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Original Citation

Tezel, Algan, Koskela, Lauri and Tzortzopoulos, Patricia (2013) Visual Management in Industrial Construction: A Case Study. In: 21th Annual Conference of the International Group for Lean Construction, 31st July - 2nd August 2013, Fortaleza, Brazil.

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VISUAL MANAGEMENT IN INDUSTRIAL CONSTRUCTION: A CASE STUDY

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ABSTRACT

Visual Management (VM) is a distinctive communication strategy that is frequently observed at lean work settings to varying degrees. It relies on the effectiveness of visual communication and catchy visual systems to create visual communication for different managerial purposes. VM in construction has generally been discussed within a building construction context to date.

This paper investigates the VM realisation means (visual tools) and attributes in the construction process of a very large industrial facility, which mainly involves mechanical and electrical construction works. A VM research on the construction site of an industrial facility will help address a gap in the field and extend the understanding of the VM applications in a different construction context other than the building construction/renovation.

The research question of how VM is realized in the industrial construction context was investigated through the case study research method. One of the biggest subcontractors of a very large gas-processing facility was studied in terms of their VM approach and applications. Interviews, site observation and photographic documentation are the main data collection methods. New VM application opportunities in pipe spool fabrication and crane management were identified. Some industrial construction specific visual systems, VM application attributes for industrial constructions, managerial insights and future application directions were also captured and presented.

KEY WORDS

Process transparency, Visual Management, Industrial construction.

INTRODUCTION

Visual Management (VM) is an important managerial strategy and a fundamental element of the Toyota Production System that creates highly visual (sensory) information fields from which people can pull information for an augmented self-management and control (Ohno, 1988; Shingo, 1989; Greif, 1991). VM directly supports other managerial efforts, such as production management, safety management, performance management, workplace management (housekeeping) etc (Tezel, 2011). One of the direct outcomes of VM is an increase in the communication ability of process elements, which is defined as process transparency (Formoso et al., 2002). Its other effects may include increased workplace discipline, continuous improvement and job facilitation (Tezel et al., 2009).

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To date, the research on VM in construction has been conducted predominantly within building construction contexts, either in the form of exploring the concept itself or analysing/explaining the applicability of some of the VM tools (Brady et al., 2012; Tezel et al, 2010; Saurin et al., 2008; Kemmer et al., 2006; Picchi and Granja, 2004; Moser and Dos Santos, 2003; Formoso et al., 2002; Heineck et al., 2002; Dos Santos and Powell, 1999). Although building construction constitutes the biggest segment in the construction industry, industrial construction with highly technological projects composes around a significant 10 % of the industry with its distinctive processes, methods and specialised trades (Halpin, 2010).

As one of the conclusions from his PhD study on the VM strategy applied in various building construction projects in Brazil and Finland, Tezel (2011) identified the need for extending the future VM research to civil and industrial construction projects. The research effort presented in this paper can be perceived as a step towards addressing that need to a degree and a continuation of the primary author's PhD work.

The paper outlines an exploratory VM research in a natural gas desulphurisation (purification) and liquidation plant construction project located in the Karakum desert, Central Asia, the home to the world's one of the largest natural gas deposits. The project is a large scale (2.25 square km), 4 billion US dollar worth Engineering-Procurement-Construction (EPC) project that mainly involves steel erection, mechanical erection (drums, tanks, vessels, generators, transformers, turbines, switchyards etc.), heavy piping, welding, electrical cable laying and termination, and electro-mechanical instrumentation activities.

The project has been managed by an Engineering News Record (ENR) top 100 main contractor that has subcontracted two major portions of the work to two other ENR top 100 contractors. The VM applications on the site were studied, as well as those of a main subcontractor, specifically for approx. 3.5 months. The studied subcontractor was employing around 5000 people at the project at the time of the study for approximately 1 billion US dollar worth industrial construction works. The research question of how VM is realised in the industrial construction context was explored with this subcontractor and on this large industrial construction.

In order to explore the research question, an analysis of the realisation of the VM taxonomy that was developed by Tezel (2011) from various building construction projects was performed in the context of the specific project. The taxonomy consists of site layout and fencing, standardisation of workplace elements, warehouse management and the 5S, pull production through the *kanban*, production levelling through the *heijunka*, in-station quality (*jidoka*) and *andon*, prototyping, sampling, visual signs, visual work facilitators, improvisational VM, performance management, system wide information, health and safety management, human resources management, *poka-yoke* and on-site fabrication. The evaluation of the taxonomy for industrial construction projects is discussed over the parameters of standardisation of workplace elements, pull-control through the *kanban* and *heijunka* levelling, improvisational VM, health and safety management, sampling and prototyping, visual signs and performance management. Some novel VM applications were identified from this study for their possible future use in other types of construction projects. In addition, various VM application propositions for similar industrial construction projects are given.

RESEARCH METHOD

The research method for the study is a single exploratory case study. According to Yin (2003), the case study is suitable when the “how” and “why” questions are asked to a contemporary event over which the investigator has little or no control. Cases are frequently used to explain the implementation of new methods and techniques (McCutcheon and Meredith, 1993).

The unit of study of the research is the VM applications on the construction site and at the subcontractor. A research protocol was prepared before the initiation of the research process. The research protocol consists of semi-structured interviews with the management (one construction manager and one site manager), documentation of practices with photos, analysis of archives and unstructured discussions with site foremen/construction crew leaders.

Some research limitations include the limited overall research time, the absence of worker views on the subject, the busy construction conditions and tight construction schedules and perhaps the absence of a full-scale implementation and analysis of one of the proposed VM systems.

RESEARCH FINDINGS

STANDARDISATION OF WORKPLACE ELEMENTS

The main contractor had contractually imposed their general site standardisation methods on the subcontractors. Therefore, a certain level of visual site standardisation with similar practices was being sustained by all parties. The walkways were clearly marked, different work trades were using colour-coded helmets and ID cards, and various site areas (e.g. smoking areas, material/waste collecting areas, welding schools, scaffolding schools, workshops, pipe-spool fabrication units, construction areas, site warehouses, offices and bus stops etc) were clearly identified (see Figure 1). The subcontractor’s manager indicated that they had not applied the 5S specifically, yet they had their own housekeeping system at their workshops, pipe-spool fabrication units, warehouses and construction areas. Indeed, the systematic cleaning, and some housekeeping methods such as shadow boarding, material name identifications and material/tool grouping were identified on the site. As a general practice imposed by the main contractor, a colour-coded material identification (by the area that the material would be used; for example, a big red circle or a yellow square on a material container indicates a specific area on the site) practice was in place for easier on-site material distribution/management. Although the number of standardised elements could be increased and their identification methods could be visually richer, the level of standardisation of the workplace elements was at a comparatively higher level for such a large construction site.



Figure 1: Standardisation of Workplace Elements: Example Applications

PULL-CONTROL THROUGH KANBAN AND HEIJUNKA LEVELLING

Neither systematic visual pull-control nor visual levelling efforts were found on the site and within the studied subcontractor. The manager and site supervisor had not heard of the *kanban* or *heijunka* system. One visual pull-control and production levelling opportunity was identified at the pipe-spool fabrication unit of the studied subcontractor. For a quick and high-quality erection, heavy pipe-spools (straight pipe sections, elbows, reductions, valves etc.) with different pipe/fitting diameters and configurations had been pre-fabricated (assembled together) mostly through welding operations. The prefabrication was managed and prioritised in a linear manner by the CPM based schedule of the piping works. This pipe prefabrication practice is not very different in essence from producing on-site concrete batches in which visual production levelling through *kanban* and *heijunka* has been successfully implemented in various building construction projects in Brazil (Tezel et al., 2010). Using the *kanban* and *heijunka* systems in such a setting for pipe-spool prefabrication remains as a noted VM research opportunity; yet the implementation requires a sufficient level of awareness from the management. See Figure 2.



Figure 2: Pipe Spool Prefabrication Workshop

Additionally, the site management underlined an unbalanced crane usage among the piping and mechanical erection crews. Cranes are one of the most critical

production elements for many industrial construction activities. There was an internal conflict among the crews for the possession of the cranes. The site manager complained that sometimes the crews deliberately retained the cranes unnecessarily long for their own use in order to hinder the other crews' work progress. The management could not cope with the negative competition over the cranes problem and track the crane usage/retention time periods effectively over the construction site. A visual crane levelling board that restricts and balances the crane distribution was devised by the primary author. Each crew leader could fill out two crane pull cards with their crew ID card, the demanded crane type, crane usage area and crane retention time period information written on and hand these cards over to the corresponding site/area manager. The site/area manager together with the crew leaders would then prioritise those demands and display one of the cards on a *heijunka* box like visual crane balance board for every crew member to see. The other card(s) could be given to the corresponding crane operator at the beginning of the day so that he/she could identify where and with what crew the crane should have been precisely at any given time. This VM solution to the crane problem was welcomed by the site management for the future application/use. See Figure 3.

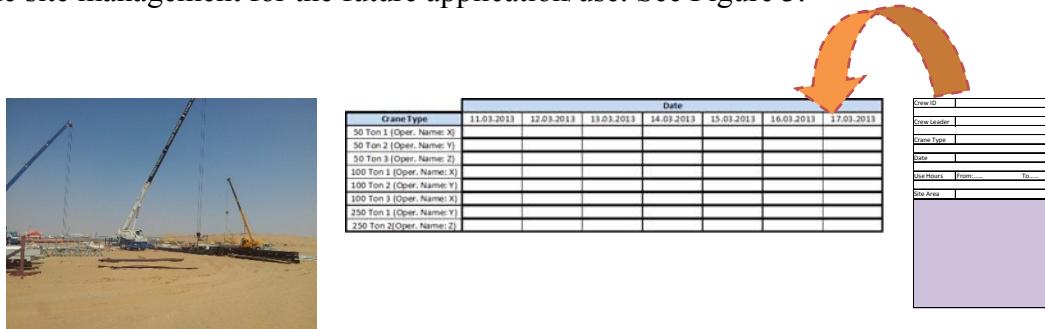


Figure 3: The Crane Levelling Board with a Crane Pull Card Sample

IMPROVISATIONAL VISUAL MANAGEMENT

Spontaneous integration of information into the environment as self-visual aids/reminders was a common practice among the mechanical erection, welding, pipe fitting, electrical installation and instrumentation crews. Writing the isometric drawing line number or the welding method/welder name on a steel pipe, marking the circular orientation on the foundation of a drum vessel, integrating the cable schedule information on a group of cables or displaying the location of a specific electrical junction box on a steel column were very common examples that one could easily come across with on the site. Those information needs could be captured by the management and material vendors in order to improve the information flow for the production crews. Some visual aids integrated on the materials/material containers were also identified. See Figure 4.



Figure 4: Improvisational Visual Management and Integrated Visual Aids

HEALTH AND SAFETY MANAGEMENT

The main contractor's and consequently the subcontractor's strongest emphasis were on health and safety (HSE) issues. The main contractor had strictly imposed their general practices on the subcontractors. Static and mobile safety signs, visual reminders, a colour-coded equipment checking system (every month a colour would be picked to identify the safety checked equipment), scaffolding safety tags (a colour-coded tag that determines if a scaffolding is safe to use or not), wind roses against gas leakages, safety barriers, posters etc. were all over the construction site. See Figure 5. *Poka-Yoke* systems incorporated into the cranes that lock the crane booms under certain environmental temperatures and above certain wind speeds were also in use.



Figure 5: Some Visual HSE Practices on Site

The subcontractor had adopted some boards to track the personnel working in confined spaces, particularly in tanks and manholes. The hazardous inert gases generated by welding and some installation activities in confined spaces are fatal. Therefore, human presence under those conditions is often constrained. The personnel intending to work in a confined space would hang its ID card on a board near the confined space and their entrance to the work area would be recorded. At a glance, who has been working since when in a tank or another confined space could be identified from the board. See Figure 6.



Figure 6: The Confined Space Tracking Boards

It was revealed from the interviews with the site and company managers that the visual HSE implementations at the subcontractor resulted from a combination of the subcontractor's past experiences and the main contractor's push. However, some implementations were not very carefully thought of. For instance, there were safety signs/boards that had been prepared solely in the English language, which is unknown to the most of the workers. When this fact was mentioned to the site manager, he indicated that the only-English boards had been put on the site to "impress" the main contractor.

SAMPLING AND PROTOTYPING

In prototyping, a dummy example of the to be constructed end product is put on display as an example for workers and management. Sampling is used to couple materials with their location of use and equipments with their corresponding work crews. Some colour coding practices for material identification has already been used. For instance, the top-layer insulation colour of earthing cables are generally yellow-green and high-voltage cables' are red. However, neither systematic sampling nor prototyping were identified on the site or at the subcontractor. Yet, there were some assembly activities in which both prototyping and sampling could be used. For example, a considerable amount of insulation and painting (pipe and vessel) works were going on on the site. For each type of pipe line and vessel, different types of insulation materials (mineral wool and cladding), their configurations, and painting coats/colours were being used. See Figure 7. Several different process regulating electro-mechanic equipments (valves, transmitters, indicators etc) were being installed on the site. Sampling and prototyping could also be used for the installation of different instruments on different equipments and pipe lines.

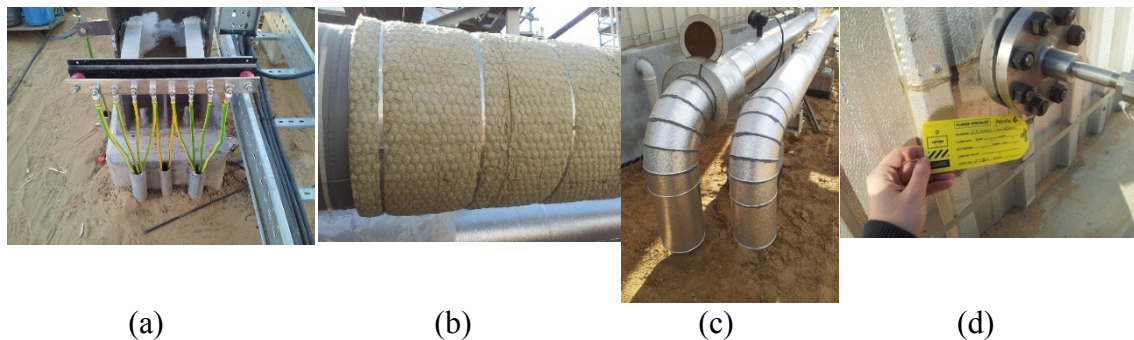


Figure 7: Cable Colour-Coding (a) and Pipe Insulation (b-c) with Instruments Attached (d)

VISUAL SIGNS

The site and subcontractor's construction processes were rich in the number of signs. Most of the signs were HSE related though. Nevertheless, an interesting quality management related mobile sign was spotted in use at the subcontractor. Around every welding process, the related process's welding procedure specification (WPS), which outlines the directions, techniques and procedures to be used as per the quality code requirements, were hang on a mobile sign. Thus, the quality inspector of the subcontractor and the main contractor, and the welder himself/herself could easily identify the required welding techniques and materials for the process (see Figure 8).



Figure 8: Mobile WPS Signs and Integrated Visual Aids

PERFORMANCE MANAGEMENT

Except for the general HSE figures posted on boards, no systematic visual performance management effort was identified. There were some personal initiatives of the crew leaders. One welding crew leader was regularly/daily posting the project drawing number and the welder name of welded joints that had failed to pass the non-destructive test (NDT)⁴ around his work area. When asked about the practice, he indicated that although exposing the failed joints could sometimes be “embarrassing” to the welders in his crew, he found that the practice had been inducing the welders to work more meticulously so as not to see their names on the failed welded joints list.

CONCLUSIONS

This paper investigates the VM realisation within a large-scale industrial construction context, a seemingly neglected aspect of the VM research in construction. VM exists on industrial construction sites. On the studied site specifically, the manifestation of this existence was essentially in the workplace standardisation and health and safety management issues. Without knowing much about various application possibilities/methods, the VM existence at the studied subcontractor essentially stems from the contractual coercion by the employer (the main contractor) and the company’s past experiences. As it was found from the solely-English VM boards on the site, in some cases, an excessive push from customers could lead to the application of quasi-VM solutions that are mainly there to “impress” the customer not to help the workforce perform better, safer etc.

Certainly, awareness of the VM concept needs to be increased at the subcontractor, if the related possibilities are to be fully exploited. A range of VM solutions compiled from different parts of the world can be demonstrated to the subcontractor through workshops. It should be noted that it is important to convey the self-management idea of VM rather than solely demonstrating some VM tools, so that the managers can devise their own VM solutions for their own needs. Academic involvement can also be beneficial. Being able to demonstrate both quantifiable and unquantifiable benefits of VM to companies is also an important parameter for motivation.

It was found that the VM taxonomy devised from building construction projects by Tezel (2011) is also relevant for industrial construction projects. There are some elements of the taxonomy that were already in use/application on the site and at the studied subcontractor (standardisation of workplace elements, visual signs,

⁴ A wide variety of non-destructive test methods, such as radiographic testing, ultrasonic testing etc that are used to identify the quality of a welded joint.

improvisational VM and health and safety management). People tend to intuitively integrate information into their work environment for increased self-management (Galsworth, 1997). There are elements to learn for researchers/construction managers from this intuitive habit. One interesting VM system for the health and safety management on site that is used for tracking the presence of the workforce in confined spaces could be adopted as a VM solution within different construction/building environment contexts.

Some application opportunities for pull-production control in pipe-spool fabrication, plant (crane) levelling, sampling and prototyping were also identified. Those identified opportunities should be applied at a full-scale in an industrial construction context and subsequently, their effects/outcomes should be evaluated. Industrial construction projects frequently involve the extensive use of plants/equipment, pre-fabrication and more complex electro-mechanical installations. It is probably best to explain the VM concept and to demonstrate its application possibilities to industrial construction managers, foremen and crew leaders so that they themselves will be capable of devising their specific VM solutions. Suppliers of those pre-fabricated equipment and electro-mechanic parts also play an important role in providing visual aids, ergonomic use, integrating essential information onto material/equipment and *Poka-Yoke* systems. The *Poka-Yoke* systems in the cranes (automatic boom stopping for safety in certain environmental conditions) on the site are examples of those.

For this specific project that is spread over a large area with many people working at heights, in confined spaces and under harsh weather/territorial conditions, no notable IT system other than the prominent office software was found. Any proposed IT system for VM solutions for such construction projects should be durable, compact, mobile and easy-to-use. Virtual prototyping can be employed to identify and demonstrate the risky situations without putting the workforce in danger.

Industrial construction projects range from large processing facilities/pipelines to off-shore gas/oil extraction platforms and wind turbines. They possess different challenges in nature when compared to building construction sites and a VM research in those construction environments will yield interesting outcomes. For instance, in relatively unbalanced settings for human beings, such as off-shore platforms, one may need to consider VM solutions that address the interoceptive⁵ senses and the notions of proprioception⁶ (kinaesthesia) and equilibrioception⁷.

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⁵ Related to the stimuli from within. Unlike the exteroceptive senses, which function through the stimulus from an external information source to the five human senses, the interoceptive senses are related to human balance, perception of position etc.

⁶ The sense of relative positioning of the body parts.

⁷ The sense of balance.

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