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Visual management and shop floor teams – development, implementation and use

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This research investigates the use of visual management, specifically communications boards in a British lock manufacturing company. The research explores the design, implementation and use of communications boards over two years. The purpose of the research was to bring design principles from the graphic design and cognitive psychology into a previously informal process and to develop Visual Management (VM) principles to guide the design of the board. The research findings have acted as a proof of process for the introduction of VM theory into the design of communications boards and provide evidence that the VM principles improved the design of the board. This enabled Team Leaders to better engage in problem-solving and continuous improvement with their teams.

Keywords: visual management; lean manufacturing; action research; continuous improvement; cellular manufacture

1. Introduction

The use of visual tools in a wider business context has been growing in recent years (Bell, Schroeder, and Warren 2013) and Operations Management (OM) practice and literature has made a substantial operational contribution (Greif 1991) to this approach. This paper focuses on the use of a visual tool specifically 'communications boards' used by cell leaders to manage production teams. It provides longitudinal action research (2 years) from the initial company objectives, collaborative design, implementation and use by cell leaders, thus encompassing the progression from concept to implementation. As such the paper contributes to the growing body of the literature in Visual Management (VM).

Visual tools are documented in a range of different sectors e.g. aerospace (Parry and Turner 2006), health care (Machado and Leitner 2010) and government (Radnor 2010). Communications boards are used to steer a team briefing and guide team leaders (TLs) in their activities (Maskell and Kennedy 2007) and were commonly developed as part of lean implementation within organisations (Hirano 1995) and as part of 'The Unipart Way' (Radnor 2010). These boards also perform a wider role of supporting performance management processes, for example, linking operational improvement to strategy. Communications boards are large format about 1.5 m by 2.5 m with several different elements that have operational and strategic data displayed (Rich et al. 2006). Their size is dictated by their use for teams of people and allows the team to all see the same data at once, enabling group discussions and shared knowledge for decision-making (Greif 1991; Jaca et al. 2014). This team is managed by a cell or team leader, whose role in a lean setting is highlighted in Bateman (2005) as key to the sustainability of Continuous Improvement (CI) activities. Thus the use of communications boards and their effective design fulfils an important need within companies seeking to practice CI. The purpose of this research is to provide an insight into the implementation of VM at cell level in a production environment. The research develops four VM principles (Figure 1) to guide the design of communications board and answers the research question:

> Can the use of VM principles developed from established graphical communication practices and literature enhance the design of communication boards at cell level?

The extant literature that has focused on reporting industry best practice in the form of case studies or 'how-to' workbooks is combined with approaches from graphic design and cognitive psychology to inform the process of VM. Thus, VM principles are developed addressing a gap in the literature.

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1. Using the right graphical tool to convey data — when bar charts are appropriate, when line charts, etc. Difference between discrete and continuous data (Few, 2006; Shah and va Hoeffner, 2002)
2. Using colour sparingly — just to highlight key features (Tufte, 1990; Shah and Hoeffner, 2002)
3. Avoid using excess borders and boxes — looking at minimum ink to data ratio (Tufte, 2001)
4. Use a board layout that reflects the flow and structure of the information you want to present (Miller, 1956, and the idea of flow from Womack and Jones, 2003)

Figure 1. Visual management principles.

The empirical setting for this research is a lock manufacturer with considerable experience of implementing lean and VM. This previous experience was important because it allowed the research to focus on improvements to current practice in VM rather than initial implementation.

2. Literature

The literature relating to VM is in the disciplines of OM, specifically lean (Imai 1997), performance measurement (Neely et al. 2000) and strategy development (Kaplan and Norton 2006, 2008). However, as one purpose of this research is to include approaches from other fields, we reference knowledge from graphic design and cognitive psychology. Examples of VM within a lean context are examined, in Fillingham (2007), Parry and Turner (2006) and Radnor (2010) as are guides for the use of VM within a lean context; Hirano (1995), Imai (1997), Liker (2004) and Galsworth (2005). More recent publications Jaca et al. (2014) and Bititci, Cocca, and Ates (2016) provide a contemporary review how VM is used. The precedent for this approach is exemplified by Greif (1991) who demonstrated how important VM is to the broader OM. However, the extent to which all of these papers examine how VM should be applied, particularly how it should be designed, is very limited, hence the inclusion of graphic design and cognitive psychology literature to aid the design of communications boards. Few (2006) provides design guidance from the allied subject of electronic dashboards and draws from graphic design the work of Tufte (1990, 2001). Graphs are very often used as individual elements as part of a communications board and Shah, and Hoeffner (2002) from cognitive psychology explores how graphs should be drawn to improve comprehension, and Miller (1956) provides guidance for the design of the whole communications board in his work on cognitive workspace. A summary of the literature is provided in Table 1.

2.1 *VM and Lean*

VM is an element of lean and is inherent in lean implementations, Radnor 2010, p. 415) cites Unipart's principles (No. 11) 'We use VM to expose problems, inspire improvement and understand situations at a glance', and Liker 2004 in his principle No. 7. In lean VM is understood as a vehicle for interpreting the current performance, thus providing a platform for break through improvement, and CI, the latter which is core to lean and the PDCA cycle (Deming 2000). The benefits are evident across sectors, for example, Fillingham (2007) drawing from experiences at Bolton Hospitals NHS trust identifies VM as part of his implementation logic, 'design visual aids so that leaders can go-and-see … the next problem they should be solving' (Fillingham 2007, 237). Parry and Turner (2006) examine VM's use, in a technology-centric Aerospace company and the visual tools identified reflect this (Parry and Turner 2006, 80). Nevertheless, the success factors identified by Parry and Turner advise against the use of technological tools such as software- and computer-based systems because they allow too much information to be accessible – not focusing on the 'vital few', and familiarity with software can create 'operator experts' taking, 'control of a board from the team and places it into the hands of a single or small number of people' (Parry and Turner 2006, 84), limiting opportunities for improvement across teams.

Hirano's (1995) '5 pillars of the visual workplace' highlights the benefits of visual controls identified as shadow boards and marking areas within the shop floor. Liker (2004) considers the use of visual controls more broadly, emphasising not only shop floor controls, but also VM in Oobeya rooms supporting management decision-making and product development. Similar to Hirano, Liker also provides examples of tables that are visual tools used to support operational decision-making such as the process control board at Kentucky parts distribution (Liker 2004, 154).

Table 1. Summary of literature.

Literature area	Source	Commentary
Visual Management and lean	Fillingham (2007)	Example of VM use in health
	Parry and Turner (2006)	Example of VM use in aerospace
	Radnor (2010)	Example of use in automotive spare supply but also how VM is integrated into a lean approach for CI
	Hirano (1995) Imai (1997) Liker (2004)	Demonstrate how VM is integrated into the ideas of lean especially for the identification of problems.
	Galsworth (2005)	Heavy emphasis on visual tools - provides many examples but very little on how to design
Visual Management and Operations Management and strategy	Greif (1991)	Main concept of 'shares vision' – key to CI
	Mills et al. (1998)	Presents a visual tool for strategy representation with 3 cases examples, practical discussion but does not engage with design aspects
	Jaca et al. (2014)	A survey of 52 companies looking at levels of use of common VM tools and its interaction with participation systems such as sugestion systems and improvement teams.
	Few (2006)	Management dashboards – principally electronic, but uses many suitable principles of design.
	Bititci, Cocca, and Ates (2016)	Examines how VM can support strategy development with 7 cases of implementation.
Design Approaches	Tufte (1990, 2001)	Many useful design principles and active practitioner website
	Shah and Hoeffner (2002)	Examines literature for the comprehension of graphs
	Miller (1956)	Principle idea one of limited cognitive workspace-this has implications for the overall design of boards and how they are structured

Galsworth (2005) reverses the approach taken by Liker and Hirano using visuality as a vehicle to introduce lean rather than visual controls as an element of lean. Galsworth argues the motivation for introducing visual tools by providing many examples. She introduces standard lean approaches such as 5S and CI but the emphasis is on the visual rather than lean.

2.2 *VM in OMs and strategy*

Predating Galsworth, Greif (1991) presents a blueprint for the visual workplace, portraying the use of visual tools and their integration in the workplace as a paradigm in itself; that using visual tools provides a shared concept of where the factory is now, where it should be, thus leading to the team-based participatory problem-solving and implementation to achieve goals. There is acknowledgement of a wide range of visual tools including 5S, visual scheduling, performance measures and mission statements. Greif does look at the design of visual tools (192–198) suggesting, for example, that charts should avoid overloading, be bold and colourful, use standardised approaches across a site but not be uniform thus reflecting differences between areas. Some of these suggestions for design are in contrast to graphic design approaches by (Tufte 1990, 2001), discussed in 2.3.

There is limited literature addressing specific visual tools in production outside of a lean context however, Mills et al. (1998) suggest using a pictorial representation for manufacturing strategy. They support the approach of using visual tools in an operational context although they explicitly state their tool is for use by managers rather than operators. This strategy tool was trialled in three organisations using an action research approach. It highlights problems with the level of detail to include 'As a communication tool there is a paradox. The more detailed and thus explicit a strategy representation becomes the more barriers can emerge to restrict its wider communication' (1082). Organisational research provides in Jaca et al. (2014) a survey of 52 companies in the Basque country exploring their use of a wide range of visual tools such as markings on the floor, visual quality control (SPC) and indicators (KPIs). They test the relationship between the use of these tools and participation schemes (improvement teams and suggestion schemes) and conclude there is widespread use of visual tools (up to 60% of firms surveyed) and identify that companies that have participation schemes also use VM. They do not resolve whether these companies are implementing lean operations although many of the aspects they discussed might be associated with a lean environment.

VM is central to performance management and particularly the linking to strategy implementation, Bititci, Cocca, and Ates (2016) document the development and use of 'strategic planning boards' in seven case companies. Each of the boards had similar components such as performance analysis (often operationalised as KPI's) and as strategy maps (Slack and Lewis 2008) although the design of these components varied between companies. Therefore, explicitly displaying strategy and its associated KPI's in a visual way support ongoing strategy development, engagement and implementation. However, the research highlighted a need for more longitudinal research in operationalisation of VM approaches.

2.3 *Design approaches to VM*

Few (2006) provides a link between types of performance measures commonly found on communications boards and graphic design. Few addresses the design of management dashboards promoted by software companies. These dashboards facilitate presentation of computerised data along with interactive interfaces to provide snapshots to managers. The dashboards differ from communications boards considered in this research, in that they are usually viewed by one person on a computer screen; however, many of the principles he discusses and problems he highlights are common to both formats.

Few cautions against the use of 'flashy' design, but rather focuses on appropriate data, effective display and usability. He provides many screenshots exemplifying good practice and also highlights 'thirteen common mistakes in dashboard design' (Few 2006). Despite Few's work being focused on computerised media, his guidelines on perception and graphic design remain true for the hand drawn communication boards, for example, human limitations of interpretation, avoidance of heavy use of colour in line with the earlier work of Tufte (2001).

Tufte (2001) considers the use of colour, grids and data density. He recommends using strong colour sparsely and grids sparingly ensuring they are not prominent suggesting the use of grey instead of the usual black, 'Dark gridlines are chartjunk [superfluous and unhelpful graphical elements]. They carry no information, clutter up the graphic, and generate activity unrelated to data information' (Tufte 2001, 113). The concept of data density is the data to ink ratio, only using ink (i.e. graphical marks) that should be used in a sparing way to convey data this is combined with the idea that people can perceive large amounts of data in a small area; this is evidenced in the production of high-quality maps (for example, British OS maps, Tufte 2001). 'Data graphics should often be based on large rather than small data matrices and have a high rather than low data density' (168).

Cognitive psychology can provide guidance on how to present data in terms of issues of perception such as how well humans distinguish differences in graph design such as angles and hue. Shah and Hoeffner (2002) provide a good starting point for graph design and consider aspects such as the visual characteristics of display including two and three dimensional formats, animation and colour by drawing on the extant literature. e.g. Few (2006) and Tufte (2001).

Examining the design of individual elements of a communications board does not address how the board should be designed as a whole, Miller (1956) provides a useful insight into the overall number of elements to be included in a communications board. His paper uses a range of pre-existing experimental data to demonstrate that people can only hold in their minds about seven 'chunks' of data at the same time. This is quite a low number, but he states that 'by organising the stimulus input simultaneously into several dimensions and successively into a sequence of chunks we manage to break (or at least stretch) this informational bottleneck' (Miller 1956, 95). The implication for designers of communications boards is that there must not be too many elements or performance measures (chunks) which cell leaders must consider or it will exceed their cognitive capacity but the internal complexity of these chunks can be quite high.

There are notable inconsistencies in design of visual tools that need to be explored and if possible reconciled: How does the idea of avoidance of overloading (Greif) and a cognitive workspace of seven (Miller) fit with high levels of data density advocated by Tufte? Also Greif supports the use of bright colourful graphics in contrast to Tufte's subdued approach. To resolve this gap in understanding, the subtlety of Miller that information should be organised into seven chunks of quite complex data enables designers of communications boards to structure data accordingly. This combined with the lean idea of flow should lead designers of communications boards to ensure the design is structured so that information flows logically, and at each level of information there are seven 'chunks'.

The issue of colour is less easy to reconcile and the authors had to decide on a high colour approach or more subtle use of colour. We found the extensive examples and wide-ranging support from across communities of Tufte's approach (see http://www.edwardtufte.com/tufte/) more convincing than Greif's. Thus the more subtle approach to colour was chosen. From this literature review the VM principles, outlined in Figure 1, were developed for use by cell leaders.

2.4 *Development of VM principles from literature*

The review of the literature identifies the gap between the available design approaches and the implementation of these approaches to VM in practice. The purpose of this research was to bring academic approaches to the mostly practice led area of VM, to this end VM Principles were developed to aid TLs developing communications boards shown in Figure 1.

3. Case company background

The case company studied was Assa Abloy, a lock-maker in Willenhall, Portobello, West Midlands. There has been lock-making at this site for many years and Willenhall has been associated with the industry for at least three centuries. Assa Abloy is an international company with sales of 42 billion SEK (£4bn) over three regional divisions; Europe, North America, Asia and the Pacific (Assa Abloy 2015). They manufacture mechanical, electro-mechanical, and electronic locks and associated door furniture for a wide range of applications.

The Portobello site employs 320 people and manufactures £75 m p.a. of product across 20 cells. The cells assemble a wide range of single and multipoint locking devices, some cells manufacture components for assembly. Assa Abloy has been implementing lean since 2006 and the use of VM and communications boards was seen as a key part of their development particularly for CI (Bateman, Philp, and Warrender 2009a). Assa Abloy's cell level communications boards consist of two sides, the PAB side and the KPI side. They are used by TLs (cell leaders) to brief their teams daily at their morning meeting and solve ongoing problems at cell level. The PAB side provides daily data on production and documents any issues; the KPI side provides a longer term aggregation of this data to allow more detailed problem-solving focusing on specific areas and measures such as quality and delivery.

The site was selected for the research because of a desire by the management to improve their VM thus enabling the VM principles to be tested by application. Assa Abloy had pre-existing experience of lean and infrastructure of VM which meant that the focus of effort could be on testing more advanced VM principles proposed in the research, rather than laying the foundations of VM practices.

4. Methodology

An action research approach was used over a period of two years. The research studies two main stages of the use of communication boards: first, design of the 'KPI' side of the board including roll out to all the cells; and second ongoing use by TLs of the boards after they had been in place for 16 months. Data gathering was achieved by observation of existing practice, semi-structured interviews and taking photographs. Action research was used to study the implementation whereby the implementation process would inform the VM theory, and the need to improve practice by introducing theoretical ideas into practice (Checkland and Holwell 1998). The following section will first examine the framework of ideas and how the researchers' lean backgrounds influenced the research and implementation approach. Then the specific research and implementation process will be examined for the two stages of research previously identified: board design and roll-out, and ongoing use. A longer explanation of the action research approach is in Bateman, Philp, and Warrender (2009b).

4.1 *Lean Implementation and framework of ideas*

The purpose of this section is to examine the framework of ideas from which the authors operate, relating how knowledge is accrued, validated and acted upon, as recommended by Checkland and Holwell (1998). In this research, the experience of the authors as lean practitioners heavily influenced their research approach so to exemplify this, lean practice principles are related to an epistemological approach. These lean practice principles are commonly used in lean implementation activities to guide improvement teams but they also affect us as researchers in terms of what can be regarded as valid knowledge: The principles are: 'Speak with data', 'Seek consensus', 'Do it now' and 'Gemba'. These principles are shorthand for a way of thinking and are further explored below.

'Speak with data' in Bowman and Wittmer (2000) attributed to Drucker means that decisions should be taken based on facts father than opinion. This can force researchers into a wholly positivist paradigm, but the practice principles should be considered in conjunction with each other, so, considering the second principle 'seek consensus' highlights a need to also take into account people's experiences and views. This approach is expressed by Liker (2004) whose '14 Toyota Way' principles provides a good insight into the framework of ideas, specifically principle 13 applies 'Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly'. The consensus approach alludes to the team-based decision-making associated with lean improvement activities and the open forum

through which a broad range of ideas can be aired. This team-based approach is in contrast to expert imposed solutions where a technical specialist develops solutions and presents them to teams for implementation.

The third principle 'Do it now!' provides an emphasis on rapid implementation of ideas and gathering data from this implementation (recalling 'speak with data' principle) as opposed to spending time on the theoretical analysis. This places the knowledge of data and ideas with people doing the implementation rather than with a theory-based expert. The approach is for the team to discuss ideas, propose solutions and try them out, usually quite informally, and gather data on the implemented solutions. This ties in with the fourth principle 'Gemba' which means the workplace i.e. the place where the solutions are to be implemented. The idea behind the Gemba principle is that problem-solving is best done where the problem exists. This allows the team to fully realise the context of the problem and generate the best solutions and in a practical sense it also reduces barriers for the 'do it now' principle.

Considering these principles in the context of a research framework places the researchers as realists employing numerical approaches but not relying on these wholly – narratives by participants are also regarded as valid data. The 'do it now' principle along with a CI environment means that prolonged data collection is regarded as having limited use, because older data about operations activities quickly becomes outdated. In addition a general approach to implementation following the Deming Cycle (Deming 2000) of Plan, Do, Check, Act was also part of the researchers' approach. This fits with the lean practice principles and particularly the check stage fitting with the 'speak with data' principle.

4.2 *Research aims and process*

The purpose of this research was to test the research question 'Can the use of VM principles developed from established graphical communication practices and literature enhance the design of communication boards at cell level?' In the context of action research, this is broken down into three aims that include the aims of the industrial partners:

(1) To improve the utility of communications boards at Assa Abloy.
(2) To improve the process of the communication board development at future workshops both at Assa Abloy and other organisations.
(3) To test the application of VM principles in a shop floor environment and improve current thinking in VM.

Thus the research would operate at three levels, practice, workshop development and improvement of theory. The implementation process (Figure 2) began at T1 with a planning meeting where a Visual Management Development (VMD) team, composed of five TLs and a quality engineer supported by a facilitator.

The implementation process broadly followed the PDCA cycle, thus the planning stage involved the VMD team and set the objectives of the activity, and introduced the VM principles; the team critiqued the board's current design and made a plan for feedback to the larger group of TLs and relevant managers. The next stage was the new design of the board. This was based on the design of the existing and involved the VMD team updating the old design against VM principle and the objectives identified in the planning stage. The next stage was to roll-out the board by installing the new design in all the cells across the shop floor, and training of the TLs. The final stage was the use of the boards by the cells. These final two stages complete the Check and Act part of the PDCA cycle.

The action research nature of the project required the research process to be wrapped around the implementation process (Figure 3). The research consisted of two parts and was conducted by all three authors taking different roles. HW performed most of the hands-on facilitation, but with a reflective role too. NB was in the role of academic bringing ideas from the literature, noting observations and conducting interviews and LP, Operations Director was able to reflect on progress of the work and how it integrated with other parts of Assa Abloy.

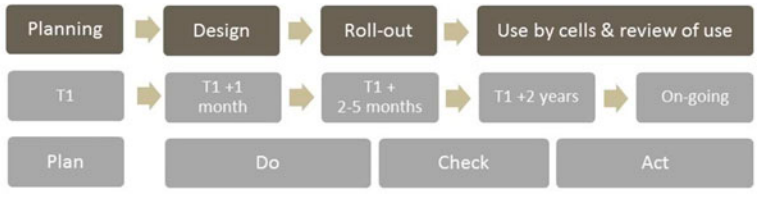

Figure 2. Implementation process, KPI board design roll-out and use.

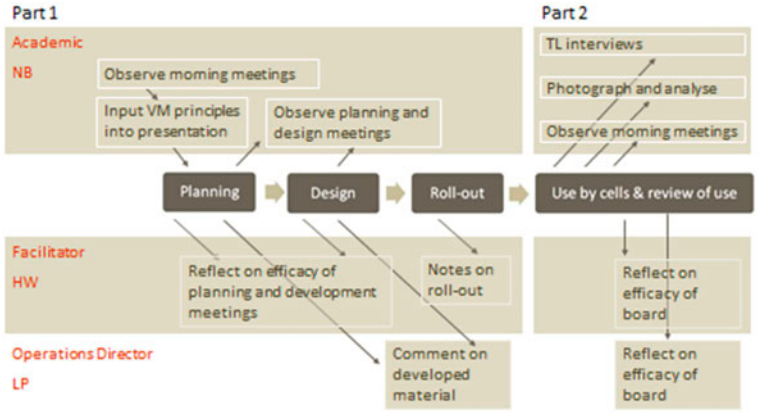

Figure 3. Research process.

4.3 *Research methods for part 1 – design and roll-out*

This section documents the research methods used in the planning, design and roll-out of the boards. Figure 3 shows NB initially observed 14 existing morning meetings by taking written notes of the process. This was done to establish the context of the research and help frame the VM principles. The purpose of developing these principles supports the third of the research aims 'To test the application of VM principles in a shop floor environment and improve current thinking in VM'.

These VM principles were then used to modify existing training materials for the design of communications boards. This updated training material was used in the planning stage of the implementation process (Figure 2) by HW for board design, thus addressing the second research aim 'To improve the process of the communication board development at future workshops both at Assa Abloy and other organisations'.

The research for the planning stage was documented by NB taking notes of the meeting and supplemented by photographs of the process. HW facilitated this meeting and he had a reflective contribution to the research methods (after the planning meeting) that supplemented the observations by NB. LP provided a commentary from a management point of view of the process, impact on other parts of the organisation and efficacy of the outcome. LP's commentary was not derived from the planning meeting itself but from the subsequent feedback meeting to the larger organisation.

The design phase research methods were similar to the planning stage with NB observing, taking notes and photographs and HW facilitating and reflecting on progress. The design stage took place over three meetings at which HW and NB were present. The final stage of part 1 of the research was the roll-out. This took place over six months with HW facilitating. At this stage, to achieve the research aims, required less real time research gathering methods and so HW took note of the resources required and time scales involved.

4.4 *Research methods for part 2 – board use*

This section documents research methods for part 2 when the boards were in use across the Portobello site and thus tests the first research aim 'To improve the utility of communications boards at Assa Abloy'. The research for this stage consisted of three elements: observation of the TL's morning meetings, analysis of the boards using photographs and semi-structured interviews of six TL's. This research was conducted by NB with additional input and observations by LP and HW.

The morning meetings are when the communications boards are mostly used and consist of the TLs conducting a meeting for their cell members and quality engineer and material supplier. This meeting sets the plan for the day and reviews yesterday's performance. It provides an opportunity to problem-solve as a team and uses data from the communications board to illustrate performance and support the problem-solving process. Observations were made of 14 morning meetings, all on the same day, by NB who took notes of what data from the boards was used and evidence of problem-solving activity from the teams.

After each morning meeting photographs of both sides of the board were taken, showing detail of; the material on the board, the TL with their board (as an aide memoire for NB) and macro shots showing the whole of each sides of the board to establish layout and flow.

The semi-structured interviews with six TLs were conducted on the same day as the morning meeting observations and were influenced by the researchers' observation of the morning meetings. These interviews allowed the TLs to comment on the utility of the boards and the interviews were structured around:

(1) When the TLs use the KPI and PAB sides.
(2) The burden placed on the TL by the need to fill in data on the board.
(3) How the TLs use the business summary.
(4) How the TLs use the KPI side.

The TLs were free to comment on other aspects they felt were important related to use of the board and their role as TL generally.

4.4.1 *Data analysis*

The photographs taken of each board were examined to identify the use of performance measures on the KPI side of the board, i.e. the extent to which the TLs were filling the data each week. This analysis of 14 boards considered a period of 13 weeks. It considered data variability over time, the extent to which TL's were documenting data over time (i.e. were any weeks missed) and identifying problems through use of the 'reasons for …' graphs. The particular performance measures used on the board are shown in Figure 4.

The use of photographs allowed a historical analysis of data use over a three-month period. Variability was included in this analysis because if the data does not vary over time there is little motivation for TLs to document it.

The semi-structured interviews were reviewed looking for themes that emerged from the observation of the morning meetings, analysis of the photographs and the interviews themselves. The research using observation, photographic analysis and interviews allowed a broad approach to be taken and took a snapshot on one day and allowed analysis of use of the board over the previous three-month period. The interviews also allowed specific issues to be explored and TL to express issues pertinent to them.

5. Results of implementation

This section reports the results of the implementation and specifically addresses research aims 2 and 3 that are concerned with industrial application.

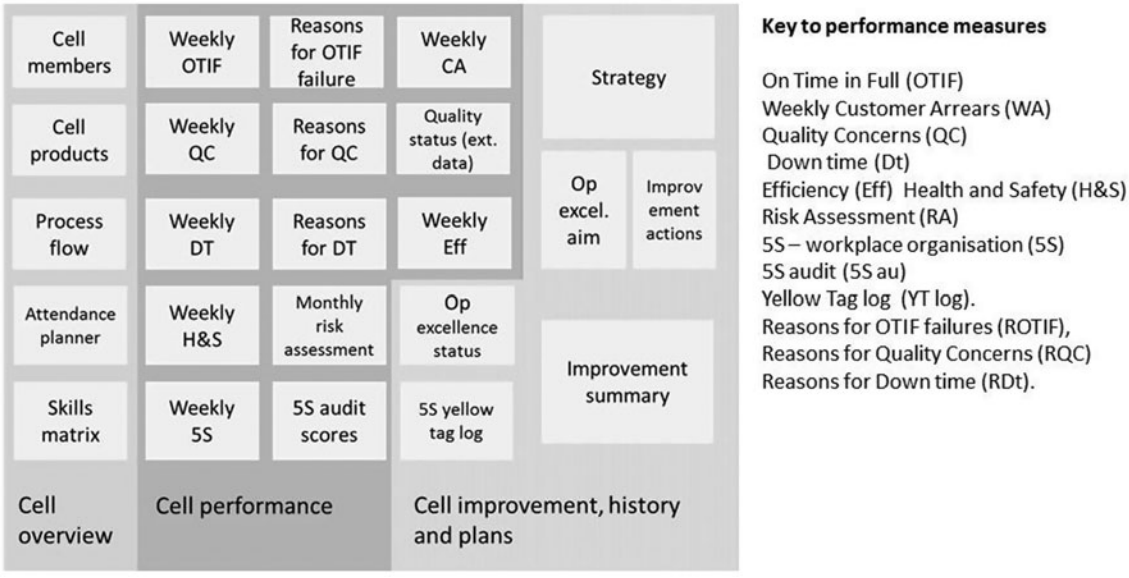

Figure 4. Schematic of communication board (KPI side).

5.1 *Part 1 design and roll-out*

The results for this section are based on observations principally by NB but with contributions from HW as facilitator and LP in a management role. It covers the first three stages of the implementation process shown in Figure 2, planning, design and roll out.

5.1.1 *Planning meeting*

The purpose of this planning meeting was to bring the initial VMD team together, identify the objectives for the redesign of the KPI board and plan a process for the redesign and roll-out to the rest of the site. From the researcher's point of view, this stage introduced the VM principles.

The objectives identified needed to be agreed by the team but in part, were already stated by Assa Abloy who had initiated the redesign process. Assa Abloy's objectives were stated on flip charts as;

(1) Develop a consistent approach for all cells.
(2) Make board measures and information easy to understand.
(3) Provide a clear link to overall company measures and targets.
(4) Make boards easy to update – help to ensure boards are always up to date.
(5) Make boards visually interesting – something that people want to look at.
(6) Ensure improvement issues are prioritised in a logical way.
(7) Build a robust link between data and actions.

These objectives were presented to the VMD team on a flip chart and the VMD team added:

(8) Simplify it and make it interesting.
(9) Make it easy to understand.

Objective 8 echoes objective 5 and objective 9 echoes 2, but 8 and 9 are from the TL point of view – the principles users, and emphasises the balance of usefulness to effort for them.

Most of this meeting was discussion of the current KPI board by the VMD team. Both in the light of VM principles, i.e. considering if the board layout reflected an appropriate briefing process, and the TLs' experience in using the board, for example, one TL said regarding an existing measure 'to my team this means nothing'. The TLs had clear ideas about what they liked, worked well and what did not, for example, Value Stream Maps were considered not to contribute to the objectives for the board design and so they were removed.

The overall design of the KPI board was considered. This macro-design process meant identifying the types of measures needed, how they might relate to each other and other reference material, such as cell skills. This was conducted using full size (A4) paper mock-ups tacked to the wall. Several iterations were required to develop a design the team were happy with and met the objectives for this stage of the process. The VM principle that was most heavily used was 'Use a board layout that reflects the flow and structure of the information you want to present'. The VMD team utilised this principle by thinking how they intended to use the board to brief their teams and in what order the graphical elements could most usefully be presented. To this end, the data were generally structured from left to right. The briefing structure identified at this stage of the design of the board became part of the coaching for material for TLs in the roll-out phase (Section 5.1.3).

5.1.2 *Design board*

The purpose of this stage was to convert the macro-design from the planning meeting into a detailed design by populating the A4 sheets with data and formulating a method of deriving the data. The design process was conducted over three meetings; two half-day and one full day. For each A4 sheet, the team considered how best to display the data, specifically; considering does it measure the right aspect, what is the best way to show this, how can we gather the data and what should its format be? This did take a great deal of consideration by the VMD and sometimes the aspiration of the macro-design was not possible.

The detailed design of each element of the board started to bring the VMD team into the remit of the first VM principle that of using the most appropriate graphical tool. The team seemed to have an instinctive feel for this principle, and were very particular about not conflating different types of data. The low use of colour they were happy to adopt and colour coding to indicate different types of data was readily implemented – with one colour adopted for assembly cells and another for component production cells. The third VM principle relating to minimising borders and graphical elements to maximise data to ink ratio was more complex. The VMD team could understand the principle but did not

have the technical skills to enact and so the detailed design of the graphs fell to HW who after a meeting would develop formats to show the team.

During the design phase, it became apparent that the representation of operational strategy was difficult to achieve. It was regarded at the management level that operational strategy should be on the board and as such it fulfilled some of the objectives in the redesign of the KPI side, namely '3. Provide a clear link to overall company measures and targets' and '6. Ensure improvement issues are prioritised in a logical way'. However, to show strategy and the link to higher level measures was a challenging element of the board design. The design of strategy representation went through several iterations but eventually a design was agreed.

Figure 4 shows a summary of the final design. The design shows three categories of data; cell overview – reference data relating to how the cell is organised; cell performance which changes weekly and monitors the status of the cell; and lastly cell improvement, plans and history which shows how the cell has progressed. Generally the flow of use, by TLs during the team meetings, would start from the top left of cell performance area and progress to the right of the cell performance section with reference to the cell overview and improvement, history and plans.

The final stage of the populate board stage was to assess the time needed by the TLs to complete the board each week. To test this and check that the board was viable, a time trial was conducted whereby two TLs completed the board for their cell. One TL took 12 minutes and the other 17. This was regarded by the TLs as acceptable and was crucial in giving confidence to the TLs to endorse the design to their peers knowing it was not too onerous to complete.

5.1.3 *Roll-out*

The roll-out phase used the board design and implemented in 23 cells across the site, phased over four months. A major element of support provided by HW was coaching TLs in how to add data to the board and how to use it as part of their role as a TL in the morning meetings.

Implementation issues were mainly focused around installing boards across 23 cells which placed a heavy burden both on HW in a facilitator's role and the support systems within Assa Abloy, with all 23 cells requiring support simultaneously. Observations from the TLs on the design at this stage included a positive support for the design of the KPI board particularly the reduction in unnecessary graphical elements (VM principle 3) and reduction in colour use (principle 2). Support for this design approach was sufficient such that the PAB side of the board was modified by applying these principles. A negative aspect of the design was regarded as the strategy representation, which was still deemed to be unsuitable and was again redesigned (twice). Generally, the reception by the TLs of the KPI boards was regarded as positive with TLs using the boards and publicised on customer visits.

5.2 *Results – part 2 board use*

These results examine the use of the boards 16 months after the roll-out phase was completed. Three data collection methods are used across 14 cells: morning meeting observations; a review of the use of performance methods using photographic analysis and TL interviews.

From the observations of the morning meetings, 10 TLs were judged to have used the data on the communications board to inform their morning meetings. Examples of using the data were demonstrating understanding such as pointing out trends during the meeting and examples of problem-solving include using data to take action. For example, one team had a discussion about reducing wrist strain from a repetitive process; another team discussed a quality problem where parts were too long. Not all the TLs had interactive meetings and some were a monologue by the TL with little contribution from their team. After the morning meeting, some TLs wanted to comment to NB on the board content, stating that the efficiency measure was not suitable – 'It's just the mix of work not efficiency', this measure drew much criticism and was also described as 'silly' and more diplomatically 'not that accurate'. Comments were also made about the strategy representation – which was out of date on all the boards. TLs commented 'Why have we not had March?' and another TL said they never used it anyway.

Despite the different approaches, all the TLs used the PAB side of the board and found it useful. The use of the KPI side was more mixed and some TLs were confident with the data, others said they never used it. It was clear that the communications boards were part of daily life for TLs at Assa Abloy, but the level of use and extent to which it was used for problem-solving were mixed. The review of the board using photographic evidence (5.2.1) provides the details of this use.

The observation process also revealed, unexpectedly, that the way the Area Managers (the level of managers above TLs) asked their TL's to use their boards was inconsistent. Some Area Managers asked their TL's to brief the KPI board

with their team whilst other Area Managers asked the TL's to take notes from their KPI board and brief as a group of TL's together in the staff canteen.

5.2.1 *Photographic review of performance measures*

This analysis of 14 boards considered a period of 13 weeks looking at data variability over time, the extent to which TLs were documenting data, identifying problems and then problem-solving. This approach allowed a historical analysis of data over a three-month period. The particular performance measures used on the board were: OTIF, WA, QC, Dt, Eff,H&S, RA, 5S, 5S au and YT log (see Figure 4 for explanation of acronyms). In addition to these graphs, causes of problems for three of these measures were also logged, specifically: Reasons for OTIF failures, Reasons for QC and Reasons for Dt.

Figures provide a summary of the performance measures use. The primary measures are shown in Figure 5. Figure 5 with how many of the 14 cells used each measure and which of these measures showed variability over time.

The most commonly used measures were: OTIF, WA, Dt and Eff. Of these OTIF was identified by the TLs as the most important, a TL commenting '(we are) mostly driven by OTIF'. From Figure 5 Efficiency (Eff) might be considered the most useful and used measure because of its consistency in being filled in by the TLs and its variability. But comments from TLs after the morning meeting undermine this supposition.

The 'reasons for' charts are shown in Figure 6 and show level of use of these charts. The 'reasons for' charts represent a deeper level of problem-solving by looking for underlying causes of re-occurring problems so would not necessarily be used for all problems. The percentage of valid recordings is calculated by the number of cells who recorded 'reasons for' divided by the number of cells where reasons might be explored. So, for example, ROTIFF (reasons for on time in full failure) all 14 cells recorded OTIF; of these 12 had some variability, in this case each of these 12 cells might want to explore the reasons for this as a route to problem-solving, but only three of the twelve have done so, i.e. 25% shown in Figure 6.

Figure 6 shows that the use of reasons chart is most commonly used for quality control issues (QC), half of the valid recordings resulted in use of the reasons chart. This is compared to down time (Dt) and on time in full failures (OTIF) that have lower levels of use, 44% and 25%, respectively.

5.2.2 *Team leader interviews*

The six interviews allowed the TLs to comment directly on the use of the boards. All of the TL liked and used the PAB side, in addition they did not find the KPI side particularly onerous to complete – a maximum of 20 min was cited. What did emerge was that some TLs were too busy dealing with day-to-day issues to properly engage with their boards. In a lean context, this would be regarded as instability in the current situation, i.e. the cell was not stable enough to allow CI to take place. Nonetheless some TLs used the boards fully and demonstrated very good understanding of the

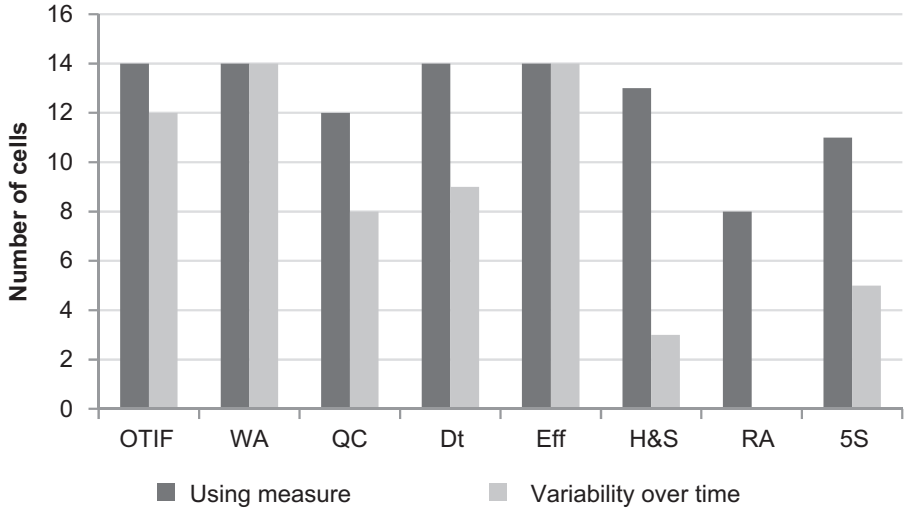

Figure 5. Use of measures and variability of measure (14 cells over 13 weeks).

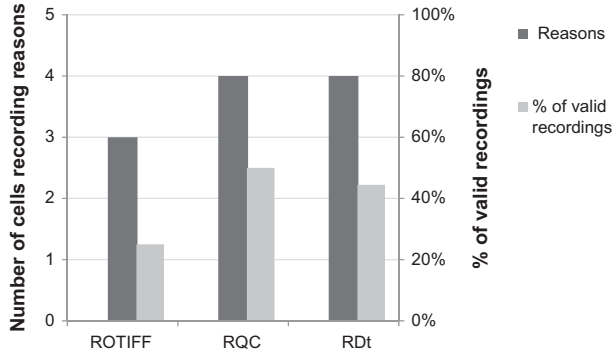

Figure 6. Use of 'reasons for' chart by cells.

data and production control principles e.g. 'I use it (the KPI board) weekly its helps clarify a reoccurring problem, if you've got shortages you may need to increase your kanban'. Between these two extremes were TLs who used and understood some elements and not others, for example, the more sophisticated 'reasons' graphs. This medium level group did perform some improvement but these were straightforward such as modifications to operating practices for safety improvement.

6. Research results and discussion

This section considers the research results derived from Section 5, the results of implementation and relates back to the research question and the third research aim firstly examining the extent to which the VM principles were used (6.1), secondly the extent to which they enhanced the design (6.2) and finally any other research results (6.3).

6.1 *Application of VM principles*

These VM principles were happily accepted by the TL, evidence from part 1 of the research shows that although the TLs generally accepted the VM principles their ability to execute these were limited by their skills and access to technology. As part 1 results state HW (facilitator) had to do the detailed design of the graphs used in the layout of the board because the VMD team were not used to using Excel type software to design graphs. This is an example of low modifiability as defined by Bresciani, Blackwell, and Eppler (2008) and shows how technology can act as a barrier for stakeholders in the design process.

6.2 *VM principles to enhance the design of the board*

The design of the board was regarded as enhanced if the board was used more, encouraged the TL's to be more involved with the data and approach was adopted for other applications. The redesign of the KPI side and PAB side has more fully involved the TLs with CI and 10 of 14 cells at the time of observation demonstrated problem-solving. This was supported by the TL interviews and the photographic analysis. The design approach was adopted and applied retrospectively to a pre-existing design on the PAB board.

For Assa Abloy, this process has been an important part of their maturation in lean terms and in tune with the lean CI approach. Development of VM techniques for Assa Abloy is an ongoing work and the design and use of the boards continue to evolve as improvements are devised and better ways of working are conceived.

6.3 *Other research results*

The interviews and observations revealed that the role of the Area Manager was an issue, with the way that Area Managers asked their TLs to use the board being inconsistent. This may have been caused by the Area Managers not being involved enough at the early phases of the design of the board and therefore not having sufficient ownership of the process. It is also possible that the three levels of use of the board identified in the TL interviews are also at least partially caused by the Area Managers, in that the low level TL users have cells that need extra resource to be stable enough for CI to take place. Stability is a prerequisite for CI as identified by Imai (1997) and Deming (2000). For the medium level users, the Area Managers may not have not coached these TLs up to the standard of the high levels users. A primary

role for Area Managers is the development and mentoring of their TL's who may have good operator skills but often need formal coaching on the management and leadership. This change of role for the TLs is also identified by Greif (1991) who typifies the change of roles for TLs as changing from instruction of commands to motivating and seeking results through influence. Thus for TLs to fulfil their role of enabling CI, they need both stability and a supported process for incorporating changes from their team, as suggested by Bateman (2005). This supported process means both the physical infrastructure of the communications boards and the managerial infrastructure of their managers.

During the roll out of the design, the burden placed on the resources required to install and start using the boards was substantial. The kinds of resources are: physical installation of the board; preparation of the sheets to populate the board; and coaching by HW on how to use the board. This kind of approach of applying one tool (in this case VM) is known as a platform (Hines et al. 2008) and often demands a high level of resources at one time.

7. Conclusions

This research tests the efficacy of the VM principles developed from the literature. It complements recent papers by Bititci, Cocca, and Ates (2016) and Jaca et al. (2014) by addressing the design and implementation of a shop floor-based VM and has acted as a proof of process for the introduction of VM theory into the design of communications boards. There is evidence that these principles improved the design of the board in the form of wider use by Assa Abloy. There is strong evidence that the TLs engaged in problem-solving and CI with their teams, thus supporting the idea that 'the use of VM principles developed from established graphical communication practices and literature can enhance the design of communication boards at cell level' raised in the research question. In terms of the research aims:

(1) To improve the utility of communications boards at Assa Abloy.
(2) To improve the process of the communication board development at future workshops both at Assa Abloy and other organisations.
(3) To test the application of VM principles in a shop floor environment and improve current thinking in VM.

The first research aim has been achieved. The second aim is addressed by the study of the design and implementation process and has highlighted a number of issues, including the role of the middle manager (Area Manager), the support needed by TLs to fulfil their role of CI, the problem of communicating strategy that relates to shop floor level and the importance of getting performance measures calculated correctly for them to be relevant to TL. The final aim to test the VM principles was demonstrated by the ready adoption by the team designing the board and furthermore was applied beyond the original design and retrospectively applied to a pre-existing design on the PAB board.

VM and communications boards are an attractive approach for organisations wanting to engage their teams and first-line managers in participative discussions and problem-solving. This research outlines an approach that was successfully taken by Assa Abloy, but also highlights the high levels of resources required. In addition it emphasises that this is an ongoing work and cannot be considered to be completed as a project. What can be considered to be completed is a change in the TLs' approach and role, evolving into a more data driven, facilitating position charged with responsibility for problem-solving at cell level. The acceptance of the VM principles demonstrates it is possible to apply theory about design to this principally practice led area. This approach represents a contribution to the field of VM.

Limitations of the research are those typically associated with single case-study research, i.e. success in the case does not guarantee achievement in other organisations. Nor does the research ensure repeatability; however, this is not the aim of action research using the PEArL approach (Champion and Stowell 2003). But detail provided allows practitioners and researchers 'recoverability', i.e. that 'learning outcomes are understandable to other parties' (Champion and Stowell 2003, 21). The approach taken at Assa Abloy is clearly possible for other organisations but the high level of commitment required is likely to be a barrier. Future work could focus on whether this level of commitment the benefits accrued is worthwhile and the VM principles could be tested in more depth for their efficacy.

Disclosure statement

No potential conflict of interest was reported by the authors.

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