



Benefits of Visual Management in Construction: Cases from the Transportation Sector in England

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Abstract

Purpose

The purpose of this paper is to explore the benefits of Visual Management (VM) systems in transportation construction projects in England.

Design/methodology/approach

Following a comprehensive literature review, the benefits of VM were investigated through action and case study research executed within two construction projects in England.

Findings

The main findings are; VM can contribute to (i) increased self-management, (ii) better team coordination, (iii) better promises or an increasing Plan Percent Complete (PPC), (iv) easier control for the management, and (v) improved workplace conditions in the transportation sector. It is important for the management to obtain the engagement of their workforce for VM through increased participation and demonstrating the actual benefits. However, managerial monitoring and control on the systems should not be underestimated.

Originality/value

The transportation sector in England has been systematically deploying lean construction techniques in its operations for a while. One of those lean techniques is a close-range visual communication strategy called Visual Management (VM). The literature on the VM implementation in construction is scarce and generally limited to the building construction context. This paper documents the benefits of VM systems for the transportation sector by using data captured through both qualitative and quantitative data collection methods. The paper also identifies a set of recommendations for similar research efforts in the transportation context in the future.

Keywords: Lean construction, Visual Management, benefits, transportation sector, England, process transparency

Paper type: Technical paper

Introduction

The deployment of lean construction has recently gained momentum in England's transportation construction and maintenance supply chain with ambitious efficiency targets (Ansell *et al.*, 2007; Network Rail, 2010; Chen *et al.*, 2012; HMT, 2012; Drysdale, 2013; Fullalove, 2013). Lean construction is an umbrella term referencing to a combination of operational practices that take their roots from the lean production system developed at Japanese automobile manufacturers and are tailored to the architecture, engineering and construction (AEC) industry (Koskela, 1997; Green, 1999; Howell, 1999; London and Kenley, 2001; Salem *et al.*, 2006). Since the 1990s, 'lean' has become increasingly prominent in construction, a development strongly influenced by the broader production and management debate, where 'lean' has been a leading production management fashion for around two decades (Jørgensen and Emmitt, 2009). The broad gamut of lean construction implementations includes Visual Management (VM) as an information management strategy based on the effectiveness of close-range sensory communication and increased process

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7 transparency (Antony *et al.*, 2003; Achanga *et al.*, 2006; Bhasin and Burcher, 2006; Parry
8 and Turner, 2006; Salem *et al.*, 2006).

9 Forming the basis for lean improvement programs, the VM strategy advises an extensive
10 information share in work operations and removal of information blockages at the points
11 where information needs might occur (Galsworth, 1997; Liker and Morgan, 2006). In
12 production management, VM and its associated visual systems (e.g. visual controls) have
13 long been cited as a fundamental part of the lean production system (Ohno, 1988; Lewis,
14 2000; Liker, 2004; Parry and Turner, 2006; Wee and Wu, 2009; Hodge *et al.*, 2011; Ortiz and
15 Park, 2011; Belekoukias, 2014). The amount of discussions on VM and its benefits for the
16 AEC industry has also been increasing (Formoso *et al.*, 2002; Picchi and Granja, 2004; Sacks
17 *et al.*, 2010a; Brady, 2014; Emuze and Saurin, 2015; Tezel *et al.*, 2015; Tjell and Bosch-
18 Sijtsema, 2015). However, those discussions are mostly centred around the building
19 construction context. Hence, there is a paucity of literature illustrating the application of VM
20 and its benefits at the workplace of transportation construction projects. Specifically, for the
21 transportation construction context in England, the current VM discourse in the literature is
22 mostly limited to the use of visual performance boards (visual indicators), with little
23 empirical study on the practical application characteristics and benefits of VM (e.g. Ansell *et*
24 *al.*, 2007; Highways Agency, 2010; Drysdale, 2013). Also, the existing VM literature in
25 construction is either conceptual (theoretical) emphasising the qualitative benefits of VM
26 systems or explores the VM strategy limitedly over one or two specific visual systems. No
27 comprehensive empirical study aiming at displaying a wider picture of the subject over a set
28 of VM tools with their both quantitative (hard) and qualitative (soft) benefits has been
29 identified. This can possibly be due to the challenges (i.e. extensive access to live-project
30 settings, longitudinal study requirements etc.) associated with capturing the benefits in a real-
31 life context. The VM discussions for the transportation sector is even more scarce in that
32 sense. However, with lean construction gaining momentum in the sector, more organisations
operating in the sector have been adopting those practical visualisation systems.

33 At the workplace, transportation projects are frequently executed over large areas in short
34 work windows by many work teams of different, specialised sub-contractors. Alongside time
35 and quality pressure, the work teams are often subject to live traffic conditions with the
36 presence of heavy construction plant, which gives raise to additional safety concerns. Also,
37 there is a clear expectation by the large public transportation clients in England for their
38 contractors to cut down on their operational wastes through innovative management
39 strategies (Network Rail, 2010; Chen *et al.*, 2012; Drysdale, 2013; Fullalove, 2013). Under
40 these circumstances, effective communication and coordination induced by process
41 transparency come to fore for operational waste reduction, timely project execution and
42 worker/ passenger safety. Therefore, the VM strategy and its visual systems have been
43 resorted to as a viable solution that does not necessitate significant investment to practical
44 coordination and communication issues.

45 There are two main contributions of this paper; (i) exploring both the qualitative and
46 quantitative benefits of four practical visual systems developed through the VM strategy
47 within two construction projects from England's transportation context and (ii) discussing the
48 characteristics of those implementations for future lean construction and VM adoptions.
49 Understanding the benefits of VM, as a fundamental part of the lean production system, is
50 important to further improve and justify lean construction deployments. The efficacy of VM
51 and the conditions of the current VM realisation within the transportation sector still need to
52 be determined. The paper is organised as such; following a comprehensive literature review
53 on the VM concept from the production management domain and its associated benefits in
54 construction, the research methodology and research findings are presented. The research
55 methodology of the study is action and case study research. The research findings include a

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7 detailed description of the characteristics and benefits of four visual systems developed
8 within two transportation construction projects. The findings are also discussed to further
9 clarify the captured benefits, implementation characteristics, research limitations and
10 opportunities for future research efforts.

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Visual Management in production management

11 There are different views in the literature as to what VM is; (i) it is defined as a sensory
12 communication strategy for increased process transparency (Tezel *et al.*, 2015), (ii) simple
13 and attractive communication approach with some distinctive visual tools and systems (Ho,
14 1993), (iii) a managerial approach that creates communication and information centres for all
15 employees (Tomkinson and Smith, 1998) and (iv) an information sharing vision that
16 facilitates continuous improvement (Imai, 1997). Fillingham (2007) suggests designing VM
17 aids so that managers can simply go-and-see what is happening and anticipate future
18 problems. According to Maskell and Kennedy (2007), VM provides information when it is
19 needed in a simple and easy to understand fashion, which in return creates transparency,
20 meaning everyone is working with the same information.

21 Three characteristics distinguish information displayed in visual systems from other
22 forms of communication, such as verbal and written: (i) the information in VM is entirely
23 determined ahead of time (pre-emptive), (ii) it relies little on written communication, and (iii)
24 information is displayed openly for the workforce to see (Galsworth, 1997). In VM, an
25 information field from which groups or work teams can pull information is created, extending
26 the access to information to a large number of people (Greif, 1991). The main motive of VM
27 is to increase the communication ability of process elements, or process transparency, and
28 self-management capabilities of the workforce (Greif, 1991; Formoso *et al.*, 2002; Liff and
29 Posey, 2004).

30 Process transparency can be achieved by making the main process flows visible and
31 comprehensible by using a combination of different visual tools as visual systems (Saurin
32 *et al.*, 2005). With created information fields, this visibility gives way to seeing as a group (e.g.
33 production status and inventory levels), acting as a group (i.e. consensus on objectives and
34 involvement in improvement activities) and knowing as a group (i.e. delivery commitments,
35 rules and schedules and management rules) (Greif, 1991; Dennis, 2015). Also, VM tools
36 facilitate managerial control (Suzaki, 1993; Parry and Turner, 2006). Galsworth (1997)
37 proposed a general classification of the basic visual tools that are used to realise the VM
38 strategy; (i) information giving (e.g. signboards), (ii) signalling (e.g. *andon* quality boards);
39 (iii) response limiting /guiding (e.g. *kanban* production control cards) and (iv) response
40 guaranteeing (*poka-yoke* systems) visual systems.

41 In practice, the initial step to realise the VM strategy is visual workplace order or the 5S
42 housekeeping programme (Mastroianni and Abdelhamid, 2003; Kobayashi *et al.*, 2008;
43 Hodge *et al.*, 2011). The 5S programme consists of those steps (Hirano 1995; Ho, 1999);
44 sorting (disposing of unnecessary items), setting-in-order (visually standardising necessary
45 items in terms of location and quantity), shining (systematic cleaning and maintenance
46 checking for space and equipment), standardising and sustaining the first three steps. The
47 main benefits of the 5S in a workplace are a decrease in the non-value adding activities (e.g.
48 searching), excess inventory, and a increase in the usable workspace, overall health and
49 safety condition and machine/equipment reliability (Hirano, 1995; Galsworth, 1997; Gapp
50 *et al.*, 2008; Ikuma and Nahmens, 2014; Jaca *et al.*, 2014).

51 Another aspect to VM is visual specifications and indicators that are used to
52 communicate standard operational practices, planned future work tasks and managerial
53 expectations (Galsworth, 2004; Dennis, 2015). Those visual systems act as coordination tools
54 for work teams to understand their current and future work scopes (Liker and Balle, 2013;
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7 Bateman and Lethbridge, 2014). Announcements, desired behaviours, best practice examples,
8 visual aids, process charts, end-product samples and A3 sheets summarising the continuous
9 improvement process or important quality practices are integrated into the workplace (Shook,
10 2008).

11 Within the VM strategy, performance figures of teams are shown openly on visual
12 performance boards and team meetings are organised regularly around those performance
13 boards to ensure understanding of the actual performance by the teams, to trigger group
14 discussions and to facilitate continuous improvement (Greif, 1991; Suzaki, 1993; Parry and
15 Turner, 2006; Radnor, 2010). In some cases, condensed and essential visual information (e.g.
16 key performance indicators, quality and safety issues, standards etc.) are consciously
17 displayed together in the same area to focus and trigger the discussions in regular team or
18 managerial meetings, in what is called *obeya* rooms or “large rooms” (Aasland and
19 Blankenburg, 2012).

20 Visual control systems are used to limit, to track and to regulate work processes through
21 simple visual clues (e.g. cards, tokens, signs, signals) (Motwani, 2003; Otiz and Park, 2011;
22 Kattman *et al.*, 2012; Mann, 2014). The renowned *kanban* system in the lean production
23 system is essentially a visual control that is operated mostly by the exchange of a specific
24 amount of cards among work units to harmonise pull-production and to realise the just-in-
25 time (JIT) logistics (Ohno, 1988; Otiz and Park, 2011). Finally, visual guarantees (*poka-*
26 *yokes*) are mistake-proofing systems that enable only the right outcome by imposing physical
27 or electro-mechanical constraints or warning systems on work processes. They have been
28 mostly used to increase process quality, safety and to reduce process set-up durations
29 (Shingo, 1986; NKS, 1988; Fisher, 1999).

30 Those visual systems often work in connection with each other and take roles in different
31 managerial practices (e.g. performance management, logistics management, production
32 management, quality management) (Greif, 1991; Galsworth, 1997; Liff and Posey, 2004;
33 Bateman and Lethbridge, 2014). Although many of those VM systems were developed in
34 manufacturing environments, they have been successfully implemented in other industries
35 (Liff and Posey, 2004). In recent years, the construction industry has also started to
36 consciously exploit the benefits of the VM strategy in its operations, often within some lean
37 construction deployment efforts.

38 **Visual Management and process transparency in construction**

39 Theoretically, process transparency in construction can be increased by (i) keeping a clear
40 and orderly workplace, possibly through the 5S, for better information flow, (ii) incorporating
41 information into processes, (iii) using visual systems to enable immediate recognition of
42 process status, (iv) having a more visible site layout, (v) improving project drawings and (vi)
43 reducing task interdependencies with better sequencing (Koskela, 1992; Heineck *et al.*,
44 2002). According to Moser and Dos Santos (2003) and Emmitt *et al.* (2012), increased
45 process transparency induced by visual systems in construction leads to (i) simplification and
46 greater coherence in decision making and production control, (ii) stimulation of informal
47 contacts throughout different hierarchical levels, (iii) contribution to introduction of
48 decentralisation policies, (iv) broadened employee engagement and autonomy in
49 management, (v) increased on-site coordination and awareness, and (vi) rapid comprehension
50 of and response to problems. Construction sites, by their nature, present also specific barriers
51 for increased process transparency; (i) they are constantly changing environments where
52 large number of teams move continuously, (ii) the site layout suffers several modifications
53 throughout a project, demanding an intense effort to update and relocate the necessary set of
54 visual devices, (iii) construction sites are relatively large places where different teams spread
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7 out, and (iv) non-removable visual barriers are incorporated into the working environment as
8 the facility is being constructed (Formoso *et al.*, 2002).

9 Following on those earlier discussions on VM and process transparency, a plethora of
10 works demonstrating the application of various VM tools/ techniques originated from the
11 manufacturing industry in construction can be seen. One of those discussions is on the 5S
12 housekeeping methodology. Empirical studies on the 5S in construction are actually scarce.
13 In an investigation on the penetration of lean construction among German contractors,
14 Johansen and Walter (2007) determined that the 5S had been employed by only 16% of the
15 contractors. Mastroianni and Abdelhamid (2003) reported a pilot implementation of the 5S in
16 an industrial building construction project. According to the authors, the real challenge for
17 the 5S for construction lies in sustaining a 5S effort.

18 One of the most frequently discussed elements of those visual systems is the card based
19 visual production control system or the *kanban* system that is used to optimise the work-in-
20 progress and realise the just-in-time production system (Monden, 1998). Arbulu (2009)
21 described the benefits of using *kanban* for managing the supply of a large number of non-task
22 specific materials in a large airport construction project. Khalfan *et al.* (2008) reported a
23 successful use of the *kanban* system in delivering selected products from suppliers and off-
24 site manufacturers on a just-in-time basis. The applicability of visual production controls (i.e.
25 *kanban* system), visual production leveling boards (i.e. *heijunka* boards) and visual quality
26 signals (i.e. *andon* system) has been widely discussed with positive results for building
27 construction projects (Tommelein and Weissenberger, 1999; Alves *et al.* 2009; Burgos and
28 Costa, 2012; Barbosa *et al.* 2013; Emuze and Saurin, 2015). Ko and Kuo (2015)
29 demonstrated the implementation of visual production control cards (i.e. *kanban* cards) and
30 visual quality signals (i.e. *andon* system) in formwork operations for building projects. Visual
31 control systems can also be used to connect the Last Planner System's look-ahead plans
32 (Ballard and Howell, 1994) with site teams (Jang and Kim, 2007; Brady, 2014). Tezel *et al.*
33 (2015) illustrated a comprehensive VM tools taxonomy and identified the implementation
34 characteristics of the VM strategy for building construction projects.

35 Developing information technologies such as Building Information Modelling (BIM),
36 mobile and wearable computing, Virtual and Augmented Reality and the Internet of Things
37 (IoT) hold the potential to support VM and help overcome some of the construction specific
38 barriers identified by Formoso *et al.* (2002). BIM based systems can provide a data-driven
39 visual background to replace conventional VM systems with digitalised systems (Sacks *et al.*,
40 2009; Sacks *et al.* 2010a,b). Tjell and Bosch-Sijtsema (2015) reported that a combined use of
41 BIM models and conventional visual systems increased the self-management capacity of
42 design teams. The IoT (sensor networks) integrated with BIM models can enrich process
43 information collating and presentation for large construction sites (Dave *et al.*, 2016).
44 Augmented construction field visualisation (Kamat *et al.*, 2011) and virtual prototyping (Guo
45 *et al.*, 2010) also contributed to increased construction process transparency.

46 Despite the growing body of research, in the lean construction research community, VM
47 is one of the least reported research themes (Daniel *et al.*, 2015). Furthermore, the discussion
48 presented above indicates that the main directions of the VM discourse in construction have
49 been either on the process transparency concept or application of some manufacturing based
50 visual systems, often within building construction projects. However, the characteristics of
51 VM systems and their benefits can be highly context dependant (Liff and Posey, 2004),
52 which necessitates an in-depth understanding of the deployment of VM in the transportation
53 context. Also, when learning from the manufacturing industry, the strategies and techniques
54 introduced in the construction industry should be accepted with appropriate modification as
55 the large number of participants in a construction supply chain and its complexity make it
56 difficult to facilitate information sharing (Titus and Bröchner, 2005). For the transportation
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7 construction context specifically, the scarcity of empirical research on VM becomes even
8 more apparent. Apart from mostly taking the building sector into its focus, the existing VM
9 research in construction is frequently based on conceptual benefit discussions over one or two
10 specific VM system(s) with a greater emphasis on the strategy's qualitative benefits of
11 implicit nature. Therefore, a comprehensive benefit analysis of the real-life application of
12 VM in construction projects with its both directly observable (explicit/quantitative) and
13 implicit (qualitative) benefits was found necessary. Although it is a fundamental part of the
14 lean production system, VM has often found itself a brief secondary place as a visual
15 communication strategy within other lean construction discussions (Picchi and Granja, 2004).
16 Also, the accounts on the use of VM in the transportation sector in England has mostly been
17 limited to a single visual system (e.g. visual performance boards). Considering the increasing
18 adoption of lean construction and VM in the transportation sector, it can be inferred that there
19 is a need to further understand what benefits different VM systems could yield in the
20 transportation context. In summary, the presented study differentiates itself from the existing
21 VM in construction literature over the following points; (i) it focuses specifically on the VM
22 strategy in the transportation sector, (ii) it presents a set of real-life benefits of both explicit
23 and implicit nature, captured in relatively longer time-windows, (iii) it covers four main VM
24 systems identified in the literature as opposed to one or two systems frequently investigated
25 in the existing accounts, and (iv) it also discusses the VM systems' associated
26 implementation characteristics and challenges in detail for future applications and
27 modifications.

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28 Research methodology

29 In order to explore the benefits of VM in the transportation sector, a mixed research
30 approach, which is comprised of the action and case study research methodology with mixed
31 data collection methods (both qualitative and quantitative), was adopted. The explorative
32 research question is how the benefits of VM manifest themselves at the workplace of
33 transportation projects. The authors are part of a research alliance with the main public
34 organisation responsible for the construction, maintenance and operation of the strategic
35 highways network in England. That alliance enabled the researchers to implement a VM
36 system (the 5S in this case) as an action research effort and to study three existing VM
37 systems as case studies in the transportation sector. The implemented and studied four types
38 VM systems include; one visual workplace order or the 5S effort (action research), one visual
39 performance system (case study), one visual specification/indicator system (case study) and
40 one visual control system (case study). Thereby, the study covered all the main types of VM
41 systems classified in the literature except for mistake proofing (*poka-yoke*) systems.

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42 Action research is used in real situations, rather than in contrived, experimental studies,
43 since its primary focus is on solving real problems (Brydon-Miller *et al.*, 2003). It is a
44 participatory process concerned with developing practical knowing seeking to bring together
45 action and reflection, theory and practice, in participation with others (Reason and Bradbury,
46 2001). It is also a powerful research strategy to advance both science and practice as it may
47 provide rich insights on real-life applications, taking its roots from grounded theories (Whyte,
48 1991). In management research, the value of action research can be seen to be in developing
49 and elaborating theory from practice (action) with pragmatic methods, tools and approaches
50 developed in real-life situations (Eden and Huxham, 1996; Kaplan, 1998). For operations
51 management, action research presents three distinctive advantages over 'traditional research
52 topics and methods' (Coughlan and Coughlan, 2002); (i) it has broad relevance to practitioners
53 and applicability to unstructured or integrative issues, (ii) it can contribute to theory, and (iii)
54 for explorative research efforts, researcher as an actor, agent of change and immersed, has
55 closeness to the full range of variables in settings where those variables may not emerge at
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all. Some issues related to action research are finding's generalisability, trustworthiness of data, ethical issues and judging of success (Eden and Huxham, 1996; Kaplan, 1998). The main reasons why the 5S was implemented are; (i) the 5S is a scarcely researched methodology in construction, (ii) it is often referred to as a fundamental step in adopting VM, (iii) the management of the project in which the 5S was implemented showed an explicit interest and support to the methodology to improve their operations with the researchers' support, (iv) the storehouse of the project presented a suitable ground for the 5S implementation.

Case studies, on the other hand, are more suitable when a phenomenon is studied in its real-life context and the researchers' control over the phenomenon is limited (Yin, 2003). As three of the studied VM systems had already been in place when the researchers started the research effort, the case study methodology was found appropriate. The unit of study of the case studies is the VM systems with a focus on their benefits, implementation challenges and implementation characteristics. The critical point for increasing the validity of a case study and action research is to triangulate the findings. To achieve this triangulation, both qualitative and quantitative data were collected from different resources. Also, for research objectivity, challenges associated with those VM systems were investigated and discussed. Research reliability was tried to achieve by collecting first-hand data as much as possible through a data collection protocol. The generalisability of the findings should be limited to construction production settings. Additionally, maintaining the anonymity of the data resources and research partners were paid attention to for research ethics. The illustrated visual systems were studied within two construction projects from the transportation sector in England; Project 1 and Project 2. The projects were chosen in cooperation with the public organisation on the following basis; (i) the projects had had comparatively more advanced VM practices in place that the researchers could study, (ii) one of the projects (Project 1) was keen for the researchers to implement the 5S, presenting an action research opportunity, and (iii) the projects were willing to be the subjects of this study with their extensive managerial cooperation with the research team. The details of the research methodology can be seen in Table 1.

{Please insert Table 1 around here}

Project 1

Project 1 is located in Northern England. It is one of the major improvement projects in England's strategic highways network to be delivered by 2020. The work is needed as the route is used by over 180,000 vehicles per day (one of the busiest in the UK) and suffers from heavy congestion and unpredictable journey times, especially during peak periods. The project is comprised of 3 individual sections and it will cover a corridor approximately 27 kilometers long with 11 junctions and 2, 3 and 4 lane carriageways along the route. A number of cameras, information signs, signals on gantries and additional lighting columns have been installed on the route as part of the project to relieve the congestion. The estimated cost of the project is 202 million GB £. The works commenced in July 2014 with a planned completion of September 2017. To avoid traffic disruptions in peak hours, night shifts have been given importance by the project management team. Project 1 has been driving its lean construction and VM efforts through a process improvement manager.

Project 2

Project 2 was completed in Southern England as a part of an ambitious plan for upgrading 72 underground stations over a 7-year period from 2013 within an estimated budget of 350 million GB £. Project 2's scope covered the upgrade of 5 stations of the total 72 with a cost of

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7 circa 25 million GB £. The site works included replacement of the life expired mechanical,
8 electrical, fire and communication systems as well as failing roofs, walls and floor finishes
9 and defective staircases. The project had to be executed at night when the stations were
10 closed, in confined areas and with constrained access. The actual site works were completed
11 between February 2014 and January 2015. Project 2 drove its lean construction and VM
12 efforts through a process improvement manager.

13 **Benefits of the Visual Management systems**

14 *The 5S*

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16 A 5S pilot project was implemented at the storehouse in a warehouse of Project 1. The most
17 frequently used equipment (i.e. safety items), materials and hand tools are stored in the
18 storehouse with a cumulative of 42 item transactions on average between the storehouse
19 personnel and the rest of the project personnel per day. In line with the project's lean
20 construction and better housekeeping vision, the management had had a 5S implementation
21 intention for a while. Also, due to lack of ownership, the management had previously failed
22 with completing another 5S pilot in the warehouse. The pilot project was commenced with a
23 kick-off meeting with the warehouse personnel by outlining the aims and objectives of the
24 project in general. The personnel then were given a comprehensive introduction to the 5S and
25 an implementation plan was agreed on.

26 The initial step in the implementation plan was to observe, identify and document the as-
27 is situation in the storehouse (see Figure 1a). Bearing inefficiencies in the storage area use
28 with motion blockages and 3 possible tripping and skin piercing health and safety hazards,
29 the storehouse floor and racks were cramped with various materials and equipment scattered
30 around. There was no visual identification of the items clearly showing the item locations,
31 item types and item replenishment levels in the storehouse. Locating the correct safety gears
32 was particularly problematic as there were many types of the same item with different sizes
33 (i.e. jackets, vests, trousers and boots) or made with different materials (i.e. safety goggles) or
34 colors (i.e. colored safety helmets for different construction trades). The arrangement of the
35 items had been done haphazardly to a great extent without much thought to systematically
36 organising the item locations as per the demand by the site personnel. The item record books
37 were casually placed among the materials on the shelving. To better capture and compare the
38 benefits, a time-motion study was executed before and after the 5S implementation on the
39 transactions of some of the most frequently requested items in the storehouse.

40 A typical item transaction process starts with an item demand by the project personnel
41 from the warehouse personnel at the storehouse counter. The warehouse personnel then
42 locate the correct item in the storehouse, bring it to the counter, find the relevant record book
43 and take note of the given item, the demanding personnel's name and personnel number in
44 the record books. For the initial step in the 5S plan, to better reflect the reality, a time-motion
45 study of the item transactions, from the start of the item demand to the completion of the item
46 handover, of one experienced warehouse personnel with more than 5 years of experience and
47 one inexperienced warehouse personnel with less than 5 years of experience with equal
chances of serving an item request were recorded separately.

48 As the first S (sort) in the 5S, the warehouse personnel were asked to evaluate the items
49 in the storehouse in terms of their short-term and long-term necessity. The less needed items
50 that would not be possibly requested in a 6-month period or more were removed from the
51 storehouse. As a result, the storehouse floor was cleared of the scattered materials and
52 equipment, which saved around 30% of the total floor area. By the introduction of
53 pigeonholes and portable drawers, vertical and horizontal space savings were achieved on the
54 storage racks. In the second S (set-in-order), the locations of the items were rearranged as per
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7 their use and demand. The more frequently requested items were located closer to the
8 storehouse counter in an easier reach. The items were regrouped and rearranged by their
9 types. The item names, item types, item locations and replenishment levels were clearly
10 marked by highlighted visual clues. A particular attention was given to the safety gears for
11 their better identification. The record books were collected in the same location, just over the
12 storehouse desk by the counter, and better organised. For the third S (shine), standard
13 instructions for cleaning and health and safety checks for the storehouse were discussed and
14 issued to the warehouse personnel. For the last two S (standardise and sustain), the project
15 management regularly control the progress and sustaining the created 5S condition in the
16 storehouse with their internal auditing practices. As the storehouse is small, the control
17 practice is relatively quick and simpler. The general condition of the storehouse after the 5S
18 can be seen in Figure 1b.

19 {Please insert Figure 1 around here}

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21 The item transaction process times for the same, most frequently requested items were
22 recorded again within the same configuration with one inexperienced and one experienced
23 personnel after the 5S pilot to compare the benefits (see Table 2). In summary, the 5S pilot in
24 the storehouse led to significant time and work savings in the item transactions, reduced the
25 standard deviations in the item transactions, increased the usable floor area, raised the
26 horizontal and vertical storage rack space utilisation, and the overall neatness, cleanliness,
27 and health and safety condition (all potential hazards were removed) in the storehouse. See
28 Table 2 for the details of the recorded 5S benefits.

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30 {Please insert Table 2 around here}

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32 The pilot 5S project implementation in the storehouse lasted for 3 months between
33 October and December 2015. The warehouse personnel's approach to the implementation
34 process in terms of their cooperation and compliance with the requirements from the authors
35 was positive in general. They also stated their content with the improved layout, health safety
36 condition and shorter item transactions in the storehouse. The personnel assured they would
37 continue experimenting with the 5S steps in the warehouse during the implementation
38 repeatedly; yet the authors' drive, leadership and impulse had been constantly necessary
39 during the implementation process. Being mostly a top-down effort, the 5S implementation
40 at the storehouse would have come to a halt without the presence and monitoring of at least
41 one of the authors. Although the warehouse personnel were mostly left to decide on the new
42 layout of the storehouse and what items to keep or remove in the first and second S as per the
43 instructions from the authors (their ideas and preferences were included), obtaining the real
44 acceptance or willingness of the personnel for the 5S was observed to be challenging. The
45 warehouse personnel had been sceptical of the expected benefits from the changes in their
46 work routines and work environment throughout the implementation. Moreover, although the
47 project has an internal training mechanism, the personnel were unaware of many 'lean'
48 concepts. It was observed from the interaction with the workforce and some managers that
49 the view to the 5S was generally narrow. The 5S was often confused for good housekeeping,
50 which is actually just a part of the methodology (Hirano, 1995).

51 It is particularly challenging to sustain a 5S effort for a long term; even for
52 manufacturing organisations where the production environment is generally more controlled
53 than construction (Hirano, 1995). In dynamic and constantly changing construction sites,
54 close managerial support, supervision and workforce ownership should be in place in order to
55 sustain the 5S (Mastroianni and Abdelhamid, 2003). Along with in-project 5S team

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champions, it can be also useful to create a constructive competition and incentivisation mechanism for the 5S among construction teams. 5S workshops and site visits could be organised to raise the awareness and the ownership. Another apparent issue is to make the 5S a standard approach across different projects. As identified by Johansen and Walter (2007), 5S initiatives often take place in small, isolated pockets in some specific projects in the construction industry. **More empirical research exploring the 5S in construction seems necessary** to advance the understanding about and to help justify the business case for the methodology. In line with this proposition, the benefits documented from the 5S pilot prompted the project management to disseminate the 5S to the rest of the construction site as a future step.

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Team performance visual boards

In Project 1, the management wanted to have an integrated visual system to monitor and coordinate their project teams' performance, which are comprised of 140 permanent staff split into 15 teams (i.e. design, technology, engineering, health and safety etc). Also, the management found that the project's meeting routines within their teams were inefficient in identifying and solving problems and needed more focusing. Therefore, an integrated visual performance board and a team meeting system were developed. The management's ultimate aspirations was that the senior management team could walk around the office every day and observe or participate in each and every teams stand up meetings where they would discuss the day's tasks and existing performance.

The initial process for engaging with the teams was via a standard 2-hour weekly meeting without any systematic meeting and follow-up structure. Actions and minutes would be taken and then typed, and circulated 3 to 5 days later. The meetings gave no clear indication as to how the teams were performing and what key issues were. As a result, many problems raised by the teams during their meetings had lingered unsolved. Also, It was a challenge for the teams to understand what other teams are engaged with and how they are performing as sharing of key information was difficult.

The management organised a series of workshops with the teams to mitigate the problem. As the result of the workshops, a generic visual performance board template around which daily meetings of the teams are held was shaped. The generic template includes a task promise part (made in public with owner, date and status), ownership of the task part, what needs to be done by when part and a team continuous improvement part along with each team's past performance figures (Figure 2). Each team stops work daily at 8 a.m. to update their visual boards. The boards are publicly open for everyone to see and a summary of the information extracted from the team boards is distributed to all of the staff on a weekly basis providing a wider understanding of the performance among the teams. Persisting or more critical issues from each team board are transferred to a specific management summary board for special attention of the senior management.

{Please insert Figure 2 around here}

The first benefit recorded after the implementation of the boards is a reduction in the average duration of the team meetings. Previously, the meetings would take around 2 hours (120 minutes) on average per week with minor deviations (approximately 13 minutes from the past records) for each team. With a more focused and systematic daily meeting approach via the visual boards, the total weekly meeting duration was calculated to take approximately 50 minutes on average with a standard deviation of 6.3 minutes for the teams (calculated over a 10 week period after the implementation of the visual boards), representing a 59% reduction in meeting durations on average with a lesser deviation.

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7 The Planned Percept Complete (PPC) indicator, which is the percentage of all actual on-
8 time task completions to all promises (plans) made for task completion for a certain time
9 period, is generally used with the Last Planner System and a good indicator of the
10 consistency of promises made, and an effective performance control tool (Ballard, 1997;
11 Sacks *et al.*, 2010b). After the implementation of the visual boards in May 2015, the overall
12 PPC of the teams has shown a general upward trend in time with an average PPC of 76% (see
13 Figure 3). The upward trend indicates a gradual improvement in the actualisation of the
14 promises made by the teams after the implementation of the boards and the meeting system.
15 In other words, the teams started to make more attainable promises or started to pay more
16 attention to the realisation of their promises. Also, the systematic meetings with the visual
17 boards enabled a better identification and quantification of the root causes of performance
18 variances of the project teams for future actions, which was mostly lacking in the previous
19 meeting system. Those causes and PPC values have been distributed to the project personnel
20 on a weekly basis for increased transparency. To capture insights from the team members on
21 the boards, an open-ended, semi-structured questionnaire about the visual performance
22 boards was distributed online among the teams for improved anonymity. The results obtained
23 from the questionnaire can be seen in Table 3.

24 {Please insert Figure 3 around here}

25 {Please insert Table 3 around here}

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28 Table 3 suggests that alongside presenting a structured and focused meeting mechanism,
29 the team performance boards help facilitate the inter-team communication, engagement and a
30 better work requirement seeing for the project teams. The process improvement manager
31 stated that it could become challenging to drive the teams to regularly use the boards. Also, it
32 was observed that it can be easy for the teams to cancel the meetings around the boards due to
33 other priorities so it is integral for the management to continuously underline that the boards
34 and meetings are important priorities. The management allowed the teams to continuously
35 improve their boards through trial and error. Therefore, no board looks the same but they all
36 share a common base structure. It was also observed that interactive handwriting practices
37 and simple physical artifacts such as post-its or magnetic pins positively contributed to the
38 teams' engagement with the boards. Rather than taking time consuming minutes or notes
39 during the stand-up meetings, which are also open to mistakes or omissions, the teams would
40 simply take photos of the updated boards for the records. As a future step, cross-functional
41 teams from the members of different project teams can be brought together to form
42 continuous improvement (CI) cells to improve some of the recurring, more significant
43 problems identified during the meetings (Bhuiyan and Baghel, 2005).

44 *Traffic management coordination boards*

45 While improving a busy highways network in a live traffic situation, permanent and
46 temporary traffic management, varying from slip road closure, lane closures and full
47 carriageway closures, become highly critical issues. Most of the time, contractors face serious
48 monetary penalties by their contracts for the number of closures they incurred. Therefore,
49 maximising the utilisation of the working window with value adding activities during a closure
50 is of primary importance to contractors. To cause less disruption, closures are generally
51 imposed during night time. Ideally, closures should be utilised as much as possible until it has
52 to be safely removed, in time for morning traffic. Consequently, if the overall utilisation of
53 closures is not efficient, construction teams require visibly more than expected closures
54 during a project.

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Suggesting a higher amount of waste in the utilisation of working windows during closures, it came to Project 1 management's attention that the amount of closures they were using was above what was expected and they began to look into this internally with their construction teams. After discussing with the construction teams and analysing the closure utilisation sheets, the management identified the following points as the main reasons for the lower closure utilisations; (i) lack of communication between different disciplines, (ii) a clearer high-level night time briefing for supervisors and managers. (iii) lack of VM to increase the closure transparency and help the construction teams coordinate their efforts and (iv) a more structured handover process from nights to days.

To improve the coordination and transparency in the utilisation of the project's closures, two visual boards were adopted between March-April, 2015. The first board is for the night-time traffic management that was created to allow all construction teams to view 2 week look-ahead traffic management program in order to maximise the use of each closure (see Figure 4a). The board is located close to the point where the construction teams have their daily meetings. The second board, which is basically a large project drawing with magnetic traffic management related pins, was put in use for the coordination meetings of the night-time traffic management personnel in the office (see Figure 4b). The traffic management personnel have been visualising their traffic management plans and coordination on the board. The board was mainly developed by the traffic management personnel as per their needs and instructions from the management through trial and error. The construction teams and traffic management personnel execute the boards with a systematic daily coordination meeting structured around them.

{Please insert Figure 4 around here}

The main benefit identified from the implementation of the traffic management visual boards is in the downward trend after March-April, 2015 (implementation of the boards) in the percentage of the project's closure working window waste, which corresponds to the total percentage of the work wastes or the unnecessary non-value adding activities against the value adding or the necessary non-value adding activities during the closures in the corresponding month (see Figure 5). Even though the total number closures for works has dramatically increased in time as the project has progressed, both the percentage of the process waste decreased, and the number of cancelled closures due to the errors or mistakes by the project personnel remained low (relative to the total number of closures). Naturally, the aim of the management is to consistently eliminate or to keep the cancelled closures reasonably low. The figures suggest a positive contribution of the boards to the coordination issues identified by the management. To capture insights from the traffic management personnel and construction teams on the coordination boards and validate the quantitative findings, an open-ended, semi-structured questionnaire about the visual coordination boards was distributed online among the teams. Even though asked, no significant input regarding the problematic points or improvement opportunities for the boards was captured. The results obtained from the questionnaire can be seen in Table 4.

{Please insert Figure 5 around here}

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7 Table 4 suggests that the traffic management teams mainly use the boards to increase the
8 work visibility between their personnel working on different shifts to identify various
9 bottlenecks, clashes, and to facilitate the work control and coordination.

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comments to summarise the key findings in
the qualitative tables

10 *Visual project control board*

11 To improve the planning reliability, to increase collaboration and to be more proactive in a
12 constrained environment, Project 2 management had decided to deploy the Last Planner
13 System. After the start of the project, the project management realised that they needed a way
14 to manage and control the site at an activity level. Moreover, the PPC figures of the project
15 were initially at around 55% to 60%, which the project management wanted to increase. The
16 main problem was identified in the coordination between the project management team and
17 different subcontractors. To tackle this issue, a 3-week look-ahead card type board was
18 introduced on site to connect the Last Planner System to different site teams (see Figure 6).
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20 {Please insert Figure 6 around here}

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22 The left hand side column of the board was color-coded as per the project areas. The
23 columns represent shifts and weeks. Bespoke cards were designed for each contractor to write
24 down and record their activities for the first 3 weeks on site. Each card was again color coded
25 to match the main schedule. These cards then populated the 3-week look-ahead boards.
26 Therefore, before the start of a shift on site, one could easily see clashes where multiple
27 contractors were planning to work in the same area. New opportunities to bring work forward
28 were also identified through the boards. At the end of every shift, the construction manager
29 reviewed progress during the shift and confirmed whether the activity was completed or not.
30 If it was completed, the construction manager would 'turn over' that activities card, revealing
31 the green back of the card. If the activity was not completed, the activity card would stay as it
32 was and allowed the project team on the days to follow up and re-plan. This helped the
33 handover process from the construction manager directing work on nights, to the project team
34 on days. Once the first week was complete and all unachieved activities were re-planned, the
35 boards were then shuffled down and Week 1 became Week 3. The subcontractor's activity
36 cards included information like the working area, date, activity, man power and the duration.
37 Few other cards for the subcontractors to use, such as, the 'Ready for Inspection' card and the
38 'Issue Card' were given.

39 A weekly progress meeting system was put in place, in which the board was re-populated
40 with the activity cards at the end of every week. The project planner would run this meeting
41 and examine the board; in particular, re-planning work site clashes and trying to exploit
42 opportunities. The issue cards would also be logged with agreed actions and owners to
43 resolve. After the implementation of the boards in May, 2014, except for a short-downfall
44 during the learning period of the subcontractors, the project enjoyed a steady increase in its
45 PPC values up to 85% at the end with an on-time project completion, which indicates a
46 better-coordinated and proactive site management at the task level (see Figure 7). This trend
47 also indicates improved planning realisation reliability from the subcontractors. To further
48 analyse the benefits, a semi-structured interview with the project management team about the
49 board was conducted. The managers were asked to evaluate the identified benefits of the
50 board on a five-point Likert scale (Strongly Agree, Agree, Neutral, Disagree, Strongly
51 Disagree) with its related challenges and their improvement suggestions (see Table 5).

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54 {Please insert Table 5 around here}

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Table 5 suggests that the visual control board mainly contributed to maintaining the coordination among different sub-contractors, reducing the work and space clashes, triggering discussions for improved work planning and increasing the PPC level of the project.

Comment [MOU23]: For Reviewer 2 comments to summarise the key findings in the qualitative tables

Discussion

Improved work coordination, triggered project team discussions and better root-cause identification of problems, which translate to an upward trend in the PPC figures, and decreased waste in limited work-windows or in regular team meetings, come to the fore as the important benefits of the visual systems for transportation projects. The associated benefits of the 5S in item transaction times and floor area savings could be more clearly calculated in that sense. Another commonality in the implementations is in the identified importance of obtaining buy-ins or engagements of the people that are going to use those systems. A degree of scepticism can be expected particularly in the initial implementation phases, as the visual systems often require some sort of a change in people's accustomed work routines. Demonstrating the identified benefits and involving people into the implementation process can be of use to overcome those barriers.

The main concern of the research is discussing the benefits of the VM systems in detail while maintaining the research objectivity. Particularly with the implementations involving a trend analysis over a period of time (i.e. team performance visual boards, traffic management coordination boards and project control visual board), it is hard to isolate the quantified benefit of a particular visual system to the overall performance from the rest of the other factors that might potentially play a role in the performance improvements. The trend analyses show the tendency towards a positive contribution to the overall performance after the implementation of a specific visual system. An experimental or quasi-experimental research design can be pursued for better benefit isolation in future research efforts. This experimentation for the benefit demonstration intent was only partially achieved with the 5S pilot study. In order to maintain the research validity, the quantitative findings were supported and elaborated by the in-depth qualitative findings obtained from the people actually involved in the use of those visual systems, as initially planned. Along with helping to mitigate any positive bias that may be present, the qualitative findings and observations of the authors also illustrate a wider picture of the benefits and implementation characteristics of the visual systems. To further increase the research objectivity, data on the challenges associated with the VM systems were also collected. The authors' main role with the 5S was facilitating the implementation process by providing the necessary guidance and theoretical know-how. For the other three VM systems, the authors remained as observers to capture the benefits and challenges associated with those systems.

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It should be noted that all those successful implementations outlined were firmly supported by the senior management of the projects with a lean construction and VM vision. The senior management made it clear to their teams that they wanted those visual systems to be developed and used in their daily work routines. Even though people were left to decide on and experiment with the implementations to a degree, the implementations were essentially top-down, starting with the identification of a need by the management and developing with constant monitoring. The visual systems were devised to counter an existing problematic situation or to improve the overall performance. Also, the visual systems were executed with a meeting and follow-up mechanism (except for the 5S, which needs constant managerial monitoring for sustaining by its definition), the outcomes of which were openly shared with the people involved. Without a systematic managerial mechanism in place, the visual systems would not be as effective. That is to say, solely creating visuals without any

systematic managerial backbone is not enough to attain the expected gains from increased process transparency.

The presented VM systems are particularly in line with four process-transparency increasing propositions for construction by Koskela (1992) and Heineck *et al.* (2002): (i) keeping a clear and orderly workplace through the 5S, (ii) incorporating information into processes, (iii) using visual systems to enable immediate recognition of process status and (iv) having a more visible site layout. Except for mistake-proofing systems, the studied visual systems cover all the VM system types classified by Galsworth (1997). The findings also empirically confirm some of the generic, conceptual benefits of VM and process transparency proposed by Formoso *et al.*, (2002), Moser and Dos Santos (2003), and Emmitt *et al.* (2012) specifically for transportation projects, which is one of the contributions of the paper: (i) simplification in production control, (ii) stimulation of contacts throughout different hierarchical levels, (iii) broadened employee engagement and autonomy in management, (iv) increased on-site coordination and awareness, and (v) rapid comprehension of problems. Additionally, it was shown that the 5S can contribute to reduction in total item transaction durations through motion economy and transaction deviations, and improved health and safe with better space utilisation in construction projects. On the other hand, some challenges or problematic points related to the VM systems were also identified. A detailed summary of the captured benefits and challenges for each VM system can be seen in Table 6.

{Please insert Table 6 around here}

Alongside empirically confirming those generic benefits of VM, the findings suggest some more transportation sector-specific contributions of VM as well; (i) VM can facilitate the coordination among transportation teams working on different shifts and in disparate geographic locations away from each other for a better short-work window productivity, (ii) with the existence of many work teams of different sub-contractors, VM systems can help impose a focused meeting mechanism for performance-reviews, better task visualisation for the teams and peer pressure for more reliable work related promises, (iii) problem and clash identification, work control and coordination of different sub-contractors working in a live traffic situation can also be facilitated for management under high scheduling and quality expectations, (iv) as transportation work teams often keep many mobile and static on-site material/component storages in different locations (i.e. along a road, railway track or around stations), the study suggests that a more extensive, standardised adoption of the 5S holds the potential to yield significant benefits in the sector.

VM offers highly practical solutions to the situations that can be improved through increased process transparency. The form and content of those visual solutions can change as per specific project conditions, project needs and people involved. Therefore, different visual solutions can be adopted even for the same problem in the transportation construction context in the future. Also, innovative visual systems can be developed to address a VM need. In line with future research efforts, experimental researches, comparing similar projects or work teams with and without specific visual systems on similar indicators, can be executed to better reflect and even isolate some VM benefits, which this research effort mainly lacks. Also, future research may put forward more varied quantitative indicators for capturing VM benefits. However, qualitative benefits of visual systems, which are hard to translate in numerical figures, should not be overlooked in those discussions.

Conclusion

With a clear support from large public agencies, lean construction and correspondingly VM have been increasingly finding a place in the agendas of the transportation construction

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7 supply chain in England. In parallel with this, more lean construction related research and
8 implementation narratives will be seen from the same context in the future. As one of the
9 initial examples of those works, this paper presents the documented benefits of four practical
10 VM systems; visual workplace structuring (the 5S), visual measures (team performance
11 visual boards), visual specifications/indicators (traffic coordination boards) and visual
12 controls (project control visual board), with their implementation characteristics.

13 The findings confirm the VM benefits identified from the literature for the transportation
14 sector; (i) increased self-management, (ii) better team coordination, (iii) better promises or an
15 increasing PPC, (iv) easier control for the management, and (v) with the 5S, an improved
16 workplace condition with decreased item transaction process times (non-value adding
17 activities or motion economy), savings in work spaces and a better health and safety
18 condition. It is important for the management to obtain the engagement of their workforce for
19 VM through increased participation and demonstrating the actual benefits. However,
20 managerial monitoring and control on the systems should not be underestimated.
21 Additionally, the challenges identified in Table 6 should be paid attention to and taken as
22 improvement opportunities while implementing similar VM systems.

23 Beyond the generic and conceptual benefits proposed in the literature for VM, the
24 findings indicate that the deployment of VM in the transportation sector holds the potential
25 to bring about some operational benefits that can address the sector's distinctive characteristics
26 and work limitations. It is argued that the conceptual benefits of VM can manifest themselves
27 in different forms in the transportation sector (i.e. increased efficiency in short-work windows
28 through better coordination, early bottleneck and problem identification of teams working for
29 different sub-contractors in disparate locations etc.). This argument is also in line with the
30 proposition that the benefits of VM could be context-specific. The manifestation of those
31 benefits supports the need for developing VM systems in cooperation with the transportation
32 sector professionals for greater relevance. In this sense, action and design science research
33 will enable researchers' experimentation with (i.e. testing IT based replacement of some
34 conventional VM systems) and involvement in the deployment of VM in real-life
35 transportation work contexts to a greater extent. In line with this, innovative and more
36 operational VM control system at the direct interface between manpower-machine/ plant and
37 manpower-soil/land on transportation construction sites can be devised.

38 VM in construction, particularly in the transportation sector, generally lacks empirical
39 research with a holistic emphasis on VM's both quantitative and qualitative benefits. In that
40 sense, future research can present new parameters for VM's quantitative benefits for
41 managers to evaluate and justify their VM efforts in a more varied way. Also, qualitatively,
42 the perspectives of different organisational roles (i.e. managers, engineers, construction
43 workers) on the same visual system can be recorded for richer insights. Empirical studies
44 comparing team or project performances with and without some specific VM systems can be
45 executed over an experimental or quasi-experimental research design. The 5S can also be
46 implemented in the transportation supply chain on a larger scale to spaces like offices, depots,
47 lay-down areas, construction sites, laboratories, maintenance vans and warehouses. The use
48 of emerging information technologies to replace or support conventional VM systems in the
49 transportation sector can present another research opportunity. Also, a detailed analysis of the
50 condition of and the opportunities for VM in Small and Medium sized Enterprises (SMEs),
51 which constitute the largest portion of the organisations in the transportation supply chain,
52 can present another research opportunity. A systematic continuous improvement process
53 linked to those visual systems possibly with continuous improvement (CI) cells can also be
54 tried. The potential of *poka-yoke* (mistake proofing) systems in source inspection (quality)
55 and for worker safety can be investigated for the sector. To better understand the business
56 case for VM in transportation, return on investment focused studies can also be conducted.

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Comment [MOU34]: For Reviewer 1 & Reviewer 2 & Reviewer 4 comments.

Comment [MOU35]: Additional future research opportunities to expand the conclusion section a little more as required by the Reviewers

Acknowledgement

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References

- Aasland, K. and Blankenburg, D. (2012), "An analysis of the uses and properties of the Obeya", *In Proceedings of the 18th International Engineering, Technology and Innovation (ICE) Conference*, pp. 1-10.
- Achanga, P., Shehab, E., Roy, R. and Nelder, G. (2006), "Critical success factors for lean implementation within SMEs", *Journal of Manufacturing Technology Management*, Vol. 17 No. 4, pp. 460-471.
- Alves, T. C. L., Barros, N. J. P., Heineck, L. F. M., Kemmer, S. L. and Pereira, P.E. (2009), "Incentives and innovations to sustain lean construction implementation", *In Proceedings of the 17th Annual Conference of the International Group for Lean Construction (IGLC)*, Taipei, Taiwan.
- Ansell, M., Holmes, M., Evans, R., Pasquire, C. and Price, A. (2007), "Lean construction trial on a highways maintenance project", *In Proceeding of the 15th Annual Conference of the International Group for Lean Construction (IGLC)*, Michigan, USA.
- Antony, J., Escamilla, J. L. and Caine, P. (2003), "Lean sigma [production and supply chain management]", *Manufacturing Engineer*, Vol. 82 No. 2, pp. 40-42.
- Arbulu, R. (2009), "Application of integrated materials management strategies", *Construction Supply Chain Handbook*, O'Brien, W.J., Formoso, C.T., Vrijhoef R., and London, K. A. (eds.), CRC Press, Boca Raton, USA
- Ballard, G. (1997), "Lookahead planning: the missing link in production control", *In Proceedings of the 5th Annual Conference of the International Group for Lean Construction (IGLC)*, Gold Coast, Australia.
- Ballard, G. and Howell, G. A. (1994), "Implementing lean construction: improving downstream performance", *In Proceedings of the 2nd Annual Conference of the International Group for Lean Construction (IGLC)*, Santiago, Chile.
- Barbosa, G., Andrade, F., Biotto, C. and Mota, B. (2013), "Implementing lean construction effectively in a year in a construction project", *In Proceedings of the 21st Annual Conference of the International Group for Lean Construction (IGLC)*, Fortaleza, Brazil.
- Bateman, N. and Lethbridge, S. (2014), "Managing operations and teams visually", *The Routledge Companion to Visual Organization*, Bell, E., Warren, S., and Schroeder, J. E. (eds.), Routledge, Oxon, UK.
- Belekoukias, I., Garza-Reyes, J. A. and Kumar, V. (2014), "The impact of lean methods and tools on the operational performance of manufacturing organisations", *International Journal of Production Research*, Vol. 52 No. 18, pp. 5346-5366.
- Bhasin, S. and Burcher, P. (2006), "Lean viewed as a philosophy", *Journal of Manufacturing Technology Management*, Vol. 17 No. 1, pp. 56-72.
- Bhuiyan, N. and Baghel, A. (2005), "An overview of continuous improvement: from the past to the present", *Management Decision*, Vol. 43 No. 5, pp. 761-771.
- Brady, D. A. (2014), *Using Visual Management to Improve Transparency in Planning and Control in Construction*, Doctoral Dissertation, University of Salford, UK.
- Brydon-Miller, M., Greenwood, D. and Maguire, P. (2003), "Why action research?", *Action Research*, Vol. 1 No. 1, pp. 9-28.

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3
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6
7 Burgos, A. P. and Costa, D. B. (2012), "Assessment of kanban use on construction sites", In
8 *Proceedings of the 20th Annual Conference of the International Group for Lean*
9 *Construction (IGLC)*, San Diego, USA.
- 10 Chen, C., Housley, S., Sprague, P. and Goodlad, P. (2012), "Introducing lean into the UK
11 highways agency's supply chain", In *Proceedings of the ICE-Civil Engineering*, Vol. 165
12 No. 5, pp. 34-39.
- 13 Coughlan, P. and Coughlan, D. (2002), "Action research for operations management",
14 *International Journal of Operations & Production Management*, Vol. 22 No. 2, pp. 220-
15 240.
- 16 Daniel, E. I., Pasquire, C. and Dickens, G. (2015), "Exploring the implementation of the last
17 planner system through IGLC community: twenty one years of experience", In
18 *Proceedings of the 23rd Annual Conference of the International Group for Lean*
19 *Construction (IGLC)*, Perth, Australia.
- 20 Dave, B., Kubler, S., Främling, K. and Koskela, L. (2016), "Opportunities for enhanced lean
21 construction management using internet of things standards", *Automation in*
22 *Construction*, Vol. 61, pp. 86-97.
- 23 Dennis, P. (2015), *Lean Production Simplified: A Plain-Language Guide To The World's*
24 *Most Powerful Production System*, CRC Press, USA.
- 25 Dos Santos, A., Powell, J., Sharp, J. and Formoso, C. (1998), "Principle of transparency
26 applied in construction", In *Proceedings of the 6th Annual Conference of the*
27 *International Group for Lean Construction (IGLC)*, Guarujá, Brazil
- 28 Drysdale, D. (2013), "Introducing lean improvement into the UK highways agency supply
29 chain", In *Proceedings of the 21th Annual Conference of the International Group for*
30 *Lean Construction (IGLC)*, Fortaleza, Brazil.
- 31 Eden, C. and Huxham, C. (1996), "Action research for management research", *British*
32 *Journal of Management*, Vol. 7 No. 1, pp. 75-86.
- 33 Emmitt, S., Pasquire, C. and Mertia, B. (2012), "Is good enough 'making do'? An
34 investigation of inappropriate processing in a small design and build
35 company", *Construction Innovation*, Vol. 12 No. 3, pp. 369-383.
- 36 Emuze, F. A. and Saurin, T. A. (2015), *Value and Waste in Lean Construction*, Routledge,
37 Oxon, UK.
- 38 Fisher, M. (1999), "Process improvement by poka-yoke", *Work Study*, Vol. 48 No. 7, pp.
39 264-266.
- 40 Fillingham, D. (2007), "Can lean save lives?", *Leadership in Health Services*, Vol. 20 No. 4,
41 pp. 231-241.
- 42 Formoso, C. T., Santos, A. D. and Powell, J. (2002), "An exploratory study on the
43 applicability of process transparency in construction sites", *Journal of Construction*
44 *Research*, Vol. 3 No. 1, pp. 35-54.
- 45 Fullalove, L.H. (2013), "Examples of lean techniques and methodology applied to uk road
46 schemes", In *Proceedings of the 21th Annual Conference of the International Group for*
47 *Lean Construction (IGLC)*, Fortaleza, Brazil.
- 48 Galsworth, G. D. (1997), *Visual Systems: Harnessing the Power of Visual Workplace*,
49 AMACOM, New York, USA.
- 50 Galsworth, G. D. (2004), "The value of vision: the language of lean production is self-
51 ordering and self-improving", *Industrial Engineer*, Vol. 36 No. 8, pp. 44-50.
- 52 Gapp, R., Fisher, R. and Kobayashi, K. (2008), "Implementing 5s within a Japanese context:
53 an integrated management system", *Management Decision*, Vol. 46 No. 4, pp. 565-579.
- 54 Green, S. D. (1999), "The missing arguments of lean construction", *Construction*
55 *Management and Economics*, Vol. 17 No. 2, pp. 133-137.
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7 Greif, M. (1991), *The Visual Factory: Building Participation through Shared Information*,
8 Productivity Press, Portland, USA.
- 9 Guo, H. L., Heng, L. and Martin, S. (2010), "Life-cycle management of construction projects
10 based on virtual prototyping technology", *Journal of Management in Engineering*, Vol.
11 26 No. 1, pp. 41–47.
- 12 Heineck, L. F. M., Pereira, P. E., Leite, M. O., Neto, J. P. B. and Pinho, I. B. (2002),
13 "Transparency in building construction: a case study", *In Proceedings of the 10th*
14 *Annual Conference of the International Group for Lean Construction (IGLC)*, Gramado,
15 Brazil.
- 16 Her Majesty's Treasury (HMT) (2012), *National Infrastructure Plan: Update 2012*,
17 Technical Report, UK.
- 18 Highways Agency (2010), *An Introduction to Lean Visual Management*, Technical Report,
19 UK.
- 20 Hirano, H. (1995), *5 Pillars of the Visual Workplace: The Sourcebook for 5S Implementation*,
21 Productivity Press, Portland, USA.
- 22 Ho, S. K. (1993), "Transplanting Japanese management techniques", *Long Range Planning*,
23 Vol. 26 No. 4, pp. 81-89.
- 24 Ho, S. K. (1999), "5-s practice: the first step towards total quality management", *Total*
25 *Quality Management*, Vol. 10 No. 3, pp. 345-356.
- 26 Howell, G. (1999), "What is lean construction?", *In Proceedings of the 7th Annual*
27 *Conference of the International Group for Lean Construction (IGLC)*, Berkeley, USA.
- 28 Hodge, G. L., Goforth Ross, K., Joines, J. A. and Thoney, K. (2011), "Adapting lean
29 manufacturing principles to the textile industry", *Production Planning & Control*, Vol.
30 22 No. 3, pp. 237-247.
- 31 Ikuma, L. H. and Nahmens, I. (2014), "Making safety an integral part of 5s in healthcare",
32 *Work*, Vol. 47 No. 2, pp. 243-251.
- 33 Imai, M. (1997), *Gemba Kaizen: A Commonsense, Low-Cost Approach to Management*,
34 McGraw-Hill, London, UK.
- 35 Jaca, C., Viles, E., Paipa-Galeano, L., Santos, J. and Mateo, R. (2014), "Learning 5s
36 principles from Japanese best practitioners: case studies of five manufacturing
37 companies", *International Journal of Production Research*, Vol. 52 No. 15, pp. 4574-
38 4586.
- 39 Jang, J. and Kim, Y. (2007), "Using kanban for construction production and safety control",
40 *In Proceedings of the 15th Annual Conference of the International Group for Lean*
41 *Construction (IGLC)*, Michigan, USA.
- 42 Johansen, E. and Walter, L. (2007), "Lean construction: prospects for the german
43 construction industry", *Lean Construction Journal*, Vol. 3 No. 1, pp. 19-32.
- 44 Jørgensen, B. and Emmitt, S. (2009), "Investigating the integration of design and
45 construction from a 'lean' perspective", *Construction Innovation*, Vol. 9 No. 2, pp. 225-
46 240.
- 47 Kamat, V.R., Martinez, J.C., Fischer, M., Golparvar-Fard, M., Pena-Mora, F. and Savarese,
48 S. (2011), "Research in visualization techniques for field construction", *Journal of*
49 *Construction Engineering and Management*, Vol. 137 No. 10, pp. 853-862.
- 50 Kaplan, R. S. (1998), "Innovation action research: creating new management theory and
51 practice", *Journal Of Management Accounting Research*, Vol. 10, pp. 89-118.
- 52 Kattman, B., Corbin, T. P., Moore, L. E. and Walsh, L. (2012), "Visual workplace practices
53 positively impact business processes", *Benchmarking: An International Journal*, Vol. 19
54 No. 3, pp. 412-430.
- 55 Khalfan, M. A. A., Mcdermott, P., Oyegoke, A. S., Dickinson, M. T., Li, X. and Neilson, D.
56 (2008), "application of kanban in the uk construction industry by public sector clients",
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7 *In Proceedings of the 16th Annual Conference of the International Group for Lean*
8 *Construction (IGLC)*, Manchester, UK.
- 9 Ko, C. H. and Kuo, J. D. (2015), "Making formwork construction lean", *Journal of Civil*
10 *Engineering and Management*, Vol. 21 No. 4, pp. 444-458.
- 11 Kobayashi, K., Fisher, R. and Gapp, R. (2008), "Business improvement strategy or useful
12 tool? analysis of the application of the 5s concept in Japan, the Uk and the Us", *Total*
13 *Quality Management*, Vol. 19 No. 3, pp. 245-262.
- 14 Koskela, L. (1992), *Application of the New Production Philosophy to Construction*,
15 Technical Report, Department of Civil Engineering, Stanford University, Stanford, USA.
- 16 Koskela, L. (1997), "Lean production in construction", *Lean Construction*, Alarcon, L. (eds.),
17 AA Balkema, Rotterdam, The Netherlands,
- 18 Lewis, M.A. (2000), "lean production and sustainable competitive advantage", *International*
19 *Journal of Operations & Production Management*, Vol. 20 No. 8, pp. 959-978.
- 20 Liff, S. and Posey, P. A. (2004), *Seeing is Believing: How the New Art of Visual Management*
21 *Can Boost Performance Throughout Your Organization*, AMACOM, New York, USA.
- 22 Liker, J. K. (2004), *The Toyota Way*, McGraw-Hill, New York, USA.
- 23 Liker, J. K. and Morgan, J. M. (2006), "The Toyota way in services: the case of lean product
24 development", *Academy of Management Perspectives*, Vol. 20 No. 2, pp. 5-20.
- 25 London, K. A. and Kenley, R. (2001), "An industrial organization economic supply chain
26 approach for the construction industry: a review", *Construction Management and*
27 *Economics*, Vol. 19 No. 8, pp. 777-788.
- 28 Mann, D. (2014), *Creating a Lean Culture: Tools to Sustain Lean Conversions*, CRC Press,
29 USA.
- 30 Maskell, B. H. and Kennedy, F. A. (2007), "why do we need lean accounting and how does it
31 work?", *Journal of Corporate Accounting and Finance*, Vol. 18 No. 3, pp. 59-73.
- 32 Mastroianni, R. and Abdelhamid, T. (2003), "The challenge: the impetus for change to lean
33 project delivery", *In Proceedings of the 11th Annual Conference of the International*
34 *Group for Lean Construction (IGLC)*, Blacksburg, USA.
- 35 Monden, Y. (1998), *Toyota Production System: An Integrated Approach to Just-in-Time*,
36 Engineering and Management Press, Norcross, USA.
- 37 Moser, L. and Dos Santos, A. (2003), "Exploring the role of visual controls on mobile cell
38 manufacturing: a case study on drywall technology", *In Proceedings of the 11th Annual*
39 *Conference of the International Group for Lean Construction (IGLC)*, Blacksburg, USA.
- 40 Motwani, J. (2003), "A business process change framework for examining lean
41 manufacturing: a case study", *Industrial Management & Data Systems*, Vol. 103 No. 5,
42 pp. 339-346.
- 43 Network Rail, (2010), *Network Rail CP4 Delivery Plan Network Availability -*
44 *Implementation Plan (v2)*, Technical Report, Network Rail, UK.
- 45 NKS (1987), *Poka Yoke: Improving Product Quality by Preventing Defects*, Productivity
46 Press, Cambridge, USA.
- 47 Ohno, T. (1988), *Toyota Production System: Beyond Large-Scale Production*, Productivity
48 Press, New York, USA.
- 49 Ortiz, C.A. and Park, M.R. (2011), *Visual Controls: Applying Visual Management to the*
50 *Factory*, Productivity Press, New York, USA.
- 51 Parry, G.C. and Turner, C.E. (2006), "Application of lean visual process management tools",
52 *Production Planning & Control*, Vol. 17 No. 1, pp. 77-86.
- 53 Picchi, F. A. and Granja, A. D. (2004), "Construction sites: using lean principles to seek
54 broader implementations", *In Proceedings of the 12th Annual Conference of the*
55 *International Group for Lean Construction (IGLC)*, Helsingor, Denmark.
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7 Radnor, Z. (2010), "Transferring lean into government", *Journal of Manufacturing Technology Management*, Vol. 21 No. 3, pp. 411-428.
- 8 Reason, P. and Bradbury, H. (2001), *Handbook of Action Research: Participative Inquiry and Practice*, Sage Publications, London.
- 9 Sacks, R., Koskela, L., Dave, B. A. and Owen, R. (2010a), "Interaction of lean and building information modeling in construction", *Journal of Construction Engineering and Management*, Vol. 136 No. 9, pp. 968-980.
- 10 Sacks, R., Radosavljevic, M. and Barak, R. (2010b), "Requirements for building information modeling based lean production management systems for construction", *Automation in Construction*, Vol. 19 No. 5, pp. 641-655.
- 11 Sacks, R., Treckmann, M. and Rozenfeld, O. (2009), "Visualization of work flow to support lean construction", *Journal of Construction Engineering and Management*, Vol. 135 No. 12, pp. 1307-1315.
- 12 Salem, O., Solomon, J., Genaidy, A. and Minkarah, I. (2006), "Lean construction: from theory to implementation", *Journal of Management in Engineering*, Vol. 22 No. 4, pp. 168-175.
- 13 Saurin, T. A., Formoso, C. T. and Borges, C. F. (2005), "Analysis of a safety planning and control model from the human error perspective", *Engineering, Construction and Architectural Management*, Vol. 12 No. 3, pp. 283-298.
- 14 Shingo, S. (1986), *Zero Quality Control: Source Inspection and the Poka-Yoke System*, Productivity Press, Portland, USA.
- 15 Shook, J. (2008), *Managing to Learn: Using the A3 Management Process to Solve Problems, Gain Agreement, Mentor and Lead*, Lean Enterprise Institute, Cambridge, USA.
- 16 Suzaki, K. (1993), *The New Shop Floor Management: Empowering People for Continuous Improvement*, The Free Press, New York, USA.
- 17 Tezel, A., Koskela, L., Tzortzopoulos, P., Formoso, C. T. and Alves, T. (2015), "Visual management in Brazilian construction companies: taxonomy and guidelines for implementation", *Journal of Management in Engineering*, Vol. 31 No. 6, 05015001.
- 18 Titus, S. and Bröchner, J. (2005), "Managing information flow in construction supply chains", *Construction Innovation*, Vol. 5 No. 2, pp. 71-82.
- 19 Tjell, J. and Bosch-Sijtsema, P. M. (2015), "Visual management in mid-sized construction design projects", *Procedia Economics and Finance*, 21, 193-200.
- 20 Tompkins, J. A. and Smith, J. D. (1998), *Warehouse Management Handbook*, Tomkins Press, Raleigh, USA.
- 21 Tommelein, I.D. and Weissenberger, M. (1999), "More just-in-time: location of buffers in structural steel supply and construction processes", *In Proceedings of the 7th Annual Conference of the International Group for Lean Construction (IGLC)*, Berkeley, USA.
- 22 Wee, H. M. and Wu, S. (2009), "Lean supply chain and its effect on product cost and quality: a case study on ford motor company", *Supply Chain Management: An International Journal*, Vol. 14 No. 5, pp. 335-341.
- 23 Whyte, W. F. E. (1991), *Participatory Action Research*, Sage Publications, Thousand Oaks, USA.
- 24 Yin, R. K. (2003), *Case Study Research: Design and Methods*, Sage, London, UK.
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Fig 1. The storehouse before (a) and after (b) the 5S

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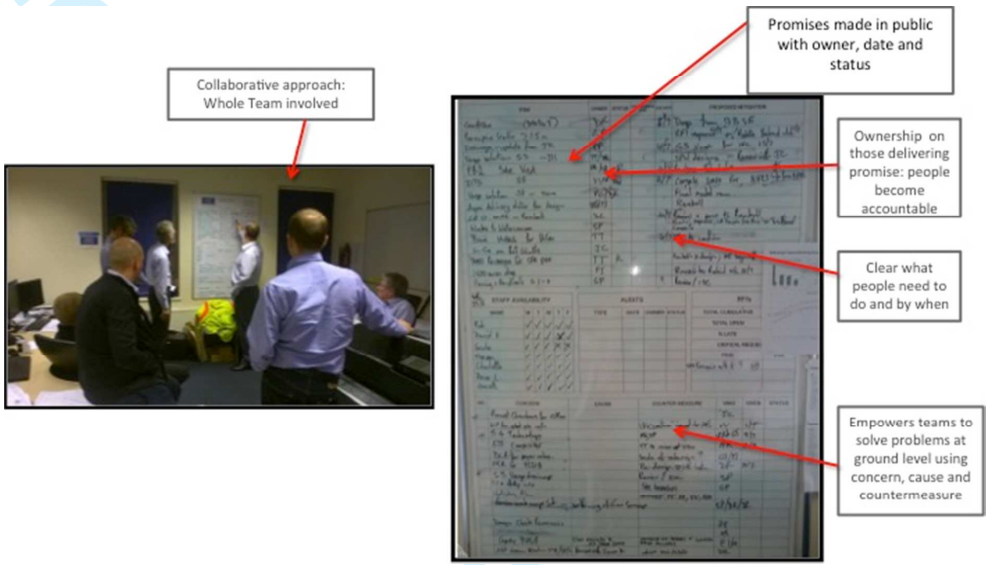


Fig 2. Visual performance board of the engineering team with the generic template

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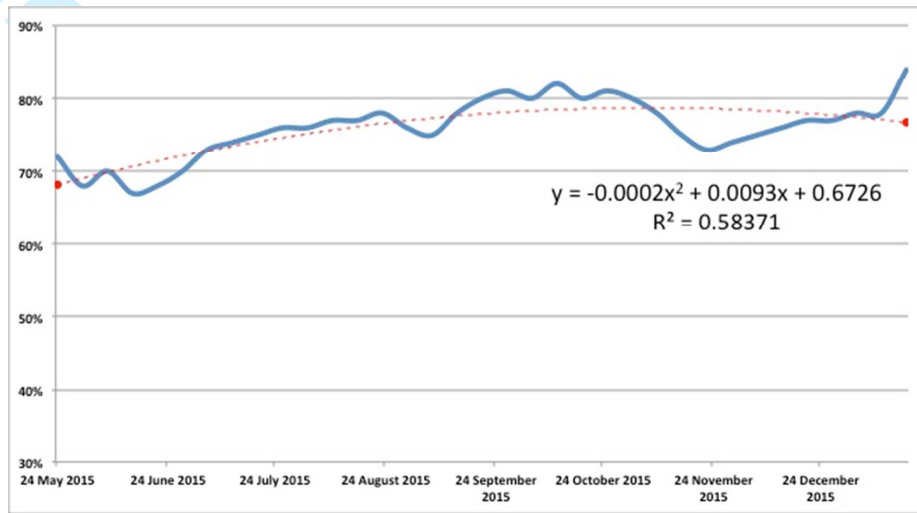
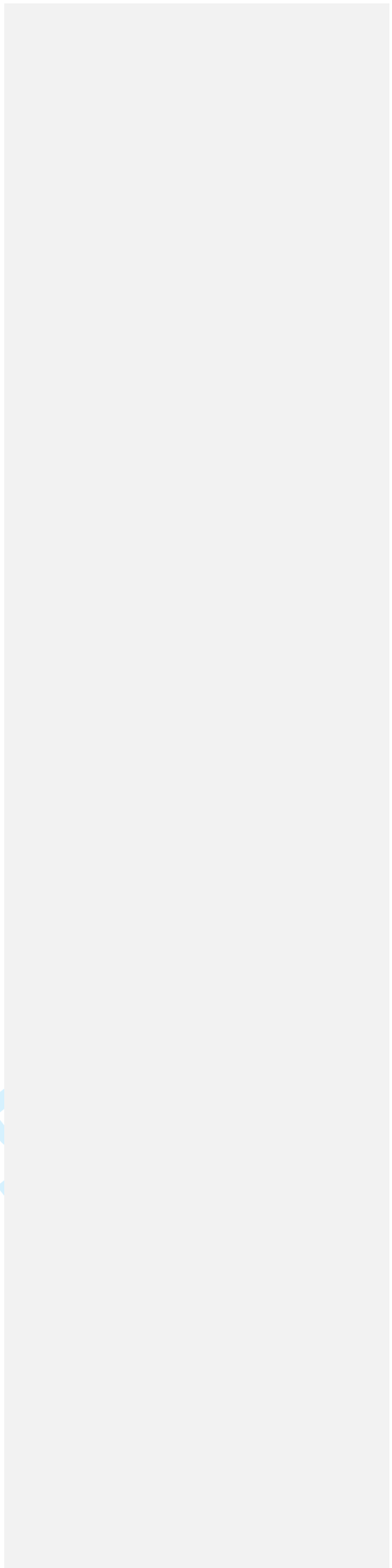


Fig 3. Gradual increase in the teams' PPC after the performance boards.



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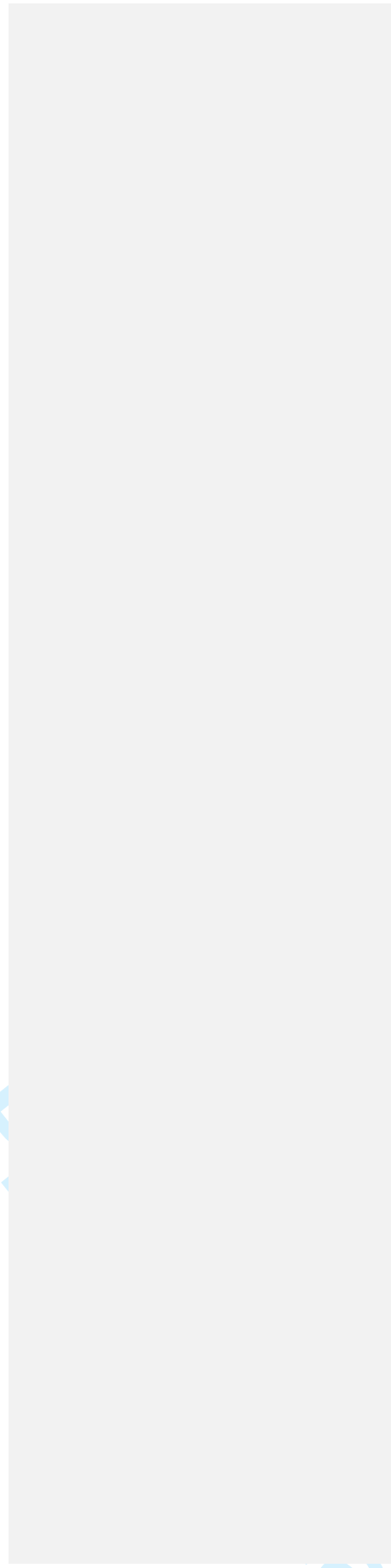


(a)



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Fig 4. Traffic management two week look ahead board (a) and the night-shift meeting coordination board with the magnetic stickers (b)



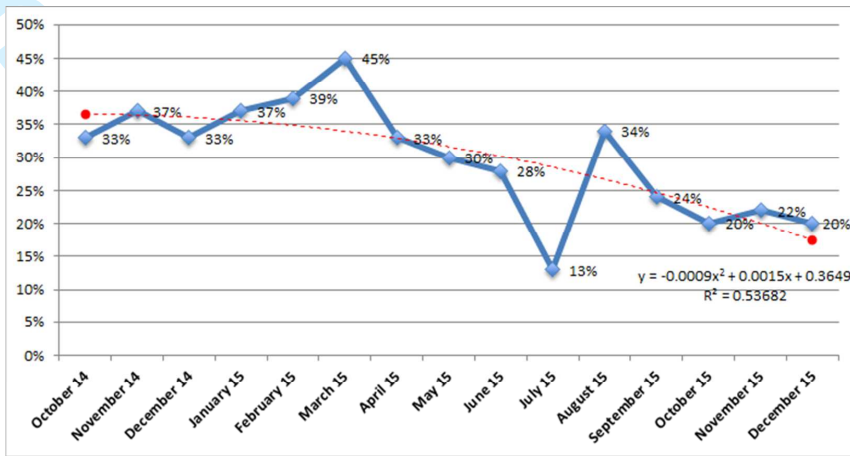


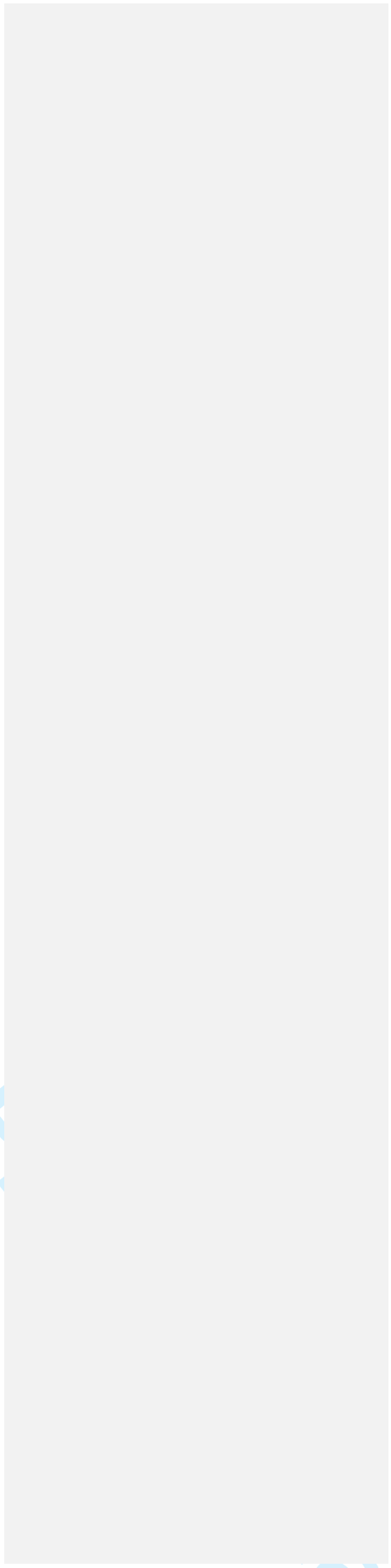
Fig 5. Decreasing percentage of the non-value adding activities during the closures

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Fig 6. The visual control board



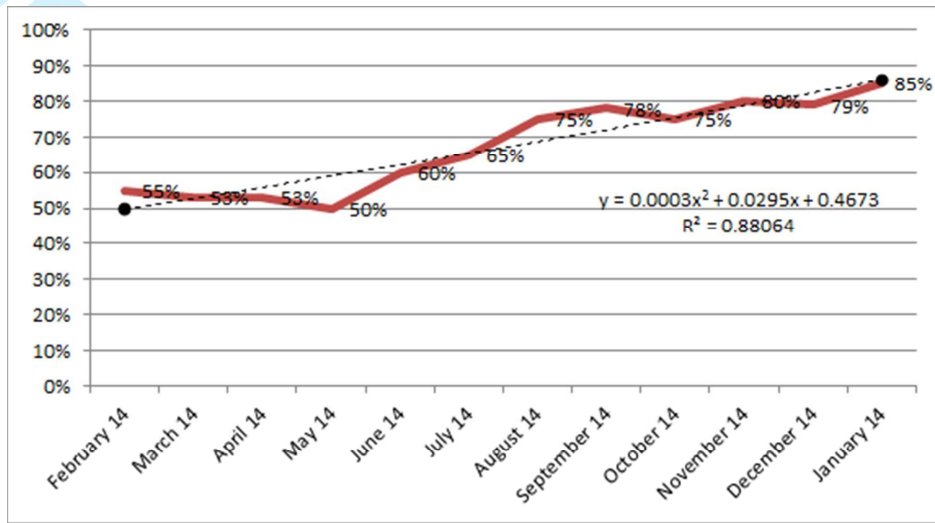


Fig 7. Steady increase in the overall project PPC after the implementation of the visual control board

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Table 1. Details of the research methodology

No	Visual systems	Project	Research methodology	Quantitative data collection methods	Qualitative data collection methods	Study time-frame
1	Visual workplace structuring system (the 5S)	Project 1	Action research	<ul style="list-style-type: none"> • Time-motion study in item transactions before and after the 5S • Comparing number of health and safety hazards before and after the 5S • Calculating saved floor area before and after the 5S 	<ul style="list-style-type: none"> • Unstructured discussions with the process improvement manager • Unstructured discussions with the warehouse personnel 	October 2015 - January 2016
2	Visual performance system (team performance boards)	Project 1	Case study research	<ul style="list-style-type: none"> • Comparing average meeting durations before and after the system • Time series and trend analysis and regression 	<ul style="list-style-type: none"> • Semi-structured questionnaire with the project teams • Unstructured discussions with the process improvement manager 	May 2015 – January 2016
3	Visual indicator system (traffic management coordination boards)	Project 1	Case study research	<ul style="list-style-type: none"> • Time series, and trend analysis and regression 	<ul style="list-style-type: none"> • Semi-structured questionnaire with the traffic management team • Unstructured discussions with the process improvement manager 	May 2015 – January 2016
4	Visual control system	Project 2	Case study research	<ul style="list-style-type: none"> • Time series, and trend analysis and regression 	<ul style="list-style-type: none"> • Semi-structured interviews with the project management team 	October 2015 - January 2016

Table 2. Benefits of the 5S implementation project

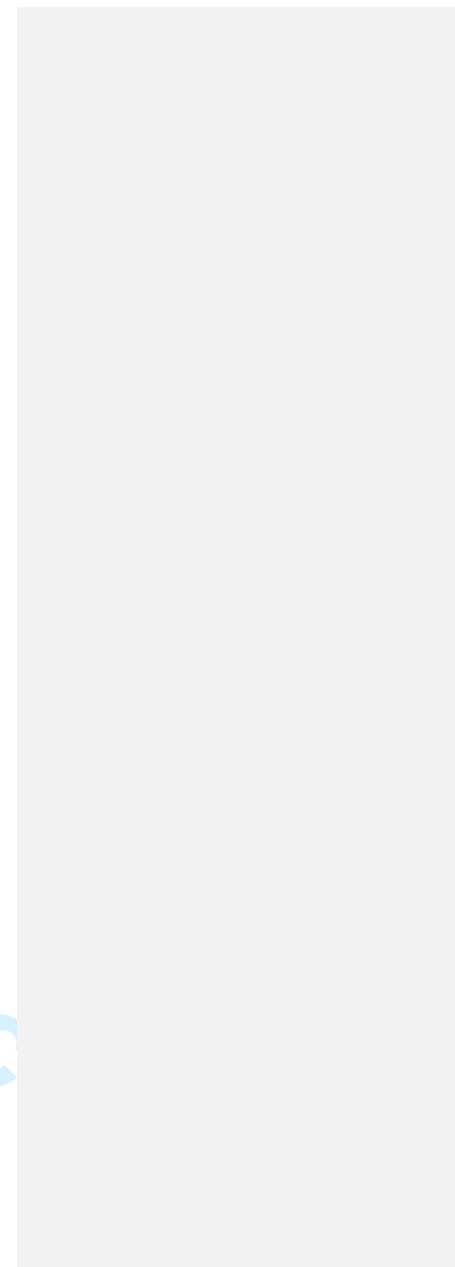
Comment [MOU36]: Table 2 changed as per Reviewer 2's comments

Benefit	Item	Number of observations (N) before and after the 5S	Before the 5S				After the 5S				Time savings after the 5S		Reduction in standard deviations after the 5S	
			Inexperienced Pers. (Aver. Sec.)	Experienced Pers. (Aver. Sec.)	Inexperienced Pers. (St. Dev. Sec.)	Experienced Pers. (St. Dev. Sec.)	Inexperienced Pers. (Aver. Sec.)	Experienced Pers. (Aver. Sec.)	Inexperienced Pers. (St. Dev. Sec.)	Experienced Pers. (St. Dev. Sec.)	Inexperienced Pers. (Aver. Sec.)	Experienced Pers. (Aver. Sec.)	Inexperienced Pers. (%)	Experienced Pers. (%)
Reduction in item transaction times	Batteries	5	67	57	4.60	3.63	37	29	3.67	3.06	30	28	20.30	15.80
	Hammer	5	48	70	3.40	2.83	35	27	2.81	2.48	13	43	17.50	12.30
	Oil	5	111	80	9.40	5.83	40	27	6.62	4.69	71	53	29.60	19.60
	Paint brush	5	87	67	5.70	3.85	63	26	4.38	3.24	24	41	23.10	15.80
	Safety gloves	5	146	86	15.30	9.05	63	38	9.58	7.13	83	48	37.40	21.30
	Safety googles	5	75	80	8.58	5.96	55	38	5.90	4.48	20	42	31.30	24.90
	Safety vest	5	136	60	29.22	14.69	60	42	14.11	10.20	76	18	51.70	30.50
	Safety helmet	5	203	85	34.26	19.50	50	40	18.0	12.74	153	45	47.50	34.60
Space savings	Floor Space	2	Available Floor Space (m2)				Available Floor Space (m2)				Floor space saving (m2)			
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Health and Safety improvements	Trip and Fall Hazard	2	Number of hazards				Number of hazards				Number of cleared hazards			
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Construction Innovation: Information, Process, Management

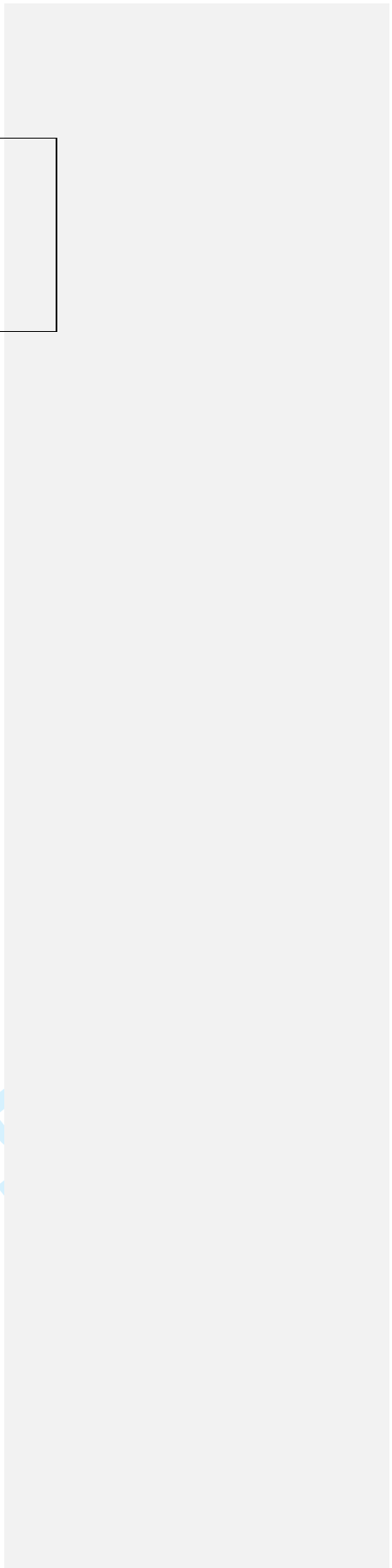
Table 3. Project 1's team members' views on the visual performance boards

Response No	What is your work team?	What are the benefits of the visual performance boards you have in your office?	Is there any negative sides or improvement opportunities for the visual performance boards?	How those visual boards help you with your meetings?	How did the boards affect the task completion in your teams?
1	Commercial	Gives awareness of what other members of the team are doing Gives reminders of priorities for the week	It's become a little bit of a 'going through the motions' exercise	We've chosen specific headings so we can keep the meetings brief and to the point - less opportunity for waffle	We have started to take our promises more seriously.
2	Technology	See what other members are working on. Tracking actions. Highlighting risk. Tracking people's movements People started to give themselves smarter objectives (better promises)	Difficult to get a daily routine/meeting suitable to all members.	Enables meeting focus/structure and makes them more efficient.	People started to think more carefully before making any promises
3	Operational Support/Communications	They are engaging and give a solid understanding as to where each of our individual team members are up to with tasks. We can refer to the vis board if a team member is not in the office and we need some information. The boards display dates for upcoming works and act as a simplified programme.	No negative. The only thing I would say for improvement is that there isn't much room for our board in the office, so when we have our meeting it is a little cramped and we have to lean over to reach the board. However, this is only a minor issue.	They are a great platform for the team to engage in conversation and communicate with each other.	
4	Health and Safety	Allowing people to know what you are up to and what you have not managed to do and why	No. It is a benefit bar the time taken to go through it on a daily basis.	It allows people to be open and know what everyone is doing and reasons for not doing things	As the boards help us see the bottlenecks and unsolved issues with their responsible, they provide an urge to take our actions seriously.

					I sometimes feel though It just shows the time we are being reactive to others poor planning
5	Health and Safety	Communication about what is being achieved, identifying what needs to be changed.	The board could be improved	Focus the discussions	
6	Health and Safety	We can see what tasks the team members are carrying out, also we can prioritise tasks which involve input from multiple team members	It is difficult to keep up the momentum daily and ensure attendance from all the team.	It helps us see the whole picture. Improves the team's coordination.	
7	Health and Safety	Visibility of what team members are doing and "Heads Up" information sharing of pressures influencing decisions making.	Members of the team would not always make themselves available for the meeting but were quick to complain that they had not been made aware of what was happening. Not enough was done identify external influences on the failure to complete objectives such as common trends and patterns.	Facilitates team discussions and early identification of the problems.	
8	Traffic Management	It focuses attention on the board and the benefits that can be derived from their use and briefing out of the results	o	Focuses our discussions.	Helps us complete the tasks on-time
9	Traffic Management	It allows people to know what is happening on a daily/weekly basis	People can easily get away from the meeting around the board	It keeps people on the course	Better promises are made now
10	Project Management	Clear, visual management so everyone can see the actions and discussion points	Since they replace formal written minutes, there is an emphasis for the individuals to	They provide a focus for the teams, and accountability for the owners of the actions.	Affected positively.

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			complete their actions in a timely manner. This needs sufficient challenge at follow up meetings.		
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Table 4. Project 1 traffic management team’s views on the traffic management boards

Team Member No	What are the benefits of the large, plastic covered project board with magnetic pins that you use for the night-shift meetings?	What are the benefits of the traffic management two-week look-ahead board around the warehouse?
1	Solve problems before they arrive with better coordination, visibility for all.	Solve problems before they arrive, visibility for all.
2	It enables all the foreman and supervisors to avoid clashes, the location of the next nights work and all are aware of he times get of e traffic management and when they can access their work location and when they need to complete works and leave site	Better coordinate and harmonise the teams’ works.
3	Enables better communication and coordination for the teams in nigh-shifts	It is good for planning the efforts beforehand. Raises awareness of what other traffic management teams do.
4	Triggers coordination and discussion. The night and day shift people can see what is going on any time without asking	The teams can do better forward planning.
5	Increases visibility for us	Helps to link the night and day shift teams

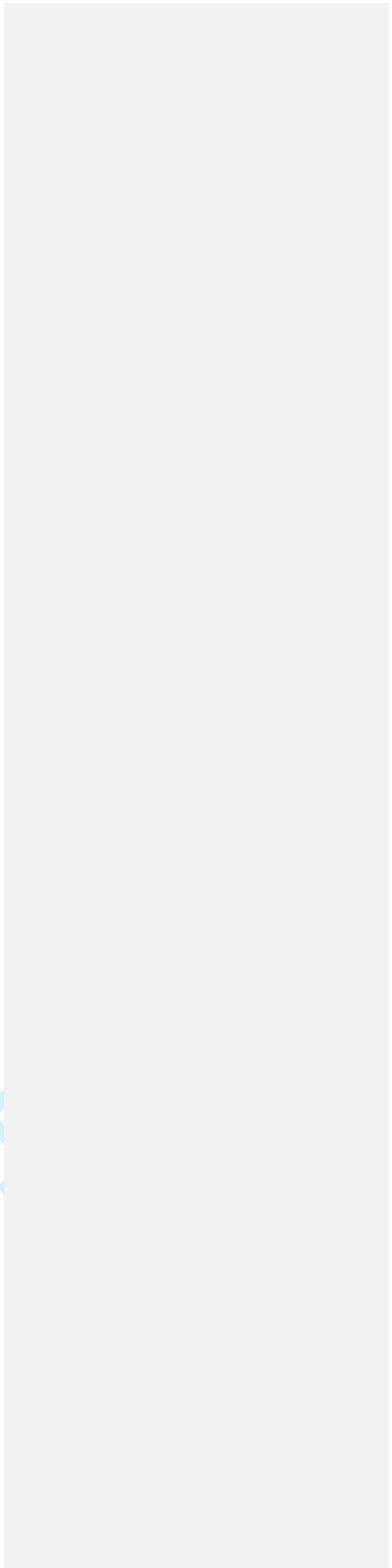


Table 5. Project 2 managers' views on the visual control board

Job Title	Increased the coordination among different subcontractors? (night and day)	Reduced the work and space clashes among different teams?	Helped the management to identify the bottlenecks in advance?	Triggered discussions among the subcontractors?	Linked the Last Planner schedules with the field personnel?	Challenges faced during the implementation?
Project Manager	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Writing the cards was labor intensive. Anticipate the increased level of management needed (but it's worth it)
Business Improvement Manager	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Selling the benefits to the project team - and then down the chain to the subcontractors
Construction Manager (day)	Strongly agree	Strongly agree	Disagree	Strongly agree	Strongly agree	Trends were not identified early enough. We could have better continuous improvement efforts linked with the board.
Construction Manager (night)	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Minimal continuous improvement for the problems identified through the board

Table 6. Summary of the captured benefits and challenges by each VM system

VM system	Captured benefits	Main Challenges
5S	<ul style="list-style-type: none"> Decrease in the item transaction times (motion economy), Decrease in the variation (standard deviation) in the item transaction times, Increase in the space utilization and Increase in the overall health and safety condition. 	<ul style="list-style-type: none"> Narrow view to the 5S, Skeptical approach of the workforce, Need for constant monitoring, control and guidance throughout, the implementation and Hardships in sustaining the 5S
Team performance boards	<ul style="list-style-type: none"> Decrease in the meeting durations, Prompting the teams to make better promises (increase in the overall PPC), Improved transparency among different work teams/individuals for better coordination and Presenting a visual information recording mechanism for planned work tasks. 	<ul style="list-style-type: none"> Maintaining the regularity of the team meetings and Need for better identification and recording of the external problem sources and patterns.
Traffic management boards	<ul style="list-style-type: none"> Contributing to the decrease in the percentage of the non-value adding activities during closures, Increase in the coordination among the night and day teams and Presenting a visual planning and discussion background (interface) for the traffic management. 	
Project control board	<ul style="list-style-type: none"> Increase in the coordination among different subcontractors, Reduction in the work and space clashes among different teams, Helping the managers identify bottlenecks in advance (facilitated project control), Triggering discussions among the work teams and Linking the Last Planner with the field personnel through self-management, contributing to a gradual increase in the overall PPC. 	<ul style="list-style-type: none"> Hardships in maintaining the continuous improvement cycle, Writing on the cards on a daily basis can be laborious and Obtaining the engagement and buy-in of people at the beginning.

Comment [MOU37]: For Reviewer 1, Reviewer 2, Reviewer 3 and Reviewer 4's comments

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Information, Process, Management

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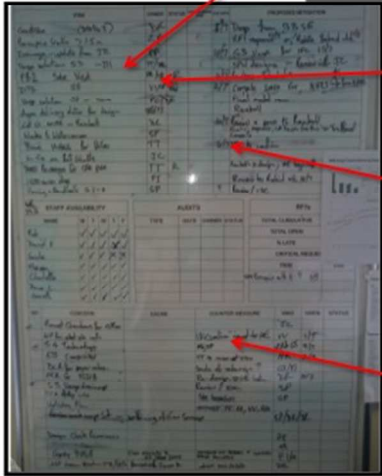


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Collaborative approach:
Whole Team involved

Promises made in public
with owner, date and
status

Ownership on
those delivering
promise: people
become
accountable

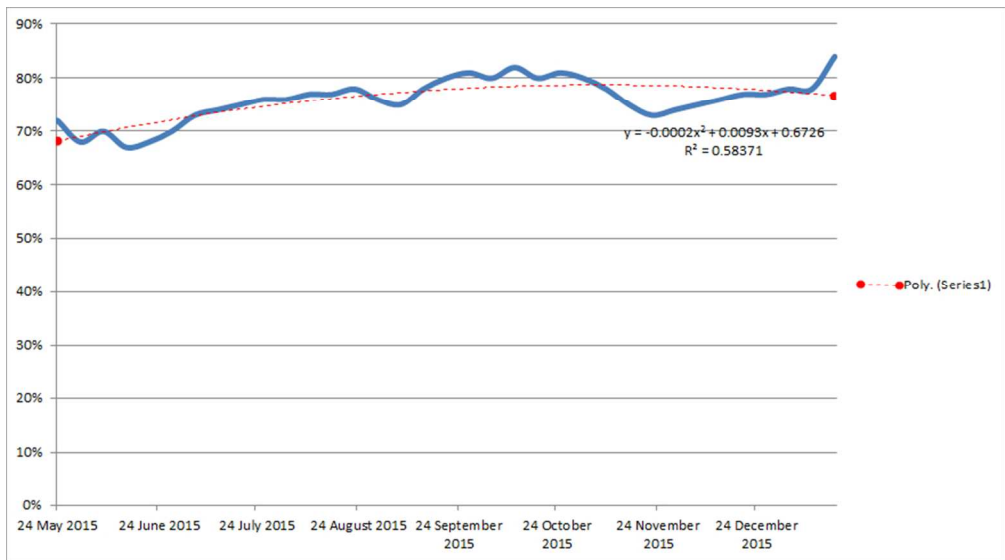
Clear what
people need to
do and by when

Empowers teams to
solve problems at
ground level using
concern, cause and
countermeasure

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Information, Process, Management

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Information, Process, Management

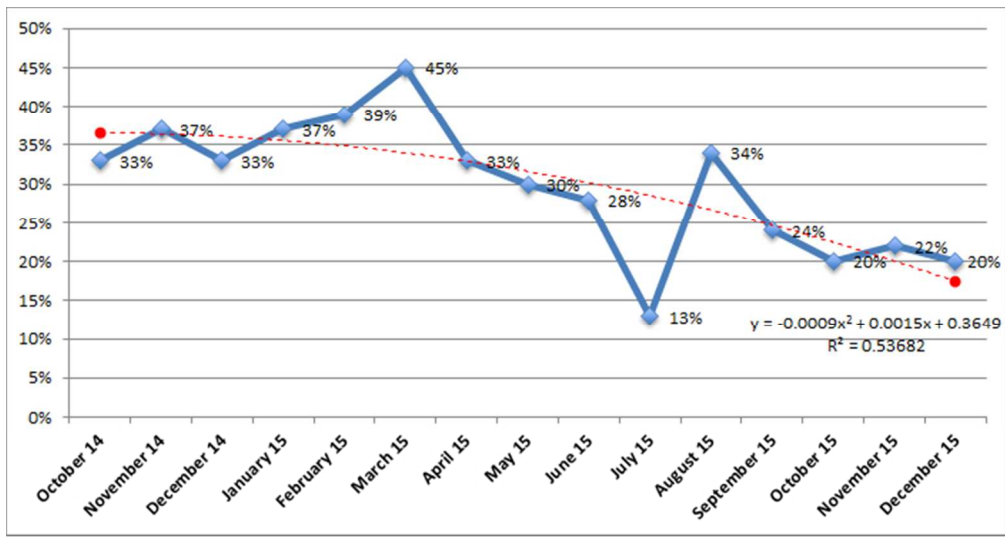
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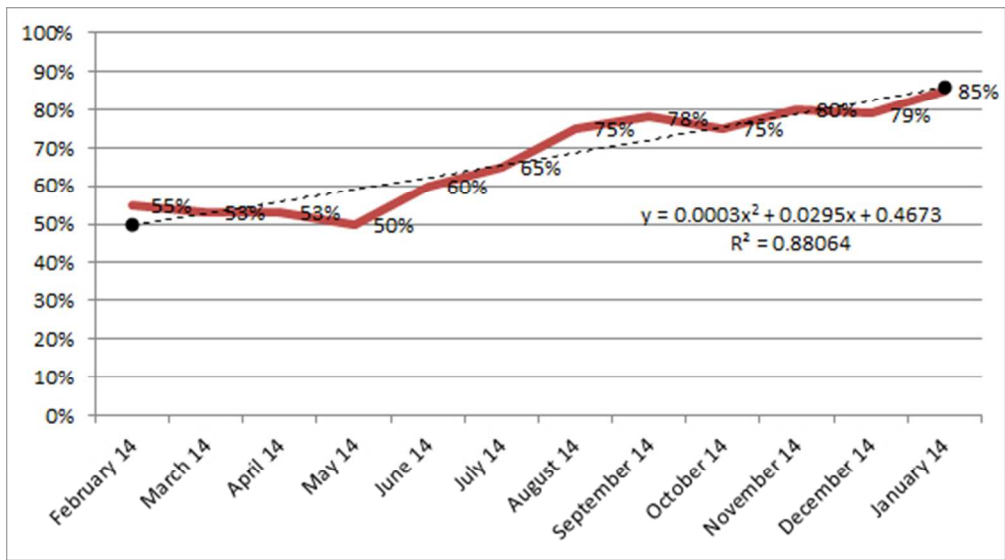
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Information, Process, Management

Table 1. Details of the research methodology

No	Visual systems	Project	Research methodology	Quantitative data collection methods	Qualitative data collection methods	Study time-frame
1	Visual workplace structuring system (the 5S)	Project 1	Action research	<ul style="list-style-type: none"> • Time-motion study in item transactions before and after the 5S • Comparing number of health and safety hazards before and after the 5S • Calculating saved floor area before and after the 5S 	<ul style="list-style-type: none"> • Unstructured discussions with the process improvement manager • Unstructured discussions with the warehouse personnel 	October 2015 - January 2016
2	Visual performance system (team performance boards)	Project 1	Case study research	<ul style="list-style-type: none"> • Comparing average meeting durations before and after the system • Time series and trend analysis and regression 	<ul style="list-style-type: none"> • Semi-structured questionnaire with the project teams • Unstructured discussions with the process improvement manager 	May 2015 – January 2016
3	Visual indicator system (traffic management coordination boards)	Project 1	Case study research	<ul style="list-style-type: none"> • Time series, and trend analysis and regression 	<ul style="list-style-type: none"> • Semi-structured questionnaire with the traffic management team • Unstructured discussions with the process improvement manager 	May 2015 – January 2016
4	Visual control system	Project 2	Case study research	<ul style="list-style-type: none"> • Time series, and trend analysis and regression 	<ul style="list-style-type: none"> • Semi-structured interviews with the project management team 	October 2015 - January 2016

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Table 2. Benefits of the 5S implementation project

Comment [MOU1]: Table 2 changed as per Reviewer 2 comments

Benefit	Item	Number of observations (N) before and after the 5S	Before the 5S				After the 5S				Time savings after the 5S		Reduction in standard deviations after the 5S	
			Inexperienced Pers. (Aver. Sec.)	Experienced Pers. (Aver. Sec.)	Inexperienced Pers. (St. Dev. Sec.)	Experienced Pers. (St. Dev. Sec.)	Inexperienced Pers. (Aver. Sec.)	Experienced Pers. (Aver. Sec.)	Inexperienced Pers. (St. Dev. Sec.)	Experienced Pers. (St. Dev. Sec.)	Inexperienced Pers. (Aver. Sec.)	Experienced Pers. (Aver. Sec.)	Inexperienced Pers. (%)	Experienced Pers. (%)
Reduction in item transaction times	Batteries	5	67	57	4.60	3.63	37	29	3.67	3.06	30	28	20.30	15.80
	Hammer	5	48	70	3.40	2.83	35	27	2.81	2.48	13	43	17.50	12.30
	Oil	5	111	80	9.40	5.83	40	27	6.62	4.69	71	53	29.60	19.60
	Paint brush	5	87	67	5.70	3.85	63	26	4.38	3.24	24	41	23.10	15.80
	Safety gloves	5	146	86	15.30	9.05	63	38	9.58	7.13	83	48	37.40	21.30
	Safety goggles	5	75	80	8.58	5.96	55	38	5.90	4.48	20	42	31.30	24.90
	Safety vest	5	136	60	29.22	14.69	60	42	14.11	10.20	76	18	51.70	30.50
	Safety helmet	5	203	85	34.26	19.50	50	40	18.0	12.74	153	45	47.50	34.60
Space savings	Floor Space	2	Available Floor Space (m2)				Available Floor Space (m2)				Floor space saving (m2)			
			15				19				4			
Health and Safety improvements	Trip and Fall Hazard	2	Number of hazards				Number of hazards				Number of cleared hazards			
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Construction Innovation: Information, Process, Management

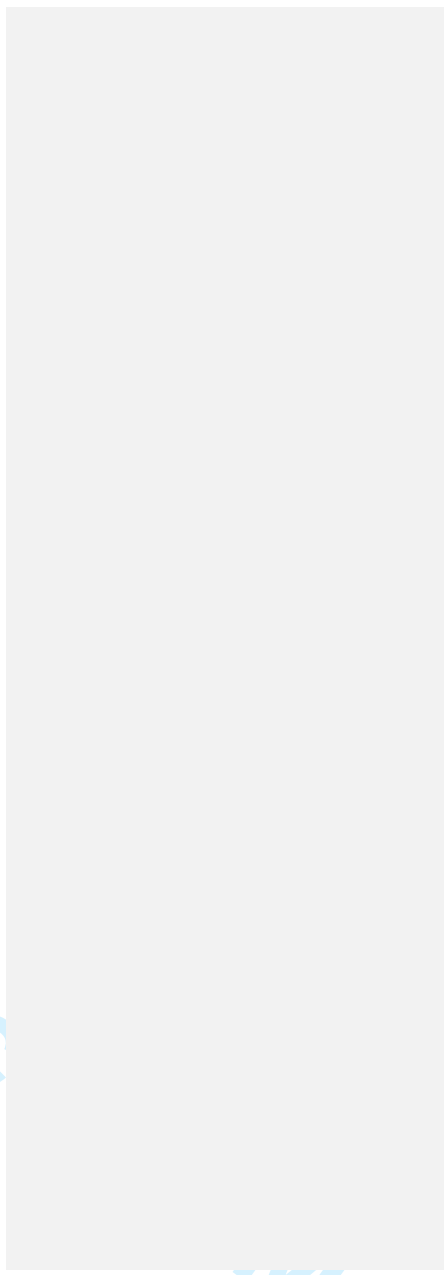


Table 2. Team Members' Views on the Visual Performance Boards

Response No	What is your work team?	What are the benefits of the visual performance boards you have in your office?	Is there any negative sides or improvement opportunities for the visual performance boards?	How those visual boards help you with your meetings?	How did the boards affect the task completion in your teams?
1	Commercial	<p>Gives awareness of what other members of the team are doing</p> <p>Gives reminders of priorities for the week</p>	It's become a little bit of a 'going through the motions' exercise	We've chosen specific headings so we can keep the meetings brief and to the point - less opportunity for waffle	We have started to take our promises more seriously.
2	Technology	<p>See what other members are working on. Tracking actions. Highlighting risk. Tracking people's movements</p> <p>People started to give themselves smarter objectives (better promises)</p>	Difficult to get a daily routine/meeting suitable to all members.	Enables meeting focus/structure and makes them more efficient.	People started to think more carefully before making any promises
3	Operational Support/Communications	They are engaging and give a solid understanding as to where each of our individual team members are up to with tasks. We can refer to the vis board if a team member is not in the office and we need some information. The boards display dates for upcoming works and act as a simplified programme.	No negative. The only thing I would say for improvement is that there isn't much room for our board in the office, so when we have our meeting it is a little cramped and we have to lean over to reach the board. However, this is only a minor issue.	They are a great platform for the team to engage in conversation and communicate with each other.	
4	Health and Safety	Allowing people to know what you are up to and what you have not managed to do and why	No. It is a benefit bar the time taken to go through it on a daily basis.	It allows people to be open and know what everyone is doing and reasons for	As the boards help us see the bottlenecks and unsolved issues with their responsible,

				not doing things	the provide an urge to take our actions seriously. I sometimes feel though It just shows the time we are being reactive to others poor planning
5	Health and Safety	Communication about what is being achieved, identifying what needs to be changed.	The board could be improved	Focus the discussions	
6	Health and Safety	We can see what tasks the team members are carrying out, also we can prioritise tasks which involve input from multiple team members	It is difficult to keep up the momentum daily and ensure attendance from all the team.	It helps us see the whole picture. Improves the team's coordination.	
7	Health and Safety	Visibility of what team members are doing and "Heads Up" information sharing of pressures influencing decisions making.	Members of the team would not always make themselves available for the meeting but were quick to complain that they had not been made aware of what was happening. Not enough was done identify external influences on the failure to complete objectives such as common trends and patterns.	Facilitates team discussions and early identification of the problems.	
8	Traffic Management	It focuses attention on the board and the benefits that can be derived from their use and briefing out of the results	o	Focuses our discussions.	Helps us complete the tasks on-time
9	Traffic Management	It allows people to	People can	It keeps	Better

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		know what is happening on a daily/weekly basis	easily get away from the meeting around the board	people on the course	promises are made now
10	Project Management	Clear, visual management so everyone can see the actions and discussion points	Since they replace formal written minutes, there is an emphasis for the individuals to complete their actions in a timely manner. This needs sufficient challenge at follow up meetings.	They provide a focus for the teams, and accountability for the owners of the actions.	Affected positively.

Table 3. Traffic Management Team's Views on the Traffic Management Boards

No	What are the benefits of the large, plastic covered project board with magnetic pins that you use for the night-shift meetings?	What are the benefits of the traffic management two-week look-ahead board around the warehouse?
1	Solve problems before they arrive with better coordination, visibility for all.	Solve problems before they arrive, visibility for all.
2	It enables all the foreman and supervisors to avoid clashes, the location of the next nights work and all are aware of the times get of a traffic management and when they can access their work location and when they need to complete works and leave site	Better coordinate and harmonise the teams' works.
3	Enables better communication and coordination for the teams in night-shifts	It is good for planning the efforts beforehand. Raises awareness of what other traffic management teams do.
4	Triggers coordination and discussion. The night and day shift people can see what is going on any time without asking	The teams can do better forward planning.
5	Increases visibility for us	Helps link the night and day shift teams

Table 5. Project 2 managers' views on the visual control board

Job Title	Increased the coordination among different subcontractors? (night and day)	Reduced the work and space clashes among different teams?	Helped the management to identify the bottlenecks in advance?	Triggered discussions among the subcontractors?	Linked the Last Planner schedules with the field personnel?	Challenges faced during the implementation?
Project Manager	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Writing the cards was labor intensive. Anticipate the increased level of management needed (but it's worth it)
Business Improvement Manager	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Selling the benefits to the project team - and then down the chain to the subcontractors
Construction Manager (day)	Strongly agree	Strongly agree	Disagree	Strongly agree	Strongly agree	Trends were not identified early enough. We could have better continuous improvement efforts linked with the board.
Construction Manager (night)	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Minimal continuous improvement for the problems identified through the board

Table 6. Summary of the captured benefits and challenges by each VM system

VM system	Captured benefits	Main Challenges
5S	<ul style="list-style-type: none"> • Decrease in the item transaction times (motion economy), • Decrease in the variation (standard deviation) in the item transaction times, • Increase in the space utilization and • Increase in the overall health and safety condition. 	<ul style="list-style-type: none"> • Narrow view to the 5S, • Skeptical approach of the workforce, • Need for constant monitoring, control and guidance throughout, the implementation and • Hardships in sustaining the 5S
Team performance boards	<ul style="list-style-type: none"> • Decrease in the meeting durations, • Prompting the teams to make better promises (increase in the overall PPC), • Improved transparency among different work teams/individuals for better coordination and • Presenting a visual information recording mechanism for planned work tasks. 	<ul style="list-style-type: none"> • Maintaining the regularity of the team meetings and • Need for better identification and recording of the external problem sources and patterns.
Traffic management boards	<ul style="list-style-type: none"> • Contributing to the decrease in the percentage of the non-value adding activities during closures, • Increase in the coordination among the night and day teams and • Presenting a visual planning and discussion background (interface) for the traffic management. 	
Project control board	<ul style="list-style-type: none"> • Increase in the coordination among different subcontractors, • Reduction in the work and space clashes among different teams, • Helping the managers identify bottlenecks in advance (facilitated project control), • Triggering discussions among the work teams and • Linking the Last Planner with the field personnel through self-management, contributing to a gradual increase in the overall PPC. 	<ul style="list-style-type: none"> • Hardships in maintaining the continuous improvement cycle, • Writing on the cards on a daily basis can be laborious and • Obtaining the engagement and buy-in of people at the beginning.

Comment [MOU1]: For Reviewer 1, Reviewer 3 and Reviewer 4's comments

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Reviewers Comments to Author	Authors Response to Reviewers Comments
<p>Reviewer 1 Comments: (There are no comments.)</p> <p>Additional Questions:</p> <p>1. Originality: Does the paper contain new and/or significant information adequate to justify publication?: Yes. I enjoyed reading the paper and it does make a contribution to our understanding.</p> <p>2. Relationship to Seminal Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?: A very good review of the literature. A strong aspect of the article.</p> <p>3. Research Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed, robust, defensible and appropriate?: The method needs to be better articulated. I am a bit confused as to whether this is action research, it is not obvious in the reporting of the findings. And if it is, do we really need justification for case studies, surely this is part of the action research method. All very confused.</p> <p>I would also like to see justification for the method and the case studies. The why question has not been addressed.</p> <p>4. Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together all elements of the paper?: Results are largely descriptive and do not follow a typical action research profile. (See comment above). In the discussion and/or conclusion I would like to see the results discussed against the earlier work. This will help the authors to demonstrate the uniqueness of their findings.</p> <p>I also find the discussion and conclusions to be a little too positive. Surely there are some less positive issues to report?</p> <p>There is no recognition of the potential benefits and weaknesses in adopting the method (action research) and the potential bias on the findings.</p>	<p>Authors' Response to Reviewer 1's Comments:</p> <p>Thank you very much for helping us improve the paper with your valuable comments. Please see our responses to your reviews below. All relevant changes were highlighted and commented in the text.</p> <p>1. Originality: Thank you.</p> <p>2. Relationship to Seminal Literature: Thank you.</p> <p>3. Research Methodology: Thank you.</p> <p>As explained in Table 1, the paper presents an action and case study research (mixed) on the benefits of Visual Management (VM) in transportation projects.</p> <p>The authors are part of a research alliance with Highways England (the main public body responsible for the construction, maintenance and operation of the strategic highways network in England), which enabled them to implement the 5S methodology from scratch as a pilot implementation in a highways construction project (the action research bit). Also, thanks to that alliance, the authors were given the chance to study three existing VM systems extensively in two transportation project (the case study part).</p> <p>The researchers participated in the implementation of the 5S in person. However, the VM cases (the other three VM systems apart from the 5S) were already in place beyond the control of the researchers in their contexts. According to Yin (2003), the case study methodology is useful to study a phenomenon in its context when the researcher has no control over the phenomenon itself. The three VM systems were all beyond the control of the researchers so their benefits were studied over the case study research methodology.</p> <p>Thereby, the study covered all the main types of VM systems (one visual workplace order or the 5S effort (action research), one visual performance system (case study), one visual specification/indicator system (case study) and one visual control system (case study)) classified in the literature, except for mistake</p>

some discussion about the authors' role(s) in implementing the changes etc would be insightful.

5. Implications for research, practice and/or society: Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?: As mentioned above, the implications need to be discussed against extant literature.

6. Quality of Communication: Does the paper clearly express its case, measured against the technical language of the field and the expected knowledge of the journal's readership? Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc. Do the figures/tables aid the clarity of the paper?: Good communication, but more detail is required as noted above.

proofing (poka-yoke) systems.

The main reasons why the 5S was implemented in the action research are; (i) the 5S is a scarcely researched methodology in construction, (ii) it is often referred to as a fundamental step in adopting VM, (iii) the management of the project in which the 5S was implemented (Project 1) showed an explicit interest and support to the methodology to improve their operations with the researchers' support, (iv) the storehouse of the project presented a suitable ground for the 5S implementation.

As three of the studied VM systems, except for the 5S, had already been introduced to the workplace when the researchers started the research effort, the case study methodology was found appropriate to study them in their real-life contexts.

The explanation above and the answers to the why question were added in the first, second and third paragraphs of the research methodology section to further clarify the research methodology (highlighted & commented).

The research methodology section was also significantly expanded as per the other reviewers' comments. Please see the highlighted additions.

4. Results:

Thank you. You highlighted some important points that should be covered.

We added a paragraph in the discussion section clearly linking the research and findings to the main literature on VM in construction. Additionally, a table summarizing the benefits captured for each VM system to further highlight the findings (Table 6) was added to the paper. (highlighted and commented)

Some captured "negative sides" or "points to improve/ consider" were added to Table 6 in the column titled "Challenges", as suggested (highlighted and commented). Those challenges were already present in the text and tables but remained we suppose a bit hidden from your eyes. Hence, the underlining and summarizing in Table 6. Also, a sentence was added to the conclusion section stressing the importance of giving attention to those challenges while implementing specific VM systems (highlighted and commented)

The recognition of the benefits of using the action research method was already present in

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<p>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60</p> <p>Reviewer 2</p> <p>Comments: This is a nice manuscript describing four case studies using Lean in transportation construction. The literature review was done well. I have a few comments to improve the description of the case studies:</p> <p>Case 1 (5S): At the end you allude that there was some resistance to the project. Do you</p>	<p>the second paragraph of the research methodology section. Some points of concern about the methodology were added to the same section in this version (highlighted and commented)</p> <p>We tried to overcome the positive bias issue by adopting both qualitative and quantitative findings to support the statements. We also tried to investigate any challenges/ issues associated with the VM along with its benefits. This was already mentioned in the second paragraph of the discussion section (highlighted and commented). A short discussion on the researchers' role was added to the discussion section in this version (highlighted and commented) to the same paragraph to elaborate the issue a little more. Also, we tried to further underline the challenges associated with those systems in Table 6. With this revision, methodological issues were better covered. Please see the research methodology section.</p> <p>Also, two statements suggesting the use of experiments or quasi-experiments for future research efforts were added in the conclusion and discussion sections. This was also highlighted by another reviewer.</p> <p>We also tried to link the findings to more transportation-sector specific conditions in the fifth paragraph of the discussion section (highlighted and commented).</p> <p>5. Implications for research, practice and/or society: Thank you. We tried to expand the findings with some discussion linking the findings to the extant literature, as suggested. However, one should also note that there is no expansive literature on VM for construction production management, particularly for the transportation sector. This paper will be one of the few empirical works in the field for construction/transportation. Please see the highlighted sections in the discussion/ conclusion sections.</p> <p>6. Quality of Communication: Thank you for your valuable comments. We tried to address them as much as we could. Please see the highlighted changes in the paper.</p> <p>Authors' Response to Reviewer 2's Comments: Thank you very much for helping us improve the paper with your valuable comments. Please see</p>
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consider the 5S overall to be sustainable? Given that's the 5th S, this warrants a bit more explanation as to the resistance, outcomes, and predicted sustainability.

- Table 2: How many observations of each item were completed? Provide averages and standard deviations either by item or overall per column. Summarize the data in the table within the text answering questions like "were there any differences between novices and experts?"

Case 2 (visual performance boards): When you report averages, either standard deviations or ranges should also be reported. It is important to understand the variability in meeting length as well as the average length.

- Table 3: You could probably condense the table by using bullet lists of responses rather than full sentences.

Case 3 (traffic management boards): This case study seems the least developed of the four. Provide more detail on the before and after processes of determining closures and how the boards affected the processes. What about the boards made the project successful?

- How do you determine and measure waste during closures?

- Table 4 is very underdeveloped compared to the quantitative feedback provided in the other cases. Did you ask about drawbacks of the system? It seems biased to only ask what the participants liked.

Case 4 (project control): Before Table 5, describe the questions and response scale. It looks like you used a Likert scale, which is very different from the other interview feedback.

For all cases with qualitative feedback in interviews, I would like to see some summary in the text, rather than just referring the reader to the table.

Discussion: Please not that one reason it is hard to isolate benefits is due to the case study design. Stronger experimental or quasi-experimental designs could help.

Additional Questions:

1. Originality: Does the paper contain new and/or significant information adequate to justify publication?: Yes, the manuscript describes the application of lean construction to a specific sector, transportation, which has not been extensively studied.

2. Relationship to Seminal Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?: Yes,

our responses to your comments below. All relevant changes were highlighted and commented in the text.

Case 1 (5S): It is indeed a tricky matter to sustain a 5S effort in the long run; even for manufacturing organisations where the production environment seems more controlled than construction. Both close managerial supervision and workforce ownership should be in place. The 5S is a relatively new approach to construction professionals. It is also often confused for good housekeeping with statements on the line "We are already doing our housekeeping". It was found that even if the workforce senses the benefits, a close control from their superintendents and their guidance to sustain the effort are absolutely necessary. It may be partly because the 5S challenges the traditional way of work in the industry. Another issue is to make the 5S a standard approach in different projects where applicable. Those kind of improvement initiatives tend to happen in small, isolated pockets in some specific projects, far from being commonplace. Mobile signs and visual clues could be incorporated into the work environment. Interesting applications combining the 5S and Virtual Reality can also be conceived. It can be also useful to have in-project 5S team champions, a constructive competition and an incentivisation mechanism for the 5S among construction teams. 5S workshops and site visits could be organised to raise the awareness and the ownership. The 5S is still trying to penetrate in the industry. Some of those discussions were added at the end of the 5S section (highlighted).

Table 2: The 5S pilot study's total number of observations, standard deviations in seconds (before and after the 5S) and reduction in the standard deviations (%) were added to Table 2 as requested.

Case 2 (visual performance boards): The approx. standard deviations of the meeting durations were added in the 4th paragraph of the section (highlighted).

Table 3: We prefer to keep the table as is in order not to lose any insights/content by summarizing the findings.

Case 3 (traffic management boards):

- Closures in highways construction projects are imposed to complete some tasks in short working-windows in a live traffic situation. In cooperation with the project management team, the waste percentages in the paper were calculated by recording the non-value adding times against the value adding and/or the non-value adding but necessary activity durations during a

the authors do a nice job of describing all aspects of previous work in the relevant areas.

3. Research Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed, robust, defensible and appropriate?: Yes, the manuscript is based on four case studies, and the authors use a mix of quantitative and qualitative measures to determine success.

4. Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together all elements of the paper?: Yes, the authors mostly present the results clearly with a mix of figures and tables. I have a few comments to improve this below.

5. Implications for research, practice and/or society: Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?: Yes, the case studies take place in an actual construction firm, giving the research high external validity.

6. Quality of Communication: Does the paper clearly express its case, measured against the technical language of the field and the expected knowledge of the journal's readership? Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc. Do the figures/tables aid the clarity of the paper?: Yes, the paper is easy to understand. There are numerous minor grammar mistakes that can easily be fixed with proofreading.

closure.

- Yes, those kind of questions (ie. How to improve the system, what needs to be done to make it better etc) were asked all the studied teams in the paper in a standard manner. You can see that by looking at the other tables. Unfortunately, we could not obtain any significant comment/input regarding that bit from the traffic management team. Instead of the online questionnaire, we could have perhaps opted for a face-to-face interview for richer insights. However, the researchers had to be careful in order not to interfere in the team's critical daily traffic management activities and exhaust the cooperative approach of the project management

The explanations above were added in the section (highlighted).

Case 4 (project control): The explanation of the Likert scale used during the interviews was added before the table as requested (highlighted).

The paper presents an extensive data collection effort with both qualitative and quantitative findings in all the cases. Within the practical limitations of a journal paper, it is hard to give detailed explanations/discussions on all the qualitative tables. Therefore, referring the reader to the tables becomes unavoidable. However, we tried to summarise the main qualitative findings in the text a bit more after each qualitative table as suggested (highlighted and commented). Also a summarising table added in the discussion section (Table 6) (highlighted and commented).

- Discussion: You are absolutely right. If conditions permit (it is not easy for researchers to gain extensive access and control in a live project situation for such experimentation), one should try to design an experiment (comparing performance with and without some specific VM tools) to better capture and isolate the associated benefits. Two statements stressing your research design comment for better benefit isolation were added in the discussion and conclusion sections as suggestions (highlighted).

1. Originality:

Thank you.

2. Relationship to Seminal Literature:

Thank you.

3. Research Methodology:

Thank you.

4. Results:

Thank you. We tried to address your comments.

Reviewer: 3**Comments:**

The paper deals with the benefits of visual management in transportation construction projects. In general, the paper that addresses an important and topical area is rather well written and easy to follow. However, when evaluated as a scientific study there are some major concerns that need to be addressed.

Firstly, the introduction section motivates the study to a certain degree but I think that much stronger theoretical positioning and theoretical justifications for the study need to be presented. Why is it theoretically relevant to study the benefits of visual management in construction (as prior research has already been conducted), what is this study's unique angle on the topic and what are the key characteristics that differentiate the transportation context from e.g. building construction projects. These key characteristics or contingencies need to be explicated in the introduction in order to be able to evaluate the uniqueness and research novelty of the study. While I think it is a relevant argument that transportation projects may reveal some different aspects or findings on the research of benefits of VM when compared to traditional construction projects I think you should present much more in-depth discussion on why you think so. In addition, I think you should also present a more in-depth theoretical grounding for your study (in addition to the practical motivation): elaborate better in the introduction that what kind of new and theoretically relevant knowledge does this study aim to produce? Please also present a clear research question for the study.

The literature review is OK and rather well written. However, what I would like to see is even a more in-depth discussion on the research on the benefits of VM and also on the presented challenges on it. I think a more analytic and critical approach to prior research would serve the study better.

In terms of the methodology, please explain what were the rationales for the case selections (why were these projects selected i.e. what was the theoretical sampling logic) and in addition why did you choose to focus on the four different VM systems? Please also state the unit of analysis, this is very relevant. I would also like to see a more thorough and detailed documentation on the number of interviewees related to the cases

Please see our response to your comments above.

5. Implications for research, practice and/or society:

Thank you.

6. Quality of Communication:

Thank you. The paper was proofread as suggested. Some minor mistakes were corrected.

Authors' Response to Reviewer 3's Comments:

Thank you very much for your valuable comments. Truly useful. Please see our responses & improvements on the paper below:

- One should note that the existing VM literature in construction is mostly conceptual (theoretical) or emphasises the qualitative benefits of VM systems. We have not spotted any comprehensive empirical study aiming at displaying a wider picture of the subject with its both quantitative (hard) and qualitative (soft) benefits; possibly because of the challenges associated with measuring them in a real-life context. Also, the existing benefit discussions generally focus on one or two VM systems out of the five main types. Admittedly, one should gain extensive access to real-life work settings for a relatively long time (kind of like a longitudinal study) to be able to fully capture the data presented in the paper. We had to do so. Additionally, the VM discussions for the transportation sector is even more scarce. However, with Lean Construction gaining momentum in the sector, more and more companies have been adopting those practical visualization systems. They do it by learning from each other or due to the exerted pressure from their clients etc. The paper not only presents a wider picture of those benefits (both qualitative and quantitative) and challenges in the transportation sector, it also does this covering 4 different types of VM systems& methodologies with their implementation characteristics. The uniqueness of the paper explained above was added to the end of the second paragraph and beginning of the fourth paragraph in the introduction section (Highlighted and commented).

(when, by whome etc.). What I did not also completely understand was the combination logic of action research and case study research and its implications for the study.

The empirical results are well described and documented. However, in terms of the discussion and conclusions I think that the study should address much more in-depth the theoretical implications of the findings. In its current form, this part of the research paper is rather weak. You should elaborate more clearly to what discussions do you contribute and how exactly. What were the unique findings of your research and how do they differ from prior findings and why? What are the implications of the transportation context in comparison to VM benefit results in other contexts and why are these different/similar? Please also discuss the limitations of your study in the conclusion section.

I wish you the best of luck in improving your paper.

Additional Questions:

1. Originality: Does the paper contain new and/or significant information adequate to justify publication?: Yes, but limitedly. I think that the authors should explicate better the novel information they produce and the theoretical implications of their context (transportation construction projects).

2. Relationship to Seminal Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?: Yes, but I think that the literature review should adopt a more analytic and critical approach to prior literature. I think also a more thorough discussion on the benefits of VM in construction is needed.

3. Research Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed, robust, defensible and appropriate?: I think that there is much to improve in terms of the methodology of the paper and particularly how it is presented. The use of the action methodology is not that clear and in terms of the case study strategy the unit of analysis is not clearly presented, the selection logic of the cases is not clear nor is the approach to theory building explicated.

- Some differentiating characteristics of transportation projects and accordingly, the explanation of why VM has been opted for were added to the third paragraph in the introduction section (Highlighted and commented)
- The research question was added in the first paragraph of the research methodology section (Highlighted and commented).
- To address the "more critical review" remark, we assumed the reviewer wants to see a better positioning of the paper against the existing literature. Therefore, we tried to outline the main gap in the existing literature and consequently why this paper address this gap in the introduction section as per the reviewer's comments (highlighted and commented). Some discussions in line with that were added in the last paragraph of the VM in construction section to improve on the criticality and to better highlight the uniqueness of the paper (Highlighted and commented). We also added some summarizing lines in the last paragraph of the literature review on why this study is different from the existing VM in construction literature.
- The research methodology section was significantly improved as per the other reviewers' comments as well, which we think better answers many of your questions now. Please see the highlighted changes. To answer some of your other questions, those projects were chosen in cooperation with Highways England because (i) they had comparatively more advanced/ varied VM practices in place for a while that we could study (ii) one of the projects – Project 1 was keen for us to help them implement the 5S – an interesting research opportunity on a scarcely researched topic in construction (iii) they were keen to be the subjects of study (very important in real-life research). There are five types of VM systems identified in the literature. The paper covers four types of them, except for mistake-proofing systems, which is one of the strengths of the paper in our opinion – a wider coverage of VM systems. Those two bits were added in the research methodology section (highlighted and commented). Also, many of your other questions were

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4. Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together all elements of the paper?: Empirical results are presented in a sufficient manner but I think that the conclusions could be significantly improved.

5. Implications for research, practice and/or society: Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?: I think that the paper's theoretical implications are not clearly presented and much work is needed in terms of positioning the findings to prior research. Practical relevance is rather clearly presented.

6. Quality of Communication: Does the paper clearly express its case, measured against the technical language of the field and the expected knowledge of the journal's readership? Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc. Do the figures/tables aid the clarity of the paper?: I think quality of communication is on a good level.

answered in the research methodology section (please see the highlighted bits). Some of your comments related to the who when etc can already be found in the paper and other tables (i.e. the number of responses can easily be seen by counting the response numbers in the tables, we clearly wrote the role of the interviewees/ respondents etc. we also wrote the research time-frame in the last column of the first table – please review the tables again). Therefore, we did not want to expand an already comprehensive paper with the information that can be easily extracted from the paper and tables. What combination logic? There is no physical link between the systems. The action research bit is on a different VM system (the 5S) and the case study bit is on the other three systems used by either different teams/locations or in different projects (Project 2). Please review Table 1 more carefully again. The focus across the VM systems is the same though; understanding how the benefits manifest themselves. The common denominator is the explorative research question.

- We tried to better link the findings to the existing literature in the discussion section (highlighted and commented). Also, we added a table (Table 6) to highlight the main findings (benefits/ challenges) associated with each of the studied VM system. (Highlighted and commented). The uniqueness of the paper against the existing works was clearly shown in the introduction and literature review sections with this revision. Please see the highlighted changes and responses to your comments above. Having put them already in those two sections, we did not want to repeat them again in the discussion and conclusion sections. Written and there now. However, we understand the concerns of the reviewers as to better highlighting the original findings of the paper in the transportation context. Alongside Table 6, some discussions were added linking the findings to more transporting sector specific conditions to the fifth paragraph in the discussion section (Highlighted and commented).

1. Originality:

Thank you. We tried to better position the research against the existing literature. Please

Reviewer: 4

Recommendation: Major Revision

Comments:

1. The introduction provides an interesting reflection on visual management and its link to lean construction. However, the link to transportation is a little tenuous which would benefit from being strengthened.
2. Please refrain from using sections within the narrative.
3. From page 3 onwards it seems to be a little confusing. It is not particularly clear what message is trying to be conveyed.
4. "Figures of teams"?
5. Why 5S? This needs defending.
6. Whilst the R.M. section provides some insight, the grounding of this approach (ontology) would benefit from being expanded as there are a lot of contradictions that could be drawn.
7. A multiple case study approach seems to be presented; but there are far too many variables to provide readers with meaningful insight.
8. The paper seems to be more of a discussion rather than development of scientific approach.
9. The discussion section is interesting but it would be nice to see something meaningful out of this e.g. new process models, maps, frameworks etc.
10. The conclusion section needs to identify the general approach and supportive rationale. This needs to be extended to tease out the precise research findings this paper offers; the link back to seminal literature in this respect; the precise nature of the assumptions made; the validity of findings in respect of generalisability, repeatability, etc. Research limitations also need to be stated. Whilst it is acknowledged that part of these have been included (in a pseudo limitation way), the delineation needs to be made clearer.
11. All et al's should be italicised.
12. English spelling should be used not American e.g. standardising, realise, actualisation, etc.

see the highlighted changes in the introduction, literature review and research methodology sections.

2. Relationship to Seminal Literature:

Thank you. We tried to increase the criticality of the literature review to better underline the uniqueness and originality of the paper, keeping in mind that this is an empirical research paper; not a systematic or synthetic literature review one. Please see the highlighted bits in the introduction and literature review sections.

3. Research Methodology:

Thank you. WE tried to address all your main comments in the research methodology section. Please see all the highlighted bits in the research methodology section.

4. Results:

Thank you. We tried improve the conclusion and discussion sections, we also added a table (Table 6) highlighting the main findings.

5. Implications for research, practice and/or society:

Thank you. We tried to better position the research against the existing literature as per your comments above. Also, the link between the findings and the literature was tried to establish better within the limitations of a paper. However, one should not overlook the real focus of the research; the comprehensive empirical findings on different VM systems in the transportation context. There lies the originality/value of the paper to the authors.

6. Quality of Communication:

Thank you.

Thanks. We really benefited from your insightful reviews.

Authors' Response to Reviewer 4's Comments:

Thank you for your review.

1. The existing literature dealing with VM in transportation is unfortunately quite scarce. Also, we tried to incorporate some discussions on that already in the introduction section (i.e. at the beginning of the first paragraph, at the end of the second paragraph etc). However, as requested, we elaborated on the link to the transportation sector in the third paragraph of the introduction section (highlighted and

Additional Questions:

1. Originality: Does the paper contain new and/or significant information adequate to justify publication?: Please see Additional Comments to the Author

2. Relationship to Seminal Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?: Please see Additional Comments to the Author

3. Research Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed, robust, defensible and appropriate?: Please see Additional Comments to the Author

4. Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together all elements of the paper?: Please see Additional Comments to the Author

5. Implications for research, practice and/or society: Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?: Please see Additional Comments to the Author

6. Quality of Communication: Does the paper clearly express its case, measured against the technical language of the field and the expected knowledge of the journal's readership? Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc. Do the figures/tables aid the clarity of the paper?: Please see Additional Comments to the Author

commented). We also expanded on the justification of the research at the end of the second paragraph & beginning of the fourth paragraph in the introduction section (Highlighted and commented).

2. Done.
3. From page 3 onwards, we tried to explain what VM is with its tools and techniques from the production management perspective (mainly within the Lean Production System in manufacturing – literature review). Afterwards, we presented a detailed review of what has been done in construction in terms of VM (literature review). We came to the conclusion that although VM is gaining momentum, there is not much empirical work on VM in construction in general and in the transportation sector specifically. Then, we presented our study on four VM systems in the transportation sector. We outlined these already in the introduction and literature review sections. The corresponding explanation at the end of the introduction section was highlighted for further clarification for the reviewer.
4. "Figures of teams"? We wish the reviewer had been clearer on the requirement here. There are already many visuals (figures) and tables in the paper. A figure from the teams' meeting can be seen in Figure 2. By the figures, if you meant numbers, the meeting numbers were elaborated in the section as requested by another Reviewer. If you asked about the linguistic use of the "figures", it was used to denote numbers, especially ones which form part of official statistics or relate to the work performance of

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	<p>the teams. A common English usage for performance numbers. We unfortunately could not spot any problem here.</p> <ol style="list-style-type: none">5. The rationale was added in the second paragraph of the research methodology section (highlighted and commented) (The main reasons why the 5S was implemented in the action research effort are; (i) the 5S is a scarcely researched methodology in construction, (ii) it is often referred to as a fundamental step in adopting VM, (iii) the management of the project in which the 5S was implemented showed an explicit interest and support to the methodology to improve their operations with the researchers' support, (iv) the storehouse of the project presented a suitable ground for the 5S implementation.)6. The research methodology section was significantly expanded as per the reviewers' comments. Please see the highlighted additions.7. The paper presents a mixed research approach; action (one VM system) and case study (three VM systems) research. In the case study bit, 3 VM systems were studied. Although there are many parameters as to the captured benefits of those VM systems, which is quite expected, the focus of the case studies is one – the VM systems in use. This should be noted. We added that sentence in the research methodology section for further clarification (highlighted and commented).8. We are sorry to read that. Yes, the paper presents some extensive data collection and discussions from a real-world setting, as one would
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	<p>expect form a research paper. However, the authors believe the paper also contains some interesting findings for both researchers and practitioners in construction management on a scarcely researched yet rapidly diffusing subject. The conscious deployment of those innovative visual systems in the transportation sector in England dates only back to the early 2010s, with the increasing attention to Lean Construction. The authors believe both practitioners and researchers will benefit from those extensive discussions in the paper for their future works.</p>
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9. We assert meaningful outputs do not necessarily come in the form of frameworks, process models or maps. Those outcomes are valuable; however, they all depend on the nature and context of research. We seriously doubt their applicability in our research context, which essentially presents the effects of the conscious, real-life deployment of a close-range visual communication strategy (VM) in construction production management. On the other hand, to address that comment we developed Table 6 to further highlight the gist of the paper's main findings. (highlighted and commented). The discussion and conclusion sections were significantly improved as well (highlighted and commented)
10. We tried to link the findings to the literature in the fourth paragraph of the discussion section (highlighted and commented). The main challenge in research was abstracting the benefits that could be directly associated with the VM systems from the overall

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	<p>improvements. This was mentioned already in the conclusion section. Experiments and quasi experiments were suggested by another reviewer and put in the discussion and conclusion section as well (highlighted and commented). A paragraph on the relevance of the findings to more transportation-sector specific conditions was added in the discussion section (highlighted & commented). Many other research related comments were addressed in the second and third paragraphs of the research methodology section in the paper (highlighted and commented)</p> <p>11. Done. 12. Done.</p>
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