LEAN PRINCIPLES AND THE CONSTRUCTION MAIN FLOWS

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ABSTRACT

This paper will discuss the five lean principles (value, value stream, flow, pull, perfection) and some specific construction characteristics, proposing three main flows for the analysis of construction: business, job site and supply flows.

In manufacturing, the three flows (from order to cash, from concept to launch, from raw materials to customer) can be well characterized inside one plant, inside one corporation, or within the total value chain. Considering the total value stream in construction, "from order to cash" has an strong interface with the cycle "from concept to launch". This cycle was named "Business Flow", or "from business concept to keys delivery", and includes the design flow as a sub-flow. The "raw materials to customer" main cycles are: the "Supply Flow" (within the total value stream) and the "Job Site Flow" (door to door on a job site).

KEY WORDS

Lean principles, flow, lean construction.

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INTRODUCTION

Lean Thinking was born in a manufacturing environment, and its diffusion is growing in different economic sectors. Several authors have focused on the interpretation of this approach for the construction sector (Koskela, 1992; Egan, 1998; Howell, 1999; Tommmelein, 1999; Vrijhoef and Koskela, 1999[2]). and its discussion is a permanent need. This paper intends to discuss Lean principles and some specific construction characteristics, and to propose three main flows for the analysis of construction: business, job site and supply flows

In manufacturing companies' design, production and sales are often managed inside one corporation. Generally in construction, the value stream involves several companies, with different roles, as designers, developers, general contractors, real estate companies, etc. A large amount of waste in the value chain is due to lack of coordination among these agents. The identification of the main flows and its leaders is very important, to understand the cooperation that is necessary for the lean transformation.

This paper will follow five Lean principles, proposed by (Womack and Jones, 1996), (Womack, 1999):

- **Value**: specify and enhance value
- **Value Stream**: identify the value stream and remove waste
- **Flow**: make the product flow
    - From order to cash
    - From concept to launch
    - From raw materials to customer
- **Pull**: let the customer pull
- **Perfection**: manage toward perfection

VALUE

Specifying value and enhancing value for the client needs the understanding of who are the direct clients and the final clients, for each company.

In construction, the customers or final clients are the users of the building (or of the infrastructure, for ex. a road). In general, there is an institutional owner (shown in Figure 1, left - Institutional Market), that identifies needs for new buildings, plans and contracts its design and construction. Examples of institutional owners are: a Hotel Chain, that needs a new hotel, a Government Ministry, that needs a new school, a Company that needs a new office building, etc.

In the development market (Figure 1, right) the user buys a building or an unit in a building. For example, a company that buys a new office or a family that buys an apartment. The user is the client of the developer; the developer is the client of the general contractor, and so on.

[2] For comprehensive literature see IGLC Conferences 93 – 99.

Each company has its direct client (who contracts and pays), but all value chain participants have as final client the user. This is not evident, mainly in institutional market, because the user doesn't buy the building, but pays for the service that is provided in that building.

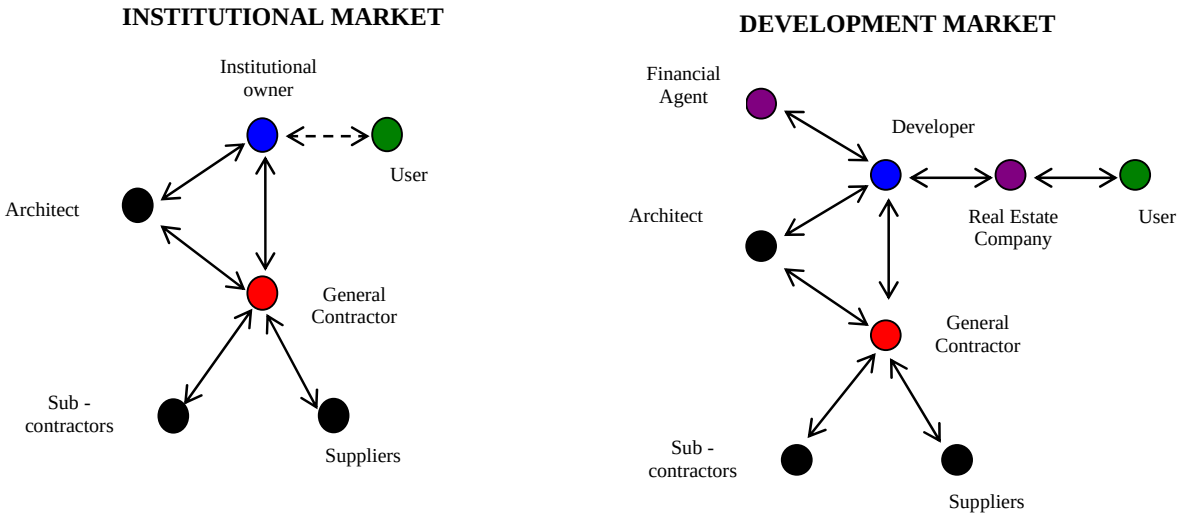

Figure 1 - Main agents' relationships and user as final client in the construction value chain

VALUE STREAM

In construction, several participants have influence over the project, mainly:

- Users;
- Owner;
- Developer;
- Real Estate companies;
- Financial Agent;
- City Agencies;
- Designers;
- Management and control company;
- General Contractor;
- Sub-contractors;
- Materials Suppliers;
- Equipment Suppliers.

For the same kind of construction and owner, the participants arrangement vary, depending on the country, region, market, etc. For example, the sub-contractors can be contracted by the general contractor, or directly by the owner; the designer (Architect) and General Contractor can be the same company. In Brazil, several companies are a combination of developer + general contractor (in Annex 1 an example of value chain is shown).

In each case, the actual value stream must be mapped, and some typical arrangements can be identified. Examples of kinds of construction and usual clients are shown on Table 1. Each kind of construction with specific technology can be understood as a product line (ex.: apartment buildings with steel structure and apartment buildings with reinforced concrete structure can be considered different product lines, for a General Contractor).

A strong cooperation among all chain participants is very important, mapping the whole value stream, identifying waste and eliminating it, improving the way constructions are planned, contracted, designed, constructed, delivered, sold, etc.

Table 1 - Examples of kinds of constructions and usual clients (general contractor as supplier).

Classification	Kind of construction	Usual Clients
Buildings	Factories	Companies
	Office Buildings	Companies
		Developers
		Government
	Apartments	Developers
		Social Housing Agencies
	Houses	Families
		Developers
		Social Housing Agencies
	Special buildings (Hospitals, Schools, Hotels, Shops, Malls, Theatres, etc.)	Companies
		Government
	Renovation and maintenance	Government
		Companies
		Families
Infrastructure	Roads.	Government
	Bridges	
	Public sanitary services	
	Dams	
	Others	
	Maintenance	

FLOW

MAIN FLOWS IN CONSTRUCTION: BUSINESS, JOB SITE AND SUPPLY

In manufacturing, the three flows (from order to cash, from concept to launch, from raw materials to customer) can be well characterized inside one plant, inside one corporation, or within the total value chain. In Construction, each flow meaning must be interpreted, depending on the participants roles in the value stream. Examples of interpretations are shown in Table 2.

Table 2 - Flows interpretation for construction

<table>
<tr><th rowspan="2">Flow</th><th colspan="6">Inside one Company (door to door)</th><th rowspan="2">Involving more than one Company (within the total value chain)</th></tr>
<tr><th>Owner</th><th>Developer</th><th>Designer</th><th>General Contractor</th><th>Sub-Contractor</th><th>Supplier</th></tr>
<tr><td>From order to cash</td><td>From the construction decision to the building operation</td><td>From sales to cash</td><td>From proposal to cash</td><td>From proposal to cash</td><td>From order to cash</td><td>From order to cash</td><td rowspan="2">From business concept to keys delivery (BUSINESS FLOW)</td></tr>
<tr><td>From concept to launch</td><td>From needs identification to completed design</td><td>From market research to sales</td><td>From contract to design delivery</td><td>-</td><td>-</td><td>From concept to launch (product)</td></tr>
<tr><td rowspan="2">From raw materials to customer</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td>From soil preparation to finishing</td><td>From materials reception to finished work</td><td rowspan="2">From raw materials to delivery in job site (SUPPLY FLOW)</td><td rowspan="2">From raw materials to customer</td></tr>
<tr><td colspan="2">(JOB SITE FLOW)</td></tr>
</table>

Considering the total value stream, "from order to cash" has an strong interface with the cycle "from concept to launch". This cycle was named "**Business Flow**", or "from business concept to keys delivery", and includes the design flow as a sub-flow. The Owner (or Developer) leads this cycle. The "design flow", lead by the Architect, is one of the most important flows, and it is considered inside the "business flow" just because of their strong relationship.

In this proposal, the "raw materials to customer" cycle is divided in the "**Supply Flow**" and the "**Job Site Flow**" (door to door on a job site), both led by the General Contractor. Figure 2 shows an integrated view of the main flows in construction, proposed in this paper.

The author believes that differences among these flows nature must be considered, for a deep study of mapping and lean principles and tools application. The business flow is mainly an information flow, that deals with contracts, specifications, plans, controls, etc., with an specific relationship among participants (shown in Annex 1). The job site flow is an information, products and services flow, in an environment different than manufacture. The supply flow involves industrial and not-industrial products, and is similar to the supply chain in any other sector. Considerations about specific construction characteristics in these three main flows are presented below.

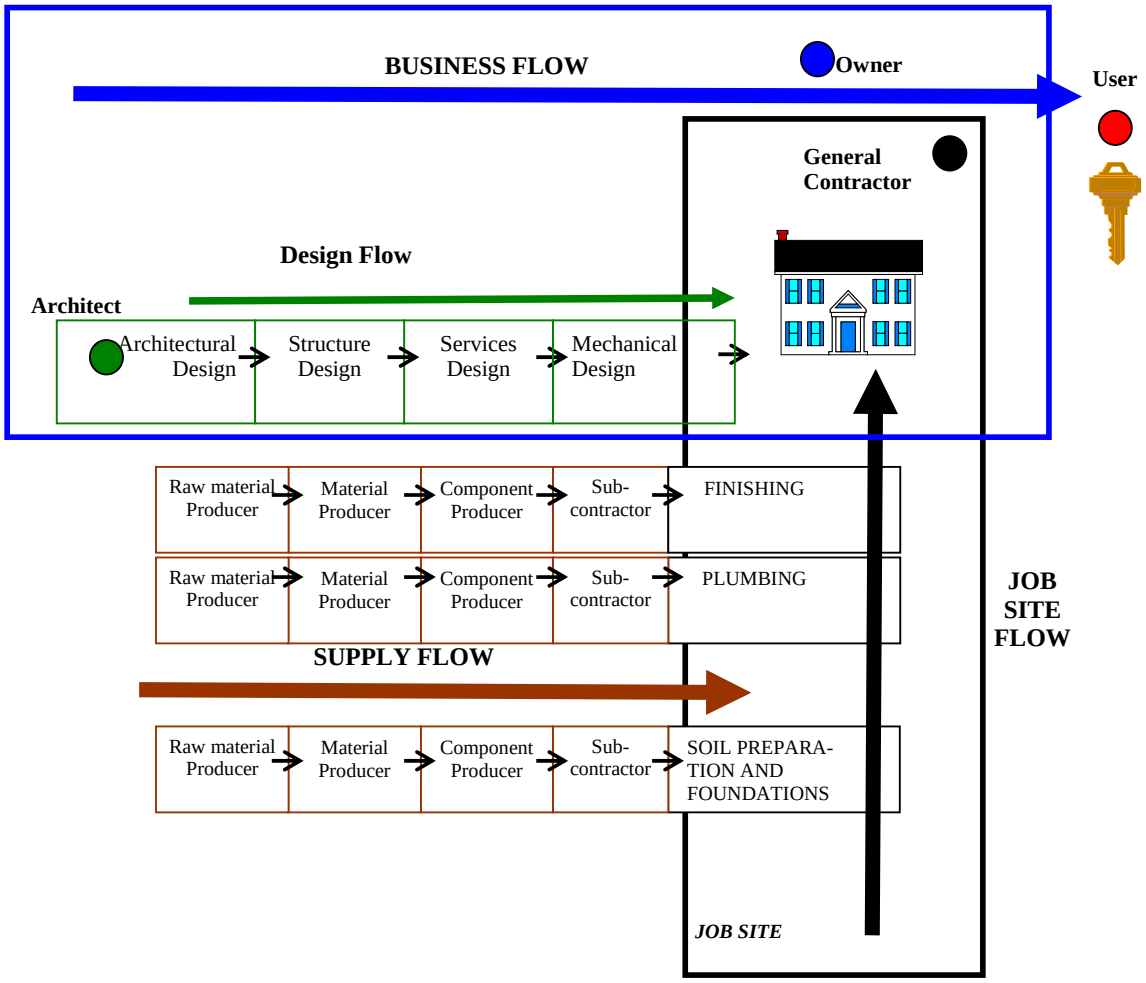

Figure 2 - Flows in construction

BUSINESS FLOW

The project generally has as main participants: the owner, the architect and the general contractor. The Business Flow represents the relationships among these participants, since the needs identification, by the Owner (or Developer), the Architect contracting, the General contractor contracting (what depends on designs), sales (for developers), the construction monitoring, reaching until the keys delivery (this flow could be extended, to include maintenance).

The project duration and construction rhythm is determined by the Business Flow, and has great impact in indirect costs. These costs (job site administrative team, rented equipment, etc.) are important in construction, varying, for example, from 10% to 25% of total construction costs in Brazilian situations. Lean approach applied to Business Flow (including other chain participants, for example financial agent, city agencies, etc.) and applied to Job Site Flow could reduce construction project lead time, decreasing wastes produced by indirect costs.

Within the Business Flow, the architect, with the participation of specialized designers coordinates the Design Flow. In a manufacturing company, generally the concept / design and production are done in the same corporation. In construction the situation is more complex: the General Contractor is in charge of production, and design involves different agents:

- the owner defines the project briefing and contracts an Architect;
- the Architect contracts other designers (structure, plumbing, etc), or the owner contracts them directly;
- shop drawings are done by suppliers (ex.: steel structure, windows);
- the design must be approved by city agencies, with rules that vary from city to city; the approval generally demands a long time.

In general, there is a lack of coordination, which causes long development duration, delays and quality problems.

JOB SITE FLOW

In manufacturing, flow mapping and future state drawing is recommended to start at a single plant, one product family, door to door. The equivalent in construction is to start at one job site, but it is important to consider:

- The influence from the value chain participants is stronger in construction than in manufacturing. Ex.: waste reduction on job site is limited, without considering sub-contractors coordination improvements, design details changes, etc.
- Job site activities are seen as specific for each job site and not repetitive, what is a barrier for improvement investments. In fact, several works are repetitive on one job site, and all the production process is repeated for all similar constructions (different design, but the same production phases). The analysis may start in one job site, but should look for improvements in the company production process, common for the product line (all cotruction sites of a specific kind, medium size office buildings, for example).

In manufacturing, there is a technology global standardization, while the construction technology vary among countries, regions, kind of construction and companies. Technology plays a great role, stimulating or blocking flow. The structure, for example, can use different technologies - steel, concrete (slabs, columns and beans, with wood or steel formwork), concrete (prefabricated), bearing walls (concrete block), wood frames. Each of them has different processes, working sequences, suppliers and sub-contractors, and different interfaces with all the other components in the building (partitions, services, finishing, etc). Each of them contains aspects that make easier or more difficult to establish the flow.

Several works on construction can be classified as “handcraft”. For decades, efforts have been done, towards the “industrialization” of construction, taking mass production as the model. Some concepts, as pre-assembly and light prefabrication, are useful to create the flow, and can be used in a pulled system, instead of a large batch system (which they were designed to).

SUPPLY FLOW

The Supply Flow is composed of several sub-flows, each of them for one building sub-system (structure, plumbing, etc.). The supply chain is complex, demanding natural products such as sand, rock, timber, as well industrialized components such as panels, windows and air conditioning devices, and job site equipment (cranes, etc.). These products are purchased from producers, dealers, shops, and sometimes from sub-contractors (work and material contracted together, authorized installers for specific components, etc.).

The purchasing process, from order to delivery, takes months in some cases. Delays are frequent (one of the major reasons of low productivity is delayed materials delivery), and occur due to different problems: delay or mistakes in design details and specifications, late job site request (poor programming), purchase process bureaucracy, supplier delay, etc. This problem is critical for components manufactured by order to an specific building (steel structure, concrete pre-fabricated parts, some windows, etc).

As in manufacturing, suppliers’ involvement is fundamental, for the Lean transformation.

PULL

Owner contracting policy is an important issue that requires detailed analyzes. Some private and governmental owners have a permanent demand, but in general they demand constructions in an erratic rhythm, with great losses in the value chain. Housing, for example, has a permanent demand, but generally contracting shows peaks and valleys, due to discontinuity of Governmental Housing Agencies policies, macroeconomic conditions, etc.

In theory, the Business Flow "pulls" the Job Site Flow, that "pulls" the Supply Flow (shown in Figure 2). In fact no flow is seen in most job sites.

General Contractor purchase policy generally pushes large batches into the job site, trying to avoid delays and lack of material. Lack of coordination in the three flows results in frequent work discontinuity.

The "push culture" is also present in development. The Developer identifies market needs, plans and contracts the construction. After some months (or years) the product is "pushed" into the real estate market, that results sometimes in a long time to have the product sold.

An effort of owners and all value chain participants towards demand stabilization is very important for the Lean transformation. A smooth pulling at the end and a pull culture, in cascade, would avoid a lot o waste along the chain.

PERFECTION

Seeking for perfection is a Lean principle understood as permanent incremental (kaizen) or radical (kaikaku) improvements, eliminating waste and improving value for the client.

To achieve perfection, one of the most important elements is standardization of work (Ohno, 1988), (Monden, 1998). Work shall be highly specified as content, sequence, timing, and outcome (Spear and Bowen, 1999). Other important concepts are autonomation and poka-yoke, assuring quality of every piece that is delivered to the next process. Manufacturing companies that are starting the Lean transformation have as a basis decades of process sheets, work instructions, work analysis, quality management, quality control techniques, etc.

However, in most construction companies, few methods are written, productivity data are rare, and almost no formal process quality control used. These subjects must be developed, as a pre-requirement for the Lean transformation. Companies that developed quality systems (registered or not) have a minimum basis to start, with work instructions and quality control checklists (Picchi, 1993). In the last years, the number of construction companies with ISO 9000 systems is increasing, in most countries, but they are nor a majority.

Therefore, it is strongly recommended that the development of work instructions and quality control should be one of the first steps, in the action plan, towards the future state.

CONCLUSIONS

If the Lean principles are discussed considering construction specific characteristics, important issues can be detected. In this paper, some of these issues were highlighted, mainly:

- Any effort toward Lean transformation in construction must consider the complex value chain, improving the collaboration among all participants: developers, owners, financial agents, city agencies, real estate companies, general contractors, sub-contractors, suppliers, etc.
- The flow mapping of present state, first step for waste identification and elimination, designing a future state, should be done in three levels:
  - ⇒ Business flow;
  - ⇒ Job site flow;
  - ⇒ Supply flow.

- ♦ Construction companies that don't have any kind of work instructions and quality control should develop them, in the first steps of Lean transformation.

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REFERENCES

Egan, J., Sir. (1998). *Rethinking construction: the report of the Construction Task Force*. Department of Environment, Transport and Regions, London.

Howell, G. A . (1999). "What is Lean Construction – 1999". *Proc. 7th Ann. Conf. Intl. Group for Lean Construction*, Berkeley, CA, July 26-28, p. 1-10.

Koskela, L. (1992). *Application of the New Production Philosophy to Construction*, Technical Report No. 72, Center for Integrated Facility Engineering, Stanford University, CA.

Monden, Yasuhiro (1998). Toyota production system: an integrated approach to just-in-time. Engineering & Management Press. Norcross, GA. 3rd ed.

Ohno, Taiichi (1988). *History of the Toyota production system.* Productivity Press, Cambrige, MI.

Picchi, Flávio A. (1993).*Sistemas da Qualidade: uso em empresas de construção de edifícios*. São Paulo, Universidade de São Paulo. (PhD Thesis)

Rother, M. and Shook, J. (1998). *Learning to see: Value Stream Mapping to Create Value and eliminate muda*. The Lean Enterprise Institute, Brookline, Mass.

Spear, Steven and Bowen, H. Kent (1999). Decoding the DNA of the Toyota production system. Harvard Business Review, sept-oct, 96-106.

Tommmelein, I, ed. (1999) . Proc. 7 th Ann. Conf. Intl. Group for Lean Constr., IGLC-7, 26-28 July at Univers. of California, Berkeley, USA. 444 pgs.

Vrijhoef, R.; Koskela, L. (1999). 'Roles of Supply Chain Management in Lean Construction". *Proc. 7th Ann. Conf. Intl. Group for Lean Construction*, Berkeley, CA, July 26-28. P. 133-146.Egan, J., Sir. (1998). *Rethinking construction: the report of the Construction Task Force*. Department of Environment, Transport and Regions, London.

Womack, J.P., Jones, D.T. and Roos, D. (1990). *The machine that changed the World: The story of Lean Production*. Harper Perennial, New York, N.Y.

Womack, J.P. and Jones, D.T. (1996). *Lean Thinking: Banish Waste and create Wealth in your Corporation.* Simon and Schuster, New York, N.Y.

Womack, J.P. (1999). From seeing to doing. *Proc. Lean Summit 99*, 13-15 June, Atlanta.

Annex 1 - Example of participants relationships in value stream (typical situation for development market in Brazil)

Legend: **Bold**: Developer/ General contractor (combined company)