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. VISUAL MANAGEMENT CONDITION IN HIGHWAYS CONSTRUCTION PROJECTS IN ENGLAND

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ABSTRACT

Lean construction has recently gained momentum in England's highways construction supply chain. The literature indicates that the current view to Visual Management (VM) within those lean implementations is limited to some VM tools. This paper explores the condition of VM, which is a fundamental sensory information management strategy in the lean production system, in the highways sector in England.

VM in construction is a scarcely researched topic, particularly outside the building construction context. The existing VM research focuses generally on the application of a specific VM tool rather than the VM strategy itself. The paper identifies the current VM condition with its realization means (VM tools), drivers, barriers and future implementation opportunities in England's highways construction supply chain through five case studies and a focus group research effort.

The main findings are; (a) the current implementation of VM, particularly on English highways construction fields, is limited, and (b) along with many drivers and implementation opportunities for VM, (c) there are also some significant barriers before VM. The main limitations of the research are that the paper discusses the issue mainly for the construction phase and limited amount of data were collected from operational site staff.

KEYWORDS

Visual Management, big room/obeya, lean construction, transportation sector, highways

INTRODUCTION

Partly due to the concrete lean construction vision from the main public client (Highways England) for significant efficiency gains, lean construction has been increasingly finding a place on the agendas of contractors operating in the highways supply chain in England (Drysdale 2013; Fullalove 2013). One of the fundamental elements of lean construction is

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Visual Management (VM), which is a visual (sensory) information management strategy. There are some specific characteristics of VM (Greif 1991); (a) the information in VM is presented to create information fields, from which people can freely pull information in a self-service fashion, (b) the information need is determined ahead of time to prevent information deficiencies (pre-emptive approach), (c) the information display is integrated into process elements (space, machinery, equipment, components, materials, tools, gadgets etc.) and (d) the communication is simple and relies little or not at all on verbal or textual information.

Galsworth (1997) proposed a general classification of VM tools, i.e.: (a) information giving (e.g. signboards); (b) signalling (e.g. *andon* boards); (c) response limiting /controlling (e.g. *kanban* cards); and (d) response guaranteeing (*poka-yoke* systems) visual tools. In practice, those VM classification types commonly manifest themselves in the forms of some conventional VM tools (Galsworth 1997); the 5S workplace structuring methodology, visual performance boards and *obeya* (big rooms), in which many Key Performance Indicators (KPIs) are located to facilitate meetings and continuous improvement, visual standard operating sheets, the A3 methodology, production, maintenance and safety control cards (*kanbans*), and warning and control type *poka-yokes* for increased operational safety, quality and reduced set-up times.

The literature on VM in construction has been accumulating (Tezel et al. 2015). However, it still mainly revolves around VM's conceptual benefits and the applicability of some conventional and IT based VM tools (i.e. the KanBIM and VisiLean prototypes by Sacks et al. (2013) and Dave (2013) respectively) in construction, particularly in building construction projects. Currently, there is lack of empirical research on VM in the highways context.

Also, without giving in-depth analyses of the realization of the VM strategy itself, the narratives on VM in the highways supply chain in England are limited to the use visual performance boards (Drysdale 2013; Fullalove 2013). This further highlights the current narrow view to the subject. The general condition of the VM strategy in highways construction and maintenance projects is unknown. Therefore, this paper aims at exploring the VM condition in highways construction and maintenance projects in England by (a) identifying its current use, (b) barriers, (c) drivers and (d) future implementation opportunities as the research objectives.

• RESEARCH METHODOLOGY

In order to realize the research objectives, the case study and focus group research methodologies were used. The initial research strategy adopted was of exploratory nature and relied on multiple case studies. Exploratory case studies are suitable when a phenomenon out of the researcher's control is investigated in its real life context (Yin 2003). Five major highway construction sites in England were visited over the course of four months (between April – August, 2015) to collect data. All sites were identified and connected through Highways England. The project sites are known to have some sort of lean awareness and efforts to advance their lean construction practices, which they drive through their process improvement managers. The data collection methods of the case

studies include site observations on the field, in the site office and compound, photographic documentation, open-ended, semi-structured interviews with process improvement managers, informal discussions with the construction managers and investigation of the site archives. To triangulate some of the findings from the interviews and field observations, a structured questionnaire was distributed to the site operational staff (i.e. civil engineers, foremen, traffic safety controller, health and safety controller etc.) at Case 2 and Case 3 and 20 responses were collected. See Table 1 for the detailed description of the case sites and corresponding process improvement managers.

Table 1: Description of the Cases

Case No	Number of Visits	Location	Project Cost	Project Scope	Process Improvement Managers
1	1	West Midlands, UK	150 million US$	New motorway construction and upgrade.	Chartered civil engineer (BSc.) with more than 20 years of experience.
2	2	Lancashire, UK	289 million US$	Upgrading the existing motorway.	MSc. in construction management. 5 years of experience in the highways sector
3	2	Cheshire, UK	316 million US$	New motorway construction and upgrade	MSc. in construction management. 3 years of experience in the highways sector
4	2	North Yorkshire, UK	543 million US$	New motorway construction.	MSc. in construction management with more than 10 years of experience in the highways sector
5	1	West Yorkshire, UK	9 million US$	Motorway/ roundabout maintenance and upgrade.	MSc. in production management with more than 8 years of experience in the highways sector

After completing the case studies, a workshop event on VM in highway construction and maintenance projects was organized to set the scene for the focus group research. The event was promoted in the Lean Construction Institute-UK's and Chartered Institute of Building's networks. Focus group research involves systematic discussions with a selected group of individuals to gain information about their views and experiences of a topic (Stewart and Shamdasani 2014). The composition of the focus group participants was as follows; 12 academics/researchers, 6 lean construction consultants working in the highways sector and 22 professionals/practitioners from the highways sector.

• RESEARCH FINDINGS

• CURRENT USE OF VISUAL MANAGEMENT

As stated by process improvement managers in Case 1, 2 and 5, the use of VM is limited, particularly in terms of its deployment on the construction areas, outside of the site offices and compounds (see Table 2). Often times, the actual on-site production takes place far

from site offices or compound areas in the highways context. Also, it was found that the shared visual information with the site personnel is mostly limited to generic health and safety information on mobile boards/trailers/vans. There are also many similarities among the projects as to the use of VM; the most commonly used VM tools are visual performance boards displaying various project KPIs in the offices/compounds. It should be also noted that some projects had shown efforts to support their VM use with IT systems (BIM and mobile computing). See Figure 1 and Figure 2 for some of the captured VM tools at the case projects.

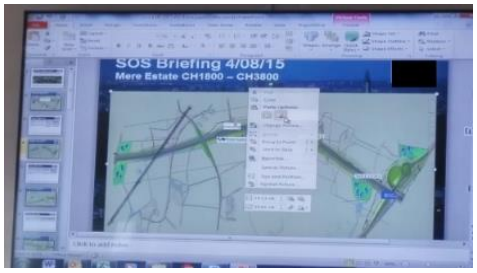
Table 2: Current VM Use at Case Projects

Case No	VM tools in offices/compounds	VM tools on-sites
1	(a) Visual performance boards, (b) an *obeya* room, (c) static near miss recording/display stations using iPads, (d) decent level of housekeeping but no 5S, (e) heavy plant/equipment tracking boards, (f) color-coded construction site ingress/egress documents, (g) the Last Planner meeting boards	(a) Different housekeeping levels among subcontractors; no 5S, (b) improvisational VM practices by the workforce (i.e. marking underground utilities with colored sticks), (c) generic health and safety information on mobile boards/vans, (d) color-coded tags for equipment safety checks, (e) limited amount of information on the schedule, (e) safety helmets integrated with sensors to warn the workforce of a dangerously close proximity with a heavy plant through vibration (warning *poka-yoke*), (f) goal posts to direct/guide heavy plant, (g) color-coded cones for traffic management
2	(a) Visual performance boards, (b) team meeting/ continuous improvement boards, (c) traffic management 2 week look-ahead board, (d) decent level of housekeeping but no 5S, (e) heavy plant/equipment tracking boards, (f) visual control boards for critical documentation, (g) color-coded construction site ingress/egress visual boards, (h) boards on which people can record their continuous improvement ideas, (i) the Last Planner meeting boards	(a) Different housekeeping levels among subcontractors; no 5S, (b) improvisational VM practices by the workforce, (c) health and safety information on mobile boards/trailers, (d) limited amount of information on the schedule, (e) goal posts to direct/guide heavy plant, (f) 72 iPads distributed to the site personnel to support the flow of information between the site and office, (g) color-coded cones for traffic management
3	(a) Visual performance boards, (b) an *obeya* room, (c) a BIM based work coordination document for the subcontractors (d) decent level of housekeeping but no 5S, (e) heavy plant/equipment tracking boards, (f) color-coded construction site ingress/egress displays, (g) the Last Planner meeting boards	(a) Different housekeeping levels among subcontractors; no 5S, (b) improvisational VM practices by the workforce, (c) health and safety information on mobile boards/trailers, (d) limited amount of information on the schedule, (e) goal posts to direct/guide heavy plant, (f) color-coded cones for traffic management, (g) color-coded tags for equipment safety checks
4	(a) Visual performance boards, (b) an extensive use of BIM in the Last Planner meetings, client engagement, 4D BIM (schedule integrated), design reviews and safety auditing, (c) decent level of housekeeping but no 5S, (d) heavy plant/equipment tracking boards, (e) color-coded construction site ingress/egress displays, (f) the Last Planner meeting boards	(a) Different housekeeping levels among subcontractors; no 5S, (b) improvisational VM practices by the workforce, (c) generic health and safety information on mobile boards/vans, (d) limited amount of information on the schedule, (e) goal posts to direct/guide heavy plant, (f) color-coded tags for equipment safety checks
5	(a) Visual performance boards, (b) decent level of housekeeping but no 5S, (c) heavy plant/equipment tracking boards, (d) color-coded construction site ingress/egress displays, (e) the Last Planner meeting boards	(a) Different housekeeping levels among subcontractors; no 5S, (b) improvisational VM practices by the workforce, (c) generic health and safety information on mobile boards/trailers, (d) limited amount of information on the schedule

(a)

(b)

Figure 1: (a) *Obeya* room at Case 1, (b) Traffic management 2-week look ahead board for the coordination of night and day shift traffic management teams at Case 2



(a)

(b)

Figure 2: (a) Creating a BIM based visual document to coordinate different work locations of the subcontractors at Case 3, (b) Use of BIM to support the Last Planner meetings at Case 4

To triangulate the initial findings, the researchers distributed a questionnaire to the operational personnel at Case 2 and Case 3 regarding the types of information they want to see more on-site, close to the operational areas. The findings support the comments given by the process improvement managers and the researchers' observations as to the need to share more varied information beyond health and safety with the site personnel. According to the questionnaire, the site personnel want to see more schedule, quality and process related information on-site (Figure 3).

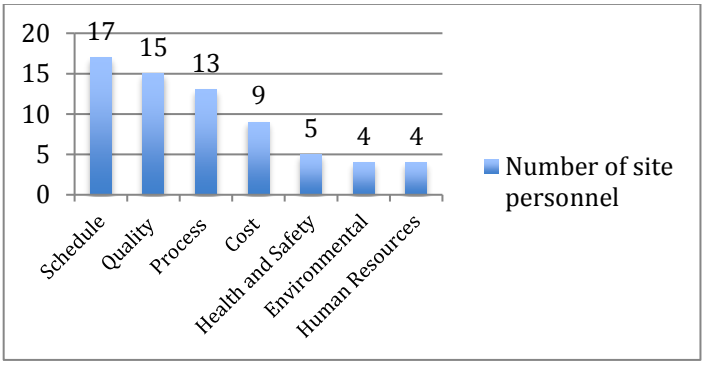


Figure 3: Types of information the site personnel want to see more on-site at Case 2 and Case 3

- **BARRIERS AND DRIVERS FOR VISUAL MANAGEMENT**

There are some barriers that hinder the further dissemination and development of VM and drivers that push the VM strategy in the highways supply chain. The comprehensive data in hand enabled the identification of some of those points for England's highways construction and maintenance context (see Table 3). Some commonalities emerge among many of the identified barriers and drivers from different data sources.

Table 3: Barriers and Drivers for VM

	Data Source	Barriers for VM	Drivers for VM
Process improvement managers	Case 1	(a) Lack of awareness of VM, (b) limited view to VM (visual performance boards), (c) lack of the business case for VM (problems in quantifying its benefits for senior management)	(a) Increasing attention given to lean construction and its techniques in the UK, (b) Increasing number of private organizations (consultants) and institutes that are actively working on lean construction (c) Highways England's commitment affect contractors' decisions, (d) cooperation with universities to drive lean construction and VM, (e) VM can help contractors work more efficiently
	Case 2'	(a) Lack of awareness of VM, (b) limited view to VM (visual performance boards), (c) lack of personnel driving VM and lean construction in highway projects, (d) lack of senior management's support and ownership, (e) lack of the business case for VM (problems in quantifying its benefits for senior management), (f) limited communication with operational staff to drive VM further	(a) Increasing attention given to lean construction and its techniques in the UK, (b) Highways England's commitment affect contractors' decisions, (c) VM can help contractors work more efficiently, (d) construction managers can delegate work to their personnel through VM (for increased self management).
	Case 3	a) Lack of awareness of VM, (b) limited view to VM (visual performance boards), (c) lack of personnel driving VM and lean construction in highway projects, (d) lack of senior management's support and ownership, (e) lack of the business case for VM (problems in quantifying its benefits for senior management), (f) limited communication with operational staff to drive VM further	(a) Increasing attention given to lean construction and its techniques in the UK, (b) Highways England's commitment affect contractors' decisions
	Case 4	(a) Lack of awareness of VM, (b) limited view to VM (visual performance boards), (c) lack of the business case for VM (problems in quantifying its benefits for senior management)	(a) Increasing attention given to lean construction and its techniques in the UK, (b) Highways England's commitment affect contractors' decisions, (c) VM can help decrease operational waste and increase work coordination
	Case 5	a) Lack of awareness of VM, (b) limited view to VM (visual performance boards), (c) lack of personnel driving VM and lean construction in highway projects, (d) lack of senior management's support and ownership, (e) lack of the business case for VM (problems in quantifying its benefits for senior management), (f) limited communication with operational staff to drive VM further	(a) VM can contribute to creating more efficient and safer construction environments, (b) Highways England's commitment affect contractors' decisions, (c) cooperation with universities to drive lean construction and VM.

Focus groups	(a) Lack of awareness of VM, (b) limited view to VM (visual performance boards), (c) lack of the business case for VM (problems in quantifying its benefits for senior management), (d) the temporary, project based structure of the industry limits the knowledge transfer for VM among different projects, (e) more pilot implementation projects for VM in the highways sector on more advanced concepts are needed, (f) lack of training documentation, (g) lack of an audit for best practices for VM, (h) limited cooperation/information share among contractors	(a) Obtaining higher lean construction implementation scores from Highways England helps contractors win future contracts; it is an important driver for contractors, (b) pilot VM/ lean construction implementation projects with universities, (c) VM will improve employee morale, work efficiency, collaboration between the main client and supply chain partners and help construction move to the production mind-set.

- **FUTURE IMPLEMENTATION OPPORTUNITIES FOR VISUAL MANAGEMENT**

The captured future implementation opportunities were divided into three main groups; the ideas given by the process improvement managers, opportunities captured from the focus group discussions and observations by the researchers. Whether the proposed VM ideas in this section will yield any benefits in the highways context is yet to be tested in the field, possibly through case study, action and design science research efforts in the future. It will also be useful to collect more data from operational site staff regarding their views on those future VM opportunities. A detailed summary of the captured data on the future implementation opportunities for VM in the highways context can be seen in Table 4. See Figure 4 for an example of the proposed visual control board linking the Last Planner's 3-week look ahead plans with site teams through the use of activity and problem cards.

Table 4: Future VM Implementation Opportunities for Highways Construction

Data Source		Future Implementation Opportunities for VM
Process improvement managers	Case 1	(a) Task-based on-site mobile boards displaying critical quality related steps, best practices and schedule expectations that show where a task is and where it should be according to the construction schedule, (b) communication of the cost of errors/mistakes in a simple manner to the workforce, (c) on-site visual method statements (for safety and quality), (d) on-the-job training documents located on-site, (e) BIM based interactive on-site boards illustrating the KPIs real time.
	Case 2'	(a) Taking daily briefings to the site level by having all the Last Planner and performance boards in the back of a van (mobile), (b) method statements could be visualized, (c) schedule and project cost related information should be taken to the site level, (d) root cause analyses and the continuous improvement process should be visualized both for the office and site staff.
	Case 3	(a) Standardized visual performance boards that can be used in different projects in the future, (b) the continuous improvement process should be visualized, (c) a standard visual control system that binds daily planning (schedule) from the Last Planner efforts with the site staff.
	Case 4	(a) Visual solutions that will demonstrate to the workforce on the site how and what they do on a day to day basis fit into the bigger picture for the project on which they work (i.e. are we ahead of schedule or behind schedule / will the job make a profit? etc.), (b) the formats of the routine reports required by the senior management and client should be simplified and shared with the workforce.
	Case 5	(a) 5S systematic housekeeping implementation to increase the level of on-site visual workplace standardization and order, (b) managers should collect VM ideas more from the on-site personnel.
Focus groups		(a) VM should extend more into actual construction sites in the form of different practices beyond performance boards, such as the 5S, pull production control (i.e. *kanbans*), mistake proofing (*poka-yokes)*, (b) it would be useful to have a visual system on which people can visually record the waste in their work processes (self-auditing), (c) the duplication of data, generated information, produced technical drawings etc. within different stakeholders and between different organizations in the sector is a form of waste; this should be tackled before information visualization, (d) showing the ultimate project

	goals and company vision is important in your VM efforts, (e) it will be also useful to visualize the connections between different work groups and processes, (f) involve the workforce into VM implementations more
Researchers' observations	(a) 5S can be tried in warehouses, material/equipment lay-down areas, offices, depots, construction compounds, material test laboratories, canteens, toilets and changing rooms, on actual construction fields, workshops, traffic control rooms, maintenance and supply vans, wellbeing facilities and material trailers, (b) the A3 methodology can be used to succinctly communicate different processes on-site (i.e. the continuous improvement, concrete or asphalt laying process etc.), (c) visual standard operating sheets on mobile boards or vans, (d) a visual control board linking the Last Planner System with site teams, (e) pull production control (*kanbans*) in materials like prefabricated elements, light poles, cables, aggregates etc. to reduce on-site stocks, (f) *heijunka* leveling for critical plant/heavy equipment (i.e. excavator, roller, asphalter), (g) extended use of cloud BIM (i.e. AutoCAD 360) for better information visualization/ flow among mobile work teams, (h) extended use of BIM based prototypes linking the Last Planner with site personnel (i.e. KanBIM or VisiLean), (i) extended use of systems integrating BIM, Geographic Information Systems (GIS) and mobile computing for advanced visual control of assets/teams on large highway construction sites.

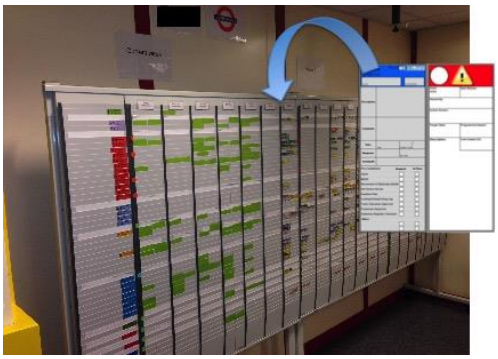


Figure 4: A proposed visual control board example from a metro station upgrade project in London (see Brady (2014) for the details of implementation)

• DISCUSSION

The main finding regarding the current use of VM is that the current VM implementation scope in highway construction and maintenance projects in England could be broadened beyond visual performance boards and extended more into the production area (construction field). Also, as identified from the cases and the questionnaire, along with the existing health and safety information, the content of the shared information on-site should be augmented to cover more schedule/programme related, quality related and process related information.

The most commonly identified points from the case and focus group studies as to the barriers for VM are the lack of awareness of VM, limited view to VM (visual performance boards) and lack of the business case for VM (problems in quantifying its benefits for senior management). For information sharing and benchmarking purposes, a collaboration platform among prominent construction groups in the sector can be formed under the leadership of Highways England. Pilot studies demonstrating the implementation of some more advanced VM concept with their both quantitative (monetary) and qualitative benefits could be conducted. Also, process improvement managers could be trained on some quantification techniques for VM benefits (i.e. statistical analysis, time-motion studies etc.). Auditing the current best-practices and innovative VM solutions in the highways

construction sector to establish a VM implementation database may also contribute to the dissemination and standardisation of effective VM practices through the supply chain.

Along with Highways England's lean construction vision as the main client, the increasing general attention given to lean construction in the UK and various practical benefits of VM were cited as the main drivers for the VM strategy. Contractors are closely following Highways England's priorities. Therefore, Highways England's lead and impetus for VM underlining the existence of various VM concepts and opportunities will positively affect the degree of VM deployments in the supply chain.

The identified VM opportunities are worth investigating further and likely to be relevant as they reflect an observed, actual implementation need coming from the sector's professionals and researchers. There are three important points to ponder while implementing the identified opportunities for VM; obtaining the ownership of senior management, the current lack of which was found to be a barrier for VM; clearly illustrating VM's expected benefits or demonstrating the business case (the need for the VM tool/system) and involving workforce in the implementation (i.e. design and use of the VM system) process.

The nature of the current VM practices is mostly office or compound-based, manual and more static, which calls for more actual site-based and dynamic VM tools supported by emerging technologies. The highways context (very large construction areas with many different subcontractors working in different locations) is particularly suitable for those types of dynamic implementations. In connection with BIM, the maturing concepts of the Internet of Things (IoT), advanced photogrammetry, rapid laser scanning (e.g. LiDAR and LADAR), mobile/wearable computing and GIS will find a greater place in lean construction and VM deployments in the highways construction and maintenance sector in the near future.

• CONCLUSIONS

This paper aims at exploring the current condition of VM in highways construction and maintenance projects in England by discussing its current use, main barriers, drivers and future implementation opportunities. Although the current VM implementations are limited in the highways supply chain, the interviewed process improvement managers and participants in the focus group were generally approving the benefits of VM discussed in the literature, which were also found among the main drivers for VM. However, apart from some evidence from Case 2 and Case 3, the general view of both managers and workforce to VM is still unknown and should be investigated in future research efforts.

The significant barriers to VM in the highways supply chain should be carefully addressed to disseminate the VM strategy further. Highways England's lead seems critical at this point. Demonstrating both qualitative and quantitative benefits of different VM tools in practice is essential to create the business case for VM. Also, different indicators for the benefits of VM (i.e. decreasing number of traffic lane closures with better coordination through VM) can be devised. Future research and pilot studies could contribute to this demonstration.

The VM opportunities were proposed for testing in the field as future research and implementation opportunities for VM in the highways context. This is to say the authors do not present the opportunities asserting that they will certainly yield benefits. Whether they will contribute to highways construction and maintenance operations are yet to be seen in future research and implementations.

The main limitations of the research are that the paper discusses the issue mainly in relation to the construction phase from the large contractors' (Tier 1's) perspective and limited amount of data were collected from operational site staff. Conducting similar research efforts for the design and maintenance phase of highway projects presents a future research opportunity for VM in construction. Additionally, the approach of small and medium size organizations (SMEs)- which constitute around 80% of the sector - to VM in the supply chain provides another research opportunity.

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