Lean Construction on-site

Knowing how lean construction and job satisfaction are related to labor productivity.

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Foreword.

This research marks the finalization of my two years as a master student in the department of Real Estate and Housing at Delft University of Technology. I did a five-year architecture bachelor in Colombia at Universidad de los Andes and then worked for two years in two construction companies. In my bachelor I was challenged to use my imagination for designing multiple projects, but in the end I was missing process-related knowledge, e.g. the project conception, the relations between stakeholders, the program design, the project and stakeholders management and the steps throughout the entire building process from Initiation Stage (Development of Concept/Idea) up to the building transformation or demolition. Being aware of this knowledge gap and the need to have a broad understanding of the construction/development process to be able to succeed in this competitive industry, this was the driving force behind my decision to study Real Estate and Housing in Delft. This program gave me the opportunity to better understand the building/development process while filling the abovementioned gaps. In short, this program had everything I was looking for.

After the first year of the masters’ program I had a broad theoretical knowledge, and due to my background in construction I was more interested in the Design and Construction Laboratory. As I was working two years on site, I am aware of the problems the construction industry experiences in relation to productivity, how low productivity results in costs overruns, time overruns, rework, materials wastes, and accidents. Additionally I became really interested in how blue collar workers interact with the job they do, how they interact between them, how they are affected by the construction management and how they can influence the construction site and productivity. I think that where I worked I always saw how the managers tried to improve the productivity on site, but they only focused on new technologies such as new materials or equipment, but they never focused on the workers and new managerial techniques, sometimes people is stubborn or afraid of change. I was motivated to start this research because I truly believe that people are the most important “piece” in the process, I think that productivity problems should be tackled by different managerial practices that involve the workers on it and by having satisfied workers. After having a first insight on lean construction, I was really interested on the subject, and thought I could do a research focused on lean construction and its benefits to productivity and job satisfaction.

I would like to thank my first mentor Dr. Ir Ruben Vrijhoef for his support and supervision during the process and all his construction knowledge input; Dr Clarine van Oel, because of her encouragement, support and dedication in the entire process, plus her methodology contribution to the study, Ir Jelle Koolwijk for stepping in when the study was a bit unclear with his knowledge and support, and Dr. Ir Matthijs Prins for his intensive supervision at the beginning of the process.

My parents made this dream come true; I want to thank them for their support, constant motivation and been always there for me. My brother and sister, for bringing a smile every time I talked with them, my grandmas and Marta for always been in touch and interested on my studies. Gustavo and Monica for their intensive collaboration and cheering during the journey and in general all the people who contributed to my studies and my experience here in Delft.
Lean construction on-site
Abstract

The construction industry has many problems; one of the main complications is its low productivity. There have been many technological efforts for trying to improve it, but they work for specific problems identified, but not for the whole supply chain. It is suggested that a different management approach could improve the problems the construction industry faces. Lean construction tools are known for improving labor productivity while increasing job satisfaction, which is also related to labor productivity. This research aims to design three questionnaires to measure these relations, and give some initial insights about the relations. The designed questionnaires help measuring the relations between the three concepts; starting or finishing the work on time, being in a hurry, feeling confident doing a task and being pressured to do a job are some ways of measuring the relations between lean construction tools, job satisfaction and labor productivity.
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Reflection.

This research is done at the Real Estate and Housing department on the faculty of Architecture at the Delft University of Technology. A literature study is done, then three questionnaires are designed (workers, foreman and site managers), and afterwards the collection and data analysis is done.

Designing a survey for blue-collar workers is not easy, as the questions’ language has to be really basic for the workers to be able to read them and answer them. Additionally this does not guarantee that they would answer it in the expected way, like the Colombian case due to alphabetization problems. The data collection was not as expected, for example in the Colombian case, only one of the construction sites answered the questionnaires, but two others, despite having confirmed their collaboration with the study and extensive follow up, never answered back even though they were contacted multiple times before and after the deadline that was set for the delivery of the surveys.

Due to the data collection problem, the research question changed. First the research aimed to know how lean construction affected labor productivity and indirectly job satisfaction and labor productivity. The questionnaire development took more time and because the data collection got stacked, the outcomes are going to be used to investigate whether the questionnaires indeed measures relations between the three concepts, and validating some relations through piloting the questionnaire and through interviews.

For the literature study it is important to know that not always all the information that is read is useful for the project; some studies does not address relevant information for the hypotheses, or do not prove what they are stating. Doing an interview with an expertise is a good idea to validate literature information and results form the study.

Lean construction, labor productivity and job satisfaction are subjects with much literature behind them, but not much that relates to the three concepts. Been able to relate the separate literature of each subject into one report requires intensive reading and critical appreciation of information, as at the end you have many information on the separate subject, but not always relevant to the relations between them.

This study taught me that for doing a research, it is a good option to start with a wider view of a subject, and then as the research goes on, it is wise to narrow down the scope of the study, in order to be able to have a valid, meaningful and significant result.
Introduction.
The global construction industry represents about 13% of the global GDP and it is expected to increase to 15% in 2020 (Russell, 2013).

This research aims to design a questionnaire to measure the direct effects of lean construction on labor productivity and the indirect effects on the same through job satisfaction. Additionally some insights of the relation between the three concepts are studied.

Previous studies have related the use of lean construction tools with higher levels of productivity (Alarcón, Ballard, Howell, Koskela, Massman & Vrijhoef,). In addition the study of Nahmens, el al, (2012) showed an increase of job satisfaction after implementation of lean methods.

‘Productivity’ is defined as “the power of being productive; efficiency; and the rate at which goods are produced” (Yi & Chan, 2014). Thus, the concept of ‘productivity’ definition consists of these components:

1. Power of being productive is the force behind production itself;
2. Efficiency is a measure of how well the factors are utilized;
3. Rate is a measure of the output of the factors of production over a defined period of time (Yi & Chan, 2014).

According to this definition, construction productivity can be seen as a measure of the outputs that are obtained in relation to the inputs used.

It is argued that as the construction industry is a labor-intensive industry, the workforce is the dominant productive resource, and according to this, the construction productivity is primarily dependent on human effort and performance (Jarkas, 2010).

Labor productivity issues are a great challenge confronted by many construction firms. Indeed it has been lower than that for other industries; for example in United States construction productivity increased between 1966 and 2003 by only 0.78% per year (Forbes, 2010).

The main factors affecting productivity in construction are:
- Managerial
- Technological
- Labor related
- Engineering
- Craft-related items (Forbes, 2010).

Rework and waste.
The construction supply chain involves a large quantity of waste and problems, most of which are caused by other stage of the construction supply chain than where they are detected. The waste and related problems are mostly caused by obsolete, myopic control of the construction supply chain (Vrijhoef & Koskela, 2000). The majority of the construction industry faults are at the design phase (50%), followed by the construction stage (40%) and in turn followed by the suppliers (10%) (Chileshe, 2004), so everyone involved in the construction process is somehow responsible for the failures of the process.

![Figure 1. Waste percentages of time in manufacturing and construction.](image)

According to UK studies the rework counts up to 30% of the construction, which can be up to 50% of the project’s total overrun costs. Only 40-60% of the potential labor is efficient, and at least 10% of the materials are wasted (Aziz & Hafez, 2013). Additional empirical evidence has shown that waste accounts for 50% of the total construction waste. Here waste is defined as ‘anything that is not required to create value for the customer/client or end-user’ (Mossman, 2009). Alarcon (1997, p.391) defines waste as “anything different from the absolute minimum amount of resources of materials, equipment and manpower, necessary to add value to the product.”
The losses produced by activities that do not add value to the product from the clients point of view, and indirect or direct generate costs, are referred to as “waste”. Waste is also recognized as: transportation, overproduction, waiting time, inventories, too much machining, moving, and making defective parts and products (Koskela, 1992). Wastes/non-value adding activities have very high levels in construction, and are measured as costs (Aziz & Hafez, 2013).

Construction performance.
Technology and Construction management are key factors influencing the development of the construction industry. Although new ideas and technologies have been used, the efficiency of the industry remains low. The main reason for this seems to be that the new technologies used cannot reduce the cost of the design and construction and at the same time improve the management of the construction process (Aziz & Hafez, 2013).

Koskela states that the construction industry is characterized by a high number of non-value adding activities, which results in low productivity (Koskela, 1992). According to Botero et al. (2004), construction and maintenance companies are among the least performing industries due to its lack of effectiveness and productivity. Sometimes these problems are caused by design errors and lack of specifications. Other sources are design modifications during the construction process, lack of supervision on workers, overcrowding of workers, high labor turnover and poor industrial safety conditions (Loera, et al. 2013).

All the afore mentioned problems affect the construction phase and result in improper composition of work, high rates of accidents, inadequate distribution of materials on site, lack of materials required, failure of providing equipment and tools, re-work activities, over costs, longer shifts, later delivery of activities and projects in general (Jarkas, 2010).

Operatives affecting labor productivity.
Although there have been significant developments in construction technologies, operatives are the key drivers in the industry. Construction labor costs embraces 30% to 50% of the overall project’s costs, in most countries (Jarkas, 2010), that is why it is an important target to improve efficiency and success of the operations in the field. Due to poor labor efficiency, only 40%-60% of working hours is actually spend on work, leaving 40% – 60% of working hours as unproductive (Forbes, et al. 2010). According to Jarkas, (2010) the following 10 factors are perceived to be most significant to the productivity of operatives:

1. Skill of labor
2. Shortage of materials
3. Labor supervision
4. Shortage of experienced labor
5. Communication between site management and labor force
6. Lack of construction managers’ leadership
7. Weather
8. Delays in responding to “Requests For Information” (RFI)
9. Lack of providing labor with transportation
10. Proportion of work subcontracted

Additional to this factors, analysis of project plan failures, have shown that about 50% of the tasks in weekly work plans are finished by the end of the plan week, and that industry could diminish most of these problems through “active management of variability, starting with the structuring of the project and continuing through its operation and improvement”(Ballard & Howell, 2004, p. 40).

In general there is no standard definition of productivity (Randolph, et al., 1990). Sometimes Labor productivity is expressed as units of output per dollar or work hours (Randolph, et al., 1990).

\[
Labor\ productivity = \frac{Output}{Labor\ cost}
\]

or

\[
Labor\ productivity = \frac{Output}{work\ hour}
\]

For this report the study of Chun & Cho (2015), would be used for knowing how to measure the labor productivity on-site. It is stated that a “variation in work flow greatly influences the construction duration” (Chun & Cho, 2015, pg 93), which influences productivity. The influence of variation and continuity of work-flow on productivity is presented on Lean construction on-site.
First, a literature review is done on lean construction, labor productivity and job satisfaction. Then three surveys are designed (workers, foreman and site-manager), which are translated into Dutch and Spanish and then answered by workers of two different construction sites in the Netherlands and one construction site in Colombia. Additionally an interview with a lean construction expert is done, to validate the data. Finally results were coded using SPSS and then analysed to draw conclusions and recommendations.

This study.
From the preceding it might be clear that reducing waste and rework and increasing labor productivity are major targets to improve project outcomes. Reducing or eliminating defects associated with products or services is a way in which an organization can distinguish themselves from their competitors (Hinckley & Barkan, 1996). Additionally, for the construction industry a successful project completion leads to high customer satisfaction (Anderson & Kovach, 2014). Unlike product design industry, the construction industry lacks a tradition of considering customer satisfaction as a major outcome. Lean construction is an alternative for the problems of productivity the construction industry faces. Labor force is one of the most important factors in the construction industry; it is thought that having higher levels of job satisfaction, improves labor productivity, and lean construction is supposed to improve the workers job satisfaction perception.
**Background.**

**Lean Construction.**

Lean construction is a “way to design production systems to minimize waste of materials, time and effort in order to generate the maximum possible amount of value,” (Koskela et al. 2002, p. 211). It is important to mention that the term of ‘construction’ in ‘Lean Construction’ refers to the whole industry, and not only to the construction phase. Lean construction aims to manage and improve the construction process, by having minimum costs and maximum value, based on the customer needs (Koskela et al. 2002). There are several approaches to lean management, but all lean (construction) thinking expects that a successful project will certainly involve interaction between project and production management (Mossman, et al. 2010). First some main concepts that are shared by several lean approaches will be discussed. Thereafter, one of these approaches, the so-called Last Planner System will be discussed as this is an application of lean management to construction industry.

According to Glenn Ballard, the conceptualization of the design and construction process as a flow of information and materials, results in a reduction of waste, by minimizing time information or materials spend waiting to be used, time spent on inspecting information or materials for conformance to requirements, time spent on reworking information or materials to achieve conformance, and time spent moving information or materials from one specialist to the next (Ballard, 2000). An appropriate application of the production control system, can improve the work to flow reliable, which results in the reduction of the projects’ cost and duration (Ballard, 2000). In the end, such a process innovation improves project productivity.

**Lean characteristics and categories of practices.**

Based on a lean construction expertise and literature, specially the articles of Etges, et al. (2012) and Salem, et al. (2006), some of the most important characteristics and practices of lean construction are presented. In the annexes section there is a table of the different categories of practices after Etges, et al. (2012) and Salem, et al. (2006).

**Bottom up approach (knowledge information management)**

“Knowledge management is the discipline of creating a thriving work and learning environment that fosters the continuous creation, aggregation, use and re-use of both organizational and personal knowledge in the pursuit of new business value” (Cross, 1998, p. 11).

The benefits of a knowledge management economy include opportunities of increasing market share, improving productivity and profitability through innovation and the effective management of knowledge assets (Anumba, et al. 2005).

For the construction industry it is important to create and sustain a knowledge culture, due to its skills shortage; having a culture where the “knowledge is valued, and where knowledge creation, sharing and utilisation are natural and instinctive parts of business process” (Anumba, et al. 2005, p. 47) would give the different actors of the process a more active paper, and need a more effective vision, leadership, coherent strategies and structures, and respect for people (Anumba, et al, 2005).

**Pulling instead of pushing resources (Pulled production)**

Taking into account the clients wishes and integrating them to the process is a main objective of lean construction. As mentioned before traditional construction management dos not consider the customer satisfaction as a major outcome, even though for having a successful project customer satisfaction is required (Anderson & Kovach, 2014).

Koskela states that for improving the construction industry, it is important to change the way of thinking, and not looking for isolated solutions to the various problems, but instead to look as a whole, an integration of all actors and factors of the process.

Scheduling the production from a customer’s need is a main concept of lean production, for been able to achieve this, reliable methods, multidisciplinary labor systems, production and logistic control (Kanban), inventory and cycle times control is needed (Etges, et al. 2012).
Monitoring for Quality (Quality control)
Lean construction projects are safer, easier to manage, completed sooner, cost less and of better quality (Aziz & Hafez, 2013). Quality is an important aspect of lean construction, which leads to Total Quality Management (TQM), which is defined as ‘Do the right thing, right the first time, on time, all the same; always strive for improvement, and always satisfy the customer’ (Chileshe, 2004).

In construction, quality refers to the compliance of the final product, eliminating the waste caused by poor quality and eliminating the wastes caused by physical interruption of flow due to a specific defect are important aspects for achieving a more productive project (Etges, et al. 2012).

Empowerment of workers
Empowerment can be described as “the process of enabling employees to make workplace decision for which they are accountable and responsible, within acceptable parameters, and as a part of the organizational culture (Price, et al. 2004, p. 27). This is an important value for lean construction, when workers are empowered; it means they are given autonomy, democracy, and flexibility (Price, et al. 2004,). The organizational context and the mode of implementation are key factor to ensure the success of empowerment between groups or individuals; when these two factors are managed effectively “empowerment can be used to promote improved productivity and quality, reduce operating costs, allow greater flexibility, increase job satisfaction, and improve motivation (Price, et al. 2004, p. 27).

Time management
A clear set of objectives for the delivery process, the aim to maximize performance for the customer at the project level, project control through the life cycle of the project from design to delivery, concurrent design and construction are the features that lean construction include (Aziz & Hafez, 2013).

According to Lauri Koskela “a construction project consists of three basic flows (design process, material process and work process) and supporting flows (Koskela, 1992). In lean systems, the flow of processes is known as the movement of information, materials and equipment through a system. This flow view describes processes as a composition of transformations and inspections, waiting, and moving information, materials, and equipment (Abbasian-Hosseini, et al. 2013).

Continuous improvement
It is important to identify the problems in the process, discuss the problems with the different groups of actors, and have feedback and an internal benchmark development (Koskela, 2000). The construction sites should be seen as a place of continuous learning, which identifies problems in current scene and project future solutions (Alarcón & Mardones, 1998)

Visual management
Consists of identifying the process and verifying if there is any deviation from the reference. Visual kanban, flow cell unit, standardized work, obeya and performance metrics are some examples of visual management in lean production. For the construction industry, visual management operates in management of nine fields: process, performance, knowledge, inventory, maintenance, safety, quality, production and image (Etges, et al. 2012).

Supply chain management
To achieve the just in time, it is important to have a logistic management and planning in input supply. For Toyota, developing a long-term partnership between manufacturer, reseller and buyer, the buyer engaging in the process of product development and the dealer in the production system are good practices for having in time and without disruption the end products (Etges, et al. 2012).

Continuous flow
“The continuous flow implementation process has four steps independent of each other: diagnosis, creation of initial conditions, planning, and finally, the control. All these steps are directly linked to the Planning and Production Control and adaptation of tools from LP. Four concepts of LP are critical in the implementation of continuous flow, stability, interdependence, takt time and work elements.” (Etges, et al. 2012, p. 3).
Last Planner System

Last Planner System is the most common approach and will be therefore discussed in more detail. There are other approaches such as Target Value Design and the Lean Project Delivery System that were specifically conceived for lean construction, but a full discussion is beyond the scope of this report. Where necessary, additional lean methods and approaches will be discussed later in this report.

The Last Planner System is defined by its inventors Glenn Ballard and Greg Howell as a philosophy, rules, procedures, and a set of tools that shifts the focus of control from the workers to the flow of work that links the together and thus proactively managing the production process (Ballard, 2000). The Last Planner System has five main integrated elements (Ballard, 1997):

1. Master Plan: shows the main activities, with its durations and sequence.
2. Phase Planning: It is a connection between the master plan and the lookahead planning.
3. Lookahead Planning: Aims to focus the team’s attention on the short-term period of up to six week.
4. Weekly Work Plan: The work performers assume responsibility and give promises for the week to come.
5. Feedback Statistics: Is the Percent Plan Complete (PPC) of promises and the reasons for non-completion of tasks, which helps in the management of the planning process.

(Zimina & Pasquire, 2012)

The Last Planner System is a management system, which main goal is to reduce the flow and process-time variability of tasks. As an outcome it aspires to never make the same mistake twice in a project and firm. Additional it stabilizes operations so optimization makes economic sense, and at the same time improves productivity (Zimina & Pasquire, 2012).

One of the principles of the Last Planner System is to have a detailed planning, as one gets closer to doing the work, as the uncertainty is drastically reduced. Doing plans collaboratively with the ones doing the work, is the second principle: with this the planning will be more accurately, as the people doing the work know better their tasks, know the latest information about the progress of the work and know the prerequisites for the work to be done. The third principle is to reveal and remove constraints on planned tasks as a team, which allow the last planners to achieve a smooth workflow. When making reliable promises, the person makes enough effort to ensure the task can be done. Finally the last principle is that when promises are broken, it is important to find what caused this and how this might be prevented, so to learn from those breakdowns. Analysing the breakdowns and take measures to prevent future breakdowns is an important advantage of the system. By analysing the process that caused the breakdown, problems with management, problematic team relationship and a hampering system become apparent, while these problems used to remain hidden otherwise (Zimina & Pasquire, 2012).

The Lean Construction Industry defines Last Planner System as “The collaborative, commitment-based planning system that integrates should-can-will-did planning (pull planning, make-ready, look-ahead planning) with constraint analysis, weekly work planning based upon reliable promises, and learning based upon analysis of PPC (plan percent complete) and reasons for variance.” (Lean Construction, 2015).

For measuring the success of the Last Planner System, the Percentage of Promises Completed on time are measured. Figure 3 shows typical reasons why tasks promised in the weekly work planning are delivered late, which is important for the continual improvement process.
Increased visualization
Its scope, based on the lean manufacturing is the transparency. It helps identify the work flow and creates awareness of the action plans on the construction site (Moser & dos Santos, 2003).

First-run studies
Aims for the continuous improvement, as in lean manufacturing. They are used to redesign critical assignments (Ballard & Howell, 1997). The operations are checked in detail, to have new ideas and suggestions on how to do the work (Salem, et al, 2006).

Table 1 is a comparison between lean construction and traditional project management approaches (Zimina & Pasquire, 2012).

<table>
<thead>
<tr>
<th>Lean Construction</th>
<th>Traditional PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus is on the production system</td>
<td>Focus is on transactions and contracts</td>
</tr>
<tr>
<td>Task, Flow &amp; Value</td>
<td>Task Goal</td>
</tr>
<tr>
<td>Downstream players are involved in upstream decisions</td>
<td>Decisions are made sequentially by specialist ad “thrown over the wall”</td>
</tr>
<tr>
<td>Product and process are designed together</td>
<td>Product design is completed, then process design begins</td>
</tr>
<tr>
<td>All product life cycle stages are considered in design</td>
<td>Not all product life cycle stages are considered in design</td>
</tr>
<tr>
<td>Activities are performed at the last responsible moment</td>
<td>Activities are performed as soon as possible</td>
</tr>
<tr>
<td>Systematic efforts are made to reduce supply chain lead times</td>
<td>Separate organizations link together through the market, and take the market offers</td>
</tr>
<tr>
<td>Learning is incorporated into project, firm, planning and supply chain management</td>
<td>Learning occurs sporadically</td>
</tr>
<tr>
<td>Stakeholder interests are aligned</td>
<td>Stakeholder interests are not aligned</td>
</tr>
<tr>
<td>Buffers are sized and located to perform their function of absorbing system variability</td>
<td>Participants build up large inventories to protect their own interests</td>
</tr>
</tbody>
</table>

Table 1. Differences between lean construction and traditional project management (Zimina & Pasquire, 2012).

Lean construction tools have been evaluated through lean implementation measurements standard and performance criteria, and it has been shown that increased visualization, daily huddle meetings, last planner and first-run studies achieve more effective outcomes than expected (Aziz & Hafez, 2013).
**Job Satisfaction.** If attention is paid to the employees’ satisfaction with their job, the employees’ functioning can be enhanced, meanwhile reducing costs associated with turnover and increased productivity (Nahmens, et al. 2012). According to Lipinska-Grabelny and Papieska, job satisfaction comes from the interface of thoughts and feelings, or cognitive and emotional perspectives. An often-used definition for job satisfaction is formulated by Muchinsky (in Nahmens et al, 2012), in which job satisfaction is “the extent of satisfaction an employee extracts from performing an assigned task.” Job satisfaction is related to tasks’ characteristics as type of work, monotony, working methods and control over the work (Nahmens, et al. 2012). Other task characteristics that were found to affect job satisfaction are related to job content, including task achievement recognition, task responsibility, task achievement, task nature and task capability. These are considered to enhance job satisfaction, whereas dissatisfier factors would do the reverse. Some long established dissatisfiers are related to job environment, and include quality of working conditions, working facilities, conditions under which a job is being performed, salary and type of supervision (Herzberg, 1967). Others (Neuberger & Allerbeck, 1978) found that co-workers, and supervisor, as well as organization and management and opportunity for development also influence job satisfaction (Neuberger & Allerbeck, 1978).

**Increasing productivity through job satisfaction.** Absenteeism creates daily disruption on the shop floor, which results in lower productivity and reduced quality; absenteeism and labor turnover are important measures of job satisfaction (Nahmens, et al. 2012). In the construction industry, job satisfaction is related to the turnover and absenteeism rates (Porter & Steers, 1973). Employee involvement is an important aspect for lean construction, as rapid response to problems requires empowerment of workers (Koskela, 1992). Empowerment involves increasing the responsibilities and abilities of front-line workers (Vidal, 2007). Empowerment is believed to increase job satisfaction, through increasing the intrinsic rewards of work. Vidal found that workers only contribute with their effort to problem-solving if they believe their interests are aligned with those of the company, and additionally the company, is willing to make a reciprocal investment in their well-being (Vidal, 2007). Interestingly, Vidal found that increased responsibilities that lean working brings along, are not always appreciated by workers. The main reason for this is that empowerment may invoke more stress and frustration to workers. Figure 4 shows that if a worker does not like to be empowered, or so to say experience job autonomy, implementation of lean measures that imply empowering of workers can cause more stress than being a rewarding experience (Vidal, 2007).

![Image](https://via.placeholder.com/150)

**Figure 4.** Relationship between participation in decision-making and problem-solving and job satisfaction (Vidal, 2007). Additionally based on the interview, it is possible to state that visual management improves productivity by giving the workers the information about it, if workers know how the project is doing, they can feel more committed and motivated, and the management parties would be more informed of the daily activities and progress, been able to respond to any problem.
Hypotheses.
This study aims to contribute to research investigating how to measure the processes that underlay the potential influences of lean methods on labor productivity. From literature, two pathways seem to be involved. Lean methods seem to directly improve labor productivity, as for instance LPS may directly increase productivity, and one indirect route as lean methods also involves empowerment of employees. By empowering employees, they gain autonomy in their work and this may indirectly influence job satisfaction according to the Job Demand / Control Support model of Karasek (Häusser et al, 2010). The main objective of this study is to develop a questionnaire to measure both pathways in a group of blue collar workers. Typically, studies involving the relationships between lean methods, job satisfaction and labor productivity concern white collar workers and other groups with sufficient literacy (Häusser et al, 2010). However, the construction phase of building projects typically involve blue collar workers, and they are unfamiliar with questionnaire research, and not all workers are expected to have literacy levels required to understand existing questionnaires. Therefore, as part of this research study, a new questionnaire was developed to measure both routes.

In figure 6, the conceptual model shows both routes representing two hypotheses concerning the potential influences of lean methods on labor productivity. The first one is the purple route, which states that the productivity problems that the construction industry faces can be improved with lean construction tools. The second route is the green one, which states that by applying lean construction principles job satisfaction is improved, and indirectly enhances labor productivity in construction sites applying lean methods.

The direct route:
The core idea of lean methods is that it is a way to design production systems to minimize waste of materials, time and effort in order to generate the maximum amount of value (Koskela, 2002; see figure 5).

Studies have shown how labor productivity is improved, when more time is spend on the value-adding activities (Abbasian-Hosseini, et al. 2013). In a study of over 400 manufacturing plants in the U.S and Europe, productivity improved after applying lean methods that reflected new production philosophy principles (Koskela, 1992).

It is thought that labor productivity particularly improved, because time spending on non-value adding activities is decreased through implementation of actually lean construction techniques.

One example of the later is increased scheduling through introduction of weekly work planning, referred to as Last Planner System tools. Last Planner System was introduced in construction industry by Ballard and is one of the most common lean methods, although there are other lean methods tools developed as well (Zimina & Pasquire, 2012). Annex 1 and 2 provide an overview of lean methods identified though literature.

Figure 7, summarizes the different emphasizes lean methods have. Whereas Last Planner System mainly addresses increased scheduling, other methods also emphasize quality control, continuous flow, visual management, supply chain management, pulled production, time management, increased scheduling, continuous improvement, bottom up approach, reliable work flow, minimize waste and workers empowerment.
**Indirect route.**

The core idea of this indirect pathway through job satisfaction is that lean methods change working methods and working environments which may affect beliefs, values and working practices of employees; Thus, Lean may affect employees’ job satisfaction (Nahmens, et al. 2012; Chatman, & Jehn, 2001). It is thought that lean methods have such an impact as it provides workers with more autonomy in their job (Häusser et al, 2010). Lean methods imply behavioural and cultural changes and encourage a one more proactive attitude. This will increase job satisfaction of the workers (Nahmens, et al. 2012). Indeed, a study in industrialized housing industry reported that after implementation of lean methods, workers’ culture and attitude changed (Hook & Stehn, 2008).

Figure 4, from Vidal (2007), shows that the satisfaction perception varies with individual work orientations, as it depends on each worker how they feel with the opportunity to participate. “The opportunity to participate may be positively related to job satisfaction but it is also positively related to stress, which is negatively related to job satisfaction.” (Vidal, 2007, pg. 273).

Figure 7 shows also the way job satisfaction is thought to affect labor productivity. Absenteeism and labor turnover is related to job satisfaction (Porter & Steers, 1973), therefore, absenteeism and labor turnover reflect the indirect way that lean methods affect labor productivity.

**Productivity.**

The questionnaire that was developed in this research aims to assess the core ideas of lean methods involved in these routes and therefore includes questions on waste of materials, time and effort. The core idea of productivity-related effects is that managerial, technological, engineering and craft related impacts could be measured through their influence on efficiency of time and efficacy of work (Yi & Chan, 2014, Jarkas, 2010, Forbes, 2010).

**Survey.**

A survey research is a “Cross-sectional design in relation to which data are collected predominantly by self-completion questionnaire or by structured interview on more than one case and at a single point in time in order to collect a body on quantitative or quantifiable data in connection with two or more variables, which are then examined to detect patterns of relationship between variables.' (Bryman, 2004, pg 699).

In this case as it was mentioned before, the aim of designing the survey, is for purpose of use in future research; in order to collect data about lean construction practices, job satisfaction and labor productivity and know the relationship between these variables. Additionally the questionnaires aim to reflect the three concepts in a consistent way, giving a reliable reading of the variables.
Lean construction on-site

Figure 7. Conceptual model.
Main research question.
The main objective of this study is to develop a questionnaire to measure the direct effects of lean methods on labor productivity (1) and the indirect effect of lean methods through its influence of job satisfaction (2a) on labor productivity (2b). More specifically the following research questions will be addressed in the remaining part of this report.

Research questions.
• How can lean concepts and labor productivity (1) be measured in a group of blue collar workers?
• How can job satisfaction be measured in a group of blue collar workers? (2a)
• How can the indirect effects of job satisfaction on labor productivity be measured? (2b)

The conceptual model is based on the literature study. The most important practices and characteristics of the relationship between variable are allocated in the correspondent arrow. Visual management is a concept that is allocated in the relation between lean construction and labor productivity and lean construction and job satisfaction. It is assigned to both routes because workers are informed about productivity on site, project flow, amount of productive hours per day; and with these information their work is influenced in a direct or indirect way, which affects productivity at the end. If workers are informed about the project, they are more involved with it, and thus they are expected to be more committed and feeling part of the project, such influencing their overall satisfaction perception.

Figure 8. Conceptual model 2.
Case studies.

**Eindhoven project description**

Date: 23 April 2015  
Spoken to: assistant project manager and site manager

**General description.**  
One of the projects in the Netherlands used for the study is a housing refurbishment project located in Eindhoven. At this moment the project is about half way of the refurbishment. It’s a project built in 1982 of 69 social rented houses and 30 social rented small apartments, the refurbishment asked by the housing corporation (project owner) consists of the bathroom, toilet, electrical board and if needed the kitchen. The decision for refurbishing the bathrooms and toilets was because of draining problems and moist.

**Lean Planning.**  
The bathroom renovation takes seven days, the toilet four days and the kitchen five days within those seven days, so in total each house is seven working days and in total there are ten workers in the project.

**Pull production in one piece flow.**  
As the project is demand driven, the inhabitants were asked when they wanted the refurbishment and if they wanted the bathroom and toilet, only one or none, but at the end all the inhabitants decided to refurbish. Additional on the site managers’ house there is a space where the inhabitants can go and relax or cook while the refurbishment takes place at their homes.

**Effect on productivity.**  
Apart from the demand driven aspect of the project, they also had a coaching and taking over tasks experiment, so they could have 100% productive days. For example the first day of refurbishment is done by the demolition workers, who learned some basic electrician tasks to be able to have a whole productive day, so transfer of activities is an important subject for productivity in this project.

**One piece flow.**  
In addition, the project culture is of collaboration between workers; for instance the plasterer had one extra hour at the end of the day, so he uses it for cleaning and organizing the houses for the next working day.

The planning of the project was done in a modular way, in which each day they start a new house and the workers know exactly where they are in the planning, what they have to do each day and how the projects is doing, they are seen as ambassadors of the project. It is a sequence, which has worked well according to the tenants and site manager.

**Effect on workers.**  
The workers feel proud of the project. Due to the project culture they feel part of it, they are committed to the process and results, and additionally they also have a good relation with the tenants, and can solve their doubts, as they know the planning and what is going on in the different houses.

**Effect on client satisfaction.**  
The level of satisfaction of the inhabitants is 9, which is a very high score for this kind of projects.

**Lean tools summary.**  
The project tools and ideas related to lean construction and lean management used are: demand driven project, line balancing, pull production, transfer of activities between workers, coaching among workers, balancing of work, reallocation of activities, collaboration between workers, just in time delivery, security of materials, autonomy of self-controlling teams.
Breda project description.

General description.
The other project from the Netherlands used for the research is located in Breda. It is a refurbishment of 79 row houses, which were built in 1940’s. The project started on November 2014 and ended on April 2015.

The construction works included the renovation of chimneys, roofing (better ventilation, renovation of gutters), new window frames with ventilation grilles and insulating glass, new front doors, new mechanical ventilation and central heating systems, impregnation of facades against penetration of moisture and insulation of facades by filling the walls. The tenants could choose for new bathrooms, kitchens and toilets. Also the layout of the houses could be changed within certain configurations.

Lean planning.
The lean techniques used for this project are focussed on intensive planning. For this, the work was organized in two production streams, one for the outside, including facades, roofs and exteriors and an inside stream that includes the kitchen, bathroom and toilets. The activities between each house vary, and in order to have a more balanced production, the houses with similar activities were grouped. The average time of renovation for the houses with kitchen, bathroom and toilet works, were around 8 to 10 working days.

Lean tools summary.
The project tools and ideas related to lean construction and lean management used are: lean planning, involvement of blue collar workers in (detail) design, daily start up meeting with foremen, collaborative culture between workers (supported by start up meeting).

Colombia project description.

Date: 11 May 2015
Spoken to: project owner

General description.
The project from Colombia used in the research is located in the coast of the country in a city called Santa Marta. It is a project of one tower with 136 apartments; the works done at this moment are basically electrical, plumbing, and drywall installations as they are finishing the project. Kankurua (projects’ name) started construction at beginnings of 2013 and would be finished ends of November 2015, having a delay of six months.

Project management.
This project is managed in a traditional way, and according to the project owner they do not use any special managerial tool. The contractors have not changed since the begging of the project, and have worked together in previous projects.
Sample.
The sample for the study was done between 3 different sites, two in the Netherlands and one in Colombia. The two cases of the Netherlands were selected because they use some type of lean construction tool(s), and for the Colombian case it was not possible to find a case where lean tools were used. In total, the study consists of 57 workers, 33 from the Colombian case, 16 from the Breda case and 8 from the Eindhoven case; 4 foreman, 2 from Colombia and 2 from Breda (Eindhoven case does not have a foreman, due to the project organization), and 5 site managers, 2 from Colombia, 2 from Breda and 2 from Eindhoven, having in total a sample of 66 person. The age of the sample varies between 19 years to 61 years, having a median of 36 years old; and the working experience between all the people sampled goes between 1 year and 46 years, resulting on a median of 12 years of construction working experience.

Questionnaire development.
As the research objective is to develop a questionnaire which is able to measure the direct effects of lean methods on labor productivity, and the indirect effect of lean methods through its influence of job satisfaction on labor productivity, the questionnaires were developed based on the literature study on the main subjects lean construction covers. The idea was to develop three questionnaires, one for the workers, one for the foreman and one for the site managers, and have a link between the three of them, to be able to collect the information required from the three perspectives. Some of the questions were only asked to the foreman and site managers, as the workers does not have this information usually.

Each question was developed under one or more category of the conceptual model (productivity, lean construction or job satisfaction), so at the end when the questionnaires would be answered in the future, collecting relevant data, it would be possible to link the information with the three categories and have conclusions about the concept relations. The three questionnaires were first done in English, and then translated into Dutch and Spanish, and then compared between by translating the Spanish version into Dutch to ensure consistency. Additionally the phrasing of the questions had to be really simple, and the answers options limited, as some of the workers do not have many study knowledge.

Table 2, is a summary of the questions categories, the questions are phrased according to the workers survey and then to the foreman survey. Annex 1 has the English questionnaires.

<table>
<thead>
<tr>
<th>Question</th>
<th>Workers</th>
<th>Foreman</th>
<th>Site manager</th>
<th>Category</th>
<th>Extra category</th>
</tr>
</thead>
<tbody>
<tr>
<td>How satisfied are you with your work?</td>
<td>Q.1</td>
<td>Q.1</td>
<td>Q.3</td>
<td>Job satisfaction</td>
<td>-</td>
</tr>
<tr>
<td>How much pressure did you feel to finish the job?</td>
<td>Q.2</td>
<td>Q.4</td>
<td>Q.5</td>
<td>Job satisfaction</td>
<td>-</td>
</tr>
<tr>
<td>Did you need to be in a hurry to finish the job?</td>
<td>Q.3</td>
<td>Q.5</td>
<td>Q.6</td>
<td>Job satisfaction</td>
<td>-</td>
</tr>
<tr>
<td>Can you decide for your own, on how to do the job?</td>
<td>Q.4</td>
<td>Q.8</td>
<td>Q.9</td>
<td>Lean construction</td>
<td>Autonomy</td>
</tr>
<tr>
<td>How much would they follow up on you, if you offer a possible solution for some problem?</td>
<td>Q.5</td>
<td>Q.10</td>
<td>Q.11</td>
<td>Lean construction</td>
<td>Job satisfaction</td>
</tr>
<tr>
<td>Communication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Job satisfaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Job security</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How confident do you feel in doing your tasks, including new tasks?</td>
<td>Q.6</td>
<td>-</td>
<td>-</td>
<td>Job satisfaction</td>
<td>Job security</td>
</tr>
<tr>
<td>Lean construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did your team receive any treat or compliment for delivering a good work?</td>
<td>Q.7</td>
<td>Q.11</td>
<td>Q.12</td>
<td>Job satisfaction</td>
<td></td>
</tr>
<tr>
<td>How many days were you able to start your job in time (the last week)?</td>
<td>Q.8</td>
<td>Q.12</td>
<td>Q.13</td>
<td>Lean construction</td>
<td>Flow</td>
</tr>
<tr>
<td>Productivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How many days were you able to finish your job in time (the last week)?</td>
<td>Q.9</td>
<td>Q.13</td>
<td>Q.14</td>
<td>Lean construction</td>
<td>Flow</td>
</tr>
<tr>
<td>Productivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How many days was it clear for you what you needed to do (the last week)?</td>
<td>Q.10</td>
<td></td>
<td></td>
<td>Lean construction</td>
<td>Flow</td>
</tr>
<tr>
<td>Productivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you feel the work is well organized?</td>
<td>Q.11</td>
<td>Q.15</td>
<td>Q.16</td>
<td>Lean construction</td>
<td>Flow</td>
</tr>
<tr>
<td>Productivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With whom did you talk about work (the last week)?</td>
<td>Q.12</td>
<td>Q.17</td>
<td>Q.18</td>
<td>Lean construction</td>
<td>Communication</td>
</tr>
<tr>
<td>With whom did you talk about all but work (the last week)?</td>
<td>Q.13</td>
<td>Q.18</td>
<td>Q.19</td>
<td>Lean construction</td>
<td>Communication</td>
</tr>
</tbody>
</table>
### Data collection

The questionnaires for the Colombian case were send via e-mail to the site manager, and he distributed them to the foreman and as the workers are on a alphabetization course, the teacher fill in the questionnaires with each of the workers. Then the answers were sent back electronically. For the Eindhoven and Breda cases the surveys were given physically to the site manager and then distributed to the workers, the results were send back via e-mail.

The variables tested were job satisfaction, through job pressure, job security, incentives and absenteeism; lean construction techniques through autonomy, communication, involvement, flow, planning, collaboration and coaching and productivity through workflow and planning.

### Data analysis method.

All the answers were organized in a excel file, and then the date was transferred to SPSS for analyzing it. A cross tabulation was done to know the relationship between lean construction, job satisfaction and productivity categories; all the questions were cross tabulated between them. The level of significance used is $p < 0.100$, that means that if any factor has a p-value below 0,100, it significantly influences the outcomes of the model.

<table>
<thead>
<tr>
<th>Week?</th>
<th>How many times did you ask your colleagues for help (the last week)?</th>
<th>Q.14</th>
<th>Q.19</th>
<th>Q.20</th>
<th>Lean construction</th>
<th>Communication Collaboration Coaching Involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>How many times did your colleagues ask you for help (the last week)?</td>
<td>Q.15</td>
<td>Q.20</td>
<td>Q.21</td>
<td>Lean construction</td>
<td>Communication Collaboration Coaching Involvement</td>
</tr>
<tr>
<td></td>
<td>How helpful do you find meeting in the morning with the other foremen, for doing the work planned?</td>
<td>Q.2</td>
<td>Q.4</td>
<td>Q.6</td>
<td>Lean construction</td>
<td>Coaching Involvement</td>
</tr>
<tr>
<td></td>
<td>How much effort does it take to explain the works to your crew?</td>
<td>Q.7</td>
<td>Q.8</td>
<td>Q.10</td>
<td>Lean construction</td>
<td>Coaching Involvement</td>
</tr>
<tr>
<td></td>
<td>Do you have enough time to explain the work to your crew?</td>
<td>Q.14</td>
<td>Q.15</td>
<td>Q.17</td>
<td>Lean construction</td>
<td>Coaching Flow</td>
</tr>
<tr>
<td></td>
<td>How much influence do you have on making changes to the project planning?</td>
<td>Q.16</td>
<td>Q.17</td>
<td>Q.18</td>
<td>Job satisfaction</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>How many questions did you receive from your crew about the works they have to do?</td>
<td>Q.3</td>
<td>Q.4</td>
<td>Q.5</td>
<td>Lean construction</td>
<td>Planning</td>
</tr>
<tr>
<td></td>
<td>Was absenteeism bellow or above average?</td>
<td>Q.21</td>
<td>Q.22</td>
<td>Q.23</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 2. Question categories.**

**Lean construction on-site**
Findings.
After designing the questionnaires and answering them in three different cases it is possible to state that the questionnaires can be used to measure the relations between the three concepts. Some of the questions accurately measure certain concepts categories, other need more elaboration. Using these questionnaires in the future would help to know which categories of practice are more relevant for improving labor productivity and/or job satisfaction through lean construction.

For measuring construction labor productivity on site, work flow is (according to lean construction practices and as mentioned in the literature study) a way to know how effectively time, money and different resources are been used, which are clear factors affecting productivity. The questionnaires has five questions referring to work flow, particularly questions 8 to 11 from the workers and question 14 form the foreman. These questions give important insights on how work is done on-site, but with the results obtained, an additional question should be added to the designed questionnaires: “How many days of full production did you have this week?”. With these questions it is possible to know if a site has a good work flow or if there are problems on it. After relating the answers of these questions with other questions, it would be possible to draw conclusions of how productivity is affected by using lean construction practices and indirectly by improving job satisfaction. Furthermore these questions are also related with lean construction practices.

Questions 8 to 10 were not answered in the Colombian case, as the site manager gave the order to the workers not to fill it in. This is why only the answers from the Dutch cases were analyzed, in which the workers correctly responded the questions. With this it is possible to affirm that the questions do work, but due to cultural differences or non-disclosure policy practice were not answered in the Colombian case.

As the literature study addresses, job satisfaction is affected by job factor such as pressure, been in a hurry and receiving treats and/or compliments. Additionally the absenteeism rate is an important measure for it. Questions 2, to 4 of the workers questionnaire and question 16 of the foreman questionnaire, were focused on measuring these aspects. For these questions the same result as the ones focused on productivity/work flow, which can be related with the other questions answers’ for having conclusions in the future on the relation of job satisfaction with lean construction and labor productivity.

Question 1 in the workers survey asked: “How satisfied are you with your work?”, which works good, but the answer options need to be changed because it was not possible to have a clear distinction between the three faces used. In order to measure how they feel about their job while having a clear distinction between the answers, it is better to have a scale from 1 to 10, so the respondents can answer it better and the conclusions can improve.

The rest of the questions are focused to know how workers work with lean construction practices, and how helpful they find them. They are focused at job autonomy, communication, involvement, job security, planning, collaboration and coaching. Some of these categories overlap with job satisfaction and labor productivity measures.

The results obtained for this research shows that if the questionnaires proposed are used, obtaining a significant amount of answers, it would be possible to know the effects of lean construction methods on labor productivity, and the indirect effects of lean construction methods through its influence of job satisfaction on labor productivity.

As it was stated before, the data collection does not provide a significant number of answers to formally answer any research question addressing the question whether lean methods both exert an direct effect on project outcome and an indirect effect on project outcome through an effect on job satisfaction. But it is possible to have some insights of the correlations between the different answers that are sensitive to measure, for the future with the questionnaires proposed. Table 3 shows the relations that were significant; In addition it has the number of the questions used for each cross tabulation and the categories the relation represent. Only the results from the Netherlands are going to be discussed, as they were the only questionnaires that were totally completed.
<table>
<thead>
<tr>
<th>Variable Name 1</th>
<th>Variable Name 2</th>
<th>P-Value</th>
<th>P-Value NL</th>
<th>P-Value COL</th>
<th>Category</th>
<th>Question # (workers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>StartOnTime</td>
<td>ClearDays</td>
<td>0.002</td>
<td>0.002</td>
<td>-</td>
<td>Lean construction Productivity</td>
<td>Q.8 Q.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flow Planning</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>StartOnTime</td>
<td>Hurry</td>
<td>0.620</td>
<td>0.103</td>
<td>-</td>
<td>Lean construction Productivity</td>
<td>Q.8 Q.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flow Job satisfaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>StartOnTime</td>
<td>FollowSolution</td>
<td>0.224</td>
<td>0.086</td>
<td>-</td>
<td>Lean construction Productivity</td>
<td>Q.8 Q.5</td>
</tr>
<tr>
<td></td>
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<td>Job satisfaction Job security</td>
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<tr>
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<td>Communication Involvement</td>
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<td></td>
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</tr>
<tr>
<td>StartOnTime</td>
<td>ConfidentTasks</td>
<td>0.001</td>
<td>0.001</td>
<td>-</td>
<td>Lean construction Productivity</td>
<td>Q.8 Q.6</td>
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<td>Flow Job satisfaction</td>
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<td></td>
<td>Job security Involvement</td>
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<td>FinishInTime</td>
<td>ClearDays</td>
<td>0.002</td>
<td>0.002</td>
<td>-</td>
<td>Lean construction Productivity</td>
<td>Q.9 Q.10</td>
</tr>
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</tr>
<tr>
<td>FinishInTime</td>
<td>ConfidentTasks</td>
<td>0.059</td>
<td>0.059</td>
<td>-</td>
<td>Lean construction Productivity</td>
<td>Q.9 Q.6</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flow Job satisfaction</td>
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</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>Job security Involvement</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ClearDays</td>
<td>Satisfaction</td>
<td>0.031</td>
<td>0.079</td>
<td>-</td>
<td>Lean construction Productivity</td>
<td>Q.10 Q.1</td>
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<td></td>
<td></td>
<td>Planning Job satisfaction</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ClearDays</td>
<td>Pressure</td>
<td>0.022</td>
<td>0.088</td>
<td>-</td>
<td>Lean construction Productivity</td>
<td>Q.10 Q.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Planning Job satisfaction</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. SPSS results summary.
Figure 12, shows that the relationship between the days the workers could start their work on time and the days they had clear what they needed to do, is sensitive to measure; this relation is measured with question 8 vs. question 10. Starting the work on time is a sign that the work has a good flow, the project planning is working and by the same means, the project is been productive. Lean tools, such as visual management and daily start up meetings achieve having clear what has to be done. Here there is a possible relation between productivity and lean construction (direct route).

Figure 13, represents the relationship between workers starting on time and not been in a hurry. This relation is sensitive to measure, as it shows how most of the workers who were not in a hurry, did start their work on time. This shows a possible relationship between workflow, job satisfaction, productivity and lean tools. Been in a hurry can cause stress to the workers, resulting on low levels of job satisfaction. Here there is a probable relationship between lean construction job satisfaction and labor productivity (indirect route).

Figure 14, indicates that the relationship between workers starting on time and been followed up on the solutions they propose for problems is sensitive to measure. Usually when workers start on time, their superiors follow up on the solutions they’ve proposed. This proves an apparent relationship between lean construction practices, productivity, workflow, communication, involvement and job satisfaction (indirect route).

Figure 15, shows that the relationship between starting on time and felling confident about doing the job is sensitive to measure. All the workers who felt confident doing their job or new tasks, started on time. Feeling confident on the job is a characteristic of job satisfaction, and as mentioned before starting on time is related to workflow, lean tools, which gives a possible relation between the three variables of the study (indirect route).
Figure 16, shows that the relationship between workers finishing on time their job and having clear what they have to do is a sensitive relation to measure. Finishing on time the job it’s by the same means related to the variables start in time is related. This is a possible relationship in which lean tools can improve labor productivity in the construction site (direct route).

Figure 17, represents the relationship between having clear what needs to be done with feeling satisfied, which is sensitive to measure. In this relation, most of the workers who are highly satisfied with their work, had clear what they needed to do all days. Having clear what needs to be done is positively related to highly satisfied workers. This is a possible relation between lean construction tools, productivity and job satisfaction (indirect route).

Figure 18 shows that the relation between finishing the job on time and feeling confident about doing the job, is a sensitive relation to measure. This apparent relation proves that lean methods indirectly improves job satisfaction, which improves labor productivity (indirect route).

Figure 19, indicates that the relationship between having clear what needs to be done and the pressure the workers feel to do the job, is a relation that is sensitive to measure. The majority of workers that had clear what they needed to do, felt little pressure under them. This represents a probable relation between lean construction tools, productivity, planning, and job satisfaction. Creating a possible relation between the three studied concepts (indirect route).
Lean construction on-site

Figure 20, represents that the relationship between having the job clear and been in a hurry is sensitive to measure. The majority of workers who did not experience they finished in a hurry, had clear all days what they needed to do. As mentioned before, been or not been in a hurry is related to job satisfaction perception, and having clear the job to lean construction and productivity, which would result on a probably relation between the three concepts (indirect route).

Figure 21, shows that the relationship between workers having clear what they need to do and workers been followed up in solutions they propose is sensitive to measure. All workers who were followed on the solutions they proposed had clear their jobs. Which creates a possible relation between lean construction, productivity and job satisfaction (indirect route).

Figure 22, indicates that the relationship between having the job clear and feeling confident doing the task is sensitive to measure. All the workers who felt very confident doing their jobs, had clear what they needed to do. This relates to lean construction principles, productivity and job satisfaction (indirect route).

Figure 23, shows that the relation between feeling pressure to finish the job and been in a hurry is sensitive to measure. In this case all the workers who had to finish their work in a hurry, felt moderately too much pressure. This results in a possible relation between job satisfaction and lean construction tools (indirect route).
Figure 24, shows that the relation between been in a hurry to finish the job and been able to decide how to do the job is sensitive to measure. Here all the workers who had little to moderately say on how to do their job were never in a hurry, which is not expected and would be interesting to study in the future. This is a possible relation linked to the variables of job satisfaction, lean construction and job autonomy (indirect route).

Figure 25, indicates that the relation of doing the job in a hurry and been followed up by a superior when offered a solution is sensitive to measure. Here most of the workers who were little to moderately follow up by their superiors when proposing a solution were never in a hurry, which is also not expected as the previous relation. This probable relation is connected with job satisfaction, lean construction tools (indirect route).

Figure 26, indicates that the relation between been able to decide or not on how to do the job and been followed up by a superior when offering a solution is sensitive to measure. Here there is a possible relation between lean construction and job satisfaction (indirect route).

Figure 27, indicates that the relation between feeling confident doing a job and been followed up by a superior when proposing a solution is sensitive to measure. Most of the works who were followed up by their superiors, were very confident doing their job. This is a possible relation between lean construction, and job satisfaction (indirect route).
Figure 28, 29 and 30, show the results summary in percentages for each question. Figure 28, refers to the total results, Figure 29 to the Dutch cases and Figure 30 to the Colombian case.

### All participants

<table>
<thead>
<tr>
<th>Question</th>
<th>Percentage</th>
<th>Dissatisfied</th>
<th>Satisfied</th>
<th>Very satisfied</th>
<th>No answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How satisfied are you with your work?</td>
<td>78%</td>
<td>2%</td>
<td>18%</td>
<td>78%</td>
<td>2%</td>
</tr>
<tr>
<td>Did you need to be in a hurry to finish the job?</td>
<td>83%</td>
<td>2%</td>
<td>18%</td>
<td>78%</td>
<td>2%</td>
</tr>
<tr>
<td>Did your team receive any form of compliment for delivering a good job?</td>
<td>50%</td>
<td>48%</td>
<td>2%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>How satisfied are you with your work?</td>
<td>78%</td>
<td>2%</td>
<td>18%</td>
<td>78%</td>
<td>2%</td>
</tr>
<tr>
<td>Did you need to be in a hurry to finish the job?</td>
<td>83%</td>
<td>2%</td>
<td>18%</td>
<td>78%</td>
<td>2%</td>
</tr>
<tr>
<td>Did your team receive any form of compliment for delivering a good job?</td>
<td>50%</td>
<td>48%</td>
<td>2%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Dutch participants

<table>
<thead>
<tr>
<th>Question</th>
<th>Percentage</th>
<th>Dissatisfied</th>
<th>Satisfied</th>
<th>Very satisfied</th>
<th>No answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How satisfied are you with your work?</td>
<td>78%</td>
<td>29%</td>
<td>71%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Did you need to be in a hurry to finish the job?</td>
<td>80%</td>
<td>12%</td>
<td>8%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Did your team receive any form of compliment for delivering a good job?</td>
<td>21%</td>
<td>75%</td>
<td>4%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>How satisfied are you with your work?</td>
<td>78%</td>
<td>29%</td>
<td>71%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Did you need to be in a hurry to finish the job?</td>
<td>80%</td>
<td>12%</td>
<td>8%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Did your team receive any form of compliment for delivering a good job?</td>
<td>21%</td>
<td>75%</td>
<td>4%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Foremen and Site manager

<table>
<thead>
<tr>
<th>Question</th>
<th>Percentage</th>
<th>Dissatisfied</th>
<th>Satisfied</th>
<th>Very satisfied</th>
<th>No answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How helpful do you find meeting in the morning with the other foremen, for doing the weekly planning?</td>
<td>67%</td>
<td>11%</td>
<td>17%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>How much effort does it take to explain the work to your workers?</td>
<td>60%</td>
<td>31%</td>
<td>17%</td>
<td>2%</td>
<td>0%</td>
</tr>
<tr>
<td>How many questions did you receive from the foremen on how to do the job?</td>
<td>78%</td>
<td>56%</td>
<td>17%</td>
<td>5%</td>
<td>0%</td>
</tr>
<tr>
<td>Was absenteeism below or above average?</td>
<td>17%</td>
<td>11%</td>
<td>17%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>Did you have enough time to explain the work to the workers?</td>
<td>78%</td>
<td>18%</td>
<td>3%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Foremen

<table>
<thead>
<tr>
<th>Question</th>
<th>Percentage</th>
<th>Dissatisfied</th>
<th>Satisfied</th>
<th>Very satisfied</th>
<th>No answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How satisfied are you with your work?</td>
<td>78%</td>
<td>29%</td>
<td>71%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Did you need to be in a hurry to finish the job?</td>
<td>80%</td>
<td>12%</td>
<td>8%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Did your team receive any form of compliment for delivering a good job?</td>
<td>21%</td>
<td>75%</td>
<td>4%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>How satisfied are you with your work?</td>
<td>78%</td>
<td>29%</td>
<td>71%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Did you need to be in a hurry to finish the job?</td>
<td>80%</td>
<td>12%</td>
<td>8%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Did your team receive any form of compliment for delivering a good job?</td>
<td>21%</td>
<td>75%</td>
<td>4%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Figure 28. Summary results.

Figure 29. Dutch results.
It is interesting to see how the culture affects the workers, for example 72% of the Colombian workers did not receive any compliment for delivering a good job, compared to only 21% of the Dutch workers. Also it is a good sign that for both cases around 78% of the foremen and site managers found enough time to explain the work to the workers, which is a goal of lean construction methods. Additionally, for the Dutch cases all workers found that the work was well organized, which is an important goal for lean construction, as it improves the workflow.

Collaboration, coaching and communication are some of lean construction focuses, that is why the questionnaires aim to know how collaborative is the atmosphere on site, and as the summary figures show there is a 80% of perceived received collaboration (questions 14), and 96% perceived given collaboration (questions 15) for the overall cases, for the Dutch cases 70% and 93% respectively, and for the Colombian case 90% and 97% respectively. Additionally figure 31 shows a network view of who Dutch workers are asking for help. From this network view, it is possible to see that the plumber and carpenter are the most central actors being related to most of the workers. Figure 32 shows the network for Dutch workers who had been asked for help. It shows again the carpenter and now the electrician are the workers who are more addressed in the site. It is important to acknowledge that these networks can vary depending the projects and moment of time.

For the questions referring to communication between workers (questions 12 and 13), a network analysis is done, to see if all workers interact between them in a formal or informal way, in addition to know who the central actor is. The formal network (Figure 32) shows when workers talk about work, and here the workers who communicate more with others are the plumber, electrician and carpenter. The informal network (Figure 33), illustrates that the same actors who were central actors in the formal network are also present here, but now the HAVC installer and tiler appear as central actors as well in social group processes. It is important to acknowledge that talking about work or socializing involves more workers than when asking for help or been asked for help was asked for. It shows the importance of informal talk, which would have been neglected if only asking about work-related communication.

Figure 30. Colombian results.
Figure 31. Ask for help network.

Figure 33. Asked for help network.

Figure 32. Informal network.

Figure 34. Formal network.
Discussion.

The questionnaires designed work for measuring the direct effects of lean construction in labor productivity and the indirect effects of lean construction through its influence of job satisfaction on labor productivity. Some modifications of the questionnaires are done for future research, which are presented on the recommendations section.

As it can be seen in Table 2, all the questions are related to one or more of the main concepts of this study (lean construction, labor productivity and job satisfaction), and also related to sub categories of the main concepts. This is with the goal of having simple questions, and asking them to the workers in a way they feel comfortable and know what they are been asked, which helps to measure the main concepts in a more detailed way. Also questions have to be related between the three levels of working on the site, to see if there are major differences on what the site manager perceived compared to the foremen and/or workers.

For measuring lean construction concepts on a site, it is important to ask questions which are related to the goals of the practice, like job autonomy, communication, workers involvement, work flow, planning tools, collaboration between workers and coaching. The questions cannot be asked directly related to the academic name such as Last Planner System tools or line balancing, as workers would not know what they are been asked about.

For measuring labor productivity between workers, it is essential to ask them about workflow and productive days in a week. Workflow can be measured by knowing if workers start on time, finish on time, the works is well organized and if they know what they need to do, which are topics addressed on the questionnaires in the three working levels.

Job satisfaction can be measured, by the absenteeism rate, which is asked to the foremen and site managers, additionally job satisfaction also has factors that affects it such as feeling pressure to finish the job, been in a hurry, empowerment and receiving compliments, which are asked in the questionnaires. As mentioned before asking about how satisfied they are works for this questionnaire, but the answering option should be on a scale from one to ten. All the questions related to job satisfaction were correctly addressed by the respondents, which means that they can be used for tackling the relation of job satisfaction with the other variables for future research and implementing these questionnaires.

Additionally the results of the Netherlands can be used for knowing how to measure the effects of lean concepts on labor productivity, the effects of lean concepts on job satisfaction and the indirect effects of job satisfaction on labor productivity between blue collar workers. With the Colombian case it is difficult to prove any relation to be measured, as the questionnaires were not completely answered due to alphabetization problems and cultural differences.

The variables of starting the job on time and finishing it on time are clearly related to how the work flows and how productive the workers are; in the Netherlands cases starting on time and finishing on time are related to how clear the workers know what they need to do each day, which can be obtained through lean methods such as visual management and a bottom up approach. With this it is possible to confirm that there is a relation between lean construction tools and labor productivity improvement that can be measured by a questionnaire. Also those two variables are related to how confident the workers feel on doing their job or new jobs, which is a variable related to job satisfaction, as when workers feel more job security the stress on doing a job is decreased, also having confident workers is a lean goal, achieved through coaching between workers, empowerment of workers and a bottom up approach or knowledge management, this proven relationship, make it possible to confirm that the link between lean construction tools with job satisfaction and labor productivity improvement can be measured with a questionnaire.

Starting on time is correlated with finishing a job in a hurry; if a worker has to finish a job in a hurry his job satisfaction is compromised, as probably the worker is not proud of the end result of the job. This relationship can prove that with these two variables the link between lean construction, job satisfaction and labor productivity can be measured with a questionnaire.
The last relation of starting a job on time is with how much a worker or foreman is followed when offered a possible solution for a problem. Following up with a worker on a solution, is a lean construction tool, which empowers the worker and at the same time affects its job satisfaction perception; and with this relation it is possible to confirm that the questionnaire can help to measure the relation of lean construction tools on job satisfaction and labor productivity.

As highlighted before, when a worker has clear what he needs to do the labor productivity is improved, and a bottom up approach, last planner system or visual management techniques can achieve this. This variable is related first with the general satisfaction perception, but the overall satisfaction measurement in the survey is not fine grained, its measurement was too rough, so this direct relationship measurement is not proved with the survey.

Also the variable of a worker having clear the job he needs to do is linked with the pressure a worker feels in finishing a job and if he needs to finish the job in a hurry. Finishing a job in a hurry or feeling pressured to do so, increases the stress on a worker, which negatively affects the job satisfaction perception. This relation between lean construction tools, job satisfaction and labor productivity can be measured with the questionnaire.

Additionally the clear job variable is related with how much a worker is followed when he offers a solution to a problem, which as mentioned before is related to lean construction tools (workers empowerment and bottom up approach/knowledge management) and job satisfaction perception. Feeling confident on doing a task is linked with job satisfaction and lean construction as mentioned before, and this variable is proven with the Netherland cases to be related with having clear the job too. These two relations just mentioned, also prove that the green rout of the conceptual model can be measured through the proposed questionnaire.

Been able to decide on how to do a job is related to two different variables measured in the questionnaire, first finishing the job in a hurry and second been followed when proposing a solution. These two relations also prove that the relationship between the three concepts studied (lean construction, job satisfaction and labor productivity) are linked and can be measured with the questionnaire.

This research showed how the questionnaire developed could measure the direct effects of lean construction on labor productivity and the indirect effects on labor productivity through job satisfaction.
Recommendations.

Based on the results obtained and how participants filled in the questionnaires some recommendations would be done for further research on the subject.

For evaluating the general satisfaction of a worker it is better to measure it on a scale from 1 to 10, so it is easier for the respondents to make a distinction between the different levels, as with the faces used in these questionnaires it is difficult to make any distinction, it is too rough.

The questions 12, 13, 14 and 15 of workers, 17, 18, 19 and 20 for foreman and 18, 19, 20 and 21 for site managers, in the option for selecting the different people, the option of site manager and foreman should be added.

It would be possible to do a formal and informal network with the pass of time with questions 12 and 13 from the workers survey, to see how the relations between the workers evolve, as the project is developed.

For assessing productivity, it would also be important to ask how many days of full work did they have on the week, as it is a clear variable for evaluating productivity on a construction site.

For having a more controlled group and answers, it would be wise to ask at the begging of the questionnaire for whom do they work for, so at the end conclusions about different contractor and the way they organize the work can be done.

For question 3 and 7 from the workers (5 and 11 for foreman – 6 and 12 for site managers) which refers to finish the job in a hurry and receiving a treat/compliment for delivering a good job respectively, the option “sometimes” should be added, as some of the workers wrote this as an answer even though there was not that option.

For the site managers’ survey, question 9 should be rephrased to: “To whom do you give liberty on deciding how to do the job?” as shown in figure 42, question 2, as the previous questions was to closed, and sometimes they do give liberty to some workers and to others they do not.

For the site manager or if possible lean construction coach Table 4 should be filled out. This table quantifies the level of implementation of lean construction tolls for the projects where the questionnaires take place. Table 4 is based on the paper of Priven & Sacks (2015), personal interviews and the literature study.

“Please fill in the next table based on the following index, thinking on the level of implementation of the following practices on the project:

<table>
<thead>
<tr>
<th>Practice</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standardization of short-term planning meetings.</td>
<td></td>
</tr>
<tr>
<td>Use of visual devices to disseminate information in the construction site.</td>
<td></td>
</tr>
<tr>
<td>Systematic update of the master plan, when necessary.</td>
<td></td>
</tr>
<tr>
<td>Participation of crew representatives in decision making in short-term planning meetings.</td>
<td></td>
</tr>
<tr>
<td>Use of indicators to assess schedule accomplishment.</td>
<td></td>
</tr>
<tr>
<td>Use of an easy to understand, transparent master plan (e.g., line of balance).</td>
<td></td>
</tr>
<tr>
<td>Coaching between workers and foremen.</td>
<td></td>
</tr>
<tr>
<td>Multi-functionality of workers.</td>
<td></td>
</tr>
<tr>
<td>Job autonomy of workers.</td>
<td></td>
</tr>
<tr>
<td>Problems identification, feedback and corrective actions.</td>
<td></td>
</tr>
<tr>
<td>Development of proactive measures and practices focused on safety.</td>
<td></td>
</tr>
<tr>
<td>Schedule the project from the customers need.</td>
<td></td>
</tr>
<tr>
<td>Optimization of storage locations.</td>
<td></td>
</tr>
<tr>
<td>Target cost management.</td>
<td></td>
</tr>
<tr>
<td>Collaboration, workers takeover activities of other workers.</td>
<td></td>
</tr>
<tr>
<td>Autonomous teams.</td>
<td></td>
</tr>
<tr>
<td>Just in time delivery.</td>
<td></td>
</tr>
<tr>
<td>Quality checking amongst workers.</td>
<td></td>
</tr>
<tr>
<td>Pulled production</td>
<td></td>
</tr>
<tr>
<td>5S’s</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Lean construction index scores.

Based on the recommendations the new surveys are proposed for using them for future research. Figures 35 to 42 show the new questionnaires, and the ones used for the piloting are on annex 1.
Please fill this questionnaire at the end of the week.

Workers survey - Please fill the following information.

| Date                      | _________________________ |
| Age                      | _____ |
| Years working in construction | ____ |
| For which contractor do you work? | _________________________ |

Please answer the following questions thinking on your last working week. Circle the answer that applies to you.

1. How satisfied are you with your work on a scale from 1 to 10? Been 1 highly dissatisfied and 10 highly satisfied.

   1 2 3 4 5 6 7 8 9 10

2. How much pressure did you feel to finish the job?

   Little  Moderately  Much

3. Did you need to be in a hurry to finish the job?

   Yes  No  Sometimes

4. Can you decide for your own, on how to do the job?

   Little  Moderately  Much

5. How much would they follow up on you, if you offer a possible solution for some problem?

   Little  Moderately  Much

6. How confident do you feel in doing your tasks, including new tasks?

   Little  Moderately  Much

7. Did your team receive any treat or compliment for delivering a good work?

   Yes  No  Sometimes

8. How many days were you able to start your job in time (the last week)?

   ____ days

9. How many days were you able to finish your job in time (the last week)?

   ____ days

10. How many days of full work did you have (the last week)?

    ____ days

11. How many days was it clear for you what you needed to do (the last week)?

    ____ days

12. Do you feel the work is well organized?

    Yes  No

13. With whom did you talk about work (the last week)? You can check more than one box.

   - Site manager
   - Foreman
   - Tiler
   - Painter
   - Electrician
   - Plumber
   - HAVC installer
   - Carpenter
   - Kitter
   - Plasterer
   - Frame installer
   - Demolisher
   - Saneerder (asbest)
   - Dakdekker
   - Steigerbouwer
   - Crane operator
   - Steel worker
   - Structure
   - Drywall installer
   - Kitchen installer
   - Waterproof installer
   - Other: ____________________________

Figure 35. New workers survey, page 1.
Please fill this questionnaire at the end of the week.

14. With whom did you talk about all but work (the last week)? **You can check more than one box.**

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HAVC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Saneerder (asbest)
- Dakdekker
- Steigerbouwer
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Waterproof installer
- Other: ..................................

15. How many times did you ask your colleagues for help (the last week)?

______times

16. How many times did your colleagues ask you for help (the last week)?

______times

a. Who asked you for help? **You can check more than one box.**

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HAVC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Saneerder (asbest)
- Dakdekker
- Steigerbouwer
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Waterproof installer
- Other: ..................................

b. How many times did they help you?

______times

17. For which crew do you work?

______times

a. Who asked you for help? **You can check more than one box.**

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HAVC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Saneerder (asbest)
- Dakdekker
- Steigerbouwer
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Waterproof installer
- Other: ..................................

b. How many times did they help you?
Please fill this questionnaire at the end of the week.

Foreman survey - Please fill the following information.

Date _________________________
Age ___
Years working in construction ___
For which contractor do you work? _________________________

Please answer the following questions thinking on your last working week.

Circle the answer that applies to you.

1. How satisfied are you with your work? Satisfaction
   1 2 3 4 5 6 7 8 9 10
2. How helpful do you find meeting in the morning with the other foremen, for doing the work planned?
   Little Moderately Much Don't apply
3. How many days was the project planning clear for you?
   ___days
4. How much pressure does your crew feels to finish the job?
   Little Moderately Much
5. Did your crew need to be in a hurry to finish the job?
   Yes No Sometimes
6. How much effort does it take to explain the works to your crew?
   Little Moderately Much
7. Do you have enough time to explain the work to your crew?
   Yes No
8. Can you decide for your crew on how to do the job?
   Little Moderately Much
9. How much influence do you have on making changes to the project planning?
   Little Moderately Much
10. How much would the site manager follow up on you, if you offer a possible solution for some problem?
    Little Moderately Much
11. Did your team receive any treat or compliment for delivering a good work?
    Yes No Sometimes
12. How many days was your crew able to start the job in time (the last week)?
    _______days
13. How many days was your crew able to finish the job in time (the last week)?
    _______days
14. How many days of full work did you and your crew have (the last week)?
    _______days
15. How many questions did you receive from your crew about the works they have to do?
    Little Moderately Much
16. Do you feel the work is well organized?
    Yes No
Please fill this questionnaire at the end of the week.

17. Was absenteeism below or above average?

<table>
<thead>
<tr>
<th></th>
<th>Below</th>
<th>Average</th>
<th>Above</th>
</tr>
</thead>
</table>

18. With whom did you talk about work (the last week)? **You can check more than one box.**

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HAVC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Saneerder (asbest)
- Dakdekker
- Steigerbouwer
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Waterproof installer
- Other: 

19. With whom did you talk about all but work (the last week)? **You can check more than one box.**

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HAVC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Saneerder (asbest)
- Dakdekker
- Steigerbouwer
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Waterproof installer
- Other: 

20. How many times did you ask your colleagues for help (the last week)?

______ times

a. To whom did you ask for help? **You can choose more than one option**

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HAVC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Saneerder (asbest)
- Dakdekker
- Steigerbouwer
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Waterproof installer
- Other: 

b. How many times did they help you?

______ times

Figure 38. New foreman survey, page 2.
Please fill this questionnaire at the end of the week.

21. How many times did your colleagues asked you for help (the last week)?

______times

a. Who asked you for help? You can check more than one box.

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HAVC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Saneerder (asbest)
- Dakdekker
- Steigerbouwer
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Waterproof installer
- Other: ………………………

b. How many times did you help?

______times

22. For which crew do you work?

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HAVC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Saneerder (asbest)
- Dakdekker
- Steigerbouwer
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Waterproof installer
- Other: ………………………
Please fill this questionnaire at the end of the week.

Site manager/Director survey - Please fill the following information.

Date ______________________________________
Age ______________________
Years working in construction ____
For whom do you work? ______________________________________

Please fill in the next table based on the following index, thinking on the level of implementation of the following practices on the project:

<table>
<thead>
<tr>
<th>Practice</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standardization of short-term planning meetings.</td>
<td>C = Complete</td>
</tr>
<tr>
<td>Use of visual devices to disseminate information in the construction site</td>
<td>N = None</td>
</tr>
<tr>
<td>Systematic update of the master plan, when necessary.</td>
<td>P = Partial</td>
</tr>
<tr>
<td>Participation of crew representatives in decision making in short-term planning meetings.</td>
<td></td>
</tr>
<tr>
<td>Use of indicators to assess schedule accomplishment.</td>
<td></td>
</tr>
<tr>
<td>Use of an easy to understand, transparent master plan (e.g., line of balance).</td>
<td></td>
</tr>
<tr>
<td>Coaching between workers and foremen.</td>
<td></td>
</tr>
<tr>
<td>Multi-functionality of workers.</td>
<td></td>
</tr>
<tr>
<td>Job autonomy of workers.</td>
<td></td>
</tr>
<tr>
<td>Problems identification, feedback and corrective actions.</td>
<td></td>
</tr>
<tr>
<td>Development of proactive measures and practices focused on safety.</td>
<td></td>
</tr>
<tr>
<td>Schedule the project from the customers need.</td>
<td></td>
</tr>
<tr>
<td>Optimization of storage locations.</td>
<td></td>
</tr>
<tr>
<td>Collaboration, workers takeover activities of other workers.</td>
<td></td>
</tr>
<tr>
<td>Autonomous teams.</td>
<td></td>
</tr>
<tr>
<td>Just in time delivery.</td>
<td></td>
</tr>
<tr>
<td>Quality checking amongst workers.</td>
<td></td>
</tr>
<tr>
<td>Pulled production</td>
<td></td>
</tr>
<tr>
<td>5S s</td>
<td></td>
</tr>
</tbody>
</table>

Please answer the following questions thinking on your last working week.

Circle the answer that applies to you.

1. How many foremen are on site?
   ________ foremen

2. How many workers are on site?
   ________ workers

3. How satisfied are you with your work? Satisfaction
   1  2  3  4  5  6  7  8  9  10

4. How helpful do you find meeting in the morning with the foremen, for doing the work planned?
   Little  Moderately  Much  Don’t apply

5. How much pressure do you have to put on the crews to finish the job planned?
   Little  Moderately  Much

6. Did the crews need to be in a hurry to finish the job?
   Yes  No  Sometimes

7. How much effort does it take to explain the work to the foremen?
   Little  Moderately  Much

8. Do you have enough time to explain the works to the foremen?
   Yes  No

Figure 40. New site managers’ survey, page 1.
Please fill this questionnaire at the end of the week.

9. How much influence does the foremen have in changing the project planning?
   Little  Moderately  Much

10. How much do you follow up on a foreman, if he offers a possible solution for some problem?
    Little  Moderately  Much

11. Do you give any treat or compliment to the crews for delivering a good work?
    Yes  No  Sometimes

12. How many days were the crews able to start the job in time (the last week)?
   _______ days

13. How many days were the crews able to finish the job in time (the last week)?
   _______ days

14. How many days of full work did the crew have (the last week)?
   _______ days

15. How many questions did you receive from the foremen on how to do the job?
    Little  Moderately  Much

16. Do you think the work is well organized?
    Yes  No

17. Was absenteeism below or above average
    Below  Average  Above

18. With whom did you talk about work (the last week)? You can check more than one box.
- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HAVC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Saneerder (asbest)
- Dakdekker
- Steigerbouwer
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Waterproof installer
- Other: ………………………

19. With whom did you talk about all but work (the last week)? You can check more than one box.
- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HAVC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Saneerder (asbest)
- Dakdekker
- Steigerbouwer
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Waterproof installer
- Other: ………………………
Please fill this questionnaire at the end of the week.

20. Did you ask for help (last week)?
   
<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>You can check more than one box.</td>
</tr>
<tr>
<td>Tiler</td>
<td></td>
</tr>
<tr>
<td>Kitter</td>
<td></td>
</tr>
<tr>
<td>Plasterer</td>
<td></td>
</tr>
<tr>
<td>Electrician</td>
<td></td>
</tr>
<tr>
<td>Plumber</td>
<td></td>
</tr>
<tr>
<td>HVAC installer</td>
<td></td>
</tr>
<tr>
<td>Carpenter</td>
<td></td>
</tr>
<tr>
<td>Painter</td>
<td></td>
</tr>
<tr>
<td>Mason</td>
<td></td>
</tr>
<tr>
<td>Frame installer</td>
<td></td>
</tr>
<tr>
<td>Demolisher</td>
<td></td>
</tr>
<tr>
<td>Saneerder (asbest)</td>
<td></td>
</tr>
<tr>
<td>Dakdekker</td>
<td></td>
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<tr>
<td>Steigerbouwer</td>
<td></td>
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<tr>
<td>Crane operator</td>
<td></td>
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<tr>
<td>Steel worker</td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Drywall installer</td>
<td></td>
</tr>
<tr>
<td>Kitchen installer</td>
<td></td>
</tr>
<tr>
<td>Other: ......................</td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td>How many times did they help you?</td>
</tr>
<tr>
<td></td>
<td>_____ times</td>
</tr>
</tbody>
</table>

21. Someone asked you for help?
   
<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>You can check more than one box.</td>
</tr>
<tr>
<td>Tiler</td>
<td></td>
</tr>
<tr>
<td>Kitter</td>
<td></td>
</tr>
<tr>
<td>Plasterer</td>
<td></td>
</tr>
<tr>
<td>Electrician</td>
<td></td>
</tr>
<tr>
<td>Plumber</td>
<td></td>
</tr>
<tr>
<td>HVAC installer</td>
<td></td>
</tr>
<tr>
<td>Carpenter</td>
<td></td>
</tr>
<tr>
<td>Painter</td>
<td></td>
</tr>
<tr>
<td>Mason</td>
<td></td>
</tr>
<tr>
<td>Frame installer</td>
<td></td>
</tr>
<tr>
<td>Demolisher</td>
<td></td>
</tr>
<tr>
<td>Saneerder (asbest)</td>
<td></td>
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<tr>
<td>Dakdekker</td>
<td></td>
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<tr>
<td>Steigerbouwer</td>
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<tr>
<td>Crane operator</td>
<td></td>
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<td>Steel worker</td>
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<tr>
<td>Structure</td>
<td></td>
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<tr>
<td>Drywall installer</td>
<td></td>
</tr>
<tr>
<td>Kitchen installer</td>
<td></td>
</tr>
<tr>
<td>Other: ......................</td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td>How many times did they help you?</td>
</tr>
<tr>
<td></td>
<td>_____ times</td>
</tr>
</tbody>
</table>

22. Who do you think are the 'central actors' of the construction site? You can check more than one box.
   
   | Tiler | Kitter | Plasterer | Electrician | Plumber | HVAC installer | Carpenter | Painter | Mason | Frame installer | Demolisher | Saneerder (asbest) | Dakdekker | Steigerbouwer | Crane operator | Steel worker | Structure | Drywall installer | Kitchen installer | Other: ...................... |

23. To whom do you give liberty on deciding how to do the job? You can check more than one box.
   
   | Tiler | Kitter | Plasterer | Electrician | Plumber | HVAC installer | Carpenter | Painter | Mason | Frame installer | Demolisher | Saneerder (asbest) | Dakdekker | Steigerbouwer | Crane operator | Steel worker | Structure | Drywall installer | Kitchen installer | Other: ...................... |
Literature.


Lean construction on-site
Annex 1.

### Please fill this questionnaire at the end of the week.

**Workers survey - Please fill the following information.**

<table>
<thead>
<tr>
<th>Date</th>
<th>_______________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>_____________</td>
</tr>
<tr>
<td>Years working in construction</td>
<td>____</td>
</tr>
</tbody>
</table>

**Please answer the following questions thinking on your last working week.**  
Circle the answer that applies to you.

- **1.** How satisfied are you with your work? Satisfaction
  - [ ] Satisfied
  - [ ] Moderately satisfied
  - [ ] Dissatisfied

- **2.** How much pressure did you feel to finish the job?
  - [ ] Little
  - [ ] Moderately
  - [ ] Much

- **3.** Did you need to be in a hurry to finish the job?
  - [ ] Yes
  - [ ] No

- **4.** Can you decide for your own, on how to do the job?
  - [ ] Little
  - [ ] Moderately
  - [ ] Much

- **5.** How much would they follow up on you, if you offer a possible solution for some problem?
  - [ ] Little
  - [ ] Moderately
  - [ ] Much

- **6.** How confident do you feel in doing your tasks, including new tasks?
  - [ ] Little
  - [ ] Moderately
  - [ ] Much

- **7.** Did your team receive any treat or compliment for delivering a good work?
  - [ ] Yes
  - [ ] No

- **8.** How many days were you able to start your job in time (the last week)?
  - _______ days

- **9.** How many days were you able to finish your job in time (the last week)?
  - _______ days

- **10.** How many days was it clear for you what you needed to do (the last week)?
  - _______ days

- **11.** Do you feel the work is well organized?
  - [ ] Yes
  - [ ] No

- **12.** With whom did you talk about work (the last week)? **You can check more than one box.**
  - [ ] Site manager
  - [ ] Foreman
  - [ ] Tiler
  - [ ] Kitter
  - [ ] Plasterer
  - [ ] Electrician
  - [ ] Plumber
  - [ ] HAVC installer
  - [ ] Carpenter
  - [ ] Painter
  - [ ] Mason
  - [ ] Frame installer
  - [ ] Demolisher
  - [ ] Asbestos worker
  - [ ] Felt roofer worker
  - [ ] Scaffold
  - [ ] Crane operator
  - [ ] Steel worker
  - [ ] Structure
  - [ ] Drywall installer
  - [ ] Kitchen installer
  - [ ] Other: ___________________________
Please fill this questionnaire at the end of the week.

13. With whom did you talk about all but work (the last week)? You can check more than one box.

| ☐ Site manager | ☐ Frame installer |
| ☐ Foreman      | ☐ Demolisher      |
| ☐ Tiler        | ☐ Asbestos worker |
| ☐ Kitter       | ☐ Felt Roofer worker |
| ☐ Plasterer    | ☐ Scaffolder      |
| ☐ Electrician  | ☐ Crane operator  |
| ☐ Plumber      | ☐ Steel worker    |
| ☐ HVAC installer| ☐ Structure       |
| ☐ Carpenter    | ☐ Drywall installer|
| ☐ Painter      | ☐ Kitchen installer|
| ☐ Mason        | ☐ Other:           |

14. How many times did you ask your colleagues for help (the last week)?

______ times

a. To whom did you ask for help? You can choose more than one option

| ☐ Site manager | ☐ Frame installer |
| ☐ Foreman      | ☐ Demolisher      |
| ☐ Tiler        | ☐ Asbestos worker |
| ☐ Kitter       | ☐ Felt Roofer worker |
| ☐ Plasterer    | ☐ Scaffolder      |
| ☐ Electrician  | ☐ Crane operator  |
| ☐ Plumber      | ☐ Steel worker    |
| ☐ HVAC installer| ☐ Structure       |
| ☐ Carpenter    | ☐ Drywall installer|
| ☐ Painter      | ☐ Kitchen installer|
| ☐ Mason        | ☐ Other:           |

b. How many times did they help you?

______ times

15. How many times did your colleagues ask you for help (the last week)?

______ times

a. Who asked you for help? You can check more than one box.

| ☐ Site manager | ☐ Frame installer |
| ☐ Foreman      | ☐ Demolisher      |
| ☐ Tiler        | ☐ Asbestos worker |
| ☐ Kitter       | ☐ Felt Roofer worker |
| ☐ Plasterer    | ☐ Scaffolder      |
| ☐ Electrician  | ☐ Crane operator  |
| ☐ Plumber      | ☐ Steel worker    |
| ☐ HVAC installer| ☐ Structure       |
| ☐ Carpenter    | ☐ Drywall installer|
| ☐ Painter      | ☐ Kitchen installer|
| ☐ Mason        | ☐ Other:           |

b. How many times did you help?

______ times

16. For which crew do you work?

| ☐ Site manager | ☐ Frame installer |
| ☐ Foreman      | ☐ Demolisher      |
| ☐ Tiler        | ☐ Asbestos worker |
| ☐ Kitter       | ☐ Felt Roofer worker |
| ☐ Plasterer    | ☐ Scaffolder      |
| ☐ Electrician  | ☐ Crane operator  |
| ☐ Plumber      | ☐ Steel worker    |
| ☐ HVAC installer| ☐ Structure       |
| ☐ Carpenter    | ☐ Drywall installer|
| ☐ Painter      | ☐ Kitchen installer|
| ☐ Mason        | ☐ Other:           |
Please fill this questionnaire at the end of the week.

Foreman survey - Please fill the following information.

Date _________________________
Age ______
Years working in construction ______

Please answer the following questions thinking on your last working week.

Circle the answer that applies to you.

1. How satisfied are you with your work? Satisfaction
   ![Smiley Faces]  ![Sad Face]

2. How helpful do you find meeting in the morning with the other foremen, for doing the work planned?
   Little  Moderately  Much  Don’t apply

3. How many days was the project planning clear for you?
   ___________days

4. How much pressure does your crew feels to finish the job?
   Little  Moderately  Much

5. Did your crew need to be in a hurry to finish the job?
   Yes  No

6. How much effort does it take to explain the works to your crew?
   Little  Moderately  Much

7. Do you have enough time to explain the work to your crew?
   Yes  No

8. Can you decide for your crew on how to do the job?
   Little  Moderately  Much

9. How much influence do you have on making changes to the project planning?
   Little  Moderately  Much

10. How much would the site manager follow up on you, if you offer a possible solution for some problem?
    Little  Moderately  Much

11. Did your team receive any treat or compliment for delivering a good work?
     Yes  No

12. How many days was your crew able to start the job in time (the last week)?
     ___________days

13. How many days was your crew able to finish the job in time (the last week)?
     ___________days

14. How many questions did you receive from your crew about the works they have to do?
    Little  Moderately  Much

15. Do you feel the work is well organized?
    Yes  No
Please fill this questionnaire at the end of the week.

16. Was absenteeism below or above average?

Below   Average   Above

17. With whom did you talk about work (the last week)? You can check more than one box.

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HVAC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Asbestos worker
- Felt roofer worker
- Scaffold
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Other: ........................................

18. With whom did you talk about all but work (the last week)? You can check more than one box.

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HVAC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Asbestos worker
- Felt roofer worker
- Scaffold
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Other: ........................................

19. How many times did you ask your colleagues for help (the last week)?

______ times

a. To whom did you ask for help? You can choose more than one option

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HVAC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Asbestos worker
- Felt roofer worker
- Scaffold
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Other: ........................................

b. How many times did they help you?

______ times

20. How many times did your colleagues asked you for help (the last week)?

______ times

a. Who asked you for help? You can check more than one box.

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HVAC installer
- Carpenter
- Painter
- Mason
- Frame installer
- Demolisher
- Asbestos worker
- Felt roofer worker
- Scaffold
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Other: ........................................
Please fill this questionnaire at the end of the week

b. How many times did you help?

_______ times

21. For which crew do you work?

<table>
<thead>
<tr>
<th>□ Site manager</th>
<th>□ Frame installer</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Foreman</td>
<td>□ Demolisher</td>
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<tr>
<td>□ Tiler</td>
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<tr>
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<td>□ Plumber</td>
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<td>□ Drywall installer</td>
</tr>
<tr>
<td>□ Painter</td>
<td>□ Kitchen installer</td>
</tr>
<tr>
<td>□ Mason</td>
<td>□ Other: ......................</td>
</tr>
</tbody>
</table>

Site manager/Director survey - Please fill the following information.

Date  _________________________
Age  _____
Years working in construction  _____

Please answer the following questions thinking on your last working week. Circle the answer that applies to you.

1. How many foremen are on site?
   _______ foremen

2. How many workers are on site?
   _______ workers

3. How satisfied are you with your work? Satisfaction
   😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊😊

4. How helpful do you find meeting in the morning with the foremen, for doing the work planned?
   Little Moderately Much Don’t apply

5. How much pressure do you have to put on the crews to finish the job planned?
   Little Moderately Much

6. Did the crews need to be in a hurry to finish the job?
   Yes   No

7. How much effort does it take to explain the work to the foremen?
   Little Moderately Much

8. Do you have enough time to explain the works to the foremen?
   Yes   No

9. How much freedom does the crews have on deciding how to do the job?
   Little Moderately Much

10. How much influence does the foremen have in changing the project planning?
    Little Moderately Much

11. How much do you follow up on a foreman, if he offers a possible solution for some problem?
    Little Moderately Much

12. Do you give any treat or compliment to the crews for delivering a good work
    Yes   No

13. How many days were the crews able to start the job in time (the last week)?
    _______ days

14. How many days were the crews able to finish the job in time (the last week)?
    _______ days

15. How many questions did you receive from the foremen on how to do the job?
    Little Moderately Much

16. Do you think the work is well organized?
   - Yes
   - No

17. Was absenteeism below or above average?
   - Below
   - Average
   - Above

18. With whom did you talk about work (the last week)? You can check more than one box.
   - Site manager
   - Foreman
   - Tiler
   - Kitter
   - Plasterer
   - Electrician
   - Plumber
   - HAVC installer
   - Carpenter
   - Painter
   - Mason
   - Frame installer
   - Demolisher
   - Asbestos worker
   - Felt roofer worker
   - Scaffolder
   - Crane operator
   - Steel worker
   - Structure
   - Drywall installer
   - Kitchen installer
   - Mason
   - Other: ____________________

19. With whom did you talk about all but work (the last week)? You can check more than one box.
   - Site manager
   - Foreman
   - Tiler
   - Kitter
   - Plasterer
   - Electrician
   - Plumber
   - HAVC installer
   - Carpenter
   - Painter
   - Mason
   - Frame installer
   - Demolisher
   - Asbestos worker
   - Felt roofer worker
   - Scaffolder
   - Crane operator
   - Steel worker
   - Structure
   - Drywall installer
   - Kitchen installer
   - Mason
   - Other: ____________________

20. How many times did you ask for help (the last week)?
   - ______ times

   a. To whom did you ask for help? You can choose more than one option
   - Site manager
   - Foreman
   - Tiler
   - Kitter
   - Plasterer
   - Electrician
   - Plumber
   - HAVC installer
   - Carpenter
   - Painter
   - Mason
   - Frame installer
   - Demolisher
   - Asbestos worker
   - Felt roofer worker
   - Scaffolder
   - Crane operator
   - Steel worker
   - Structure
   - Drywall installer
   - Kitchen installer
   - Mason
   - Other: ________________

   b. How many times did they help you?
   - ______ times

Annex 1.7. Site managers’ survey, page 2 (English version).
21. How many times were you asked for help (the last week)?
_________ times

a. Who asked you for help? You can check more than one box.

- Site manager
- Foreman
- Tiler
- Kitter
- Plasterer
- Electrician
- Plumber
- HVAC installer
- Carpenter
- Painter
- Mason

- Frame installer
- Demolisher
- Asbestos worker
- Felt roofer worker
- Scaffolder
- Crane operator
- Steel worker
- Structure
- Drywall installer
- Kitchen installer
- Other: __________________________

b. How many times did you help?
_________ times
<table>
<thead>
<tr>
<th>Scope</th>
<th>Technique</th>
<th>Requirements</th>
<th>Criteria/change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow variability</td>
<td>Last Planner System</td>
<td>Reverse phase Scheduling 6-week look-ahead Weekly work plan Reasons for variance PPC Charts</td>
<td>Pull approach Quality Knowledge Communication Relation with other tools</td>
</tr>
<tr>
<td>Process variability</td>
<td>Fail safe for quality</td>
<td>Check for quality Check for safety</td>
<td>Actions on the job site Team effort Knowledge Communication Relation with other tools</td>
</tr>
<tr>
<td>Transparency</td>
<td>Five S’s</td>
<td>Sort Straighten Standardize Shine Sustain</td>
<td>Action on the job site Team effort Knowledge Communication Relation with other tools</td>
</tr>
<tr>
<td>Increased visualization</td>
<td>Commitment charts Safety signs Mobile signs Project milestones PPC charts</td>
<td>Visualization Team effort Knowledge Communication Relation with other tools</td>
<td></td>
</tr>
<tr>
<td>Continuous improvement</td>
<td>Huddle meetings</td>
<td>All foreman meeting Start of the day meeting</td>
<td>Time spent Review work to be done Issues covered Communication Relation with other tools</td>
</tr>
<tr>
<td>First-run studies</td>
<td>Plan Do Check Act</td>
<td></td>
<td>Action on the job site Team effort Knowledge Communication Relation with other tools</td>
</tr>
</tbody>
</table>

# Annex 3.

<table>
<thead>
<tr>
<th>Categories of Practices</th>
<th>Description</th>
<th>Lean production references</th>
<th>Lean construction references</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Continuous Improvement</strong></td>
<td>Problems identification in the process, groups of problems discussion, implementation of activities feedback and internal benchmark development. Furthermore, organizations should be seen as a place for continuous learning, which identifies problems in the current scene and project future solutions (value stream mapping, PDCA).</td>
<td>Spear and Bowen (1999), Liker (2004), Womack et al (1990), Mann (2005)</td>
<td>Alarcón and Mardones (1998), Koskela (2000)</td>
</tr>
<tr>
<td><strong>Standardized Work</strong></td>
<td>Use of standard operation cards, measures to avoid waste in productivity and quality. Enable the identification and understanding of the deviations. As standardization is achieved, the product quality, process quality and labor quality are increased (continuous improvement).</td>
<td>Spear and Bowen (1999), Shingo (1989), Womack et al (1990), Koskela (1992), Koskela (2000), Gallardo et al (2006)</td>
<td></td>
</tr>
<tr>
<td><strong>Safety and Sustainability</strong></td>
<td>The lack of safety is a major source of waste in construction. Beyond meeting mandatory requirements and legislation, it is expected from construction safety management the development of proactive measures and practices. Application of lean practices is also a way to reduce environmental damages. In reducing wastes in the processes is a way to implement sustainable features.</td>
<td>Cambraia et al. (2005), Salem et al. (2006), Bae and Kim (2007), Song and Liang (2011), Koskela (1992)</td>
<td></td>
</tr>
</tbody>
</table>

| | Pulled Production | Visual Management and Performance Metrics | Planning and Production Control | Layout e Flow |
| | One of the main concepts in the LP development is to schedule the production from a customer’s need. For this mean some character are necessary: very reliable methods, multidisciplinary labor systems, production and logistics control (kanban), inventory and cycle times control. | Visual management, in LP, is to identify the process and verify if there is any deviation from the reference instantly. In construction the visual management operates in management of nine fields: process, performance, knowledge, inventory, maintenance, safety, quality, production and image. For the LP, examples of visual management and control are visual kanban, flow cell unit, andon, standardized work, obeya and performance metrics. | Establish methods of production, distribution and control in every step of the process, and, in the same time to develop flows an understand the activity connections is essential in LP. One of the most widespread practices in construction aimed at planning and control of production activities is the Last Planner. Existence of an overall schedule, schedule of medium-term to eliminate restrictions and schedule short-term with the definition of activities by staff shall comprise the PPC in construction sites. | Storage location optimization, locations and layouts study in order to reduce transport wastes and dislocations. To observe the internal flows, how people are connected and map delivery of the product for a specific work post at the right time, involves inclusive the PPC. |
| | | | | | |
| Quality Control | Quality in LP is inherently built into the production process. The total quality control (TQC) implies eliminating waste caused by poor quality, as it is perceived, as well as to eliminate wastes caused by physical interruption of flow due to a specific defects or a deviation of the pattern. In manufacturing, quality is directly linked to process control, in construction, it is concerned the compliance of the final product. |
| Logistics and Supply Chain Management | There must be logistic management and planning in inputs supply to achieve the just in time. The idea of LP at Toyota was to develop a long-term partnership between manufacturer, reseller and buyer, the dealer engaging in the production system, and the buyer in the process of product development. |
| Information Technology and Communication | Information Technology (IT) works with the production, distribution, storage, usage and safety of all information. In construction, the first uses of IT systems were applied to the flow control of the supply chain and design software. It is also necessary to develop adequate communication systems between productive teams. |
| Design Management and Product Development | More then establishing the premises of implementation and compatibility of different designs, the design phase needs, within the LP, capture and transcribe the value perceived by the customer into the final product. For this, are necessary the use of methods of market research, customer satisfaction analysis and feedback analysis, for example. |
| Costs Control | Cost reduction has been a Toyota’s goal since Taiichi Ohno began the movement “waste reduction” in Japanese plants. Currently, Toyota has developed the Total Budget Control System, where monthly information are crossed to monitor the budget for all divisions of the company. In constructing measures of target cost management and continuous improvement groups were presented as a measure to reduce waste and cost |
| Continuous Flow | The continuous flow implementation process has four steps independent of each other: diagnosis, creation of initial conditions, planning, and finally, the control. All these steps are directly linked to the Planning and Production Control and adaptation of tools from LP. Four concepts of LP are critical in the implementation of continuous flow, stability, interdependence, takt time and work elements. |
| Quick Setup | In LP, the quick setup system enabled the production of multiple models and served the change in consumer demand by reducing the time of setups on the assembly line. Quick setup is a characteristic that must be achieved if we are to meet the change in market demand. |
| Total Productive Maintenance | Routine and programmed maintenance for tools and equipment to prevent or identify, away from the activity, defects that may come to halt production. There should be a standard procedure for each tool, piece of equipment and function and this should be followed on a daily basis. In civil construction works carried out in some industrial sectors, procedures such as good safety at work practices are used. |
| Liker (2004), Rother and Shook (2000) |
| Liker (2004), Rother and Shook (2000) |
| Picchi and Granja, (2004), Bulhões et al., (2005), Ballard and Howell (1998b) |
| Shingo (1989) |
| Black (2007), |

Q1. What do you think about lean construction?
It's useful, it promotes productivity and quality, which is good.

Q2. How do you think it is compared to traditional construction management? What are the main differences and benefits?
It's based on commitment, more than on control. It aims to have an integrated approach between productivity and quality more than the traditional, it also aims to establish a stability in the production system, which traditional construction does not do by definition. I think that is compared to traditional.

Q3. The end result, how do you think it is affected by lean construction?
Less quality defects while adding more security about delivering on time and on budget. And based on pull principles, it will facilitate the delivery of the project with a high level of customer satisfaction addressing more to the wishes of the client.

Q4. Do you think the wishes of the clients are also a problem for lean construction?
Well yeah, because that would introduce instability, because you have to be ready for diverse kind of variations in demands from clients. And what they want, how the want it, when they want it and that kind of factors do increase instability, if you are not ready for it, so a big risk for lean construction is that the system of construction is not ready to take such kind of like variations, because it is a instable system as it is, already.

Q5. And how would lean construction cope with that problem?
Well lean construction's aim is to contribute increasing the stability system, so you can introduce or include more clients' desires, clients' wishes. So it helps by stabilizing your construction system. And if you got it stabilized, which in construction is not very possible, so lean construction increases stability to the system, the production system, then you are able to cope with pull, with variations in designs, clients wishes and I think you will have a system or a way of working that will better take on board the client wishes.

Q6. And then, how do you think lean construction affects labor productivity?
It needs to increase labor productivity, because of the extensive planning, because of commitment of firms to planning; it has to do with commitment of firms and individuals amongst themselves on site, and being ready, on being programmed, to be willing to take on board activities of others, as the Eindhoven case that is happening, and this was planed for productivity; so to assure that the workload of a worker would be eight hours planned, and what is planned gets delivered, and then it requires to see whether it works out or not, because of the commitment amongst the workers it would be able to achieve those eight hours of efficiency, eight hours per day. Besides of what it has been planned to have full days of maximum production, they were able to respond to changes or to respond to high and low speeds, and distribute, redistribute or reallocate amongst themselves. As a result of the autonomy control, because of the high levels of autonomy, they know the clients they work for, they know how it has been planned, because they have the desire to think about on how to organize a most efficient way as a team. So that is a kind of like a case create of the organizing the job, and how you can best organize a better job, etc.

Q7. Which ones were the main tools used in the Eindhoven case?
We would call them in the lean manufacturing “line balancing”. Which is a way of working to redistribute the amount of work per house in this case, and in car manufacturing would be per car, in such a way that the flow, the line would be in balance; so the amount of work and the amount of labor, capacity available and speed of the work are in balance. In Eindhoven’s case, balancing equipment and workforce in order to keep the flow was addressed by keeping the work going per house constantly, in order to reduce the lead time per house.
renovation, so it was eleven days, now its been reduced to seven working days, and to keep those in a day, keep the work going and steady and therefore labor organized to full production, full productivity and the equipment was organized to full productivity, and availability of materials, and that would be kind of formally just in time delivery. We did security, security level of materials and we secure the exchange of work, so all the workers were skilled, were trained to do certain work for others. That would be self-controlling teams (name in the Netherlands), in lean terms you would call it also autonomous teams.

Q8. Which ones do you thin, apart from line balancing are the most powerful tools for improving labor productivity?

I think, in this case it was a very simple project, not so much material flows, but in larger projects like in the BK faculty at TU Delft, the availability of materials on the spots, on site, so just in time deliveries are key. So that would be now, line balancing, you would have just in time delivery, you would have visual management, you would have...

Q9. How would visual management improve labor productivity?

Because you give information to the workers about productivity, and because you know how the flow goes, how the amount of productive hours per day score, you would be informed and directly or indirectly your would act based on the information.

Q10. So for the productivity, the most powerful tools...

Quality checking amongst workers, so what would you have is a Kaizen kind of system or the traffic lights. The traffic lights on the line, and if there is a quality problem they directly stop the line and they need to fix it before the line proceeds, and in the Eindhoven case it was used too, in construction we use it in other way, the work who follows the other, would check with the proceeding worker, based on which the next worker needs to work, or the next trade, for instance you have the plasterer and the next guy is the tiller, if the plaster is not been neatly flat, then the guy who do the tiles can’t proceed, and if he finds out too late, and the guy who proceeds did not inform him, or in general didn’t check with each other, this is words enough to go ahead, this kinds of like quality checking from one to another, comparable to the button where in car manufacturing they put the light on, green is ok and orange is a potentially problem and red is I’ve seen the problem, we have to solve it. That kind of systems you can do it in a variable or personal way too, which we do in construction. And that works in the same way, so the principle and effect of that kind of system, we call the manifestation of that kind of traffic light, and the systematic kind of like introduction of that kind of systems you see in car manufacturing are far more official, formal and known, than in construction. In construction it’s up to whether they understood this and whether they introduce it amongst the workers. But that’s how it goes for safe productivity, if there are quality problems, and you find them at your start, you can’t start, then your day of production is gone.

And I would say on high level pull production; what we did in Eindhoven also is that we asked the clients of the houses, the residents, what they wanted to have and when, and we would do activities that the residents would like, and then on the level of the project we increased productivity. Because we were able to know per house what was desired, and what had to be done, that increases productivity too. So that’s the level of information based on pull mechanism, so let the client decide what’s to be done and when. This kind of mix or these methods we applied to increase productivity.

We did a model house, the first house and what we did is check if there were any surprises, technically or approaches wise in a house after you started demolition. And what we did is to that kind of like checking of the quality on which the work was done, and the other kind of checking we did is to do state proof production, is that we made this model house and we checked it before we started production, so started the line I would say, with the people from the housing corporation and with the residents. Is this the quality level you want? Do we miss anything? And based on that, we organized the production with the full days of production, etcetera, in a mistake-proof way, so we were sure we couldn’t make any mistakes and we did it in such a way.
And that kind of checking, that kind of like prototyping allowed the firms to do the mistake-proof production, in a lower level than you would do Poka Yoke, in a mean that you would do fixings only in one way. The Poka Yoke is far more technological, than what we do with the houses. What we also did was the 5S’s, in which it is a clean work place.

Q11. And how would the 5S’s improve the productivity?

Well first of all, you would be able to enter to your workplace without falling over or having to make detours for getting from far away to reach your work. The other way is that you wouldn’t need to clean up the mess of others before you can start, so it’s a bit of entrance on the workplace, you wouldn’t have to clean it up. You wouldn’t need those extra activities that you only have to do when it is a mess.

Q12. And then, how does lean construction affect the overall planning of the project?

Well, the overall planning of the Eindhoven houses is shorter, from eleven to seven days, and since they would start a house every day the all fashioned way or the lean way then in theory that would mean that you would have a reduction of four days, also for project. But that is only execution, so what you would normally have then, is delivery, second delivery and some times third delivery if there would be quality problems. So extra work, afterwards, this we will reduce, but we need to wait obviously to reduce to zero. So what you normally would plan in the planning you saw, is the plan and a buffer at the end, and the last few activities are for administration and all that kind of stuff. This would include actually deliveries, because in case a delivery would be failing because of quality problems, that would be reduced, and I’m not sure how many days that would be. The other reduction would be in the preparation of the project, because of the intensive way of preparation, so we compress the time of preparation in a shorter time we have highly intensity of the contributions of the firms, of the project managers of the work preparative goals. I wouldn’t know how many weeks that would be.

Q13. But in general that would be applied for all projects, the lean tools effects on planning?

Yes. Normally the planning you would do lean planning in one afternoon. Because you would be doing planning with the whole bunch of firms, and you would put it on the board and if it is a simple project, you would be ready in one afternoon, and in a more complex project it would be two or maybe three afternoons. And that kind of like collective planning, collective engineering will enable to prepare a project in a much shorter time, but more intensive.

Q14. How do you think lean construction affect the project flow?

It improves all the effects I just mentioned, all signs or names of flow. Also predictability.

Q 15. How do you think lean construction affect the construction site atmosphere between the workers?

Hugely, what we did particularly with the productivity gain, so full days of production, so that the guys would be there all day, and since they are all day there, then they need to get together along. Because of the intensive preparation, they all ready new each other before the start of the project. Because of the exchange of work amongst each other, they needed more intensive communication and instructing each other, teaching each other how to do certain kind of activities, to know what they need to do. Another effect would be for the guys who are instructing the others, or giving work to others, they need to take instructing, and if we are to took on boar activities than the work got more interesting, and the understanding amongst each other, arbour what wind of work they would do increased. And all that kind of effects, like intensive planning, intensive preparation, intensive control, everybody on the same project all day, having lunch together, starting the day together, ending the day together, taking over each others work, instructing each other, having more pride from work; because of these kind of mechanisms the residents assessed this work much higher in figures, than would normally would do, in a scale from 1 to 10, they scored 9.5, which is very high. That gives these guys’ also extra pride, extra valuation. They value their work more, than normally they would
do. And that includes the management, and that obviously observes and notes by management. So they all together increase or improves atmosphere.

Q 16. And that also includes commitment to the project?

Yes, it increases the commitment to the work, so they say they do eight hours per day, but generally they do more. Well, formally it is eight hours per day, but if they wouldn’t be able to do an eight hours work in eight hours, without any complain they would make nine hours and that is a sign of commitment.

Q 17. Do you think lean construction affects in a negative way the workers?

It may, particularly at the start. I am now speaking like of a project half way. But if it is a team without experience in this kind of working, they would experience particularly at the start of such a project, a new way of working as high levels of stress, high levels of pressure. Commitment also can be scary if it’s imposed on them, so they have to be committed because the boss says so, that is kind of an external motivation. It needs to me internal, and an external motivation, as pressure, that you would be acting committed that can give extra pressure on them, and then it may affect workers negatively, in general if this happens to roughly like exponent workers, in general that kind of effects you would be on the beginning if they are not experienced at lean working yet, and if they were not supported enough. But in this case we supported in every way; there was consultancy on the planning, although if we squeezed from eleven to seven days, with them we secured that they were comfortable with the seven days, and with the full days of production.

Q 18. So you talked with them to know if they agreed and with cope with that planning strategy?

They were introduced to a certain way of working and to this kind of planning before we started, and they were able to give their insight of what they were responsible. If you do that, then you would reduce that kind of harm potentially, and in fact you would have in the start such a new way of working that maybe they found stressful, and they are already stressed, would be the response, or even how you put pressure on them. So that would be kind of a negative atmosphere at the beginning. And if you know where it comes from then you can prevent it, as we did on the case of Eindhoven, where these guys had been working together more often, so they weren’t inexperienced, so we wouldn’t have that effect, I would suppose.

Q 19. How do you expect them to behave using lean construction tools?

I think in a creative and constructive way, so we measured/count the amount of inventions per day they come up with. And they can be small stuff, they can be process oriented, small innovations, sometimes not innovations but we call them bright ideas. The guys per day at least, per house need to come with one idea. On a daily base or weekly base, we register how many bright ideas or the workers have proposed innovations, during the work, and knowing how many of those ideas are followed up by the site manager if needed. If certain innovation needs certain level of investment, or needs a quote or management, and vice versa management or obligations, commitments to follow up at least 50% of those ideas if needed. If they need support, they would get it. It is 50% because not all of the ideas are always feasible on a small project like this one.

Q 20. Do you have any example of any of the ideas?

When they did the toilets, for instance it was a very easy task to put an outdoor crane for the garden. And it was an idea of one of the guys, so if you do the work pipes in the toilet and then a external crane, then the residents would have a water crane to do their garden. This for example implied a small investment, because you have to buy the cranes, and this was applied and has been hugely positive for the satisfaction of residents. Another one is very easy one, some of the guys who do the plaster, they have their van full of the packs of their materials, and they would like to have their van in front of the house, so what they did is that every afternoon they reserved the parking space, that would have a negative effect on residents, but since they checked it with the residents, they were able to understand why we did it, and they applauded why we did it, because its safe for their backs moving stuff and residents also understood that it would reduce the delays potentially if they were able to do it. And that is not kind of
innovations, but it is a measure taken, proposed by the workers in the neighbourhood, in coordination or communication with the residents to assure the productivity, assure the lead time and to reduce the levels of injuries you will have in your back potentially carrying all that stuff. Another one would be that normally they would break the tiles in the toilets and with a higher threshold that is under the doors they would be able to leave the old tiles and tile over the old tiles. So that kind of small inventions were done and proposed during construction and in overall thirty innovations in six weeks time and 28 of them have been followed up.

**Q 21. How do you think lean construction affects job satisfaction?**

I think they are more willing to keep the planning; they are more willing to make full days of production, they are more willing to discuss quality issues in order themselves to reduce them, they are more willing to ask and more willing to discuss work organization and exchange their work if its amongst workers, so in all case I suppose it’s a side effect of lean trying to improve labor productivity and job satisfaction and that increase potentially and influence the adaptation of lean.

**Q 22. What do you think about coaching and collaboration between the workers?**

Yes, that is another good thing, called Kata coaching which is lean. I think I explained before how we did it, and they really had to coach each other, it was expected.

**Q 23. What would be the benefit of giving a say to the foreman or to the workers on the general planning of the project?**

Insight, commitment and their ideas, so what you could do is give good information for insights, so you know what is expected and what is the next level of involvement, is that they would be able to be involved in the whole setting of the planning and giving information and in the communication with residents, to do it directly. So the guys did the communication directly with residents and do directly the delivery of the work after finishing to the residents. So its not only been able to know the information, soon for insights and to influence it before the work starts and to be able to increase autonomy.

**Q 24. Is there a negative part of the foreman or workers having a say on the planning?**

Well, they would try to delay, to buy time, they would all try to explain to you why things are impossible, and they would try to safeguard themselves from potential failure because of the lack of time. Maybe not willing to step into something, which they do not understand and which is perfectly human, and we would respond in the same way I think, but been able to cope with that and to play it in a positive setting and enable them to be mistaken, if it happens and not blaming on the other with the new way of working on peruse on person, who for instance makes a mistake and you take out that kind of pressure, and they may be relief and start thinking along with the way of thinking you like them to do. So first respond maybe not been too enthusiastic about this, because they would have a say about themselves.

**Q 25. How much liberty or freedom would you give a worker on deciding how to do their job?**

After the planning has been set, so what you would do, and always be doing in lean is that you would reserve a place for autonomy and for giving opinions and giving liberty and giving autonomy after the system is been set in place. And in a car factory, you would understand what I mean, the way of working with the traffic lights, there is the line that goes, there is the level of education of the whole workers, the workers know what is going on there, so the system in all respect is set, project wise, technological wise, so its all mistake proof, and which can’t be put together in a wrong manner, that is impossible and everybody know in detail all the drawings and how the car needs to be produced, so is all a system round, the individual in the system. And after that is set they leave it to the autonomy or the self-control or the innovative brainpower of the workers to be able to introduce to its higher levels possible in the system and to innovate and improve the system from within, and what that would do, is that after the system has been set which you don’t put a system in concrete, but you put the units or heart of the system it selves and giving liberty or autonomy, obligation to improve if they can. And that kind of Kaizen, which is lean, is all human base and then you relay on the human system and the ability
and support of that human being been able to improve the system, so its symbiosis.

Q 26. According to the conceptual model there are two routes relating lean construction with labor productivity. Do you think the two routes are valid, or there is one more valid than the other on, for improving productivity as an end and major goal?

Well the first route refers to the system, and the second one is the human in the system. So I suggest that lean construction is first than job satisfaction, you would have earlier the lean construction tools for having higher levels of satisfaction. You do the systems first, the mechanisms, the procedures, so lean planning for instance is a procedure and as side effects you would have higher levels of commitment, and with higher levels of commitment, then planning is more stable and predictable. Obviously the human is more important in the system, although if the system is good enough the human are interchangeable or exchangeable.

So maybe we can change the diagram and have job satisfaction after labor productivity?

No, I think job satisfaction is good in the diagram, but in need to direct labor productivity gains and indirect. The scheme is correct. You could debate on the importance or the sequence of the routes.

But the two routes are valid then?

Yes, and you need them both.

So you don’t prefer on of the routes?

I think there is a symbiosis; they need to be both there. Lean aims at both, setting up the system no matter what the human thinks, the system as it is, aiming at productivity.

Do you think something should be changed or added to the diagram?

No, you should keep it. It is good.