USING DESIGN SCIENCE TO FURTHER DEVELOP VISUAL MANAGEMENT APPLICATION IN CONSTRUCTION

Denise Ann Brady[1], Dr. Patricia Tzortopoulos[2] & Dr. John Rooke[3]

ABSTRACT

This paper presents preliminary results of an ongoing PhD work, focusing on the further development of Visual Management (VM) application in Construction using prescriptive research through Design Science. The aim of the paper is to present a case study that describes how a Visual Management Method (VMM) was developed and implemented to improve transparency on a construction site and to consider how this method can make a contribution to Visual Management theory. The VMM incorporates visual tools that are applied together to plan, measure and visualise work on a daily basis. The paper concludes with a discussion on how the VMM relates to the literature on Visual Management and determines the next steps to be taken to refine the method and provide theoretical contributions.

KEYWORDS

Design science, visual management, lean implementation

INTRODUCTION

The main sources for discussions of Visual Management (VM) in construction are the lean construction related papers. Some of the previous work on the area has focused on the application of visual management tools and the demonstration of its applicability in a construction context, as discussed by Tezel (2011). While these isolated applications provide valuable contributions, it can be argued that a more comprehensive approach could lead to a deeper understanding of Visual Management in construction and broader results. The importance of implementing broader solutions as opposed to isolated tools was considered by Picchi et al., who stated that "when tools are implemented in isolation, poor implementations of lean concepts are observed (Picchi, et al., 2004)". The same authors proposed a framework for such broader solutions based on the five lean principles: value, value stream, flow, pull and perfection. Scenarios were presented as to how a broader application of lean thinking can be applied to job sites and it was determined that no such implementations exist, which presented a challenge for future research and practical implementations (Picchi et al, 2004). The authors acknowledge that while the application of isolated tools are important steps towards lean dissemination in job sites, the use of lean

[1] PhD Student, School of the Built Environment, University of Salford; UK. brady_denise@web.de

[2] Senior Lecturer, School of the Built Environment, University of Salford; UK. Phone +44 161 295 4284; p.tzortzopoulos@salford.ac.uk

[3] Research Fellow, HaCIRIC, School of the Built Environment, University of Salford, Greater Manchester. Phone +44 161 295 6344; j.a.rooke@eml.cc

tools based on a broader lean system analysis is necessary for more significant results (Womack and Jones, 1996; Liker 1997; Rother and Shook, 2000). This paper presents a Visual Management Method (VMM) that was developed initially in practice to address a practical problem faced on a construction site. This practical problem was lack of transparency in daily operations onsite, which led to difficulties in communication, decision-making and general progress in daily work. The VMM also addresses a theoretical problem which is the lack of broader, holistic solutions when implementing Visual Management (Picchi et al., 2004; Tezel, 2011). Design Science is being applied as a research strategy to solve these problems, as discussed as follows.

LITERATURE REVIEW

Visual management is a system for organisational improvement that aligns organisational vision, core values, goals and culture with other management systems, by means of stimuli (information), which directly address one of the five main senses: sight, hearing, feeling, smell and taste (Liff and Posey, 2004; Tezel, 2011). VM uses visual aids to improve processes and communication and promote continuous improvement (Ho and Cicmil, 1996). It makes abnormalities visible so that corrective action can be taken (Imai, 1997) and it enhances communication by making information easily accessible in a production setting (Liker et al., 1995).

Galsworth (2005) proposed an application framework for VM in manufacturing consisting of four main levels: visual order, visual standards, visual measures and visual guarantees. Visual order is the foundation level and refers to the 5S concept of systematically cleaning, organising and standardising the workplace. Visual standards focus on providing workers with visual information to support their tasks. Visual metrics is the preceding level which focuses on creating transparency of metrics for the workplace as a whole so that abnormalities are highlighted and corrective action can be taken. Finally, the visual guarantee refers to reducing human error to a minimum by introducing visual controls (for example floor markings) and poke yoke (mistake proofing device).

Tezel (2011) developed an in depth study of VM in construction, and concluded that it tends to focus on the use of isolated visual tools borrowed from manufacturing, leading to a relatively narrow approach. These tools are sometimes explained secondarily as part of a lean construction implementation effort with poor connection to a strategy, i.e. "*the wider discussion needs to show different Visual Management Practices and their connections on a construction site and /or company in a holistic manner*" (Tezel 2011: 96). In his work, Tezel identified and classified 19 different types of Visual Management tools used in construction, which provides a basis for future VM implementations. The research presented as follows builds upon such previous work and aims to provide a holistic method for the implementation of VM.

RESEARCH METHOD

Design Science is a research method for producing innovative constructions, intended to solve problems faced in the real world and, by that means, to make a contribution to the theory of the discipline in which it is applied (Lukka, 2003). Design Science products can be of four types (March and Smith, 1995): constructs, models, methods and implementations. Rather than posing theories, design scientists strive to create models, methods and implementations that are innovative and valuable to both theory development and improvement to practice. Peffers, et al (2007) proposes steps for Design Science research consisting of: 1) Problem identification and motivation, 2) Define objectives for a solution, 3) Design and development, 4) Demonstration, 5) Evaluation and 6) Communication.

Design Science was chosen for this research because it involves the development of a solution with practical and theoretical relevance. Design Science is also a suitable strategy for this work since the Visual Management Method was developed initially in response to a practical problem, but had not been formally thought through. The Design Science steps 1-6 do not necessarily have to take place in that order, which is the case in this work. Design science "could result from the existence of an artefact that had not yet been formally thought through" (Peffers, 2007). In the course of the research, the aims, objectives and structure of this VM method will be refined, to make a contribution to the theory of VM and to its application in practice.

Table 1 illustrates how Design Science is being applied to this research. It shows the steps as proposed by Peffers (2007), with the corresponding research activities and anticipated outcomes. It can be noted from the table that the research is being carried out in stages that are referred to as "cycles". The first cycle is very much practically focused, since the initial development of the VM method was in direct response to a practical problem. Using the practical problem as a starting point, the researcher carried out an analysis onsite to fully understand the issue and to gather data and ideas that would help when defining the objectives for a solution. The objective of this analysis was to:

- Gather first impressions of the daily operations of the site and to gain a snapshot of the delivery date performance during that particular timeframe (i.e. was the work that was planned to be carried out on a particular day actually completed on that day?). Identification of any obvious sources of waste on the project.
- Identify / verify main problems onsite and improvement opportunities.

Table 1: How Design Science is being applied to this research

Timescale	....2007 2008					
PRACTICAL CYCLE	Problem ident-ification and motivation	Define objectives for a solution	Design and Develop-ment	Demon-strate	Evaluation	Commun-ication
Activity	1) Definition of practical problem (case study)	1) Definition of objectives for solution of practical problem (case study)	1) Design and develop solution on practical objectives	1) Demons-tration of solution in case study	1) Does it solve the practical problem? Benefits of implement ation.	1) Final report
Outcome 1	1) Practical problem identified	1) Objectives for solution identified	1) First design developed for practical use	1) Description of practical application	1) Improve-ment points in practice	

	......2009..............................2012..............................					
PRACTICAL & THEORETICAL CYCLE	Refine problem	Refine objectives for a solution	Improve design	Demon-strate	Evaluation	Commun-ication
Activity	1) Refine practical problem by reviewing literature on practical problem 2) Clarify barriers in implement-ing lean methods in construction from literature and practical experiences	1) Re-definition of objectives for a solution based on theoretical knowledge and first practical experience 2) Review other examples of using VM in Lean Manufacturing for possible important learnings for objectives (participant observation)	1) Adaptation of first design of solution taking learnings from practical case study and re-definition of objectives into consider-ation	1) High-lighting of main differ-ences	1) Evaluation of improved method	1) Summary of results
Outcome 2	1) Refined problem based on literature review	1) Refining of objectives for solution	1) Improved solution	1) Descripti on of main differ-ences in practice	1) Feedback on improved concept	1) Present-ation and commun-ication of results

After the analysis, a brainstorming phase, which was carried out by the researcher and a colleague, took place to develop ideas of what method could be used to improve the problem areas highlighted both before and during the analysis. These ideas contributed to the initial development of the VMM, as described below (practical cycle shown in Table 1 above). The final part of the case study focused on the implementation of the VMM on one building site. The learning's gathered from this implementation flow into the second "cycle" of the Design Science strategy called "the practical and theoretical cycle" (right side of Table 1). In this cycle, the original practical problem is reviewed and refined based on the literature. An evaluation of the first implementation in the "practical cycle" is carried out parallel to understanding of how the VMM relates to the literature, to rethink the objectives of the solution based on the literature and finally, to propose an improved solution that also contributes to the theoretical underpinnings of Visual Management.

CASE STUDY: DEVELOPMENT OF INITIAL METHOD

The VM method was developed and implemented to solve a practical problem, as part of a case study on a building site in Germany. The practical problem experienced was a general lack of transparency in daily operations on the construction site which led to problems such as a lack of communication, too much information, slow decision-making, lack of clear responsibilities, unsatisfactory interfaces between planning and contracting companies, no process orientation and different perceptions of quality.

BACKGROUND

The project involved the construction of a block of residential apartments in Germany. Since 2007, the researcher has been employed by a company specialising in project management in construction, as a Process Consultant in Lean.

The goal of the case study was to develop a method to improve transparency onsite in general, by introducing a visualised daily planning system that brought clarity, aided communication and decision-making and simplified information. It was also intended that by visualising work, progress could be measured and possible waste could be avoided: overproduction, waiting, transport, over processing, excess inventory, unnecessary movement, defects, unused employee creativity (Liker, 2004) and making-do (Koskela, 2004). The case study includes the design of the method and its preliminary implementation (practical cycle in Table 1).

VISUAL MANAGEMENT METHOD (VMM)

The VMM provides a framework for applying a number of visual tools simultaneously to a construction project with the objective of improving transparency, which in turn will aid communication, decision-making and day to day planning of activities. Its focus lies in the simplification, visualisation and measurement of work on a daily basis to ensure target milestones are met, quality is improved and construction workers are actively involved. The VMM seeks to provide a broader solution for implementing Visual Management as mentioned in the literature review and this will require further consideration in the future.

VISUALISATION OF DAILY WORK

The focus point of the VMM is the construction board (Figure 1), which is situated in a central area of the building site. The function of the construction board is to display the daily work packages and to act as a physical central point of meeting and discussion for all involved in the construction project.

Initially, construction cards or work packages were defined, planned and prepared by the researcher together with the foreman and contractors in advance. This involved a thorough analysis of the main construction processes on the master plan so that work could be broken down to a monthly, weekly and then finally daily level. In a similar way, the Last Planner system breaks work down into assignments of weekly activities. However in the VMM, the work packages take on a physical form of a construction card which has its own individual identity and is used to indicate status of completion. Each construction card represented 1 unit of work for one company for any given day. It showed the worker capacity needed for this unit of work, the material needed, where the work would be carried out, when, and by whom.

Individual cards would be collected by the responsible worker each morning and taken with them to the area of work where it would be displayed to indicate work-in-progress (Figure 2). This encouraged the active involvement of the worker and provided him with a physical platform to communicate problems and propose solutions.

By visualising these work packages, a daily operational planning was not only enabled, but also it was clear to "see" what work was carried out where and which areas were currently vacant. It highlighted further possibilities of eventually reducing overall lead time by planning additional work in vacant areas. It was also clear to see at just one glance at the board, which work was completed, which was in progress and which was delayed. During this case study, it was found that the board simplified and improved communication onsite.

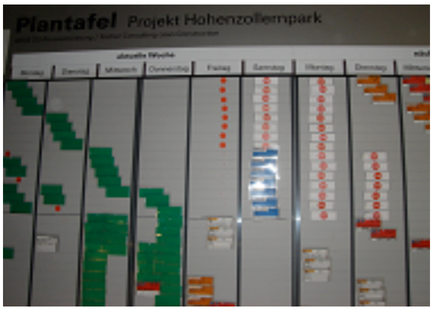

Figure 1: Visualisation of daily work

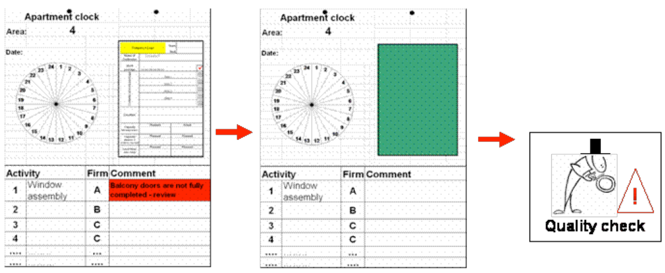

Figure 2: Apartment clock

USING VISUALISATION TO IMPROVE QUALITY

Different visual aids were combined to support continuous improvement of quality within the VMM. For example colour coded cards (visualised on the construction board), the action plan displaying identified improvement actions and the visual Key Performance Indicators (KPI's) were used together to improve quality.

This worked as follows: the construction cards were taken from the board and displayed on a visual sign (known as the apartment clock in this case), which was located at the area of work (see Figure 2). On completion, the worker would turn the card around to the green side which indicated that work was complete. This was a signal to the foreman to check the work to ensure it met the expected quality standard. If the work was ok, the foreman would place the construction card back on the construction board, green side up to indicate satisfactory completed work. If the work was not of acceptable quality, the foreman would turn the card back around to the "in-progress" side and make a note of what needed to be improved on the "apartment clock" at the area of work. If the problem was a more serious issue that couldn't be solved quickly the corrective action was noted and displayed on the action plan, which was situated near the construction board in a central area visible to all. This ensured a timely reaction to quality problems so that they were rectified while contractors were still onsite (saving time) and preventing the same problems from “spreading” to other areas. Finally the quality control process would be completed by the foreman by updating the KPI’s, described below.

VISUALISING PERFORMANCE MEASUREMENT

The definition, measurement and visualisation of KPI’s was a further element of the VMM. Two KPI’s were defined and measured: Delivery Date Performance and Quality. These were chosen since the most important aspects for the investor of the construction project were that it was completed on time and that it met optimal quality standards. Delivery Date Performance was calculated in a very simple way: the work on completed cards (green) was checked on a daily basis by the foreman. If a company had planned to complete 6 cards and only completed 3, their Delivery Date Performance was 50%. This is a similar measure to PPC as used in the Last Planner System only it was measured on a daily basis. From the number of completed green cards, a metric was calculated to reflect the Quality KPI. The goal for Quality was always 0 (Zero defects) so if 6 completed cards had just 1 quality mistake the metric would be 1/6 = 0,16. The Forman determined if there was a mistake and what corrective action needed to be taken. The more defects, the further away from 0 and the worse the Quality KPI would be. Corrective actions were noted and displayed on the action plan and completed as soon as possible (see Figure 3). Progress of KPIs was monitored and displayed on the site information board. Positive results generated a positive atmosphere on the job while negative results encouraged participating companies to do better. It was found that the visualisation of the KPI’s helped to generate this competitive element between the participating subcontractor companies which had a positive effect on the project. During the 6 weeks of implementation of VMM, it was observed that the quality delivered by some contracting companies had improved in some cases by at least 50% and the Delivery Date Performance was improved in some cases from 0 to 100%. This could be established by comparing the development of the two KPI’s (Delivery Date Performance and Quality) from week to week.

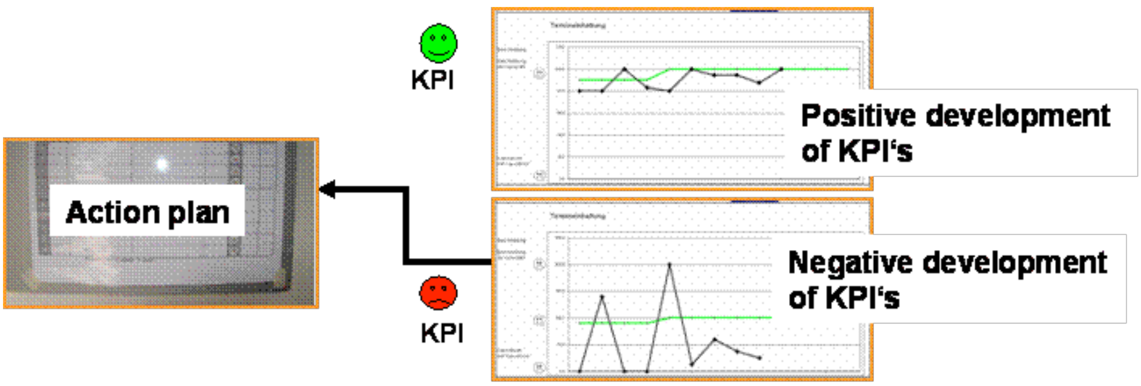

Figure 3: Visualisation and measurement of KPI’s

In addition, the VMM also used visual tools to improve on site material planning and to provide an opportunity to improve individual sub processes using Kaizen, but this will not be expanded upon at this point due to the length limitations of this paper.

HOW VMM RELATES TO PREVIOUS WORK

There are two main areas in the literature to which the VMM can relate and contribute to. The first is a contribution to Tezel (2011) work, which lacks an implementation method for VM and an action research element in its practical implementation. VMM is a practical demonstration of most of the visual tool areas classified by Tezel. Tezel further identified the lack of ability to quantify the benefits of Visual Management in the literature, as an area in Visual Management research to be further developed. The VMM attempts to bring clarity to the practical benefits of using Visual Management in construction, by measuring progress of the work visualised on the construction board (ie: work completed on time and quality). Furthermore, Tezel also identifies a need to include a reflection of workers' understanding and perception of Visual Management in future research efforts (Tezel, 2011:276). The VMM is used by both management (contractors and foreman) and the workers on site and can only be successfully implemented with the active participation of all parties.

The VMM aims to provide a framework for a holistic approach to future Visual Management implementations, which has been lacking in the Visual Management research to date. Table 2 below shows the elements from Tezels Taxonomy that are evident in the VMM either directly (as a direct result from one of the elements of LCM) or indirectly (as a bi-product of the VMM ie. through improvement actions). Only 4 from a total of 19 elements were not evident.

Table 2: Presence of Tezels classified elements in the VM method

	Tezels Visual Management Taxonomy	Was the element present at project start yes/no?	Was the element present after LCM implementation: Yes (*directly / indirectly) / No *Directly meaning as a direct result of one of the elements of LCM and indirectly meaning as by-product of LCM through improvement actions for example
1	Site Layout and Fencing	No	**Yes. Directly** (LCM area) **and Indirectly** (floor marking, logistics board)
2	Standardisation of the workplace elements	No	**Yes. Directly:** (construction card, apartment clock)
3	In the warehouse	No	**No.**
4	5S	No	**Yes. Indirectly:** (as a result of the action plan)
6	In the Elevators	No	**No.**
7	Pull production through the Kanban	No	**Yes. Directly:(pull system using** construction cards and board)
8	Production levelling through Heijunka board	No	**No.**
9	In-station quality (jidoka) through Andon	No	**Yes. Directly:** (quality control using color coded cards, apartment clock, KPI's)
10	Prototyping	No	**Yes. Indirectly** (visualising how the end result should look like for quality purposes)
11	Sampling	No	**No.**
12	Visual signs	No	**Yes: Indirectly:** (happy / sad faces on KPI's, FIFO signs)
13	Visual work facilitators	No	**Yes. Directly:** (all elements of LCM are designed to facilitae work) **Indirectly** (no entry signs developed through improvement actions as a result of LCM system)
14	Improvisational visual management	No	**Yes. Indirectly**: floor markings for material
15	Performance management through visual management	No	**Yes. Directly: (visualisation of KPI's)**
16	Distributing system wide information	No	**Yes. Directly:** (logistics board, construction card, information board)
17	Human resources management	No	**Yes. Directly:** (construction board, construction cards)
18	Poke-Yoke	No	**Yes. Indirectly**: (blocking off areas with tape to prevent entry)
19	On-site prefabrication	No	**No.**

The elements not evident are: 1) in the warehouse: no actual warehouse as such for material existed on the case study project. Material was stored in a disorderly fashion in a vacant room and throughout the building. Using the VM method however, this situation was improved as areas were designated for material storage. 2) In the elevator: the elevators were not functioning at the time of the case study which meant that no visual tools were used there 3) Sampling: coupling materials with their location of use and equipment with their corresponding work gangs was not evident due to the high level of independent contractors involved in the project who had their own equipment 4) Prefabrication. For further development of the VM method, these missing elements will also be considered further to see if it would be feasible to integrate these to further improve the current method.

The second body of literature to which this VM relates to is that of Galsworth (2005). As mentioned in the literature review, Galsworth proposes a framework for applying visual management in manufacturing. The framework consists of four incremental levels. Table 3 below shows the different levels of Galsworths Visual Management framework and how the current VMM relates to this. Three out of four of the levels defined by Galsworth are demonstrated by the VMM in this work but more consideration needs to be given to these in the future.

Table 3: Relevance of the VMM to Galsworths framework

	Galsworths implementation framework for manufacturing	VVM for construction
1	**Visual order:** 5S systematic workplace cleaning, organising and standardising	1. In the VMM "Visual Order" is introduced by clearing defining and visualising daily work packages in order to enable a more stabilised work environment throughout the entire site. However, the traditional 5S is not yet integrated into the method and is an area to be considered for further improvement.
2	**Visual standards:** Providing workers with highly visual standards and displays to support them in their tasks.	2. With the VMM, the construciton board, the construction cards and the actionplan are all visual standards that support the construction workers in their daily tasks.
3	**Visual measures:** focuses on creating transparency of metrics for the workplace as a whole so that abnormalities are highlighted and corrective action can be taken.	3. The VM method also involves the visualisation of KPI's on a daily basis. Where problems occur, corrective actions are defined and displayed on the action plan.
4	**Visual guarantees:** level refers to reducing human error to a minimum by introducing visual controls	4. By defining the daily work packages in advance, this prevents work being started in other areas that are not ready which controls the work flow. However, this is also an area to be considered for future improvement in the the VMM:

CONCLUSION

The VMM method represents a broader application of Visual Management in construction as opposed to applying single tools in isolation. The next steps of this research in the context of Design Science will be to further develop the existing VMM based on a deeper analysis of the literature and the learning's gathered from this case study. The objectives of the VMM solution will be further refined to ensure that not only a practical problem is solved but also that the VMM will make a theoretical contribution to the development of broader solutions for application in Visual Management. As highlighted in table 1 above, the next steps of this research include: 1) a deeper literature review of the need for a broader solutions in Visual Management implementation 2) a further analysis of the relationship between this VMM and existing literature 3) formal evaluation of VMM method 4) proposal of an improved VMM based on all learning's from literature and formal evaluation.

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