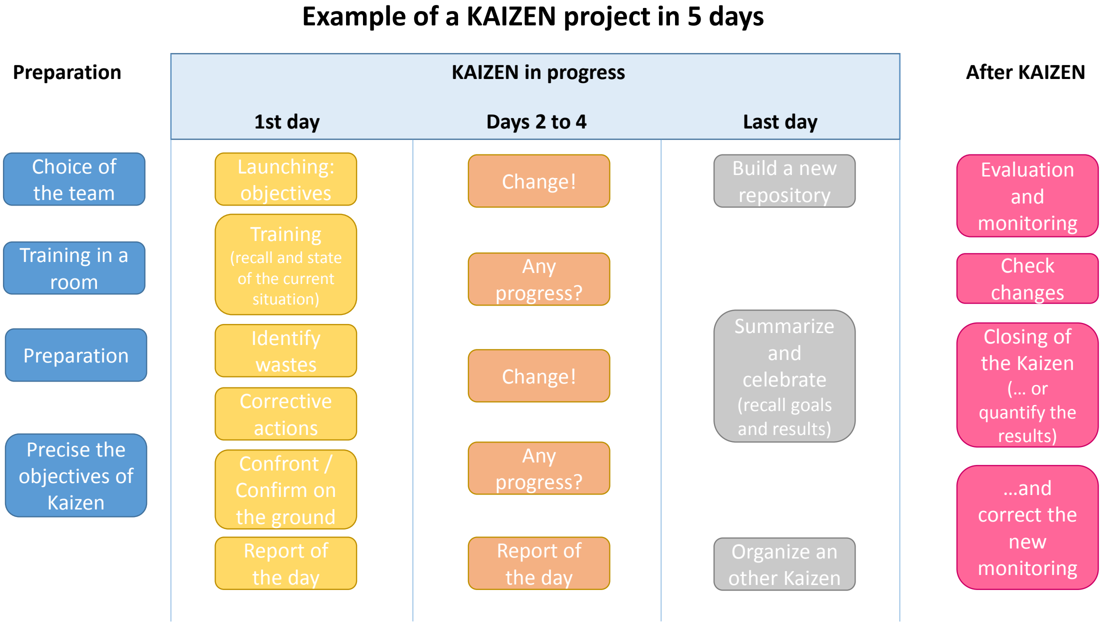


Figure 4 : Example of a KAIZEN project in 5 days

3.3 Value Stream Mapping

VSM is a tool used to visually map the flow of production. It shows the current and future state of processes in a way that highlights opportunities for improvement. VSM exposes waste in the current processes and provides a roadmap for improvement through the future state. It identifies activities that:

- create added value (AV)
- bring no added value (NAV)

VSM can be organized in 4 steps, within a perimeter that starts with raw material and information transformation and that ends with a product ready to be delivered to the end user or final client.
Step 1: define the scope of analysis
According to the needs and problems identified, the VSM tool can be implemented at different levels of an organization:

- Strategic level (macro): whole process, at the scale of one or several companies
- Operational level (micro): manufacturing process of a specific product
- Detailed level: analysis of a procedure or a specific operation.

Step 2: Map current status
On a building site for example, for a process than needs to be studied, the task consists in reporting the operations carried out to realize that process:

- Work time (in seconds)
- Waiting time (in seconds)
- Stocks and materials stored on the workstation
- Handling modes
- Security problems and ergonomic constraints
- Material, human and tool flows.

The mapping of the process distinguishes tasks with added value and those without added value.
Step 3: develop the future state
Once the mapping finished, the main constraints that slow down the flow and/or that do not generate any added value can be modified:

- Move workstations in order to keep only those with added value;
- Remove steps not really essential;
- Optimize flows: standardize, work on zonings, create buffer stocks;
- Set up a visual management in order to master quickly any situation.

Step 4: change the current state in a future state
The working group defines the plan action to set up to transform the current process in the future process. The actions flow directly from the future state defined previously. They are prioritized regarding their impact and the ease of implementation. The project leader coordinates the deployment of the action plan that starts immediately.

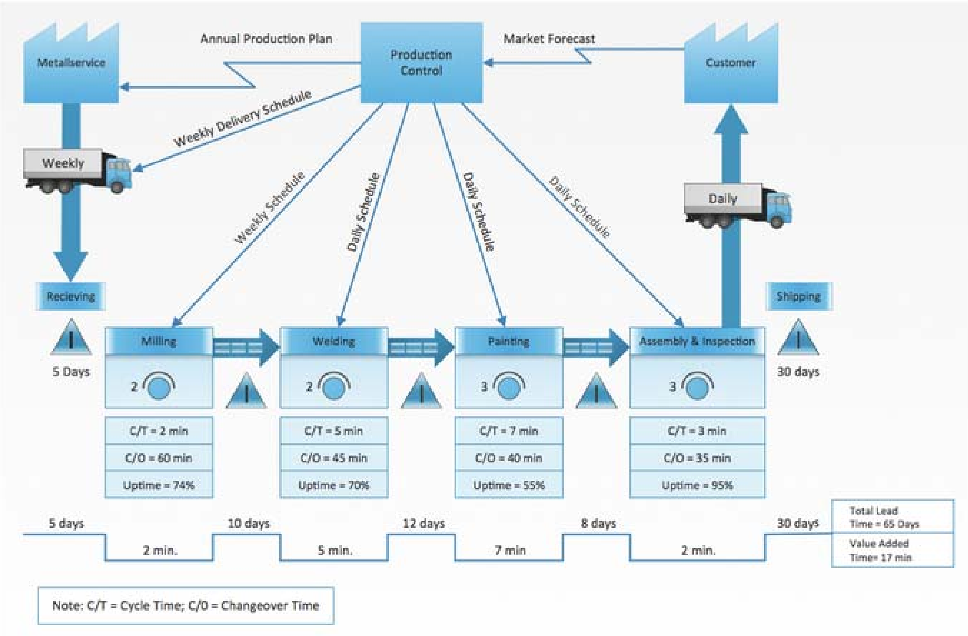


Figure 5: Example, This sample Value Stream Map shows how customer value is created in the steps of manufacturing, production control, and shipping processes (source: Conceptdraw)

3.4 Last Planner® System

Unlike other lean tools used in construction, LPS did not emerge from the Toyota Production System, rather, it was an approach developed by construction practitioners specifically for the construction industry. The initial principles of the LPS were to: (1) improve workflow and (2) improve plan reliability and predictability[1],[2].

The development of the LPS in the early 1990s resulted in the consulting work of Glenn Ballard and Gregory Howell's in the industrial construction section.

[1] Ballard, H.G., (2000). The last planner system of production control. PhD thesis, University of Birmingham

[2] Ballard, G., (1993). Lean construction and EPC performance improvement. In: L.F. Alarcón, ed. Lean Construction. Rotterdam, Netherlands: A.A. Balkema Publishers

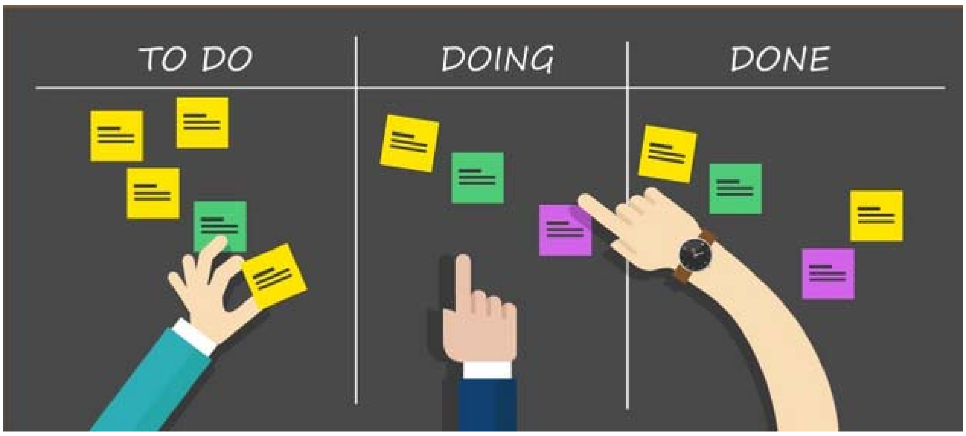
LPS is an easy-to-use, spreadsheet-based tool that is mainly visual and easy to use on site. After a short training, all the companies implicated on the building site define and plan all their tasks on a week basis, over a period of 2 months (organizational checklist).

The LPS is a production control system in which the "last planner", that is, the one who performs the last task, is in the best position to inform about the possibility of a planned job. This feedback is crucial in guaranteeing the performance of a given task. If it is planned in the overall planning (should be done) and everyone has verified that it could be done, then there is no reason (except hazards) that it can't be carried out.

5 steps of LPS		Reliability
Master schedule	Classic planning (structure and/or hinge) with identification of milestones and construction sequences	40 – 50%
Phase planning	Development of the sequences and compression of the schedule with all the participants for the 3 or 4 me to come	50 - 70%
Look Ahead Planning	Team planning for the next 6 to 12 weeks Identification of constraints, definition of the actions to be carried out	70 - 90%
Production Planning	Detailed planning by the "last planners" Only activities without any constraints / barriers	90 - 100%
Analysis of PPC (Percent Plan Complete)	Identification of the reasons for failures Continuous improvement through PPC	

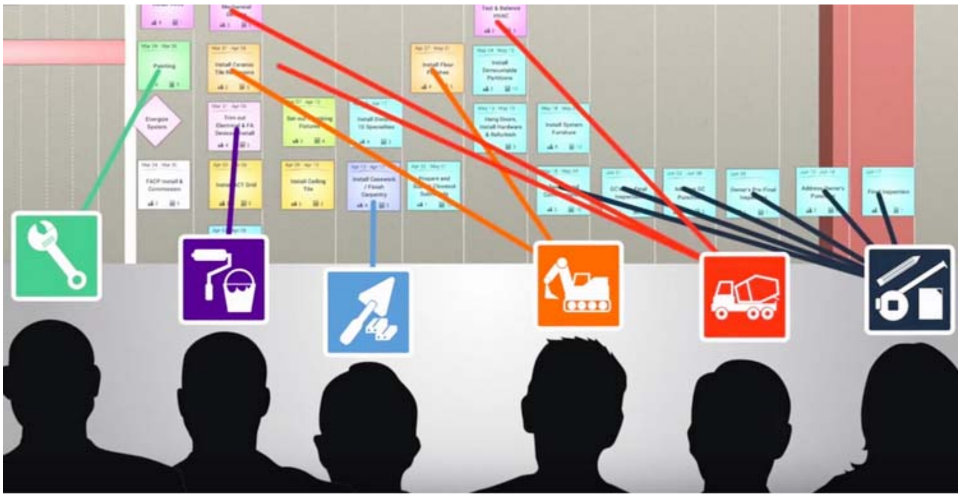
LPS is based on 4 pillars:

1. Participatory planning: the one who does the work is the one who makes promises (estimated time and cost, quality to be delivered and milestones to be respected). If a promise can't be held, then it should not be made. This implies that each actor has the ability to say "no I can't".



Participatory planning (source: www.leanconstructionblog.com)

2. A collaborative definition of the inputs and outputs delivered by each bed officer is required for each work package (to avoid unnecessary expectations due to misunderstanding of requirements and interdependencies).



Collaborative definition of inp (Source: https://www.touchplan.io/)

3. The "last planner" is directly responsible for the monitoring and control of his work. If a promise can't be met, a cause tree will be established to deal with the sources of pollution and desynchronization and prevent them from becoming recurring.
4. Frequent meetings to share "what remains to be done" in real time are needed to adapt, collectively and at the same pace, to inevitable changes during the project (the impact of changes on inputs and outputs is known to all, and continuously).

What LPS changes

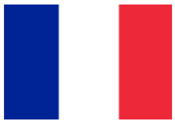
Traditional planning	Last Planner® System
- Planners plan and doers do - Thermostat model of control (reactive) - Inconsistent learning from plan failure - Scheduled tasks are pushed onto does without regard to readiness - It is assumed that planning produces perfect plans	- Planning is done collaboratively - Control is proactive (making ready) and reactive - Systematic learning from plan failure - Doers are required to commit only to ready tasks - It is assumed that all plans are forecasts and all forecasts are wrong

One main principle of LPS is that it Strengthens collaboration by bringing together all the companies around the planning and identify the blocking points in advance to coordinate the work of companies in space and time.

4 Case studies

Many examples of companies who have engaged Lean projects exist. In the sector of construction, most examples are related to big companies and very few are specific to wood construction. The following examples focus on wood construction companies.

MINOTCi
INDUSTRIEL EN CHARPENTE BOIS



Number of employees: < 50
Turnover (2015): 5,5 M€
Part of a group of: 230 employees, 30M€
Example of characteristic products:

- Light frame truss (70% of production)
- Traditionnal carpentery

1. On what perimeter was LEAN implemented?

☐ The whole company ☒ Part of the company: production of light frame truss

2. For what reasons did the company started implementing LEAN?
   - o Optimisation of the production line
   - o Search of better productivity
   - o Market benchmark

3. When did it start?
   The Lean initiative started in 2012 and implemented in 2013. The approach led to several decisions, some of which are still operative: hiring a team leader, material investment (stacker), 5S at the workstations, flow management. On the other hand, others were not maintained, for example mutual assistance at the workplace

4. What tools were used?

☒ 5S
☐ PDCA
☐ VSM
☐ Kaizen
☒ Visual management
☐ Kanban
☐ TPM
☐ 6 Sigma
☐ Gemba Walk
☒ SMED
☐ Poka-Yoke
☐ Other (precise)

5. What were the different steps and methods used to implement Lean tools?

Several training sessions were organized and the company was accompanied by an expert to:

- Identify “non added value” at different workstations
- Diagnosis to identify what was already in place in the company
- Follow production indicators and communicate on these indicators
- Implementation of the action plan

In took 6 months between the kick-off and the first results.

6. How did the employees react to changes implemented by Lean?

Generally speaking the employees reacted well; they were open to changes aiming to improve working conditions. The project was guided by a pluridisciplinary team: general and production management and 2 operators played the role of relay to their colleagues. The focus was put on the improvement of working conditions. Productivity was a second argument explained afterwards to the employees.

7. What were the evolutions/results obtained? Did you have indicators to follow?

The company identified to main evolutions:
- the weekly communication on productivity indicators (productivity / absenteeism and work accidents / budget compliance scheduled hours) which allow a real-time return on performance and a better projection regarding the organization to come
- the hiring of a team leader
- the introduction of a productivity bonus

8. Did you identify any limits to Lean?

What’s most interesting is the philosophy behind the Lean word, and the “hunting of non added value”. But we had to hire a team leader to achieve our results. The figures show now that the initiative was beneficial.

9. What advice would you give to a company who wants to implement Lean in its activity?

The major success factor is to implicate the employees from the very beginning of the project.
Impliquer le personnel, l’intégrer à la démarche dès le départ. Le personnel est force de proposition.
Pointer les aspects concrets (conditions de travail, tâches inutiles, …).

Number of employees: < 50 (17)
Turnover (2014): 3,7 M€
Part of a group of: <50 employees, 0,5M€
Example of characteristic activities/products:

- lumbering
- sawmill
- parquet flooring

1. On what perimeter was LEAN implemented?

☒ the whole company ☐ Part of the company

2. For what reasons did the company started implementing LEAN?
   - o Optimisation of production
   - o Produce more with the same number of employees but without working more hours
   - o

3. When did it start?

The Lean projet was carried out in 2012 – 2014. Several aspects of the projects still remain today: display and sharing of information, production scheduling

4. What tools were used?

☐ 5S
☐ PDCA
☒ VSM
☐ Kaizen
☒ Visual management
☒ Kanban
☐ TPM
☐ 6 Sigma
☐ Gemba Walk
☐ SMED
☐ Poka-Yoke
☐ Other (precise)

5. What were the different steps and methods used to implement Lean tools?

We started with a training session of 2 days and then an expert from the French National Association of Standardization (AFNOR) followed our progress.

6. How did the employees react to changes implemented by Lean?

At the very beginning the employees asked questions about the final foal of the approach. Today, they are quite satisfied about what was achieved and what is still applied.

7. What were the evolutions/results obtained? Did you have indicators to follow?

Productivity has indeed increased, as well as our reactivity. However, the global context of the company changed a lot between the beginning and the end of the approach so it is difficult to clearly identify the benefits of this Lean approach. Besides, it enabled us to achieve other results that were not identified at the beginning like a better use of some machines and a better management of bottleneck.

8. Did you identify any limits to Lean?

Applied to our context, we didn't see any limit.
Non, pas trouvé de limite par rapport à leur situation.
Méthode applicable chez eux quel que soit le nombre de salariés.

9. What advice would you give to a company who wants to implement Lean in its activity?

A lean approach offers a different vision of your organization. Communication is a key issue. In our project

Between 2012 and 2014, AFNOR (French Association of Standardization) helped Burgundy (French region) companies of the wood industry to implement Lean management in their activities. The objective of this collective program was to help the participants rethink their organization, to implicate the employees, reduce useless costs, master time and satisfy customers, while improving working conditions.

Number	Employees and turnover	Main activity	Actions	Results
1	98 employees 15 M€ (2013)	Lumbering	- Implementation of ritual management - Creation of working groups - Control of production with relevant indicators - Computerization of production	- Productivity gain - Fluid communication - Approach to decision-making
2	103 employees (81 handicapped workers) 2 M€	Carpentry, green spaces, cleaning	- Build skills in lean tools - Better organize production - Improve ergonomics - Improve production operations - Better identify the status of a product	- Improvement of manufacturing times - Federative approach
3	38 employees (34 handicapped workers) < 1 M€	Carpentry, conditioning	- Improve inventory management - Improve production flows - Train staff - Map the organization	- Support for change - Questioning of production practices - Restore meaning to work - Putting the client at the heart of the work

			- Define the goals to achieve - Revisit existing practices	
4	15 employees 4 M€	Flooring	- Identify blockings and bottlenecks - Establish follow-up tools and indicators - Reliability of production	- Reduce the failure rate - Better decision-making - Optimize the implementation - Rethinking all material flows
5	33 employees 6 M€	Light frame truss	- Involve local management - Appropriate new methodologies (5S, asset management) - Set up the proximity Skills - Invest in suitable equipment	- Removal of repetitive and physical tasks - Creation of emulation within teams - Exceeding budgetary targets
6	62 employees 12 M€	Second transformation of wood	- Improve the organization - Gain visibility on production - Identify productivity gains through a cost analysis	- Creation of a driver position - Rationalization of production on Operations with higher added value - Improvement of working conditions (Cleanliness, storage and circulation)

Arbonis was created in 2015 after the leader VINCI (1 400 M€ turnover) redeem four production units in France that produce glulam and timber frame construction. It now count more or less 300 employees with of turnover of 44 M€. There are four design offices and therefore it became quickly difficult to share information. According to the market conjuncture, prices are a fixed parameter. Therefore in order to achieve savings the first reflex was to optimize purchases and then workforce. So afterwards the only way to pursue efforts was to identify waste. This is how the Lean initiative started.
In our approach, Man is in the heart of the system and the first step was to transpose the general philosophy to the company’s culture.
In took 3 months to set up the lean program:

- Accompanying change: to make employees understand that we are in a continuous process and that we are obliged to progress (PDCA), improvements must be supported by standardization
- Common culture of quality, supported by tools: use of the 5S tool
- Process control: use of tools like AMDEC and VSM
- Planning control: LPS

Implementation of tools
5S
The 5D tool was applied to 3 manufacturing workshops, each on one plant.
In order to allow the 5D tool to be implemented easily and to be adaptable, the company has defined 3 code colors corresponding to frequencies of actions (example: the blue code means "daily" associated with the "sort" step applied to slings, which means that the slings must be evacuated daily. The pilot projects were carried out by workshop managers who became autonomous in the process.
VSM
This involves identifying the strengths and weaknesses of an industrial process at each of its stages.
LPS
With this method, the last intervener gives his need and the chain above him adapts itself to respond these needs. We talk about need and coherence between tasks, which makes it possible to define critical paths and to define a planning.