CONCEPTUAL LEVEL

Paweł Nowak

Jerzy Rosłon

Warsaw, August 2017

Table of contents

1. Lean Principles

Basic definition of Lean management is "Production system able to reduce systematically all wastes that are included in the activities in order to satisfy the customer"[1].

One of the main goals of lean project management is creation and removal of bottlenecks in the production process in order to accelerate growth and increase productivity. "Lean" is a systematic method for the elimination of waste ("Muda") within a manufacturing system. Lean also takes into account waste created through overburden ("Muri") and waste created through unevenness in work loads ("Mura"). Muda means in Japanese "futility; uselessness; wastefulness", *Muri* - means "unreasonableness; impossible; beyond one's power; and is a key concept in the Toyota Production System (TPS); and *Mura* - means "unevenness; irregularity; lack of uniformity.

Lean production (sometimes referred to as lean manufacturing) was pioneered by Toyota in Japan after the second world war. The Toyota Production System was considered to be the most efficient in the world, and it was recognised that their lean production principles could be applied not only to any other manufacturing process, but also to other business activities.

The term 'lean construction' is an adaptation of lean production techniques applied to the construction industry and can be characterised as techniques aimed at maximising value and minimising waste.

Important elements of the implementation of Lean principles into company activities are as follows:

<u>See the Value from customer point of View</u>

In order to make responsible decisions in the project, it's vital to understand the customer point of view. Every manager is entitled to inspect the customer values thoroughly and design products, processes and methods that will satisfy investor needs. There are many tools that can help achieving the goal of having the will of the customer inspected. Those tools help to avoid some dangers and identify risk for example: Ishikawa Chart, Brainstorm Meetings, Risk and Opportunities Graph etc. Having the Value seen from the customer point of view allows team to establish direction of path taken in the project.

<u>Organize process in value streams</u>

Creating value stream improve the efficiency of the project processes. Every process – from designing through work execution to evaluation and acceptance of works) has to be

[1] Koch T., 2011

esigned in the way that will maximise VA (value added) and minimalize NVA (Non-Value Added) – activities that don't transform the work in progress of the project[2]:

VA - VALUE ADDED EXAMPLES

- Having the subcontractor selected
- Adjust formworks
- Pouring concrete slab
- Painting
- Installing roof cover
- Installing door frame

It have to be done correctly otherwise all activities thought to be VA become NVA, because of reworks and corrections and i.e.: waiting for new doorframe, because the error installing an element for the first time.

NVA – NON VALUE ADDED EXAMPLES:

- Moving material from place to place – number of times that worker have to move
- material MUST be minimalized, perfect case is when material delivered i.e. precast
- concrete columns are installed directly from the delivery truck
- Looking for material – storage places has to be arranged and marked in order to
- eliminate time looking for material
- Waiting and delays – the worst of all – delays can be avoided having identified risk in
- the first place and carefully designed schedule
- Looking for information – every project should have the person delegated to keeping
- smooth information flow. Information must be correct – it is better not to give
- information than giving the wrong one
- Reworks and corrections – avoiding ones is vital – in the way of lean thinking there is
- no room for mistakes – activities happen once
- Uncoordinated logistics
- Unused ideas

The factors listed above as an example of NVA (non-value added) in order to maintain lean have to be minimalized or if possible excluded – it represents 8 most common wastes:

- too much stock (generating waste of space and transportation on site problem with having financial assets allocated to early – cash flow disorder),
- too much movement (generating waste of time for the workers and accident hazard),

[2] Seyer N. J., Williams B. 2014

- chaotic transport (generates loss on productivity and disorganisation),
- reworks (generating waste of material, time and morale),
- delays (workers waiting inactive for decision, project, material, etc.),
- overproduction (risk of reworks i.e. having build 90% of structure of curtain wall
- without having decision if there are plans for change),
- over-process (too many unused ideas).

Keep flows without stopping

The key thing is to avoid stopping the flows – cash flows, transports, works. In order to do that project manager is bound to create such schedule that will not be susceptible for risk. Risk cannot be avoided but can be managed and minimalized.

Make people responsible for activities

Delegating activities is important for the project manager, because he cannot do all things by
himself. Making people responsible is increasing their importance for the project, but also is letting them know they will be held accountable for the outcome.

Continue mastering principles 1-4 until perfection and monitor effects.

Lean construction is conducted in accordance with similar principles to those of lean thinking:

- **Elimination of waste.** Application of lean construction is justified by various weaknesses of construction work processes, which include:
  - High levels of material stocks on site. These result in unnecessary long-term “freezing” of capital, they lead to unnecessary logistic processes and potential damages, e.g. due to unfavourable weather conditions;
  - Maintenance of too large, badly organised warehouse areas. This leads to disturbances in the flow of materials and loss of time due to searching for those materials which are needed at the time;
  - High susceptibility of construction manufacturing to defects. The lists of faults which are made during acceptance, sometimes reach several thousand items. These are partially due to insufficient qualifications of the work teams engaged, or due to insufficient supervision of the work processes;
  - Insufficient preparation of production. In many construction companies, due to limited staffing of the production preparation department, it is impossible to warrant the appropriate production planning on site.

- **Constant process flow.** The aim of this principle is to establish a production structure in accordance with the assumptions of even work methods. By dividing the facility into small work sections, it is possible to eliminate activities that do not generate value. Moreover, continuity and eveness of employment of work teams is ensured. Identification of reserves allows for reduction of the production cycle. The reserves include:
  - Time reserves. Preparation of the work schedule is associated with planning a time reserve for individual tasks. These reserves are necessary due to uncertainty of the predicted weather conditions, untimely delivery of materials and services and other factors. Without proper control, it is impossible to use and transfer these reserves from one activity to another;
  - Space reserves. Use of space for production purposes and for storage is more effective if continuous process flow is ensured;
  - Reserves of means. Excessive reserves of means can be detected more easily and quickly if continuous process flow is ensured.
- ***The "Pull" principle.*** This principle is based on the Japanese "Kanban" method ("visible description"). The method allows for visualisation of flow of construction materials on the site. It is aimed at control of production processes, focused on the necessary and real consumption of materials in the place of assembly. The latter production unit is supplied by the preceding unit only with the necessary operational means. As a result, it is possible to improve the construction manufacturing processes through reduction of complexity. Logistic processes and construction and assembly production processes are operating in accordance with the "signal given" and they are understood as a system in the sense of a control loop. This allows for avoidance of large stock accumulation. The "pull" method allows for reduction of susceptibility of construction works to the potential disturbances of construction processes. For instance, auxiliary processes are activated when they become necessary for implementation of basic processes (Just-in-Time). In such case, the potential disturbances in basic processes have no direct impact on auxiliary processes. This allows for reaching greater flexibility. In the case of fluctuations of capacity, it is possible to regulate the inflow of means directly.
- ***Constant improvement.*** The Japanese "Kaizen" philosophy is based on the assumption that everything requires improvement and the standards achieved can be made better. In terms of construction manufacturing, it can be stated that the appropriate strategies are established, but usually they are not implemented to the

sufficient extent. Construction is still struggling to attain the highest quality of performance, specified in the contrast. It may be helpful to apply long-term process optimisation methods, such as:

- Introduction of the so-called Best Practice, such as the PDCA system (Plan-Do-Check-Act, see Manual M13);
- Ensuring the flow of information from the entire corporation (all construction sites) to each site, e.g. within the framework of the Project Communication Systems (see Manual M10);
- Professional development of employees, who are at the core of the corporation profile and culture.

- **Documentation of processes.** Implementation of lean construction requires a high degree of clarity of processes due to application of the appropriate control methods. The level of advancement of processes and the possible defects or disturbances in implementation must be specified and documented, taking into account the advancement of the schedule, costs and quality problems. This can be attained e.g. by:
  - Defining processes necessary to manage a given construction site which is associated with specification of the appropriate indicators and means of control and reporting;
  - Applying proper means for systematic information gathering on the condition of building processes (progress of works), e.g. various sensors;[3]
  - Application of means for organisation, use and analysis of data (information) on the condition of processes (progress of construction works) (see Manual "Computer Methods in Construction").
- Cooperation. Implementation of lean construction requires strict cooperation with various project partners. Within the framework of a given project, it is necessary to organise the non-uniform group of participants of a construction undertaking so that, assuming the proper division of works, competences and responsibility, all of the necessary design and production processes are implemented on time, assuring the appropriate quality, within the framework of the budget specified. Organisational structures and processes are characterised by a substantial number of organisational links which, in the first place, have to be properly defined (see chapters 1 and 2).

One of the methods of application of lean construction is the so-called last planner

[3] Motzko, C. et al. (2007); Pflug (2008)

system. The central component of this method is the organisation or person acting as the last planner, who operates in between the construction planning and manufacturing processes, and, depending on the level of advancement of construction works or the condition of the detailed design documentation, confirms continuation of the production processes. In the so-called “look ahead” plan, activities are defined for the next 4 to 6 weeks, serving as a basis for a weekly work plan. The construction management and the designers, cooperating closely, approve the implementation of the investment stages, for which it has been assured that the design process has been fully completed. In particular, in construction projects, in which specific design processes take place simultaneously to construction (*fast track projects*), systematisation of processes as described above is highly reasonable. The measure of progress in design and implementation of construction works is the *percent plan complete,* a quotient of tasks completed to the total number of tasks, specified in the weekly work plan.

2. System thinking

The ”lean” terminology is currently used in the context of defined concepts and methods of simple and clear (“lean”) organisation of processes, which may refer to production, management or administration. It is associated with lean thinking and lean management terminology. Lean management can be divided into lean production, lean development and lean administration. The basis for the modern lean production philosophy is offered by Toyota Production System (TPS). One of the fundamental components of TPS is elimination of waste, which should result in shortening the production cycle, improving production quality, reducing costs and improving mutual coordination and communication between employees.

Lean thinking emerged in those branches of industry which operate on a fixed, regular basis. “It shows the way to recognise the value, the continuous performance of tasks that create value always, when there is demand for it, and the fully effective implementation of value“[4]. At the core of lean thinking is the concept of elimination of waste from production, management of work deadlines, human resources, construction processes, production means, machines, and equipment and construction materials. The “muda” phenomenon in production processes was discovered by Taiichi Ohno (1912-1990).[5] *Muda* includes:

- Defects of products that are qualified for elimination;
- Production of items for which there is no demand, resulting in ever-increasing stock;

[4] Womack, J.P., Jones, D.T.: Lean Thinking, Campus, 2004, p. 23
[5] ibidem

- Implementation of processes which are not effective and efficient;
- Unplanned movement of personnel and unnecessary transport of materials to another place without a specific objective;
- Employees waiting upon subsequent production processes due to delays occurring at the preceding workstations;
- Goods and services that do not meet the expectations of clients.

Lean thinking is subject to five key principles:

1. *Definition of value*. Definition of value serves as a basis for lean thinking. The value of the product (e.g. the construction facility) is specified in accordance with the criteria of the client, adapted to their needs and manufactured by the producer. The process of value definition should be synchronised, if value is created by many companies. Various objectives of various companies involved may lead to conflictswhich are associated with risks of a failure to meet specific value requirements. On the other hand, there is a chance that proper application of lean thinking in an organisation oriented towards value, resources will be released to improve its effectiveness. Thus the methods of organisation of processes and structures should be linked to economic analyses in relation to the definition of value.
2. *Identification of the total value stream for every product.* The value stream consists of all required specific activities, allowing for leading a given product (e.g. a construction facility) through three areas of management: design (concept, structure, preparation of production, launching of production), management of information (ordering, establishing of deadline, delivery) and transformation (from raw material to finished product). Within the framework of the value stream analysis, various categories of activities can be established. These include:
    - Value creation activities (the main process): from the client's perspective, they lead to increase of value. Thus, they increase the value of the product (e.g. construction facility) for the client throughout the process. These activities should be subjected to scheduled and continued optimisation. Examples of activities that create value are: construction, assembly, processing and means of increasing the "ideal" value of the product (marketing);
    - Activities which do not create value, but are (still) necessary (auxiliary processes): these contribute only indirectly to an increase in the value of the product (e.g. a construction facility). They support the value creation activities, and therefore they are also referred to as supporting works. These include:

preparation of machines, internal transport, planning and control of production, preparation of reports and statistics (controlling);

- Activities which do not create value (unproductive and erroneous activities – waste): these are the activities which are usually unplanned; they do not contribute, either directly or indirectly, to product value creation. These include erroneous activities (including those from the first two categories) which cannot be used because of the errors or defects that occurred in the process of their implementation. Examples of such activities are: temporary storage, discontinuation of production due to shortage of parts, additional works, disturbances, late deliveries due to erroneous information, removal of defects (unplanned).

3. *Continuous value flow* (flow of activities that generate value for specific products). The aim of continuous flow is to generate the value of the product (e.g. a construction facility) in an even manner. With reference to the organisational structure, this leads to creation of specific (individual) teams for every product having the appropriate qualifications for the value creation process. It is necessary to apply the appropriate decision-making methods in a team. An example here may be the Quality Function Deployment. For the appropriate production process, it is necessary to define the production batch. Within the framework of methodology, it is possible to apply the principle of belt-system production, in which individual production stages are implemented continuously in a specific order, while the resources are being consumed evenly. This principle is supported by the “just in time” methodology. This methodology, in the context of production, means that procurement is synchronised with production. It is a production and logistic strategy aimed at creation of overall flows of materials and information along the value creation chain, which is aimed at quicker completion of order and increasing of their flow speed.[6]
4. *The ”pull” principle.* The ”*pull*” principle means that the latter production unit is supplied by the preceding production unit with the operational means as necessary. As a result, the process speed is defined by the latter production unit. This results in reduction of stock levels.
5. *Aiming at perfection.* The entire organisation works on concepts of products and production which allow for elimination of waste (*muda*). The number of errors should be constantly reduced. It is necessary to eliminate system failures, quality deficits,

[6] Pfohl 2000

standstills etc. This requires devising processes and instructions that are clear, allow for definition of target conditions and warrant specification of current conditions in a manner that allows for their active control and modification. Through critical control of activities we obtain an increase in the share of value generation within processes. Emphasis is put on those processes which generate value and thus increase benefits for clients (internal/external). To this end, all activities which are not necessary are systematically detected and limited or eliminated. As a result, the process costs are visibly decreased.

The basic impulse for devising and implementation of such lean production philosophy originated at the Toyota Production System (TPS) car factory, when the then-director, forced to introduce savings, reduced the production resources by 25% (that is, the production area, the investment planned and staffing).

”All we do is control the project duration time, from the placement of the order until receipt of payment. In addition, we shorten the time designated for the project implementation by removing all the unnecessary activities, which bring no benefits, from the process.”[7]

The basic TPS components are:

- Just in Time. Just in Time means, in general, that the appropriate part of production is available at the appropriate time, in the required quantity and quality and in the right place. The dominant principles are the pull principle, meaning that the successor obtains the appropriate quantity of the product from the predecessor, and then the principle of constant flow of value, that is, coupling the processes of value generation and reduction of the production batch size. The third principle is that of even work, that is, synchronisation and division of a construction facility into work sections, maintaining a relatively even level of labour demand for each of these;
- Quality and stability. These include, in the first place, the principle of error prevention. This has been applied in such methods as 5S, Poka Yoke or TPM. It is about early detection of errors during implementation and their early reporting. Permanent elimination of errors can be achieved thanks to such methods as 5W or Kaizen (“constant improvement”);
- Constant improvement. Products, processes and qualifications of employees must be constantly developed and improved. This is supported by the KAIZEN principle of continuous improvement and aiming at perfection of processes using the so-called philosophy of small steps. Within the framework of the KAIZEN philosophy, in a given

[7] Ohno 1993

corporation, any employee may report proposals/remarks concerning changes, which are always considered by the superiors. The employees do not have to fear any disciplinary sanctions or loss of their jobs.

- Employees and partners in the culture of the corporation. Employees are at the core of the organisational culture. In TPS this means, among other things, that the management is present where value is generated. The high quality requirements are demanded also from their partners and sub-suppliers. This improves the necessary stability of processes. As for sub-suppliers, the principle of long-term partnership and continuity is applied.

3. Lean Enterprise

The lean management philosophy, after some modifications, can be applied to the construction industry under the term “lean construction.[8] Translation of the ”lean” concept to construction depends on modification of the methods which were devised for regular, fixed-basis industries as needed due to the specific nature of construction, thus:

- Limiting waste;
- Structuring the product value generation processes (e.g. in terms of a construction facility);
- Partnership-based cooperation.

In the context of lean construction, it is necessary to mention Laurie Koskela, who, in the early nineties, dealt with application of lean management in construction. He stated that it was necessary to complement the transformation aspect (input-output relations) of the construction manufacturing process by adding the component of flow of activities, resources and information, as well as understanding of value (TFV theory,[9] see figure 1.1).

[8] Kaiser, J.: Lean Process Management in der operative Bauabwicklung, doctoral thesis, TU Darmstadt, 2011
[9] Koskela, J.: Application of the New Production Philosophy to Construction, 1992

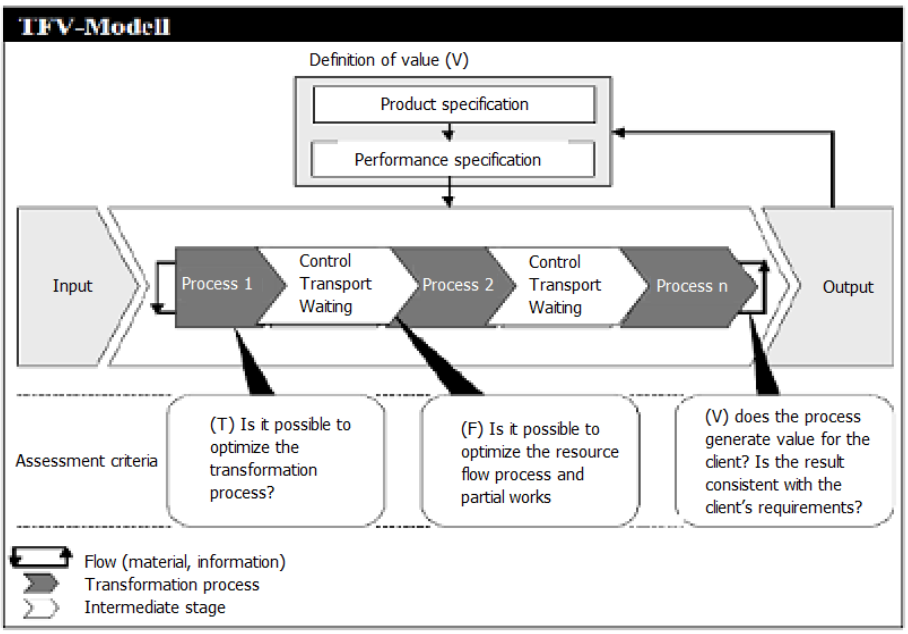

Figure 1.1. TFV *Model* [10]

When lean construction is applied, the core element should always be the employee. Work time organisation is a significant component of occupational health and safety. Limitation of the scope of work, organisation of work division (e.g. during the day) and the associated difficulties at work are only selected components of the processes of organisation of construction works. Rationalisation methods in work processes must be introduced taking into account the work organisation, which has been materially and professionally justified. From the perspective of construction, in the organisation of work duration it is necessary to take into account the binding provisions of the act on collective work agreements. Therefore, according to the legal provisions in force in Germany [*Tarifrecht*], the work time indicator tables, approved by parties to the collective work agreement serve as a basis for the corporate division of production processes (the area of piece wages). These were prepared in accordance with the labour science methodology and they are representative of processes on ordinary construction sites.

The work time indicators for general construction industry (ARH tables[11]) provide for:

- 10% time for rest;
- 20% additional time (unplanned waiting time, additional tasks, personal breaks e.g. toilet);
- 70% basic time (main task + auxiliary task + planned waiting time).

[10] Kaiser, J. 2011
[11] Handbuch Organisation Bau

In the case of a boarding work team, the main tasks include:

- Transport of wall formwork within the construction site;
- Placement of formwork and assembly of joints;
- Placement of supports, evening out of formwork;
- Assembly of work scaffolding.

Auxiliary tasks include:

- Cleaning;
- Putting in order.

Main and auxiliary tasks serve the implementation of the work task directly or indirectly. In construction, these are the activities that generate the value of the product (e.g. the construction facility). These include the logistics, carried out according to the plan (e.g. transport of formwork). It is always the necessary component of the production process, since the construction facility (or its part) usually meets the conditions of the agreement only within the framework of specific spatial coordinates (value generation), regardless of the principle of performance of works. Time for rest is necessary and obligatory. Construction works belong to the category of hard physical work. They are characterised by multiple load, such as carrying of heavy weights, exposure to cold and unfavourable weather conditions, piecework system, exposure to dust and noise, as well as emission of other substances (see figure 1.2).

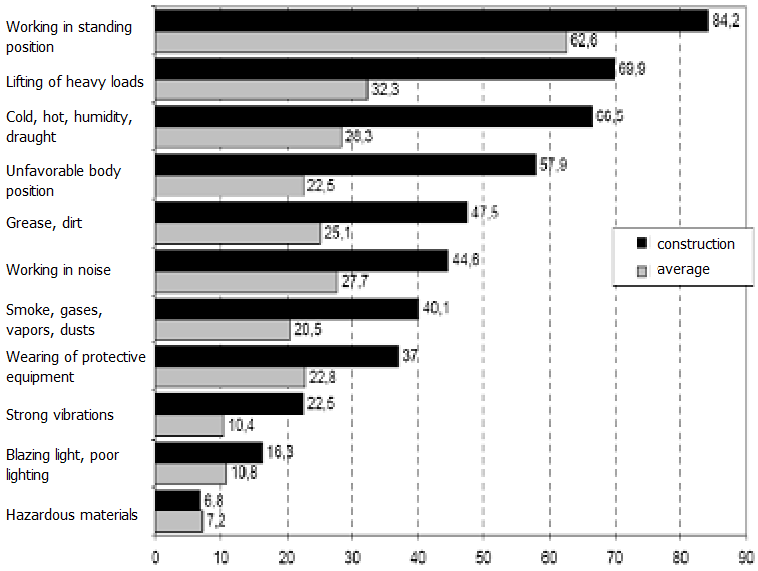

Figure 1.2. Physical load of work and requirements to be met by men at work [12]

[12] Hartmann/Seidel (2007)

High loads are associated, in particular, with shell state facilities; the work tasks of concrete placers, carpenters and scaffolding assembly workers. Works of these groups are categorised as “hard” (see table 1.1).

Research results, which have been confirmed by practice and published, show that long periods of work may lead to serious health deterioration, intense stress and tiredness symptoms. At the same time, the risk of accidents increases. Discussion of the possibilities of rationalisation in the area of personally conditioned work breaks is taken into account in the additional time category; however, due to physiological reasons, it cannot be disregarded. Work breaks during the basic work times which are dependent on the course of construction processes, reflect the current state of technological progress, and thus they are a function of the technology applied.

	N	Loads			Work performed with difficulty
		Up to 10 kg	10-25 kg	Above 25 kg	
Installers	519	9.8	37.5	48.4	16.4
Bricklayers	539	3.5	33.4	51.6	26.2
Concreters	112	4.5	30.4	59.8	32.1
Wood-workers	192	3.6	27.6	60.4	21.9
Roofers	308	8.4	34.7	53.2	15.3
Scaffolding installers	76	1.3	22.4	73.7	34.2
Road workers	67	1.5	37.3	56.7	23.9
Assistants	143	7.0	32.9	54.5	18.9
Insulation/ drywall installers	143	11.9	35.7	45.5	16.1
Glazers	81	1.2	49.1	45.7	24.7
Interior finishing workers	71	2.8	38.0	57.7	14.1
Carpenters	57	8.8	36.8	45.6	10.5
Painters	404	11.4	64.9	20.0	14.9
Construction machine operators	51	17.6	21.6	39.2	21.6
Cleaners	94	40.4	29.8	13.8	11.7
Office workers	112	26.8	18.8	12.5	9.8
Construction professions group N<50	181	11.6	26.5	56.4	26.0
Total with other profession	3413	9.5	36.7	45.5	19.5

Table 1.1. Loads associated with carrying of heavy weights by men[13]

[13] Hartmann/Seidel (2007)

4. Lean Management

Lean Management. The central part of the lean management idea is generation of value and elimination of any waste which emerges within the framework of manufacturing of goods and services. All activities and resources which are not necessary to raise the quality of the product are considered to be unneeded and should be eliminated, like the stock levels and materials stored, waiting for processing. The target increases in production capacity, as well as faster production, are significant factors in terms of competition and market share. At the same time, well-organised and flexible production allows for manufacturing of individualised, specific products of the highest quality. In practice, this means application of selected principles, methods and means, which are to be positioned in between the strategic and operational perspective.

5. Integration to the Construction Industry

Presented below is the construction process system used in building practice (see figure 5.3), which has been devised in accordance with the lean construction principles.[14]

This construction process system is divided into three planes: objectives, processes and methods and principles. Innovation of this approach is due to the fact that in the area of processes and methods, a combined structure of three planes has been defined: order completion management oriented at processes, operational management of performance and systematic constant improvement. The structure is explained below and its significance is illustrated by a practical example.

Systemic plane of objectives. At the core of the system of objectives is the client and the issue of compliance with their needs and expectations. This basic objective serves as a basis for introducing the following partial objectives:

- Effectiveness: increased effectiveness of processes to reduce the construction costs, e.g. through limiting waste in the implementation of work processes;
- Clarity: to warrant the overall, systematic action, it is necessary to define the construction processes clearly. The following components are necessary to achieve this objective:
    - Precise definition of the position and competences of the employee in the project organisation;

[14] Kaiser, J. 2011

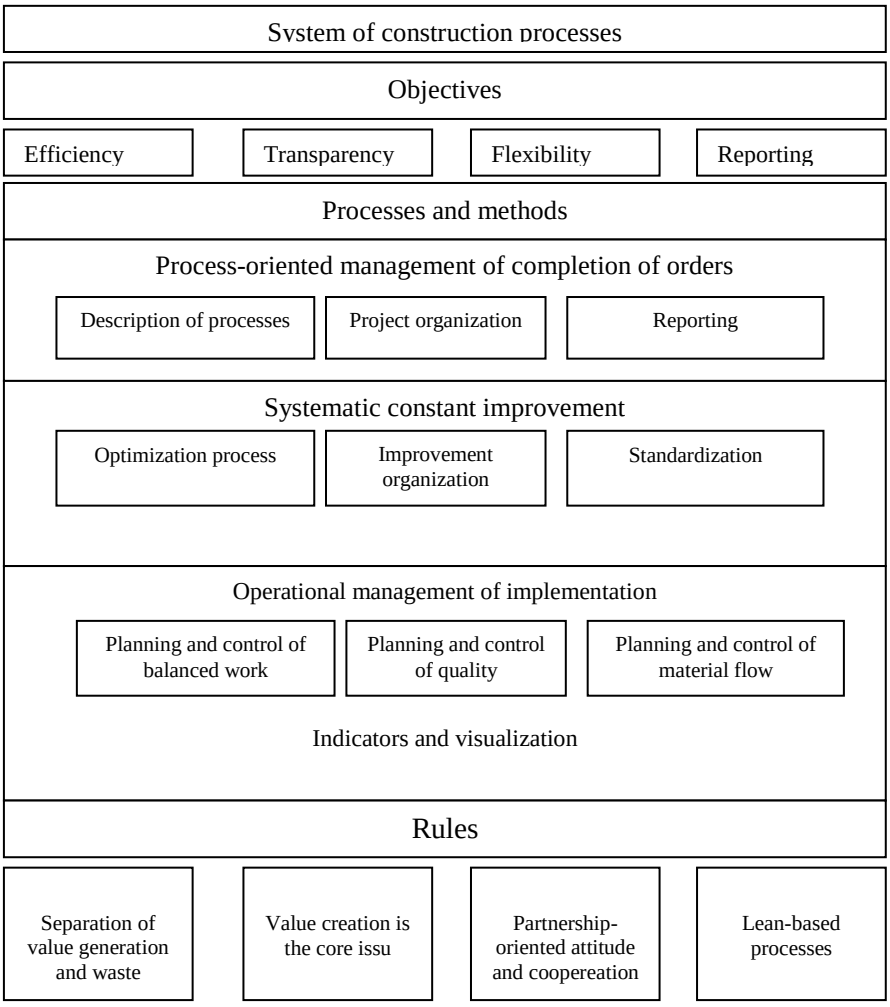

Figure 5.3. Structure of the construction process system in accordance with the lean methodology[15]

- Devising the proper monitoring tools to obtain an image of the status of implementation of processes, e.g. through specification of the appropriate process indicators;
- Introducing methods of visualisation, allowing communication of the process status to employees directly and on the site;
- Formulation of the information flow system.

- Flexibility: construction organisations are sociotechnical systems which allow for implementation of complex and dynamic process structures. Thus, cooperation requires high flexibility of the project participants to make sure that the necessary means of control of specific processes are implemented on time;

[15] Kaiser, J. 2011, also Porsche Consulting

- Stability: processes in construction projects should be implemented stably. Such factors as weather conditions, the right of the ordering party to make changes in the scope of works, unexpected soil conditions or withdrawal of subcontractors require the tools and methods for standardisation of the process implementation.

The systemic plane of principles. The systemic plane of principles along with its components reflects the lean management perspective, thus:

- Separation of value generation from waste: value generation in the economic sense is defined as the difference between the production value obtained and the works performed earlier.[16] Within a corporation and within the framework of the process of implementation of a specific construction project, it is necessary to develop the awareness of employees of the objective (high significance) of their works, which generate a combined value (e.g. of the construction facility) from the perspective of the client. It is necessary to distinguish activities associated with increase of value (basic processes, resulting in direct increase of value), hidden waste activities (auxiliary processes which are necessary to conduct the basic processes without generating direct increase of value for results) and open waste activities (e.g. waiting time due to disturbances);
- Centralisation of value generation: orientation of the enterprise on the process of value shaping. Moreover, focus on the place of value generation. In the context of the above discussion, particular emphasis should be put here on the issue of the construction site, discussed in chapter 4;
- Partnership-based cooperation: in the sociotechnical system of the construction project, in order to implement it efficiently, it is necessary to establish a link between the essential qualifications of employees within the framework of the enterprise. This pertains to relations with the ordering party and the appropriate offices, as well as all subcontractors, suppliers, designers and other external entities;
- Organisation of processes according to lean methods: in relation to the construction site, it is necessary to ensure solid representation of work gangs, since the workplaces are “mobile” within the structure of the facility under construction. It is also necessary to define the work sections according to the target dimensions defined. Particularly significant is the process planning according to the principle of even distribution, on one hand it is necessary to even out the use of resources, on the other hand to ensure flexibility of performance of works in the case of disturbances.

[16] Gabler Wirtschaftslexikon

This can be attained thanks to the “pull” principle. In particular, the project management and the next work gang should be informed of completion of individual processes. Thus, at least partially, we attain the distribution of raw materials and operational means as necessary. The last component of the rule is aiming at perfection, that is, constant development and improvement of the construction work processes.

The systemic plane of processes and methods. Objectives and principles are implemented on the plane of processes and methods. This is a dynamic structure, within which there is interaction between operational management of performance of works, which is process-oriented, and management of the order completion. This interaction is regulated by systematic improvement of the flow and organisation of construction works in accordance with the principle of Continuous Improvement Process **CIP** (KVP Kontinuierlicher *Verbesserungsprozess*). The components of this system plane are:

- Process-oriented management of order completion. It is subject to two principles: process-orientation and the so-called “front loading”, which is based on early, careful analysis of tasks, along with specific planning of production in order to identify quickly the weaknesses, as well as the existing potential. A description of the construction process can be attained e.g. on the basis of a schedule of implementation of subsequent stages of construction works. An adequate example has been presented in figure 5.4. Apart from standard components, such as the project implementation stages and milestones, the so-called “quality gates” are of significance. They establish milestones, used to check whether all of the tasks mentioned have attained the required status in terms of progress and quality of works. Only after all conditions are met, the next stage can be launched. Standardised reporting is a significant component of these planes.

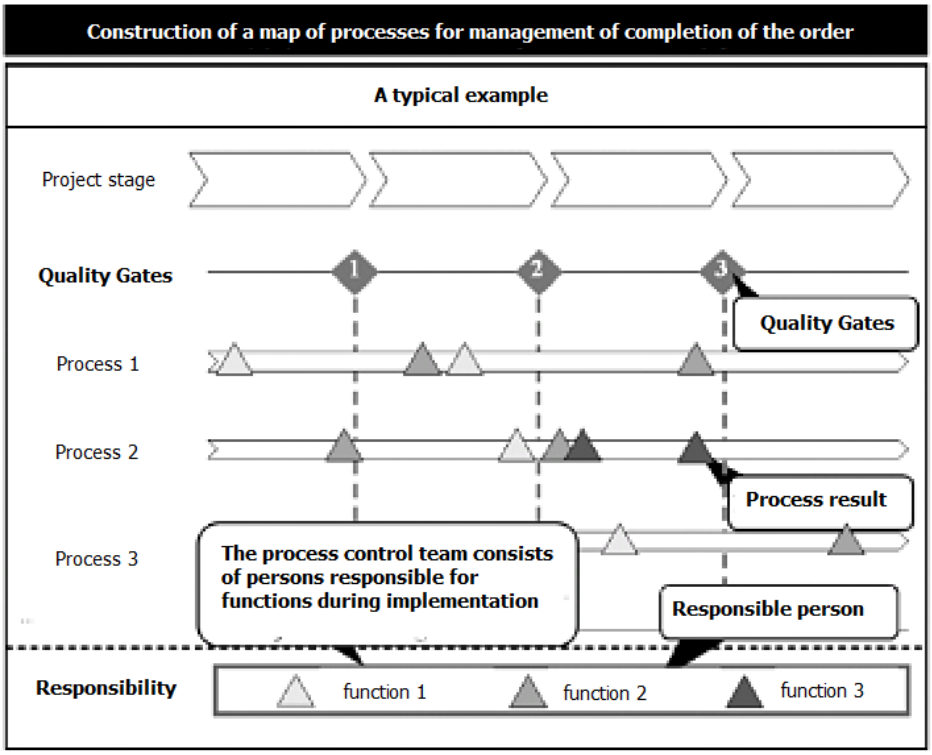

Figure 1.4. Example of a process map [17]

- Operational management of implementation. Operational management of implementation refers directly to the stage of preparation of works and the entire construction process. At the core are the production processes. Individual undertakings are subordinated to the common goal: efficient and effective implementation of the construction facility. A significant aspect is continuous production, understood as even work distribution. The appropriate methods of operational management of construction undertakings and their implementation are described in the appropriate literature on the subject.

As a result, precise weekly schedules for implementation of works should be established for all work teams, providing a specific reference to the production process. In order to adapt and verify the progress of the implementation and production processes, it is necessary to conduct meetings, as explained in the last planner system methodology, presented above. The appropriate qualification methods will allow for establishment of self-controlled, autonomous work gangs, able to determine their work progress independently on the basis of the appropriate visualisation media. A visualisation medium is a very significant component of work on a construction site. Advancement of specific sections of works should

[17] Kaiser/Khodawandi 2008

be discussed directly on the site, so that the project participants can talk about the important parameters such as the deadlines, cleanliness and order on site, the quality, general information and the appropriate indicators.

Figure 1.5 presents collectively the principles and factors decisive for success of the lean construction methodology.

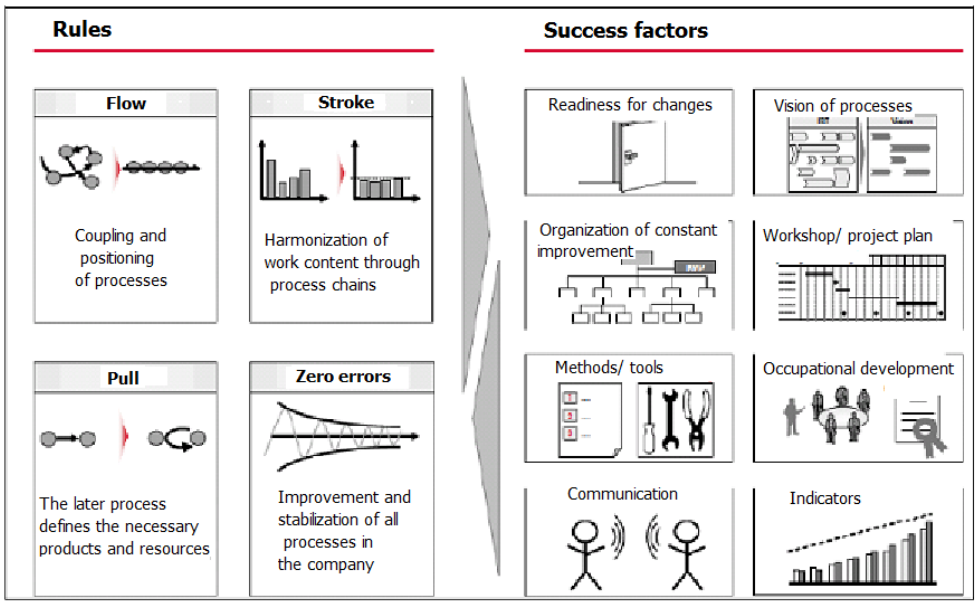

Figure 1.5. Application of rules and factors that are decisive for successful implementation of lean construction[18]

Introduction of a production system based on lean construction, and thus initiation of components of a learning organisation in a construction enterprise, is a substantial challenge. In the first place, it is necessary to make or at least stimulate the entire organisation to become ready for changes. The normative, strategic and operational management processes should be controlled in terms of their mutual cohesion. As for the basic processes, various changes will take place thanks to use of new, different methods and tools of management and modern methods and processes of communication. Moreover, it is necessary to commence the implementation of the entire construction process in accordance with the principle of Continuous Improvement Process (CIP). In addition, the entire construction enterprise as an organisation should dispose of the qualified management staff and personnel prepared to implement the construction works planned. Of course, all these activities require the appropriate financial expenditures as well.

[18] Kaiser (2008)

How Lean Design & Construction differs from other forms of project management[19]:

- Control is redefined from “monitoring results” to “making things happen,” with a measured and improved planning process to assure reliable workflow and predictable project outcomes.
- Maximizing value and minimizing waste at the project level is the goal, versus the traditional practice of attempting to optimize each individual activity.
- Value to the customer is defined, created and delivered throughout the life of the project, while traditional practice calls for defining requirements at the outset for delivery at the end, despite changing markets, technology and business practices.
- Coordinating action through pulling and continuous flow, as opposed to the traditional, schedule-driven push which places an over-reliance on central authority and project schedules to manage resources and coordinate work.
- Decentralized decision-making through transparency and empowerment provides project participants with information on the state of the production systems and empowering them to take action.

Some of the varied principles underpinning **lean construction** include[20]:

- Improving communication.
- Eliminating waste and errors.
- Direct intervention to drive immediate and apparent change.
- Improving work planning and forward scheduling.
- Specifying value from the perspective of the customer.
- Identifying the processes that deliver customer value (the value stream).
- Eliminating activities that do not add value.
- Ensuring the working environment is clean, safe, and efficient.
- Continuous improvement.

Some of the techniques that can be adopted include:

- Using modelling and visualisation techniques to improve planning and communication.
- Early planning, to improve workflow, focussing on defining achievable tasks and avoiding mistakes, duplicated effort, out of sequence working and activity that does

[19] www.leanconstruction.org

[20] www.designingbuildings.co.uk

not add customer value. The objective is the maximisation of workflow and the minimisation of performance variation rather than point speed.

- Look-ahead scheduling.
- Pre-fabrication and modular building to reduce activity on site and better distribute the workload.
- Just-in-time deliveries.
- Value management techniques.
- Integrating the supply chain through partnering and collaborative practices.
- Benchmarking techniques and the use of key performance indicators.
- Last Planner System
- Critical path analysis and management.
- Risk management techniques.
- Continuous improvement from one project to another.

6. Questions and Answers

1. Lean management doesn't involve:

a) Lean production

b) Lean thinking

c) Lean development

d) Lean administration

2. The "pull" principle means that the latter production unit is supplied by the preceding production unit with the operational means as necessary.

a) TRUE

b) FALSE

3. What doesn't belong to reserves according to "Lean management"?

a) Time reserves

b) Money reserves

c) Space reserves

d) Reserves of means

4. Please select assign activities below to the right type:

VA (value added) activities:……

NVA (Non-Value Added) activities:……

a) Having the subcontractor selected (VA)
b) Adjust formworks (VA)
c) Pouring concrete slab (VA)
d) Moving material from place to place (VA)
e) Looking for material (NVA)
f) Reworks and corrections (NVA)

5. Name principles of lean construction:

Elimination of waste

Constant process flow

The "Pull" principle

Constant improvement

Documentation of processes

6. The basic TPS components are:

a) NPV analysis, Quality and stability, Constant improvement, Employees and partners in the culture of the corporation.

b) Just in Time, Quality and stability, Constant improvement.

c) Just in Time, Quality and stability, Constant improvement, Employees and partners in the culture of the corporation.

d) Constant improvement, Employees and partners in the culture of the corporation, Earned value analysis.

7. Describe elements of CIP:

……

Process-oriented management of order completion. Operational management of implementation.

8. How Lean Design & Construction differs from other forms of project management, give at least 3 examples:

- **Control is redefined from "monitoring results" to "making things happen," with a measured and improved planning process to assure reliable workflow and predictable project outcomes.**
- **Maximizing value and minimizing waste at the project level is the goal, versus the traditional practice of attempting to optimize each individual activity.**
- **Value to the customer is defined, created and delivered throughout the life of the project, while traditional practice calls for defining requirements at the outset for delivery at the end, despite changing markets, technology and business practices.**
- **Coordinating action through pulling and continuous flow, as opposed to the traditional, schedule-driven push which places an over-reliance on central authority and project schedules to manage resources and coordinate work.**
- **Decentralized decision-making through transparency and empowerment provides project participants with information on the state of the production systems and empowering them to take action.**

7. Bibliography and further reading

Davenport, T. H.: Process Innovation Reengineering Work through Information Technology. Boston, MA, 1993

Gabler Wirtschaftslexikon

Hammer, M., Champy J.: Business Reengineering. Die Radikalkur für das Unternehmen. (1993)

Handbuch Arbeitsorganisation Bau 1.03 Richtzeiten Schalarbeiten mit loser Schalhaut, ZTV Verlag, Neu-Isenburg

Hartmann, B., Seidel, D.: Muskel-Skelett-Erkrankungen im Bauwesen, BG BAU, 2007

Jaworski, K.M.: Metodologia projektowania realizacji budowy,Wydawnictwo Naukowe PWN, 1999

Kaiser, J.: Lean Construction. In: 18. Kasseler-Darmstädter Baubetriebsseminar, Kassel 2008

Kaiser, J.; Khodawandi, D.: Applikation der Automobilentwicklungsprozesse in der Bauwirtschaft. Tiefbau 12/2008

Kaiser, J.: Lean Process Management in der operativen Bauwirtschaft, Manuskript, 2011

Klingenberger, J.: Schnittstellen der Technischen Gebäudeausrüstung bei Bürogebäuden. In: Festschrift anlässlich des 65. Geburtstages von Univ.-Prof. Dr.-Ing. Eberhard Schubert. Düsseldorf: VDI 2003

Koch, T.: Jak stosować metody Lean Manufactoring (Oszczędnego Wytwarzania) do wprowadzania innowacji, Politechnika Wrocławska, Materiały z Konferencji E-Narzędzia i Technologie generatywne jako ścieżka do innowacji, NOT, Warsaw, 2011

Minasowicz, A.: Chosen Techniques of Construction Risk Analysis. Proceeding of the Third International Conference on Construction in the 21st Century. CITC-III Athens, 2005

Minasowicz, A.: Economy and financial management In construction, Biblioteka Menedżerów Budowlanych - Leonardo da Vinci PL/06/B/F/PP/174014, 2008

Minasowicz, A.: Feasibility study of construction investment Project assessment with regard to risk and probabilisty of NPV reaching, Organisation , Technology and Management In Construction, An International Journal, p. 10-14, 2009

Motzko, C. et al.: Dokumentation und Simulation von Bauprozessen mithilfe von Bildverarbeitungssystemen, 2007

Pflug, C.: Ein Bildinformationssystem zur Unterstützung der Bauprozesssteuerung. Dissertation, Institut für Baubetrieb, Technische Universität Darmstadt, 2008

Seyer N. J., Williams B.: Lean For Dummies®, 2nd Edition, 2014

Womack, J. P., Jones D. T.: Lean Thinking, Campus 2004