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GUIDELINES FOR DEVISING AND ASSESSING VISUAL MANAGEMENT SYSTEMS IN CONSTRUCTION SITES

Caroline Valente[1], Fernanda Brandalise[2], Marinna Pivatto[3], and Carlos Formoso[4]

Abstract: Visual Management (VM) has gained a prominent place in the Lean Production Philosophy, and is strongly connected to the core principle of increasing process transparency. However, the use of VM in construction sites is still relatively limited, and there is not much literature on the implementation of this principle. This paper proposes guidelines for devising and assessing VM systems in construction sites. It is based on a set of benchmarking studies, and on an empirical study conducted in a housebuilding firm that is widely recognised as a leading company in the implementation of Lean Construction in Brazil. Initially, an overall assessment of the VM system implemented in one construction site was conducted. Then, a more focused analysis was made on the installation of drywall internal partitions. The main contributions of this investigation are related to the need of integrating visual devices in the managerial routines of the company, as well as to the difficulties of providing autonomy to the production crews, and the need of decentralized production controls.

Keywords: Visual Management, Transparency, Production Planning and Control.

1 INTRODUCTION

Process transparency can be defined as the ability of a production process (or its parts) to communicate with people (Formoso et al., 2002). This is achieved by making the main process flows visible and comprehensible from start to finish, through organizational and physical means, measurements, and public display of information (Koskela, 2000). If process transparency is successfully implemented, most problems, abnormalities, and types of waste that exist can be easily recognized in order to allow remedial measures to be taken (Igarashi, 1991). Galsworth (1997) defines visual system as a set of visual devices (indicators, signals, controls and guarantees) that are intentionally designed to enable the sharing of information between people. Tezel et al. (2016) define Visual Management (VM) as a sensory strategy for information management. It includes messages communicated through any of the five senses - taste, touch, smell, and hearing as well as sight (Galsworth, 1997). Ewenstein and Whyte (2009) suggest that visual objects may either be (i) unavailable to be changed ("frozen"), or (ii) amenable to be changed ("fluid"), often as part of collaborative processes. These categories correspond, respectively, to static and dynamic visual devices, as described by Bititci et al. (2015) and Tezel (2011). Another distinctive aspect of VM is that it is intended for a group, and not just for an individual. Whereas in

[1] Msc. Student, Building Innovation Research Unit - NORIE, Federal University of Rio Grande do Sul, Brazil, carolinevalente@gmail.com

[2] Undergraduate Student, Building Innovation Research Unit - NORIE, Federal University of Rio Grande do Sul, Brazil, fernandampbrandalise@gmail.com

[3] Production Engineer, Cassol Pré-Fabricados, Brazil, marinna_pp@hotmail.com

[4] Professor, Building Innovation Research Unit - NORIE, Federal University of Rio Grande do Sul, Brazil, formoso@ufrgs.br

a conventional workplace most messages are transmitted by specific information channels, such as meetings and memos, in visual factories an information field is created, extending access to information to a large number of people (Greif, 1991).

Tezel et al. (2016) proposed a taxonomy of functions for VM, including transparency, discipline, job facilitation, and on-the-job training. Recent research also suggests that VM systems can mitigate problems related to the management of complex production systems (Viana et al., 2014), and contribute for a cultural change in the organization (Valente and Costa, 2014). In fact, besides increasing process transparency, VM involves other Lean Production core principles and practices, such as reducing variability (Formoso et al., 2002), and continuous improvement (Bernstein, 2012).

Although a growing number of visual management practices in construction have been reported in the literature, the application of those practices in construction sites is still very limited: visual devices are mostly used in site offices to support managerial decisions, and only health and safety "frozen" warning boards are usually found in construction site working areas (Tezel et al., 2016a). Moreover, research on the process of devising and implementing visual management systems is relatively scarce (Tezel et al., 2015). Recent research has mostly focused on the definition of categories for existing visual management practices (Tezel et al., 2016b) or on the impacts of visual systems devised for specific purposes, such as production planning and control (Brady, 2014), or material supply (Arbulu, 2008; Costa and Burgos, 2015). In fact, the introduction of visual devices is often viewed as something intuitive and based on common sense (Beynon-Davies and Lederman, 2016), without considering the demand for information in a systematic way, or the mental models of potential users.

Nicolini (2007) states that producing some visual devices require a great deal of "non-visual" work that is often hidden, and that ends up being neglected by the research initiatives on this topic. Such hidden work is part of existing managerial processes, and is fundamental to perform other tasks that are necessary for creating a transparent environment, such as processing and analysing information, and devising improvement measures. Nicolini (2007) also suggests the somewhat paradoxical possibility that visual practices are by definition not only visual, and that the visual part is, in fact, only the emerging tip of a much bigger iceberg.

Moreover, visual management can be regarded as a leaner way of knowledge management (Rooke et al., 2010). According to Eppler and Burkhard (2007) the creation and effective transfer of knowledge through visualization involve five perspectives: (i) what kind of knowledge is visualized (content); (ii) why this knowledge should be visualized (purpose); (iii) for whom this knowledge must be visualized (target group); (iv) in what context this knowledge should be visualized (communicative situation: participants, place, media); and (v) how knowledge can be represented (method, format). These issues are connected to the hidden work involved in visual management.

This paper proposes guidelines for devising and assessing visual management systems, understood as sets of visual practices that should be integrated to managerial processes. These guidelines are meant to be a prescriptive contribution, i.e. it should be used as a reference for companies that intend to develop or refine visual management systems to support production management in construction projects.

2 RESEARCH METHOD

Design Science Research was the methodological approach adopted in this investigation. It is a way of producing scientific knowledge that involves the development of an artifact to solve a real problem (Holmström et al., 2009). This investigation was divided into two stages. The first stage consisted of a set of benchmarking studies, in which the visual management systems of five companies outside the construction industry were analysed. Four of the companies were from the manufacturing industry, and the fifth one developed digital solutions (Table 1). These companies were chosen because they had very advanced visual management systems, some of them very well integrated to managerial processes. Each visit involved direct observation of production facilities, and one interview with a manager directly involved in the visual management system.

Table 1: Industrial sectors and interviews carried out in benchmarking studies

Company	Industrial Sectors	Interviews
A	Gear and Couplings	Industrial Manager
B	Rigid and Flexible Packaging	Process Engineering Analyst
C	Agricultural Machinery and Equipment	Process Engineer
D	Soft Drinks	Continuous Improvement Assistant
E	Digital Solutions	Head of Operations

The second stage of the research project consisted of an empirical study carried out in a construction company (named Company F), in which the visual management system adopted in one construction site was assessed. This is a large housebuilding company from Brazil, with branches in 17 different states. Company F develops and builds commercial, residential (mostly for the higher middle-class) and, more recently, health-care projects. This firm was chosen because it is well known as a leading company in Brazil on the implementation of quality management and lean construction practices. In fact, it was included as one on the best practicing companies on visual management in Brazil in a report produced by Tezel et al. (2010). The empirical study was carried out in a health-care construction project, a short-stay hospital located in Porto Alegre. This project was chosen because it was considered to be the most advanced one in terms of implementation of Visual Management in the Porto Alegre Metropolitan Region. This empirical study was divided into two phases.

The first phase consisted of an overall assessment of the visual management tools that had been implemented in the construction site. Six site visits were undertaken, in which a wide range of visual devices was assessed. Some visual devices were excluded from this study, such as visual indicators located in the site management office, mostly used in the production planning and control process, as well as boards that displayed very simple, "frozen" information (e.g. safety warnings), as the main focus of this assessment was the support provided by visual management in the execution of construction processes. A protocol was devised for guiding data collection related to each visual device, including the content, type and function of information displayed, the target group, the visualization format, the management area assisted by it and if it was static (“frozen”) or dynamic (“fluid”). The main outcomes of this phase were the identification of improvement opportunities related to the existing visual management system adopted by the company, and an assessment of the degree of integration of the visual devices to existing managerial systems.

The second phase consisted of a detailed analysis of the visual management devices that supported the installation of drywall internal partitions. The main reasons for choosing this process was: (i) it plays a key role in site installation, due to the large number of interdependences with other processes; and (ii) it uses mostly industrialized components, and has a relatively short lead time, creating improvement opportunities that can be rapidly implemented.

Multiple sources of evidence were used in this empirical study: (i) interviews (40-60 min) with two site managers, the foreman, a technical assistant, interns, four workers involved in material supply, and two warehouse keepers; (ii) direct observation of the construction site (13 visits), including visual devices and production operations; (iii) analysis of documents (conventional production plans, visual schedules, inventory sheets, standard operating procedures and flowcharts); and participant observation in a planning meeting. Based on the data collected in this investigation, some improvement initiatives were developed by the company, and the results were also observed by the research team. The results of this study were discussed with representatives of Company F in three discussion meetings and two seminars.

3 RESEARCH FINDINGS

3.1 Benchmarking studies

Some visual management best practices were identified in the five benchmarking studies. Firstly, in all five companies' visual devices were highly used to support rituals of daily meetings that usually take place in the morning, before the start of the work shift, and lasts from five to thirty minutes. The agenda usually consists of: follow-up of the previous day production, problems occurred in the latest shift, the current day's schedule, weekly indicators analysis and action plans for performance improvement. Those companies also used visual charts that are made visible to all workers and keep the information available and accessible at a glance to users, providing rapid feedback. Another best practice was the effort to standardize processes and operations, not only for value-adding activities, but also for inspection, logistics and safety operations. Finally, high importance was given by the five organizations to the use of A3 reports as a tool for problem solving and communication. All of them developed A3s to solve and document production and administrative problems, contributing to mitigate system's complexity. In some of the companies, the A3 chart had standardized sections.

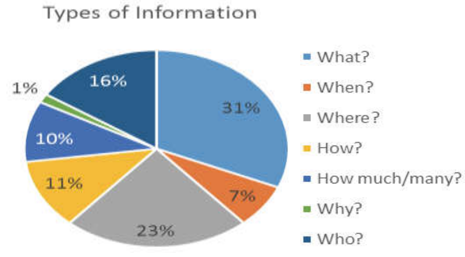
3.2 Overall assessment of visual management devices

Figure 1 presents the classification of visual devices adopted by Company F, according to the functions performed and type of information used, based on the classification proposed by Eppler and Burkhard (2007). This information provides insights on how visual devices are integrated to existing managerial systems.

Regarding the functions of each visual device, Figure 1(a) indicates that more than half of the visual devices performed functions of identifying or informing something, which refers to the most basic types of visual tools (indicators or signs). Only 13% of tools were used for data or activity control functions, and only 5% were intended to guarantee an action by using an error-proof device. Hence, the adoption of more powerful tools, such as visual controls and guarantees, was identified as an improvement opportunity, in order to increase the impact of visual devices in work standards.

Concerning the type of information displayed, more than half of the devices were intended to identify or inform. A large percentage (31%) of devices portrayed information that responded to a "what?" question, followed by devices that answered "where?" (23%) and "who?" questions (16%). One surprising result was the very short percentage (1%) of visual tools associated to a "why?" type of question. Answers to this type of question usually relate to the reason or purpose for a particular action or attitude, which often refers to the company's beliefs, values, and culture. The lack of this type of information on visual devices can be related to the typical role of task execution played by the labour force in the construction industry, assuming that it is not necessary to know much about the purpose of things.

(a) Visual tool functions



(b) Types of information

Figure 1: Classification of visual tools according to the functions performed and types of information associated

The relatively low level of participation of workers in the visual management system was also made evident by the source of the information to be disseminated in visual devices. As shown in Figure 2, most visual device information was produced by the site managerial team. Workers were rarely involved in the conception, or updating of visual devices, despite the fact that they had useful information for production management. Consequently, the site management team had to spend a considerable amount of their time in production control activities, which is contradictory with the idea that process transparency should be used for increasing the autonomy of the labour force.

Based on a comparison between the practices of this company with the ones analysed in the benchmarking studies, it is possible to identify two spirals in visual management. A positive one is when controls become simpler and problems are more easily detected, which enables the production crews themselves to perform those controls. In that case, there is more autonomy and responsibility for production crews, reducing the burden of control for the site management team, who can spend more time in studying, evaluating, and rethinking processes in order to make them more transparent and improve performance. In the negative spiral, if the processes are not transparent, problems are more difficult to be identified and controls are more complex and time-consuming, demanding much effort from the site management team. This hinders production teams from having autonomy to perform these controls and take responsibility for detecting problems. In that situation, the site management team becomes overwhelmed with controls and there is not much time left for process improvement, making them even less transparent.

Around half of the visual devices were related to production planning and control, including productivity evaluation tables, and daily activities sheets for labourers. Twenty-two percent of the devices were concerned with quality management, such as work standards, inspection sheets and quality policy panel, although none of them visually displayed data on defect rates or abnormalities. Some information deficits were identified in other managerial processes, such as safety, waste detection, and logistics management. Regarding safety, although workers were encouraged to report near-misses, most visual devices were static, or displayed accident rates and action plans after accidents. In addition, although some visual practices were fairly well connected to the production planning and control and quality management processes, the integration between visual devices and some other managerial processes was relatively weak. As a large number of visual devices were static and had only informative or indicative character, little feedback could be pulled out from them to support problem-solving or mitigate complexity.

Moreover, none of the visual devices was designed to support the creation of knowledge at the level of construction workers.

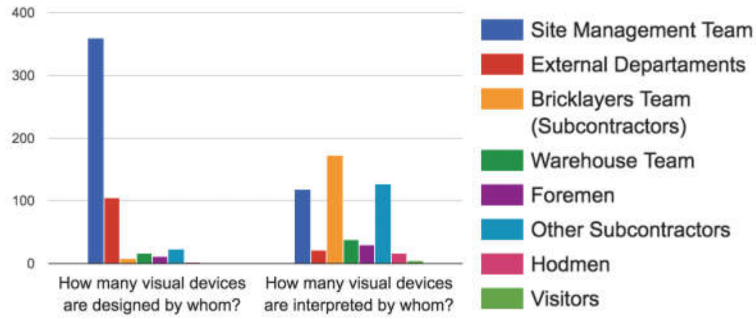


Figure 2: Graph of participation of agents at site's visual management system

The results presented above can assist the company in adjusting its visual management system in two complementary ways. Overall, it seems to be important for Company F to seek a balance on the use of visual devices among different managerial processes and to use visual devices that offer more support for production control and improvement. It would be better to have a smaller number of dynamic visual devices that effectively support decision-making and encourage reflection and collaboration, rather than having a large number of devices, most of them with a low impact in production management.

3.3 Analysis of the Drywall Process

Company F has implemented several visual devices for this process, such as physical prototyping, templates, inspection sheets, standard operating procedure flowchart, kanban for supplying materials, visual schedule for each floor, and material control sheets. Some of these visual devices are dynamic, such as inspection and material control sheets. Another good practice was the fact that some of those visual devices were well integrated. For instance, the physical prototype was used, among other things, to adjust the amount of materials for each kanban. By contrast, some problems were detected in the kanban system. Due to an implementation problem, cards were sometimes used simply as inventory distribution sheets. Some of the information was not very clear for the labourers in charge of transportation, and the batches were not adequately distributed in each zone of the building.

Based on discussions carried out in this investigation, the site management team decided to improve the kanban system. Figure 3 presents the new format of the card, which is more intuitive, and easier to understand than the previous one. Some additional controls were included, such as the amount of materials that left the main storage area. However, some problems related to leftovers or lack of material persisted, mostly due to mistakes in the preparation of transportation batches, and poor communication between team members. Due to the changes introduced, mostly concerned with giving more autonomy to workers, some improvements were identified: 6% reduction in gypsum plasterboard waste; reduction in the time spent counting components, higher productivity of the material supply teams, better organization of inventories, and increase in the motivation of the employees. It is worth noting that the material supply team spent 33% of their time waiting for the panels to arrive in the elevator, due to interference from other material supply operations. Thus, more time should be spent in standardizing and coordinating logistics operations.

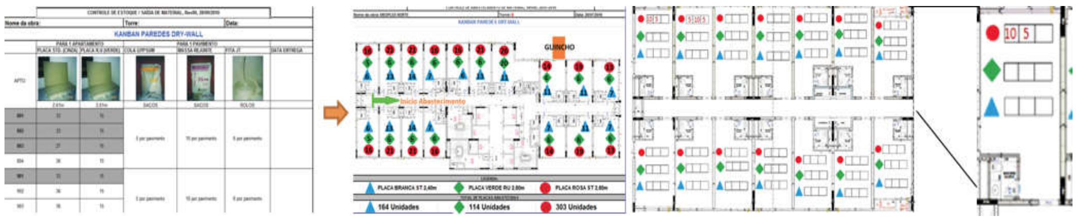


Figure 3: Old version (left) and new version (right) of kanban

4 Discussion and conclusion

Based on the literature review, in the benchmarking studies, and especially in the empirical study carried out in Company F, a set of guidelines for designing, implementing and assessing a visual management systems have been proposed: (i) *Support communication rituals in collaborative meetings*: visual devices should be associated to learning initiatives and moments of reflection. When a visual device plays this role, it becomes important to people and relevant to the process. Stopping in front of the performance board or visual device, even for a few minutes in a daily ritual, is a strong evidence that this artefact is useful; (ii) *Ensure rapid feedback*: a visual management system should provide timely information and quick feedback so that corrective actions can be taken; (iii) *Encourage the joint processing of information*: a visual management system should support collaborative activities in organizations. Some visual devices can be used as catalysts to facilitate a variety of tasks, from the generation of ideas to decision making, planning, knowledge sharing and learning (Eppler and Bresciani, 2013); (iv) *Consider the mental models of the users*: the assumptions, beliefs, generalizations, illustrations, and previous experiences that influence the behavior and understanding of the users should be considered in the design of visual management systems. This reduces the amount of information to be provided in visual devices, and make them easier to be understood by users; (v) *Contribute to a cultural change*: a visual management system can change the way employees feel about their work, contributing to increase morale and motivation, by promoting collaboration, decentralizing decisions, and increasing the degree of autonomy among production teams; (vi) *Mitigate problems related to system complexity*: complex systems are unpredictable environments, full of uncertainty and variability. Some visual devices can provide some support to deal with this complexity by sharing the right information on time and removing information barriers in the work environment.

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