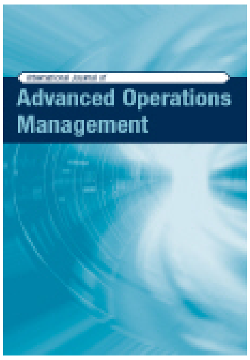


International Journal of Advanced Operations Management

ISSN online: 1758-9398 - ISSN print: 1758-938X
https://www.inderscience.com/ijaom

Visual management in the era of Industry 4.0: perceived advantages and disadvantages of digital boards

Robin von Haartman, Linda Samen, Lisa Bengtsson, Stefan Eriksson

DOI: 10.1504/IJAOM.2023.10052710

Article History:

Received:	20 December 2021
Accepted:	26 September 2022
Published online:	13 March 2023

Visual management in the era of Industry 4.0: perceived advantages and disadvantages of digital boards

Robin von Haartman*, Linda Samen,
Lisa Bengtsson and Stefan Eriksson

Department of Industrial Management,
Industrial Design and Mechanical Engineering,
University of Gävle,
Kungsbäcksvägen, 80176 Gävle, Sweden
Email: Robin.vonHaartman@hig.se
Email: linda.samen@orangecyberdefense.com
Email: lisa-bengtsson@hotmail.com
Email: Stefan.Eriksson@hig.se
*Corresponding author

Abstract: The purpose of this paper is to investigate digitalised visual management, with a focus on the relative advantages and disadvantages of digital and analogue boards in manufacturing. The case study of this paper was conducted at two different business units within the same large multinational company, Sandvik. Data was collected through 15 unstructured and semi-structured interviews with managers and machine operators. More advantages than disadvantages with digital boards were found. Only two disadvantages are absolute, while the other disadvantages can be counteracted to some extent. Currently there is a shortage of studies exploring advantages and disadvantages of digital boards as visualisation tools. This paper is based on a single case study focusing on stoppage causes, and thus cannot be fully generalised to all manufacturing companies or all contexts. The actual performance effects of analogue and digital boards were not examined in this paper. The findings are applicable for managers considering investing in digital boards in manufacturing, to be used for continuous improvement but also for other production-related applications.

Keywords: continuous improvement; visual management; Kaizen; improvement boards; Industry 4.0; lean manufacturing; digital lean; display boards in production.

Reference to this paper should be made as follows: von Haartman, R., Samen, L., Bengtsson, L. and Eriksson, S. (2023) 'Visual management in the era of Industry 4.0: perceived advantages and disadvantages of digital boards', *Int. J. Advanced Operations Management*, Vol. 15, No. 1, pp.24–41.

Biographical notes: Robin von Haartman is an Associate Professor of Logistics and Supply Chain Management at the University of Gävle, Sweden. His areas of interest include manufacturing strategy, digital lean, and green logistics.

Linda Samen is currently working as an Advisor within the cybersecurity area in Stockholm, Sweden. She has received her Bachelor of Engineering in Industrial Engineering and Management from the University of Gävle, Sweden. Her area of interests includes change management, agile management, customer success, cybersecurity and cybersecurity awareness.

Lisa Bengtsson has received her Bachelor of Science in Engineering with specialization in Industrial Engineering and Management from the University of Gävle. She currently works as a Global Planner at Sandvik Mining and Construction Tools.

Stefan Eriksson is a Lecturer in Logistics at the University of Gävle, Sweden. His areas of interest include manufacturing logistics and warehouse management.

1 Introduction

There have been four industrial revolutions, with the fourth, also known as Industry 4.0, currently ongoing and especially concerned with connectivity (Liao et al., 2017; Lu, 2017). Dombrowski et al. (2017) agree and see digital networking of people and equipment as a key aspect of Industry 4.0. In a systematic literature review, Chiarini (2020) finds that relevant topics for future research include automated collecting and sharing of data, as well as developing the skills to analyse and interpret the data in order for employees to take appropriate actions.

Bhuiyan and Baghel (2005) mention that due to the need to stay competitive, organisations have needed to develop methods to improve quality and/or processes, to reduce waste and to simplify the production line. One of the most commonly used methods for achieving these improvements is lean production (Liker, 2004; Emiliani, 2006), where the focus is on the ability to improve (Rother, 2009). Womack and Jones (2003) explain that a visibility where everyone can see the current production status is a critical part of the principles and techniques of lean. Building on the arguments of Womack and Jones (2003), Ortiz and Park (2011) discuss the 'visual factory' and its significance. The visual factory is about making information available, which means that the information that production personnel need to make the right decision is available at any given time and place (Parry and Turner, 2007). According to Womack and Jones (2003), a whiteboard is a good example of visual control and of how it is possible to make information visible in such a way that all employees can see it and take the necessary measures. Parry and Turner (2007) emphasise the use of boards, claiming that the board is the hub of the improvement work. These whiteboards, commonly used in lean production, are analogue and typically easy to use.

However, digitalisation and Industry 4.0 promise many benefits (Riezebos et al., 2009; Liao et al., 2017; Chiarini, 2020). For example, with the help of digitalisation, information can become more accessible and facilitate visual guidance and control during improvement work (Meissner et al., 2018). However, currently there is a shortage of studies exploring the actual advantages and disadvantages of digital boards as visualisation tools. The purpose of this paper is thus to investigate digitalised visual management, with a focus on the relative advantages and disadvantages of digital and analogue boards in manufacturing.

The paper is based on a case study of a large multinational engineering group, with the studied production units located in Sweden. Managers and operators from multiple units of the same company were interviewed as well as one provider of digital boards for production environments. This paper will be limited to improvement work aimed at minimising machinery stoppages and the role digital and analogue boards can play.

2 Literature review

The concept of lean is many decades old and can be traced back to its origin as the Toyota production system (Liker, 2004; Emiliani, 2006). The huge success Toyota achieved in the automotive industry did not go unnoticed, and lean subsequently spread, first to other automotive companies and then to other sectors throughout the world (Marley and Ward, 2013; Bhutta et al., 2017). Throughout the process, the lean concept has evolved from focusing on production efficiency by consistently and thoroughly eliminating waste to 'continuous improvements' and 'respect for people' (Emiliani, 2006; Rother, 2009). Imai (1997) and Marley and Ward (2013) also put the prime emphasis on continuous improvement or kaizen. Successful lean approaches are often seen as a combination of 'hard' (routines and structures) and 'soft' (culture, attitudes) aspects (Solaimani et al., 2019). Previously, there has been a debate on whether the digitalisation trend is compatible with lean (e.g., Powell, 2013). This argument has partly been built on the fact that the Toyota production system was designed in *contrast* to Western companies' reliance on IT and automation (Riezebos et al., 2009). Likewise, Hirsch-Kreinsen (2016) discusses the 'clash' between Industry 4.0 and established production practices such as lean. Lately, the arguments and empirical evidence have pointed towards a more synergistic relationship between the two concepts. For example, both Rossini et al. (2019) and von Haartman et al. (2021) found strong correlations between lean practices and digitalisation. Rosin et al. (2020) mapped which particular components of Industry 4.0 fit well with which particular components of lean, finding many examples of synergistic relationships. Similarly, Saxby et al. (2020) found some elements of lean, and most of all continuous improvement, to be helpful when integrating new Industry 4.0 technologies.

2.1 Waste

Ortiz and Park (2011) mention that a large part of lean is about reducing waste. By developing, maintaining and improving the visual factory, a significant amount of waste can be minimised or eliminated. Womack and Jones (2003) also mention that a company can increase efficiency by visualising, reducing and eliminating waste. Lean distinguishes among seven, or in some cases eight, different types of waste (Ortiz and Park, 2011): overproduction, overtime, waiting (for information, components or tools), movement, transport, inventory, production of defective products and unused competence.

Nilsson et al. (2019) claim that it is digital waste to use digital lean boards instead of analogue lean boards, because the majority of the data used in an analogue improvement board is printed from digital platforms in any case. However, if the displayed data is not used for improvement, it can also be considered a waste (Alieva and von Haartman, 2020), irrespective of the type of board. Nilsson et al. (2019) base their claim on Sutrisno and colleagues' (2018) definition of digital waste, such as duplication of work, poor planning, poor measurement, poor coordination, increased overheads and overdesign. Alieva and von Haartman (2020) discuss how uncollected, unused and unprocessed data leads to more waste in production. Systematic methods for collecting, analysing and using data are likely to lead to reduced waste, whether it is done manually or automatically. However, the abundance of data in contemporary manufacturing means that it could be unfeasible to collect and process the data manually (Tao et al., 2018). However, there is a risk of displaying too much data, which is greater when done automatically (Parry and Turner, 2007). According to Weber et al. (2017), one of the main goals of Industry 4.0 is the integration of IT systems in production, which relies on collecting, storing, processing, transforming and integrating data.

2.2 Visual control

According to Womack and Jones (2003), total visibility, where everyone can see relevant data, is a critical lean principle. The authors explain that transparency and visual control are needed to clearly highlight the current state of the production system so that any problems can be observed with a quick overview. According to Womack and Jones (2003) and Poksinska et al. (2013), whiteboards are a good example of visual control that show how it is possible to make information visible to all employees and give them a sense of data ownership, so they can take necessary measures. On such boards, key values of the production system can be shown in numbers or via simple diagrams (Poksinska et al., 2013). Information boards and visual inspection inform observers about the status of the factory and can warn if, for example, the takt time is not reached and actions need to be taken (Womack and Jones, 2003). Ortiz and Park (2011) discuss the importance of having a visual factory, the entire production and support functions in a visual management system that includes visual communication and visual control. In short, visual control is about making key business, product and process information available at the right time, in the right place and to the right target group, throughout the factory (Ortiz and Park, 2011), which is also a key aspect of quality control in the Industry 4.0 era (Chiarini, 2020).

2.3 Continuous improvement and boards

A central part of lean is continuous improvement, i.e., a long-term improvement programme that involves most, if not all, employees (Liker, 2004). If this is not permanently included in a companywide lean way of working, there is a risk that the positive effects that have been achieved in the short term can disappear and bring the company back to where its lean journey began (Rother, 2009). The improvement work is about slowly but surely reducing waste in operations and thereby increasing the share of value-creating activities (Bhuiyan and Baghel (2005). The improvement work can also be seen as "a companywide process of focused and continuous incremental innovation…" aimed at both products and processes (Bessant et al., 1994).

Establishing effective improvement work requires visualising the waste and deviations in production. Poksinska et al. (2013) describe the board as a relevant tool and hub for the improvement work. A board contains, among other things, ongoing activities, who is responsible, where in the plan-do-check-act (PDCA) cycle the activity is located, and when it should start and be ready (Eaidgah et al., 2015). According to Parry and Turner (2007), a notice board serves as a good meeting place for employees to discuss the ongoing improvement work and how they should prioritise new tasks. If a company wants to achieve results, it must be clear what the improvement is about, who is responsible and when it should be ready (Eaidgah et al., 2015).

Swartling and Poksinska (2013) mention the following areas as crucial in continuous improvements: communication, visualisation and cross-functional and cross-competence improvement work. These are all linked. For example, visualisation is used for communicating important information to employees and to get feedback from them. Moreover, visualisation can contribute to enhanced feelings of empowerment by making visible the improvements that have been made. Whiteboards can be used to visualise the work around continuous improvements and can contain information about the current status of operations and improvement work (Swartling and Poksinska, 2013). If the employees are given responsibility for the improvement work from proposals to implementation, this will motivate them in the improvement work.

2.4 Digital boards compared to analogue boards

Meissner et al. (2018) mention several advantages of digitalisation in the manufacturing industry. One advantage is that the information from production does not need to be retrieved manually by the staff, which saves them time. Digitalisation contributes, according to Meissner et al. (2018), to higher transparency of the production process; one advantage is that problems are made visible at an earlier stage compared to a non-digital system. Hultin and Mähring (2014) found in a study at a hospital that one advantage of digital pictures was that the staff could access the same information regardless of where they were. Similarly, managers can help operators from a distance when the board is digital and thus not only available in a specific physical location as an analogue board is (Meissner et al., 2018).

Nilsson et al. (2019) reported benefits of having digital boards compared to analogue boards at the workshop level. One of the benefits was the archiving of data and having the data stored in the IT system, compared to having it in respective individual managers' mobile devices. The latter also makes the system vulnerable, as some managers may be the only people with access to vital information. With a digital system, managers also have instant access to historical data. By using or archiving data, transparency in a company is enhanced and the creation of knowledge silos is avoided (Nilsson et al., 2019). One company noted after the implementation of digital lean boards that the feedback from the employees had increased, and it was easier to make changes and the process was more manageable. These effects were due to the fact that information was concentrated in one place and easy to find.

Despite the advantage of staff not having to manually retrieve data, there is also a disadvantage when the employees do not take part in retrieving the information. This may make them less likely to identify with the information. Parry and Turner (2007) discuss the factors that contribute to the success of visual management and conclude that companies should stick to analogue visual control systems, as visual management systems should be kept simple and only include information that adds value to the process. Parry and Turner (2007) explain that a software or computer-based system provides the ability to display redundant information, while the limited space of a physical analogue board means that the focus must be on what is actually relevant to visualise. This critique is also consistent with Meissner et al. (2018), who explain that, due to the high availability of data, there is a risk that a company monitors too many key performance indicators (KPIs). Parry and Turner (2007) also point to digital boards requiring more knowledge in the digital field, which will limit some people's ability to make full use of them. This makes local experts in the factory inevitable. To counteract this problem, Nilsson et al. (2019) emphasise the need to train shop-floor operators. A digital board is also more expensive than analogue boards, and technical support may also be required (Parry and Turner, 2007). Table 1 summarises the relative advantages and disadvantages of digital and analogue notice boards.

Table 1 The advantages and disadvantages of digital improvement boards

Advantages	*Disadvantages*
Staff do not have to download data manually to the board (Meissner et al., 2018).	Staff identify less with the information (Meissner et al., 2018).
Automatic updating of data (Meissner et al., 2018)	Redundant information is displayed on the board (Parry and Turner, 2007).
Higher transparency of the production process (Meissner et al., 2018)	Too many KPIs are monitored (Meissner et al., 2018).
Not linked to a physical place (Hultin and Mähring, 2014; Meissner et al., 2018).	Requires some digital knowledge (Parry and Turner, 2007)
Digital archiving, unlike a whiteboard where the information disappears when it is erased (Nilsson et al., 2019)	The board and accessories are expensive (Parry and Turner, 2007).
All information is gathered in one place (Hultin and Mähring, 2014; Nilsson et al., 2019).	

3 Methods

Case studies aim to investigate contemporary phenomena in real-life situations where the researcher has little or no control over events (Yin, 1994). The strength of case studies lies in that the researcher is given the opportunity to investigate complex relationships and processes. According to Yin (1994), one of the strengths of case studies is that they can include various types of evidence such as documents, interviews and artefacts.

The case study of this paper was conducted at two different business units within the same large multinational company, Sandvik: Sandvik Coromant (referred to as simply Coromant) and Sandvik Mining and Rock Technology (SMRT). In different departments within these units, the participants had different roles. Thus, different working methods were noted, analysed and compared with each other and with the theoretical frame of reference. This paper does not distinguish among the different business units, collectively referring to them as Sandvik. Sandvik is a relevant case to study, as it is a global engineering group where industrial production takes place. Advanced production machinery are a central part of their operations, and it is important to reduce stoppages. Moreover, Sandvik is one of the most innovative companies in Sweden, ranked fifth in terms of number of patent applications (Nyteknik, 2018). Most importantly, the company has lately been developing and introducing a digital concept called CoroPlus which is a collection of digital products for helping their customers in the metal-cutting industry reduce waste and increase productivity such as CoroPlus Machining Insights. In addition, a supplier of digital notice boards, Mevisio, is included in the study to get the perspective of an IT system supplier. Sandvik is a potential customer/partner of Mevisio.

During the course of the work, a total of 12 semi-structured interviews were conducted with employees with varying titles from Sandvik. Of the interviewees, four were machine operators, two technical managers, and one from each of the following job titles: maintenance engineer, method development engineer, Six Sigma black belt, line manager, production manager and generic engineer. The interviews with Sandvik discussed digital and analogue boards and improvement work, partly in general but also more focused on the causes of stoppages. The interviews lasted about 45–60 minutes each and took place over Microsoft Teams (due to COVID-19 precautions).

Before the interviews, questions were sent to the interviewees in advance, so that the respondents could prepare. Follow-up questions and new questions were added during the interview. All interviews were recorded and transcribed. If ambiguities arose when transcribing the data, the interviewees were contacted again via the Microsoft Teams chat feature. In addition, three unstructured, 60-minute interviews were also conducted, where the purpose of the interviews was to find out more about the employee's work.

Different sources of information, perspectives and knowledge allowed for triangulation (Yin, 1994), with the purpose of increasing validity. Another tactic to increase validity was to establish a trail of evidence (Yin, 1994), in the systematic collection of data. To further increase the validity of this work, key interviewees were given the text that summarised their interviews in order to ensure that nothing was misinterpreted or distorted. Yin (1994) states that statistical generalisability is not relevant for case studies, whereas analytical generalisability is a more appropriate tactic. The interviewing of people from several different production units has also increased generalisability to some extent.

4 Case description

Coromant sells tools and cutting services. The company employs more than 7,900 people and owns more than 3,100 patents worldwide. SMRT employs about 15,000 and is active in the mining and construction industry, where they deliver machines, tools, services and technical solutions.

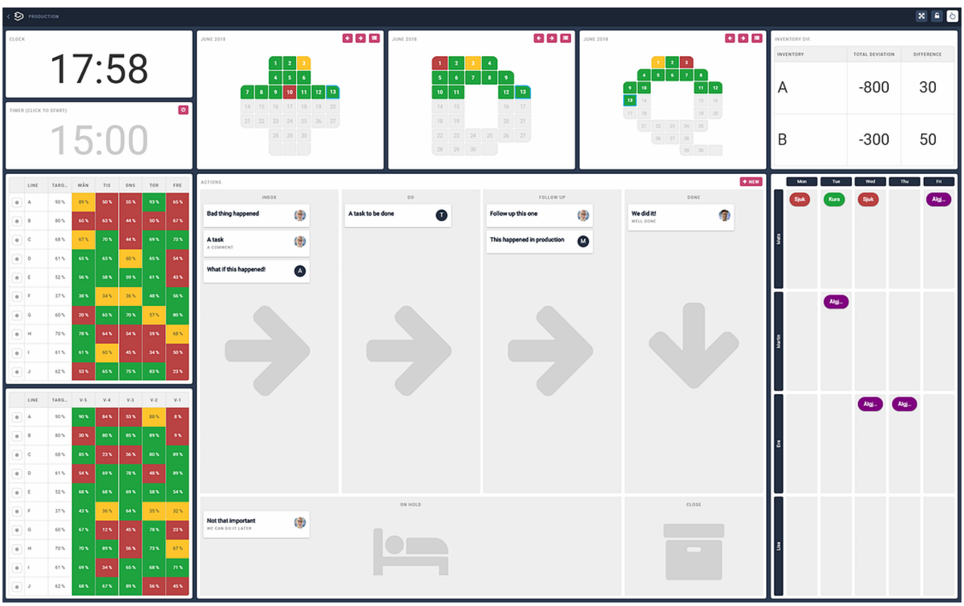
When the work started, Sandvik Coromant and Mevisio had just started a collaboration with the aim of designing a digital board based on Coromant's digital product CoroPlus Machining Insights. Mevisio offers a digital platform built up of several modules that can be integrated with other systems. The idea was that Mevisio would extract data and information from the Machining Insight system and display it on digital boards. Mevisio is a small company that offers a digital platform that delivers digital visualisation for managers and teams in operations. The company's customers include both manufacturing companies and public healthcare providers. Mevisio's boards are always customised and are used for daily control, 5S and continuous improvement.

4.1 CoroPlus Machining Insights

CoroPlus Machining Insights is a system that collects and analyses manufacturing data in order to improve workshop efficiency and total equipment efficiency. The system collects information continuously from machines, where, among other things, it can show the distribution between operating time and downtime, and provide information about machine stoppages. Operators can fill in reasons for why the machinery has stopped and also categorise whether it is a planned or unplanned stop. They can then specify further details, for example, whether it is a planned stop due to service or an unplanned stop due to tool failure. Stoppage causes can also be automatically classified using the noise and vibrations that the machines make. When an alarm occurs and the machine stops, it can be programmed automatically to categorise a stop cause.

The system also includes a feature for suggestions for improvement, which is referred to as creating a ticket. Operators can assign tickets to themselves to make themselves responsible for performing the improvement. When creating a ticket, the following information is required: categorisation (e.g. maintenance, operations, programming or quality), free text comments, machine number and machine group.

Figure 1 Example of a digital board (see online version for colours)



Source: Mevisio

4.2 Improvement work at Sandvik

Because interviewees work in different departments, the methods for continuous improvement also differ, and two different modes were detected. One of the methods is more digital, whereas the other is primarily analogue.

4.2.1 Analogue improvement work in department 1

Every morning, the production team has a so-called pulse meeting where they examine the current status using associated information. During the meeting, they use two analogue boards, where, among other things, information is provided about the improvements that are relevant, who is responsible for the action, start date, planned end date and the actual end date. Current PDCA cycles can also be shown on the board, along with a graph of the number of improvements made. The procedure states that they print the PDCA cycles on paper, which they then put up on the board. The board serves as an overview of improvement work that is taking place right now. In addition to the pulse meetings, at weekly improvement meetings the operators speak freely about the problems or wishes that exist. During these meetings, they can show, among other things, an extract of current causes of stoppage. They also have monthly meetings, where they discuss the biggest stoppage causes in the past month. To know which machines should be prioritised during these meetings, they classify, based on annual forecasts, which machines are most important. Table 2 shows a summary of the meeting.

Table 2 Boards and tools for different meetings

Frequency	*Daily*	*Weekly*	*Monthly*
Participants	Operators	Operators	Production technicians
	Production technicians	Production technicians	Flow manager
	Flow manager	Flow manager	Maintenance engineers
			Maintenance planners
			Production-technical manager
			Plant manager
Boards and tools	Pulse board	Microsoft Teams	Effecto
	Improvement board	Word	One Note
	Target boards	Excel	PowerPoint
	(all analogue)	Fadector	Power BI
		Power BI	(all software)
		(all software)	

A problem mentioned in one of the interviews was that the operators were not particularly involved in making improvements. This could be due to the operators feeling monitored and due to deficiencies in information sharing. Due to shift work, not everyone noticed when a person implemented an improvement, and those operators received no information or feedback. They sometimes felt that nothing was happening and that it did not matter how many suggestions they submit.

All interviewees use the same programme showing machine utilisation rate and the identified stoppages. When a stoppage occurs, it is displayed as a deviation in the machine time line in the programme, giving the operator the opportunity to go in and choose a main cause, a sub-cause and then add free text comments in more detail on the cause. This can be problematic for two reasons. The first problem is that when the stoppage cause is analysed, it is difficult to sort among the causes and takes some time to analyse the data. One reason is that there are only two levels of categorisation, and the comment that the operator can make is written in free text and thus cannot be used as a filter when searching the database. The second problem is that it is not mandatory for the operator to fill in and classify the cause of the stoppage. This means that not all stoppages are registered, as it is dependent on the commitment of each operator. Even when the operator registers the stoppage in the system, the information may be insufficient. Some of the interviewees mentioned that they had been given goals regarding what percentage of the stoppages they should comment, typically ranging from 80% to 90%.

4.2.2 Digital improvement work in department 2

Previously, department 2 had weekly meetings, where they gathered in front of a whiteboard and collected suggestions for improvement as they arose. If the operators came up with suggestions for improvement during the week, they could bring it up at the weekly meeting. However, the number of received suggestions for improvement was considered too few. A suggested reason was that employees felt uncomfortable speaking in public.

Today the company uses Microsoft Forms to collect improvement suggestions. In the production area, there are QR codes that operators can scan with their mobile phones to open a suggestion form. In the form, the operator can choose either machine or machine group and then describe the actual improvement proposal. It is voluntary to fill in their names in the proposal, but employees are encouraged to do so in order to show that someone actually wants this improvement. In some cases, the description of the improvement may also be unclear and follow-up questions need to be asked. Following the introduction of Microsoft Forms, the number of improvement suggestions increased and the majority also write their names on the proposal.

The submitted answers are entered into an Excel file and are automatically entered into the Microsoft Teams Planner as an activity. In the software, the company has different groups for each production flow; every group has an improvement board. Depending on what the operator has written in the improvement form, the improvement proposal will end up in the Teams group that applies to that particular flow and for the machine or machine group for which the improvement applies. The production technician responsible for the machine automatically becomes responsible for the activity, but it is usually not the same person who will actually implement the improvement.

The operators are involved in the improvement work and can be responsible for the improvement if appointed by the production engineer. The operators only have access to their own team group and cannot see improvement suggestions for others. Previously, there was no automatic division of responsibilities for the activities in the planner, and the weekly meetings were used to go through the proposals one by one and to delegate tasks to different managers, which meant the process could take quite some time. The process became more efficient when the production technicians automatically became responsible for an activity and began to delegate it to a suitable employee.

Currently, weekly meetings take place in front of an 80-inch touchscreen where they monitor progress in the improvement work. In addition to the view with the improvement suggestions, there is a view with diagrams. One of the diagrams shows the distribution of improvement status: not started, ongoing, late and completed. Another diagram illustrates how many improvement suggestions there are for each machine or machine group. A third chart shows the classification of improvements as urgent, important, medium or low. The responsible person is also shown in a chart, where the status (not started, ongoing and late improvements.) of tasks is shown for all individuals. The manager responsible for delegating the improvement proposals uses this diagram to see what the division of responsibilities currently looks like and who would be an appropriate person to delegate a new improvement proposal to.

Improvements may not be implemented if they are considered not feasible or to require excessive effort for the value added. This type of prioritisation of proposals is based on a 2×2 priority matrix, where the degree of value assumes one axis and degree of effort assumes the other. Suggestions that require little effort and generate the greatest value get the highest priority. The responsible manager was involved in most Teams groups and had his own view where he could get an overview of all the improvement proposals in the different groups.

As mentioned, it is usually not the one who submitted the improvement proposal who will carry out the improvement because employees may avoid submitting proposals that generate more work for themselves. An advantage to using an improvement board in Microsoft Teams Planner is that the work is now continuous and the operators have access to the board whenever they want via mobile phone or the computers in production area. An interviewee mentioned that the transition to working in different places during the COVID-19 pandemic was easier because they were already familiar with working in the software. However, there has been a reduction in the number of improvement proposals during the pandemic.

4.3 Advantages and disadvantages of digital and analogue boards

In the interviews, respondents had clear opinions about the advantages and disadvantages of analogue and digital boards. Although the majority of those interviewed currently only worked with analogue boards, they came up with opinions about what they thought could be the effects of a digital version. The summary in Table 3 is based on the interviewees' experiences, knowledge, thoughts and ideas.

Table 3 Relative advantages of digital and analogue boards in the case company

Advantages	*Disadvantages*
Digital boards	
Automatically updated: employees do not need to spend time updating the board.	There may be restrictions on what and where you can write and draw on a digital tablet.
Increased accessibility: the board is not attached to a physical location.	The screen may stop working/break.
The data displayed is always based on the same values and the same calculations.	Costs more, both the purchase of the screen and access to the support function that can help with technical problems.
There is an official version of the data that is agreed upon.	Employees identify less with the data as they have not retrieved it themselves and added it to the board. This can also make them overcritical of the information and data displayed on the board.
The data is stored. It can then be used retroactively for analysis and learning.	
It is possible to show trends with the help of historical data.	
Data from several systems can be collected and visualised in one place.	

Table 3 Relative advantages of digital and analogue boards in the case company (continued)

Advantages	*Disadvantages*
Digital boards	
The data can be broken down and examined on site via the screen.	
You can work directly on the screen.	
It is possible to change which view is currently visible on the board, with no need to erase previous information as you would have to do on a whiteboard.	
If the digital screens are located in several strategic locations, the digital whiteboard acts as a fast and easy information channel.	
It's easy to create charts and graphs and thus easy to visualise information.	
Analogue boards	
Easy to write and draw what and where you want, for example on a whiteboard with a pen.	Data and calculations may differ depending on who did the calculation and then updated the board.
The employees identify themselves more with the data as they have produced it and added it to the board. This can lead to taking greater responsibility and higher motivation to improve things.	An analogue board requires an employee to update it. For example, he or she must print a new paper/value and then go to the board to update it.
It is quick to get started. No previous knowledge is required for using one whiteboard and a pen..	It is easy for the employee to be unable to complete an update or forget it.
	Incorrect data may occur. Wrong numbers can be written down and information can distorted on the way to the board.
	It is attached to a physical location.
	What is written is not saved. When it is erased, it disappears permanently.

5 Discussion

After examining both the theory and the empirical evidence, it is evident that digital and analogue boards have both advantages and disadvantages. Meissner et al. (2018) mention two advantages to using a digital board that contribute to saving time, confirmed by this case study:

1. the staff do not personally have to produce the data to be displayed on the board
2. they do not need go to the board physically to update it (see also Hultin and Mähring, 2014).

Because the data usually comes from digital systems, it is a digital waste not to use a digital board and not to integrate the systems (Nilsson et al., 2019; Sutrisno et al., 2018).

Moreover, unnecessary movement is considered a waste (Ortiz and Park, 2011), waste that will be reduced by an automatically updated digital board, placed in a strategic location.

5.1 Attitudes towards the board

A negative consequence of automatically updating information, as Meissner et al. (2018) demonstrate, is that employees may identify less with the information on the board. This was also highly emphasised by one of the interviewees from Sandvik: employees feel more responsible if they have personally written down an unfavourable KPI on the board, compared to getting it served on a digital screen. Another thing to be vigilant about mentioned by Meissner et al. (2018) and during the interviews, was that the employees could be critical of the information and data displayed on the board when they had not produced it themselves. To counteract these potential problems, one idea would be to include the employees in the implementation process of the board and the decision about which KPIs, calculations and information the board will display. This allows them to gain an understanding of where the numbers come from and gain greater confidence in them. This is in line with Swartling and Poksinska (2013), who state that employees' motivation towards improvement work can be strengthened if they are given responsibility throughout the improvement process. Designing the board together would have the added benefits that all would agree on how values are calculated and displayed. In an analogue board, there may be various ways of presenting data.

It is the employees who will ultimately use the board: it is irrelevant how good a board and its functions are, if the employees are not motivated to use it. In the case company, some employees did not fill in the reasons for every stoppage. There must therefore be motivated employees and clear working methods for the board to be useful. From the start, the employees should receive help and support in learning to use the new tool. This may counteract what Parry and Turner (2007) mention as a disadvantage of digital boards: they require some digital knowledge.

5.2 Storage and integrating with multiple systems

An advantage of digital platforms is that all information is stored and that it can be stored in one place, as opposed to analogue whiteboards, and this saves time. Not archiving data can reduce transparency in the company and create silos of knowledge, with only those who present knowing where it is archived (Nilsson et al., 2019).

If the board used is digital, it is possible to connect it to the different systems so all the information needed can be stored on the same platform (Hultin and Mähring, 2014; Weber et al., 2017). This way staff only need to use one platform when searching for information, which was also mentioned by Nilsson et al. (2019) Another advantage expressed by the interviewees from Sandvik was that they could work directly in the digital board if it is integrated with the different systems. As mentioned, the employees lost motivation when they did not receive feedback on the improvement suggestions they made. With all information in the same place, it would be easier to share information about improvement activities with relevant operators, which could increase motivation.

A digital board also has a higher risk of interference than an analogue board, which would not be affected by a power outage. This problem could be solved by using a backup power supply. When it comes to the digital boards in this case study, another disadvantage and limitation is that they are largely dependent on some type of connection to work. Often an internet connection is required in order to connect with and synchronise with other tools and systems.

5.2 Information on the board

Despite the advantage of having large amounts of information collected and stored on one platform, and the platform not being limited to a physical location, it is important not to show unnecessary information just because it is possible. Meissner et al. (2018) argue that data availability and access to a lot of information can result in too many KPIs that do not add any value. This can lead to employees being overloaded with irrelevant and unnecessary information. Parry and Turner (2007) mention that the advantage of an analogue board is its limited space: staff must prioritise what is actually relevant to show. For a digital board with its unlimited space, the problem could be solved by periodically reviewing what information is actually used.

Even though the limited space of analogue whiteboards may be seen as an advantage, more or larger whiteboards are still needed if the board space is simply not enough for the required information. Although the amount of information displayed on the board could be reduced, more boards may also be desirable because they can serve different purposes. For example, Sandvik uses three whiteboards with different purposes: pulse meetings, improvements and targets. The advantage of a digital board is that it can have different views on a single screen, which was indeed considered an advantage by Sandvik. The views can also be adapted based on the target group, e.g., different teams may want to show different things on their own board.

In the interviews, it emerged that a disadvantage of digital boards is that there may be restrictions on what and where you can write, draw and edit. This is easier to do on a whiteboard, as an employee can just pick up a pen and write what and where he or she wants. It was also mentioned that charts can be easier to create and view on a digital board. However touchscreen keyboards can also be difficult and time consuming to use. When using a digital board, the user is also limited by the characters offered by the keyboard, which can be a problem when writing in some languages.

5.3 Costs

Another disadvantage of having a digital board compared to an analogue one is that it is more expensive, as Parry and Turner (2007) mention, and this was evident in the case study. There are costs involved in both the software and the actual digital screen. If a digital platform like Mevisio is used, support may also be needed if problems arise with the platform or if the company wants to make changes to the board that require some special skills.

Although a digital board entails implementation costs, the use of the board can contribute to reducing both costs and waste. Waste, according to Ortiz and Park (2011), should be eliminated or at least reduced if a company wants to be more efficient, and stoppages, waiting and unnecessary movement can be considered waste. With an analogue board, the staff may need to wait for the necessary information until someone updates the board during the next meeting. If the board is automatically updated, staff do not have to wait. Alieva and von Haartman (2020) considered uncollected, unanalysed and unused data as digital waste. This case study found that the use of digital boards could reduce digital waste by making data collection, data analysis and data usage easier and more efficient compared to a traditional whiteboard.

5.4 Digitalisation during the COVID-19 pandemic

The fact that the board can be used regardless of physical location has been the most significant advantage during the pandemic. The production department had already begun to digitalise the improvement work and were thus well prepared. When the virus outbreak came to be classified as a pandemic, it required all industries to start working more digitally. While some factories completely shut down, Sandvik chose to protect critical employees while allowing staff who can to work remotely from home. Digital boards can play an important role in, for example, production, but also in other daily meetings.

5.5 Summary of the advantages and disadvantages with digital boards

In summary, there are both advantages and disadvantages with digital boards. Some of these have only been found in the literature and some only in this case study, while some were found in both. Overall, more advantages than disadvantages were found, and there are also many advantages than disadvantages shared by the literature and the interviews (Tables 4 and 5). Some of the identified disadvantages can be counteracted and avoided by taking certain measures (Table 5).

Table 4 Relative advantages with digital boards

Advantage	*Literature*	*Empirical evidence*
Personnel do not need to manually fetch data	✓	✓
Is updated automatically	✓	✓
Quick and easy channel for distributing information		✓
Possible to escalate (share to superiors) via the board		✓
Saves time		✓
Not tied to a physical location	✓	✓
More efficient meetings and communication		✓
Allows remote work		✓
KPIs on the board are always based on the same calculations		✓
Integrates with several systems, all information in the same place	✓	✓
Can work directly on screen		✓
Digital archiving	✓	✓
High transparency of the production process	✓	
Several views regardless of the size of the board		✓
Easy to create visualisations, e.g., through diagrams		✓
Flexible design		✓

Table 5 Relative disadvantages with digital boards

Disadvantages	*Literature*	*Empirical evidence*	*Can be counteracted*
Personnel do not 'identify' with the information	✓	✓	✓
Requires digital knowledge	✓	✓	✓
Displays unnecessary information	✓		✓
Too many KPIs	✓		✓
Limitation on what you can write and draw		✓	✓
High costs	✓	✓	
The screen can stop working		✓	

6 Conclusions

The purpose of this paper was to investigate digitalised visual management, with a focus on the relative advantages and disadvantages of digital and analogue boards in manufacturing. We found more advantages than disadvantages with digital boards (Tables 4 and 5). Only two disadvantages are absolute, while the other disadvantages can be counteracted to some extent. The absolute disadvantages are costs and external disturbances such as power outages and more frequent breakages.

In the interviews, new advantages and disadvantages not found in the literature were discovered and examined, which is the first contribution of this paper. Moreover, no literature was found that connected improvement boards with causes of stoppages, and this is the second contribution. Generally, the paper contributes to the literature on how digital technologies can be used to collect, interpret and share data for smarter decision making, which Chiarini (2020) suggested as relevant topics for research. The findings are highly applicable to practitioners, especially for managers considering investing in digital boards in manufacturing, to be used for continuous improvement but also for other production-related applications.

This paper is based on a single case study focusing on stoppage causes, and although it covered multiple units and departments of a large engineering company, these results cannot be fully generalised to all manufacturing companies or all contexts. However, many of the findings were in line with the identified literature and can provide some analytical generalisability (Yin, 1994). Many advantages and disadvantages were identified in this paper, but some might be more important than others. The relative importance of these advantages is an interesting area for future studies. This study did not systematically study the impact of digital improvement boards on performance, such as quality, productivity or the reduction of waste. Exploring and testing these effects is also an interesting avenue for further research.

Acknowledgements

The authors would like to thank Markus Eriksson and Francis Richt for providing access and assisting data collection at Sandvik Coromant. We would also like to thank Beth Chapple for editing the paper.

References

Alieva, J. and von Haartman, R. (2020) 'Digital muda – the new form of waste by Industry 4.0', *Operations and Supply Chain Management*, Vol. 13 No. 3, pp.269–278.

Bessant, J., Caffyn, S., Gilbert, J., Harding, R. and Webb, S. (1994) 'Rediscovering continuous improvement', *Technovation*, Vol. 14 No. 1, pp.17–29.

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, https://doi.org/10.1108/00251740510597761.

Bhutta, M.K.S., Egilmez, G., Chatha, K.A. and Huq, F. (2017) 'Survey of lean management practices in Pakistani industrial sectors', *International Journal of Services and Operations Management*, Vol. 28, No. 3, pp.309–334.

Chiarini, A. (2020) 'Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research', *The TQM Journal*, Vol. 32 No. 4, pp.603–616, DOI: 10.1108/TQM-04-2020-0082.

Dombrowski, U., Richter, T. and Krenkel, P. (2017) 'Interdependencies of Industrie 4.0 & lean production systems: a use case analysis', *Procedia Manufacturing*, Vol. 11, No. 1, pp.1061–1068.

Eaidgah, Y., Maki, A.A., Kurczewski, K. and Abdekhodaee, A. (2015) 'Visual management performance management and continuous improvement. A lean manufacturing approach', *International Journal of Lean Six Sigma*, Vol. 7 No. 2, pp.187–210.

Emiliani, M.L. (2006) 'Origins of Lean management in America', *Journal of Management History*, Vol. 12, No. 2, pp.167–184.

Hirsch-Kreinsen, H. (2016) 'Digitization of industrial work: development paths and prospects', *Journal for Labour Market Research*, Vol. 49, No. 1, pp.1–14.

Hultin, L. and Mähring, M. (2014) 'Visualizing institutional logics in sociomaterial practices', *Information and Organization*, Vol. 24 No. 3, pp.129–155, https://doi.org/10.1016/j.infoandorg.2014.05.002.

Imai, M. (1997) *Gemba Kaizen: A Common Sense, Low-Cost Approach to Management*, McGraw-Hill.

Liao, Y., Deschamps, F., de Freitas Rocha Loures, E. and Ramos, L.F.P. (2017) 'Past, present and future of Industry 4.0 – a systematic literature review and research agenda proposal', *International Journal of Production Research*, Vol. 55 No. 12, pp.3609–3629, https://doi.org/10.1080/00207543.2017.1308576.

Liker, J.K. (2004) *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*, McGraw-Hill, New York, NY.

Lu, Y. (2017) 'Industry 4.0: a survey on technologies, applications and open research issues', *Journal of Industrial Information Integration*, No. 6, pp.1–10, DOI: 10.1016/j.jii.2017.04.005.

Marley, K.A. and Ward, P.T. (2013) 'Lean management as a countermeasure for 'normal' disruptions', *Operations Management Research*, Vol. 6, Nos. 1–2, pp.44–52.

Meissner, A., Müller, M., Hermann, A. and Metternich, J. (2018) 'Digitalization as a catalyst for lean production: A learning factory approach for digital shop floor management', *Procedia Manufacturing*, No. 23, pp.81–86, https://doi.org/10.1016/j.promfg.2018.03.165.

Nilsson, A., Brobak, T.T.E., Jørgensen, N.D., Larsen, M.K., Damhus, R.D., Mathiasen, J.B. and Tambo, T. (2019) 'Hidden waste factors in Lean management: towards improved shop-floor communication and management', *15th European Conference on Management, Leadership and Governance*, 18–19 October, Portugal, pp.297–304, https://doi.org/10.34190/MLG.19.015.

Nyteknik (2018) *Här är svenska företaget som söker flest patent i Europa* [online] https://www.nyteknik.se/innovation/har-ar-svenska-foretaget-som-soker-flest-patent-i-europa-6902811 (accessed 26 March 2021).

Ortiz, C.A. and Park, M.R. (2011) *Visual Control: Applying Visual Management to the Factory*, Productivity Press, New York, NY.

Parry, G.C. and Turner, C.E. (2007) 'Application of lean visual process management tools', *Production Planning & Control*, Vol. 17 No. 1, pp.77–86, https://doi.org/10.1080/09537280500414991

Poksinska, B., Swartling, D. and Drotz, E. (2013) 'The daily work of Lean leaders – lessons from manufacturing and healthcare', *Total Quality Management & Business Excellence*, Vol. 24, Nos. 7–8, pp.886–898.

Powell, D. (2013) 'ERP systems in lean production. New insights from a review of Lean and ERP literature', *International Journal of Operations and Production Management*, Vol. 33, Nos. 11–12, pp.1490–1510.

Riezebos, J., Klingenberg, W. and Hicks, C. (2009) 'Lean production and information technology: connection or contradiction?', *Computers in Industry*, Vol. 60, No. 4, pp.237–247.

Rosin, F., Forget, P., Lamouri, S., and Pellerin, R. (2020) 'Impacts of Industry 4.0 technologies on lean principles'. *International Journal of Production Research*, Vol. 58, No. 6, pp.1644–1661.

Rossini, M., Costa, F., Tortorella, G.L. and Portioli-Staudacher, A. (2019) 'The interrelation between Industry 4.0 and lean production: an empirical study on European manufacturers', *The International Journal of Advanced Manufacturing Technology*, Vol. 102, Nos. 9–12, pp.3963–3976.

Rother, M. (2009) *Toyota Kata*, McGraw-Hill Professional Publishing, New York, NY.

Saxby, R., Cano-Kourouklis, M. and Viza, E. (2020) 'An initial assessment of Lean management methods for Industry 4.0', *The TQM Journal*, Vol. 32, No. 4, pp.587–601.

Solaimani, S., van der Veen, J., Sobek II, D.K., Gulyaz, E. and Venugopal, V. (2019) 'On the application of Lean principles and practices to innovation management', *The TQM Journal*, Vol. 31, No. 6, pp.1064–1092.

Sutrisno, A., Vanany, I., Gunawan, I. and Asjad, M. (2018) 'Lean waste classification model to support the sustainable operational practice', *IOP Conference Series: Materials Science and Engineering*, Vol. 337, https://doi.org/10.1088/1757- 899X/337/1/012067.

Swartling, D. and Poksinska, B. (2013) 'Management initiation of continuous improvement from a motivational perspective', *Journal of Applied Economics and Business Research*, Vol. 3, No. 2, pp.81–94.

Tao, F., Qi, Q., Liu, A. and Kusiak, A. (2018) 'Data-driven smart manufacturing', *Journal of Manufacturing Systems*, Vol. 48, Part C, pp.157–169.

von Haartman, R., Bengtsson, L. and Niss, C. (2021) 'Lean practices and the adoption of digital technologies in production', *International Journal of Services and Operations Management*, Vol. 40, No. 2, pp.286–304.

Weber, C., Königsberger, J., Kassner, L. and Mitschang, B. (2017) 'M2DDM – a maturity model for data-driven manufacturing', *Procedia CIRP*, Vol. 63, No. 1, pp.173–178.

Womack, J.P. and Jones, D.T. (2003) *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Simon & Schuster, London.

Yin, R.K. (1994) *Case Study Research: Design and Methods*, 2nd ed., Sage Publications, Thousand Oaks, CA.