

# **THE ROLE OF VISUAL MANAGEMENT IN COLLABORATIVE INTEGRATED PLANNING AND CONTROL FOR ENGINEER-TO-ORDER BUILDING SYSTEMS**

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## **ABSTRACT**

Visual Management is a key approach in the implementation of Lean Production. It emphasizes the importance of developing easy-to-understand visual devices for sharing knowledge within an organization. Such visual devices can play an important role in mitigating the complexity of engineer-to-order production systems. A major difficulty in managing engineer-to-order prefabricated building systems is the need to integrate planning and control of different processes, such as design, fabrication and assembly on site, in a multiple project environment. This paper reports preliminary findings on the implementation of visual devices for collaborative and integrated planning and control in a Steel Fabricator, which designs, fabricates and assembles steel structures. The aim of this paper is to understand how visual management tools can contribute to improve the effectiveness of planning and control in this environment. A set of visual devices have been used in the planning and control system in this company, including a panel that makes available information about 200 simultaneous contracts in an easy-to-understand way. The implementation of those tools has enhanced the participation of different people in the planning process from operational levels or from the different production units.

## **KEYWORDS**

Visual Management, Collaborative planning, Engineer-to-order

## **INTRODUCTION**

Visual Management (VM) is one of the key approaches in the implementation of Lean Production, as it provides an easy to understand way to share production information (Liker 2003). This is achieved by making the main process flows visible and easy to understand from start to finish, through organizational and physical means, measurements, and public display of information (Koskela 2000). However,

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an overload of information may hinder people from doing what they should. For Galsworth (1997) information must be pulled as needed, exactly where and when is needed. Therefore it must be fresh and available at a glance, physically close to the process as possible so that it becomes indistinguishable from it (Galsworth 1997).

VM supports the achievement of transparency by sharing the most valuable information and removing information barriers in a given workplace (Koskela 1992; Tezel 2011). It is an orientation towards visual control in production, quality and workplace organization (Greif 1991). Symbols, signs, colours, sometimes sounds and odour not only convey information but also limit responses in varying degrees (Tezel 2011). It can be understood as a standard to be applied from which deviations are immediately recognizable (Koskela 1992).

The need of up-to-date information about processes is increased when flexible outputs are necessary, since changes in product specification and personnel assignments require precise and immediate dissemination (Formoso et al. 2002). For Kurtz and Snowden (2003) even in a chaotic and non-predictable production environment the development of tools to share the right information is a way of mitigating the complexity in these production systems.

When a process is transparent, the main source of information is the process itself, breaking the common hierarchical structure of order giving (Greif 1991). The way information is shared would also affect the way production is managed. There is a strong link between the incidence of non-value adding activities and information deficits in the workplace (Formoso et al. 2002). Instead of carrying out value adding activities, people often spend most of their time searching, wandering, or waiting for the tools, materials, and information they need in order to do their work (Galsworth 1997).

The use of VM may also bring benefits for the planning and control system, by making available production information in an opportunistic way, in which planning decisions and observations will develop the plan, as suggested by Hayes-Roth and Hayes-Roth (1979). According to Johnston and Brennan (1996), this approach can be understood as a form of *management-as-organising*, in which managers need to learn from production to precisely define the following goals. For those authors, this approach contrasts with the commonly adopted *management-as-planning* approach in which managers set the goals previously to the start of the project and controlling is limited to monitoring the progress of activities against a plan. The challenge is that using the *management-as-organising* approach, managers cannot make a straight connection between goals and operational activities, which is actually largely illusory in a highly uncertain environment (Johnston and Brennan 1996).

The use of VM tools increases the capacity for processing information and reduces the feedback time for action-taking, so that control can be integrated to execution (Alvarez and Antunes Jr. 2001). Therefore, visual tools might help the implementation of the management-as-organising approach essentially in high uncertain production environments, like the one under analysis in this paper.

This paper reports the preliminary findings of the implementation of visual devices for collaborative and integrated planning and control in a Steel Fabricator, which designs, fabricates and assembles steel structures. The scope of this company is to deliver complete assembled building or steel structures, according to client needs. Most components are pre-engineered, but the building is designed specifically for

each project. Therefore, it can be understood as an engineer-to-order (ETO) production system.

Engineer-to-order environments have become important for the construction industry in emerging economies, due to the growing trend of using prefabricated components. In this kind of production environment there is a strong dependence of the production system on client decisions, which might interfere even in the product specification during the fabrication process. Therefore, a major difficulty in managing engineer-to-order prefabricated building systems is to integrate planning and control of different processes, such as design, fabrication and assembly on site, in a multiple project environment. Therefore, the aim of this paper is to understand how VM tools can contribute for improving the effectiveness of planning and control in such environment.

In the following sections the case study company is briefly described, as well as the production planning and control system that existed at the beginning of this study. Following, the method for defining the visual tools and the implementation process are presented. Lastly, research findings are discussed.

## **DESCRIPTION OF THE COMPANY**

The company involved in this investigation has three business units: (a) light steel structural systems for warehouse and industrial buildings; (b) high rise buildings; and (c) heavy structures for bridges and off-shore platforms. This study is focused on the operations of the first unit.

As stated by Bertrand and Muntslag (1993), an ETO company is usually divided into a series of production units. The main production units of this company are: design, fabrication and assembly. There is also a Planning Department, which is in charge of producing long-term project plans, from design to the delivery of components on site.

The organizational structure is hierarchically arranged, so for each department there is one manager, who leads a team of coordinators. In the assembly department, unlike the others, there are two different managers, one focused on administrative issues and the other focused on controlling production rates. The coordinators of the latter are in charge of managing projects from the beginning of detail design; therefore these coordinators are called project managers.

Since 2006 the company has experienced changes in its main production processes and even in their culture, following the lean production philosophy. One of the most important changes is batch size reduction, by dividing a project into a set of stages, as shown in Figure . Each stage is divided into sub-stages, which contains a set of specific products that can be assembled independently. Design, production and assembly control is mostly based on those sub-stages, which happen after conceptual design is approved by the client. By dividing a project into stages, the company assumes that there is no need to produce all the pillars at once, emphasizing the importance of finalizing all the different products, or sub-stages before moving to the next.

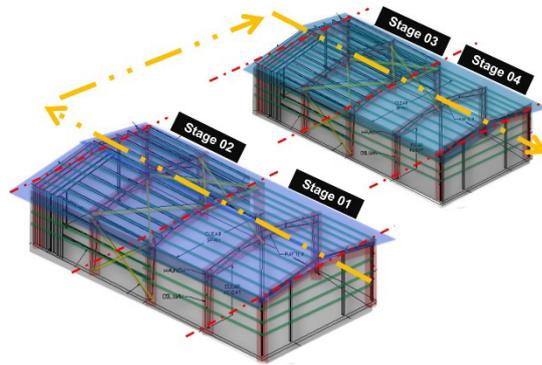


Figure 1: Reduction of batch size by dividing the building into stages

### **BRIEF DESCRIPTION OF THE PLANNING AND CONTROL SYSTEM**

One of the basic problems of the way the planning and control system had been carried out, which was hindering most of improvement attempts, was the focus on maximum utilization of capacity. The management practices worked as if the company was producing a repetitive product, as in a make-to-stock system.

Soman et al. (2007) pointed out that when production depends on customer orders, the focus of production planning should be on order execution. Therefore, performance measurements should be order focused, e.g. average response time and average order delay. When products are made previously to a customer order, such as in a make-to-stock production system, performance measurements are based on utilization of capacity, e.g. line items fill rate, throughput, and average inventory levels.

However, it was possible to observe in this company, on several occasions, the importance given to the amount of tonnages produced, which was one of the main metrics, over the completeness of a stage. The improvements proposed during this research project were focused on making information about the execution process in the construction sites available to the plant, to enable this information to be used as a guide for what should be produced next, instead of only looking at volume metrics.

Figure 2 shows the existing production planning and control system before starting the implementation of Last Planner, revealing the different levels of planning and control, as well as the scope of each level: the whole company or only a production unit. During this research project the Last Planner System started to be implemented in the design (see Wesz et al. 2013) and assembly units. This implementation initiative was carried out at the most operational level of control, involving a small number of teams both at design site assembly. For this reason, there was a need to improve planning and control at a tactical level, in which the information from several teams needed to be consolidated in order to control the production unit as a whole. The visual tools described in this paper are focused on the tactical planning and control level.

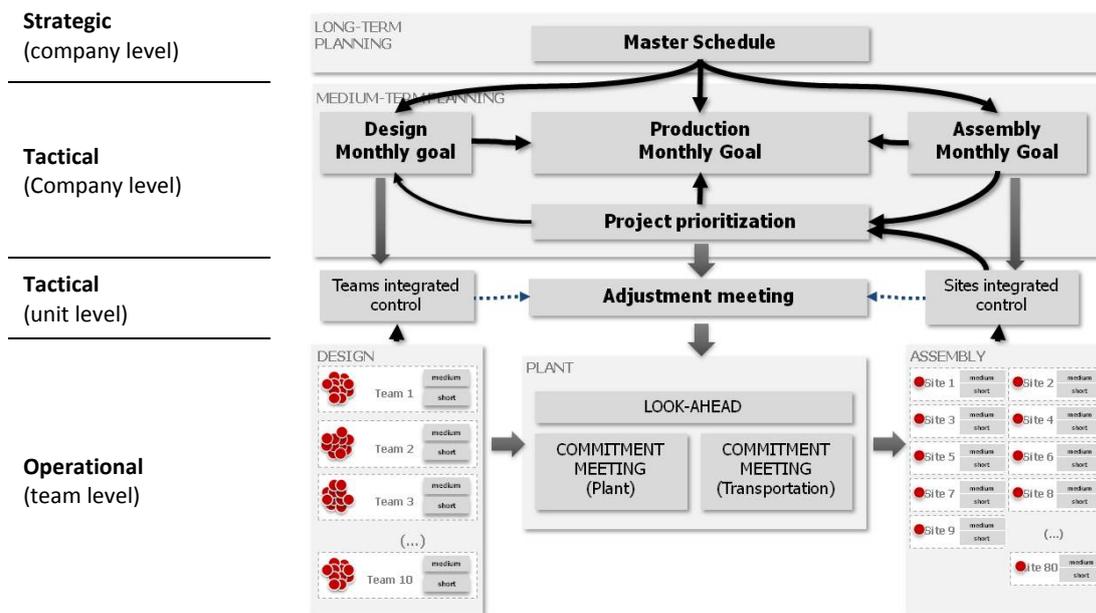


Figure 2: Existing planning and control system in the company

Regarding the tactical unit level, the design unit held weekly meetings in which the production of each team was analysed and the load of projects to be produced were balanced according to the available capacity. In the assembly process, each project manager gathered the information, and there were no meetings to analyse the situation of the different construction sites. The main source of information from the assembly was a meeting called project prioritization, in which the project managers could give a status of the production process to the Planning Department. This department should, in turn, use this information to make adjustments in the master schedule to define the monthly target of each production unit, without the constrained projects and ensuring the maximum utilization of capacity.

The weekly adjustment meeting focused on monitoring the completeness of a stage, according to the monthly target. Although the meeting name seems to refer to flexible plans – plans that could be “adjusted”, in fact the meeting was based in a management-as-planning approach. The main objective of the meeting should be to put together representatives from the design, plant, transportation and assembly department to define the most important projects on which to work. However, since this information was not formalized, the main control was focused on the previously established monthly target.

## RESEARCH METHOD

This research process has been carried out in close collaboration and engagement of the managerial staff of the company, being very similar to an action-research investigation. There were learning cycles involving the main five stages of this approach: diagnosing, action planning, action taking, evaluating, and reflection, as suggested by Susman and Evered (1978).

The implementation of the visual tools was part of a wider research project in which the whole production planning and control system has been redesigned (see Viana et al. 2013). The trigger to start the development of the visual tools came from

the company and its use was a turning point in the development of the planning and control system, since it enhanced participation, helping teams work collaboratively.

The decision to apply the visual tools described in this paper was the result of a series of meetings in which the goal, design, type of information and update procedure were defined. The meetings were held weekly during two months together with the representatives from the Planning and the Continuous Improvement Department of the company. After the basic structure was defined, the tools were presented to managers and to representatives from the tactical level from the plant, logistics and design departments. The implementation reported refers to the attempts of the Design Department to structure a method for planning and control, and the implementation of a collaborative board at the tactical level in order to integrate the operational and tactical information from each production unit.

## **THE IMPLEMENTATION PROCESS**

Implementation of the visual tools started as an aid to change some of the traditional practices from the planning and control system of the company. The aim of the visual tools was to promote collaboration between the planning department and the production units, so that both process transparency and feedback could be enhanced.

## **COLLABORATIVE BOARDS IN DESIGN**

The design department has developed, in partnership with the Planning department, a method to integrate the information on the outputs of different teams. The idea was to improve an existing planning meeting by making it possible to discuss with the representatives of all projects under production in this department that had a close relationship with the client. They also tried to avoid overloading their teams.

The proposed method was divided into three levels. Level 1 concerns the tactical level from the company, as shown in Figure 2. At this level, the design long-term planning is performed by the Planning Department, which is informed by feedback from the lower planning levels. Level 2 is concerned with the tactical level within the production unit, when the Design Department integrated medium-term planning meeting is held. It is a weekly meeting involving representatives of the planning department and a representative of each design team, where the external constraints to the teams should be analyzed. In this meeting, the design department goal is set once a month, looking four weeks ahead. Also, the design department's integrated medium-term plan is set, and updated every week, looking four weeks ahead for the potential conceptual design assignments and two weeks ahead for the potential detailed design assignments. The planning horizon for detailed design is shorter than for conceptual design, setting up a process that can be pulled by the production manufacturing plant. Figure 3 presents the visual management board of the conceptual design teams, looking four weeks ahead, which supports level 2 of the design planning and control method.

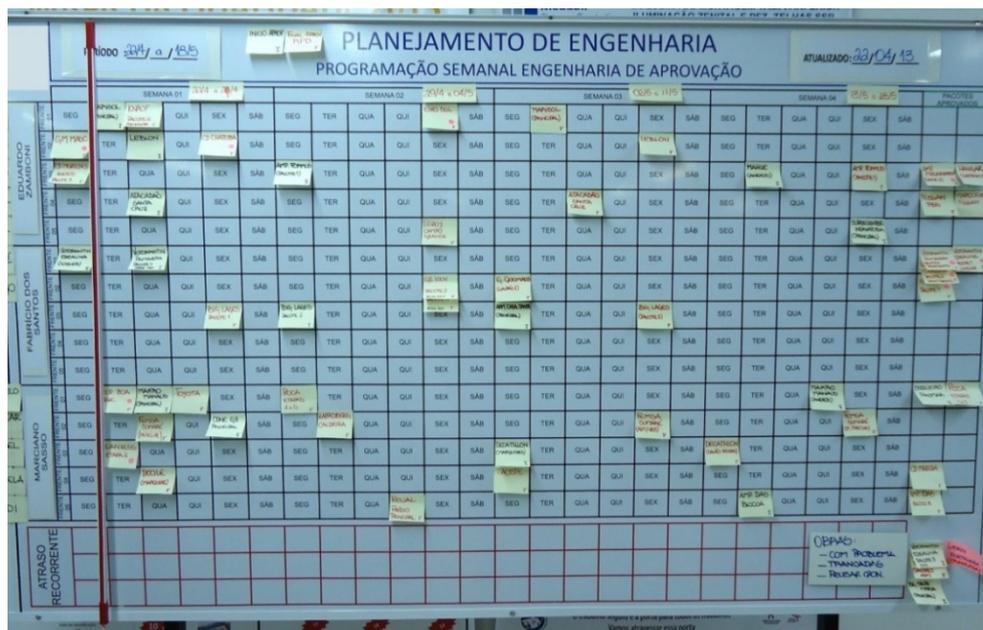


Figure 3: Visual management board of the conceptual design teams

Finally, Level 3 is the operational planning level, carried out by individual design teams, which was also supported by a visual control. A weekly meeting was carried out in each design team, in which a short and a medium-term plan was produced, in which the internal constraints of the teams were analyzed, producing a buffer of sound assignments to be undertaken in the short-term plan.

### COLLABORATIVE BOARD IN THE INTEGRATED PLANNING AND CONTROL

The aim of visual controls at the tactical level (see Figure 2) was to provide a clear overview of what was happening at the production units. The first version of a board integrating production information from each department was developed in collaboration with the planning and the continuous improvement department. During the first meeting for discussing the board with company managers, it was proposed to use the adjustment meeting as the mean to update the board and discuss the changes and problems in the production units.

In fact, the adjustment meeting was not reaching the goal of receiving a feedback from operational levels of control. The idea was that the visual tools would enhance this level of control, by providing an overall understanding of the production, and its status in each unit. The integrated control board was developed containing four important items of information about each production unit: (a) **urgent sub-stages**, including batches that are late or that should be produced earlier than scheduled; (b) **monthly target**; (c) batches that **can be produced**, consisting of a backlog of products based on the position given by project managers about the construction site status; and (d) the ones that should **not be produced** regardless of the master schedule, as shown in Figure 4.





Figure 5: Visual management board during the adjustment meeting

The above mentioned problem of having too many projects in the urgent line had a positive effect, since it brought to light a discussion over how the monthly targets were established and the importance given to delayed items. When discussing the design of the board in the meeting with the managers and planning coordinators, there was a common understanding that a delayed project is the same as an urgent project, but the use of the board revealed that this was not true.

When people started to have a closer interaction with monthly targets, through the use of the board, they started to question why a sub-stage within the schedule would appear in the urgent line and not on the target line. It became clear that there were disconnected strategies between what was the main target for the Planning department and the real available workload of the production units. There was a common understanding that planning and control should be based on a management-as-planning approach, which avoids learning from operational levels and developing flexible plans.

The board started to be used in March, the adherence to the monthly target can be seen in Figure 6. Although the adherence to the target improved over time, after 5 months using this version of the board, the company realized that it was still low. So a new criterion was defined for urgent and can-produce projects. The idea was that the board would start the month only with the information from the goals. In the course of the month, delayed sub-stages would go to the urgent line, so that this line would only report the most important projects for the production units. However, this also required a review of the way monthly targets were defined. Consequently, the planning department agreed to consider all the projects available for production (even the ones which had already been assigned in a previous month) in the target definition.

The idea for the “can be produced” line was to give up-to-date information about available designs. Sometimes design coordinators face problems with the decision making process of a given client, when design development is stopped. Those managers tend to move on to a different project in order to achieve the amount of tons targeted for the month.

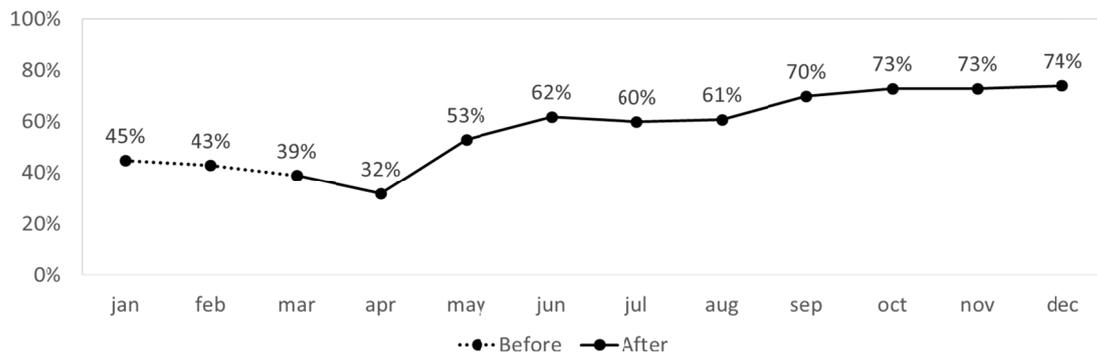


Figure 6: Adherence to the monthly target

The results of the use of the board vary according to the perceptions of each department. In the Planning department, there was a disapproval because of the paperwork needed to update the board and also because it revealed old practices from this department which started to be questioned. By contrast, the benefit of being aware of what was happening in different production units were perceived.

For the plant and logistics departments, it was important to have a unified plan. Before the use of the board, they used to receive a number of informal plans, and it was not clear which one was the most important. The design department have not benefitted very much from the integrated planning and control board. As it was focused on the assembly needs, the most important projects for the assembly had often already the design finished. In fact, design teams had improved productivity and control by using a collaborative board within the department, which enhanced the communication between teams and aided the way workload could be share through the teams.

The problem of not having rolling plans for the monthly targets was also discussed in this occasion with the Planning department, who were not willing to increase the frequency of target definition because of the amount of work required. Although the process could not be put into practice, this was one of the topics of the last workshop in this study, when the coordinators from the design and the plant scheduling departments agreed with the importance of receiving updated targets more frequently, instead of a frozen, pre-defined plan that could not be followed.

## CONCLUSION

This paper reports the implementation of some visual tools to enhance the production planning and control system in an engineer-to-order of steel building systems, in an attempt to understand how such tools can improve the effectiveness of planning and control in such environment. An engineer-to-order production system has much uncertainty because of its dependence on client decisions, and the need to predict lead times and allocation of capacity.

The use of the visual tools improved planning transparency. In the case of the Design Department, each team started to realize what was going with other teams. In the case of the integrated planning board, information about production became available to the assembly process, what used to be a black box. It enabled each unit to understand what was about to be delivered, creating an aid for correct negotiations.

Through the board of the design teams it was also possible to avoid idleness and overloaded teams by the use of a collaborative approach in the planning meetings. The integrated planning board enabled all the production units to look at the same goal, which was given by the assembly – the final production process within the company scope. The availability of the previously hidden data made people question the old practices such as the tendency to produce only the heaviest batches, and the top-down approaches of the Planning Department that could not understand the problems of the production.

There is still some resistance to implement the procedures of a more flexible and collaborative planning and control system. This is mainly due to the assumption of a management-as-organizing approach that is difficult to accept by the traditional way of planning. Although the company observed some benefits from using the boards and the collaborative meetings, it remains in managerial decisions a management-as-planning approach. The result of this implementation process was fundamental to the development of the research project on which this paper is based.

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