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Effects of Visual Management on Efficiency and Innovation in Product Development

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Effekterna av Visuell Projektledning på Effektivitet och Innovation i Produktutveckling

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Sammanfattning

Bolag har under de senaste decennierna upplevt stora förändringar. Snabb och radikal teknologisk utveckling och ständig förändring av både affärsmodeller och konsumtionsvanor, för att nämna några få, har gjort det komplicerat och lagt press på organisationers produktutvecklingsprocesser. Att ha en effektiv produktutvecklingsprocess och samtidigt lyckas innovera i dagens konkurrenskraft har visat sig vara en svår uppgift. Företag står inför flera utmaningar gällande innovation och affärsprocesser för innovation och har svårigheter att hitta lämpliga och effektiva verktyg och metoder.

Det övergripandet syftet med detta arbete är att undersöka hur organisationer som jobbar med produktutveckling kan öka sin innovations- och effektivitetsförmåga genom att använda visuell projektledning. Syftet med visuell projektledning är att förbättra en organisationers förmåga att vara innovativa och effektiva genom att sammanfläta vision, värderingar, normer och mål med andra ledningssystem, arbetsprocesser och arbetsmoment. Anställda kan påverkas av visuell projektledning till den mån att organisationens prestation i helhet påverkas. Det finns fortfarande många frågor att besvara och ny kunskap att hämta om hur visuell projektledning nyttjas på bästa sätt. Till exempel förståelsen för vilka andra faktorer som kan mediera effekten visuell projektledning har på organisatorisk prestation.

Det övergripande syftet av detta arbete konkretiseras i en forskningsmodell med fem tillhörande hypoteser. Hypotes-testning utförs i en jämförelsestudie med fyra stora organisationer. Empiriska data samlas främst genom enkäter med anställda som nyttjar visuell projektledning, där totalt 144 anställda svarande. Dessutom genomförs semistrukturerade intervjuer med personer kunnig i designen och processen av det använda visuella projektledningsverktyget.

Studien visade att visuell projektledning inte har någon direkt effekt på innovation och effektivitet, utan snarare en indirekt effekt. Visuell projektlednings positiva effekt på effektivitet medieras av

effektivt beteende och den positiva effekten på innovation medieras av en ökad kognitiv förmåga hos de anställda.

Detta arbete bidrar till förståelsen av hur visuell projektledning påverkar organisatorisk prestation. Genom statistiska analyser belyses tidigare forskning som visat på att ledningsverktyg och processer som bäst indirekt har en påverkan på organisatorisk prestation. Ett förslag till ramverk presenteras som en början på ett försök att visualisera det komplexa sambandet som finns mellan visuell projektledning och organisatorisk prestation.

Praktiska implikationer är att ramverket kan användas som ett guidande verktyg för designande av proceduren för visuell projektledning genom att lyfta speciellt aktuella aktiviteter. För chefer betonas det att målet inte bör vara att utveckla det mest avancerade eller nya visuella verktyget; snarare fokusera på att förbättra de anställdas kognitiva förmåga och främja effektivt beteende.

NYCKELORD: Visuell ledning, Visuella verktyg, Organisatorisk prestation, Innovation, Effektivitet, Produktutveckling, Effektivt beteende, Kognitiv förmåga, Kunskapsdelning.

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Abstract

The business environment has during the last decades gone through major dramatic changes. Rapid and radical technological development and continuous change in both business practices and behaviours of the population, to name a few, have complicated and put pressure on organizations' new product development (NPD) processes. Having an effective and efficient NPD process while succeeding in innovation in today's business environment is a big challenge. Organizations face multiple organizational and process type barriers to innovation and have difficulties in finding suitable successful and efficient tools and methods.

The overall purpose of this paper is to investigate how organizations dealing with product development can increase their innovation and efficiency performance, i.e. organizational performance, with the use of Visual management (VM). The aim of VM is to improve organizational performance by connecting and aligning organizational vision, core values, norms, and goals with other management systems, work processes and workplace elements. The individual elements of VM can affect how encouraged the employees are to perform in the workplace, hence having an effect on organizational performance. However, there are still many questions to be answered and new knowledge to be gained regarding how to best utilize VM, such as the understanding of what factors mediate the impact VM has on performance.

The overall purpose is further concretized in a research model with five related hypotheses. A hypothesis-testing is performed in a comparative study with four large organizations. The empirical data is primarily collected through surveys with employees utilizing VM, with a total of 144 respondents. In addition, semi-structured interviews are performed with each department utilizing the visual tool; the interviewees being knowledgeable in the design and process of utilized VM.

VM appears to have a substantial effect on innovation and efficiency performance. However, it has no direct effect, rather it exhibits indirect effects. VM's positive effect on efficiency

performance is mediated by efficient behaviour, and VM's positive effect on innovation performance is mediated by an increased cognitive ability.

This paper contributes to the understanding of VM's impact on organizational performance. By statistical analysis it highlights previous research stating that managerial tools and processes indirectly has an effect on organizational outcomes. Proposed framework is a beginning of visualizing the complex relationship existing between VM and organizational performance in a product development setting.

Practical implications are that depending on desired outcome in the use of VM, the framework can act as a guidance in the procedure of VM meetings, by highlighting certain activities. For managerial, it highlights that the goal should not be to develop the most advanced or novel visual tool; rather focus on improving the employee's cognitive ability and efficient behaviour.

KEYWORDS: Visual Management, Visual Tools, Organizational Performance, Innovation, Efficiency, Product Development, Efficient Behaviour, Cognitive Ability, Knowledge sharing.

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Lastly, we would like to express our deep gratitude for the opportunity to work with something so interesting. This has without doubt been one of the most challenging and valuable experiences in our life so far. Thanks to all the great and knowledgeable people we got to know throughout our project. We hope we meet again!

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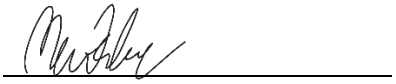

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Introduction

The business environment has during the last decades gone through major dramatic changes. Rapid and radical technological development and continuous change in both business practices and behaviours of the population, to name a few, have complicated and put pressure on organizations' new product development (NPD) processes. Having an effective and efficient NPD process while succeeding in innovation in today's business environment is proven to be a big challenge as today's complex society requires profound knowledge in information and communication management (Ekman, Jackson, 2006). Organizations face multiple organizational and process type barriers to innovation (Crane, Meyer, 2011) and have difficulties in finding suitable successful and efficient tools and methods for R&D projects (Brettel et al., 2012).

Despite the dramatic change in the business environment, the NPD practices have gone through relatively few changes, but in recent years the need for wide and deep change and knowledge in management has gained more spotlight (Murata, 2019).

Studies have shown that management tools and techniques influence the organizational performance indirectly at best (Nohria, Joyce, Roberson, 2003) and academics and practitioners acknowledge that today's contemporary management practices must move towards more open and inclusive ones for organizations to truly fit the future (Johnson and Broms 2000; Ghoshal 2005). One management practice that has thrived during the last decades, which Bititci et al. (2015) argue is perfectly in line with these requested future management practices, is Visual management (VM).

VM brings together and combines pertinent management dimensions and company information, and intuitively and quickly the information is portrayed and processed in a comprehensible way for individuals with different technical backgrounds (Spath, Nøstdal, Göhring, 2005). The aim of VM is to improve organizational performance by connecting and aligning organizational vision, core values, norms, and goals with other management systems, work processes, and workplace elements (Liff and Posey, 2004).

VM has been developed mostly by practitioners rather than through theoretical insights. VM is sometimes referred to as a "folk theory", due to the fact that the VM principles are established by the practitioners that tend to be built on anecdotal cases of apparent good practice, rather than foundations established in the academic theorizing (Beynon-Davies, Lederman, 2015). Besides a few exceptions in the field of production management (Bateman and Lethbridge, 2014; Parry and Turner, 2006) and management of healthcare operations (O'Neill and Jones, 2011; O'Brien, Bassham and Lewis, 2014), there is still surprisingly little knowledge about VM in the academic literature.

There are still many questions to be answered and new knowledge to be gained regarding how to best utilize VM. For instance, the development of design guidelines for visual devices are badly needed (Valente & al. 2017) and the understanding of what factors mediate the impact VM have on product development performance has been pointed out as a research gap in earlier works (Lindlöf, 2014). Lindlöf (2014) also points out that there is a need for statistical analysis of VM in NPD.

The much-needed VM principles and foundations established in the academic theorizing; the need for theoretical knowledge about proper design guidelines for VM and mediating factors between VM and organizational performance; and the call for statistical analysis, open up for further empirical investigations within the field. Therefore, the overall purpose of the research presented in this paper is to explore the effects of VM on organizational performance in a literature study and comparative study with statistically analysed results.

Exposition of Theory

In this section, the theoretical framework for this research paper is presented, which includes concepts, tools, and definitions that are related to the research purpose. The two main theoretical fields reviewed and considered central to the study are organizational performance and VM.

First, an exposition of organizational performance theory is presented. The main organizational performance metrics investigated are innovation and efficiency. This includes a discussion on existing literature on Efficiency and innovative work behaviours as well as efficiency and innovation performance.

This leads into the second part, where VM in organizations and specifically in the product development process, is presented. This includes different views on VM, its components and elements, its supportive role in other managerial practices, and VM functions, classifications and tools.

Finally, the relationship between VM and organizational performance is being explored. This includes activities and behaviours in VM helping organizations become more innovative and efficient in product development.

The review is presented to emphasize and justify the outline of the study presented in the latter part of this paper, and the need for further research contributions within the field. The findings from this latter part of the literature study serve as the primary input for the structure of the research model as well as the formulation of five hypotheses which the comparative study is based on.

Barriers and Opportunities for Organizational Performance

Product development has been described as the life blood of any business organization and in today's turbulent dynamic environment it's an activity that, together with innovation, should be given crucial business consideration for improved organizational performance (Udegbe, Udegbe, 2013). Even though this is a well-known need and challenge, few companies are highly successful more than half the time, which leads to significant challenges for product development teams (Petrella, 1996). Among many other challenges, this includes time pressure, creation, team diversity and spirit, dynamics, decision-making and details (Udegbe, Udegbe, 2013).

For a product development process to be successful, the development of the product must meet its goals and performance expectations (Ekman, Jackson, 2006). However, companies are struggling with implementing an efficient product development process, which according to Siriam (2002) can be explained by numerous barriers, such as the high number of different phases in the product development process, and thus disciplines, that all have to collaborate. To overcome these barriers, it requires that the organization has great communication and coordination skills to be efficient and manage the complexities in the development process, such as carry out the activities concurrently (Duffy, Andreasen, Donnell, 1999). Organizations today face challenges in coordinating large amount of information as well as managing the overlapping of coupled product development activities, which in turn, with given target budgets and resources, demand great knowledge in how to best allocate, coordinate, plan, and track the resources involved in product development (Ekman, Jackson, 2006).

Despite the well-known importance of organizational performance in today's business environment, little research has been made seeking to understand what facilitates desirable performance outcomes according to Kroll (2016). However, some remarkable findings have been made showing that product development and innovative drive provides an enabling environment to achieve a higher level of performance, which influence the overall organizational performance (Liu, Luo, Shi, 2002).

Two general aspects to assess when measuring organizational performance has been suggested to be efficiency and effectiveness (Farooq, 2014). Efficiency measures the input output relationship while effectiveness measures aspects such as sales, output, value added creation and innovation. One aspect of the effectiveness measurement that has been pointed as a very important direct driver of organizational

performance is innovation (Borocki, Orcik, Cvijic, 2013). To understand how organizations can improve their organizational performance by working more efficiently and innovative, challenges and obstacles organizations face as well as the behaviours that enhance innovation and efficiency has to be uncovered.

Innovation Challenges and Innovative Work Behaviours

Before targeting challenges and certain work behaviours, the term innovation has to be clarified. There are some differences in the academic literature of what the term means, and the definition seems to have changed subtly over the last several decades. One succinct definition of innovation is that it is a multidimensional concept that not only refer to innovation as an outcome, but also as a process (Crossan & Apaydin, 2010). This definition has some similarities to Gupta et al. (2007) who states that innovation is not only referred to an outcome or new idea but also a process from which new idea emerges.

Succeeding with innovation is not easy for companies when the competitive pressure increases due to globalisation, saturated markets, shorter product life cycles and greater pricing competitiveness. Hence, most new product ideas fail in the end. (Binz et al., 2011). For an organization to achieve the initiation and introduction of a new and useful idea, process, product or procedure, the employees should have certain coveted intellectual capabilities (Frank et.al., 2007) and innovative work behaviours (Farr, Ford, 1990). The required elements innovative work behaviours are the following: (1) Idea exploration: looking for ways to improve current products, services or processes or trying to think about them in alternative ways (Farr, Ford, 1990); (2) idea generation: the combination and reorganization of information and current concepts to solve problems or to improve performance (Kanter, 1988); (3) Idea championing: expressing enthusiasm and confidence about the innovation, being persistent, and getting the right people involved to build coalitions (Howell, Shea, Higgins, 2005); and (4) Idea implementation: the effort and result-oriented attitude to make ideas happen.

Obstacles to Efficiency and Efficient Work Behaviours

Due to increasing complexity and individualization of technical products and systems, together with shortened development times, the risk of failure for product development teams has increased (Binz et al., 2011). It is not only necessary to do the “right things”, but the teams also have to do “things right”, thus being efficient. To overcome these hindrances and become more efficient, product development has to be based on lean and reliable processes (Binz et al., 2011).

Further, Munthe et al. (2014) points out that deviations are one of the most critical aspects management must pay attention to in product development. Söderholm (2008) shows by empirical studies that extensive meetings creating continuous flow of information is one solution to deal with emerging deviations.

Visual Management

One management practice that seems to unravel these issues and challenges organizations have with efficiency and innovation performance is VM that have thrived during the last decades. However, managing projects and constellations of individuals with visual aids is not a new theory, but date back to the Egyptial Royal Cubit almost 4500 years ago (Tezel, Koskela, Tzortzopoulos, 2009). VM can be seen to have its roots in the five key Principles of Shingo, the 5Ss, that stands for the Japanese words Seiri (sorting), Seiton (arranging or setting in order), Seiso (sweeping or cleaning), Seiketsu (standardizing or integrating the first three principles into work) and Shitsuke (sustaining discipline) (Hirano, 1995).

However, VM is more often associated with the concept of lean production and is an essential element of the highly acclaimed Toyota Production System (TPS) which extensively integrates VM in operational and managerial activities (Liker, 2004).

Visual Management Definitions and Functions

Discrepant definitions of VM exist in academic literature, many researchers however refer it to organizational management practices (e.g. Puyou et al., 2012; Scott and Orlikowski, 2012). Within the theoretical framework for the research presented in this paper, VM adopted within the management of product development in organizations will be in focus.

In the literature, different perspectives of VM are highlighted. Some authors emphasize its simple, attractive, and efficient communication approach thanks to the various visual devices used (Eaidgah et al., 2016). Other authors point out that it can be used as a performance measurement tool when using it as a communication and information centre where strategic directions, performance, results, and improvement initiatives are visualized and discussed (Bazán et al., 2019). Suski (2019) describes it as a tool used to increase organizational performance by connecting and aligning organizational vision, values, culture, and objectives with other management practices, such as process-, production- and quality management. It can also serve a broad range of functions within an organization, such as transparency, unification, management by facts, and creating shared ownership (Tezel et al., 2009). Further, VM is sometimes addressed as a tool that complements humans, since we are visually, audibly, and tactilely oriented (Liker, 2004), and it's pointed out that VM increases employees cognitive ability (Lindlöf, 2014), due to the fact that at least one of the five human senses; sight, hearing, touch, smell, and taste are addressed in VM (Suski, 2019).

Even if definitions and perspectives of VM in literature and practice are quite broad, the essential purpose of VM seems to be coherent throughout the literature. Bell (2013) divides the purpose into three essential elements; it's self-regulating: the actual vs. the planned outcomes are conveyed; it's self-explaining: quickly and easy it conveys the current situation and how the standardized work should be performed to prevent errors and variations; and it's self-ordering: it instantly and intuitively shows when something is not right. In other literature, a fourth element is expressed, which is that VM over time is becoming self-improving; the visual devices are constantly providing feedback on the employees' performance and the performance of the company itself (Galsworth, 1997).

The purpose of VM is further realized through six critical components. King (2019) defines them as 1) A clean, visual, and well-organized work area; 2) Basic visual displays, where e.g. roadmaps and the process are displayed; 3) Visual schedules; 4) Andons and metrics that define the condition and the status; 5) Management by sight; 6) frequent employee communication.

VM is often implemented in terms of ideas of the visual workplaces (Grief, 1991), which are structured with information giving (indicating), signalling, limiting (controlling) and guaranteeing visual devices that realize the four elements of the VM purpose, mentioned in the previous section (Tezel, Koskela, Tzortzopoulos, 2009). The visual indicators give information, e.g. with safety signals; the visual signals grabs the viewers' attention and expects them to react, e.g. with andon systems; the visual controls limit responses and guide human actions, e.g. with Kanban cards; and visual guarantees guarantee only the desired outcome or reduces variability, e.g. with Poka-yokes (Beynon-Davies, Lederman, 2015). VM employs at least one or a combination of these four different visual devices.

The Affordance Theory Applied on Visual Management

In the literature of VM, the individual objects that make up VM are in focus. Eppler and Burkhard (2007) and Galsworth (2005) for instance, focus on the objects' different representational forms and organizational expectations, or "disciplines", they set on the employees' behaviours.

Lately, the theory of affordance has been studied in VM practices, which suggest that the accomplishment of VM does not lay in individual isolated objects, but through the operation of whole systems (Beynon-Davies, Lederman, 2017). Since it first appeared in the work of Gibson (1977; 1979), the concept of affordance has been applied in numerous disciplines, such as human-computer interaction

(Norman, 1999) and information systems (Leonardi, 2011). The affordance theory explains the link between the articulation of a tangible or physical artefact and the actions taken in some domain of coordination. Gibson defines it as “what the environment furnishes or provides”. According to Beynon-Davies and Lederman (2015) the idea is that actors directly perceive the opportunity for action made possible both by the effectivities of the actor and by structures in the environment.

Further, Beynon-Davies and Lederman (2019) state that for certain structures within the physical environment to afford action the actor must have certain cognitive or action capabilities for performing action. However, it is not stated exactly what these capabilities are, but it can be argued that for the actor to be able to perform innovative and effective actions, the desired capabilities are likely to be some sort of innovative and effective behaviours.

Beynon-Davies and Lederman (2017) recognizes that the definition of affordances by Gibson is not sufficient for covering the purpose of VM. Hence, they define three layers of action, i.e. articulation, communication and coordination, that are connected by the affordances of the visual devices. Also, they distinguish between first-order affordance, i.e. how the articulation of physical and tangible objects allows communication, and second-order affordance, which connects communicative action with coordinated work actions.

For developing the VM theory further Beynon-Davies and Lederman (2017) call for new ways of thinking through what patterns of articulation, communication and coordination are wanted in certain work settings. Based on this, it would be of interest to analyse the informative actions, which involve communicative conventions, that the manipulation of the visual objects in VM triggers.

Visual Management Tools and Practices

According to Tenzel, Koskela and Tzortzopoulos (2016), VM is realized through the use of multiple different visual tools that have different roles and achieve different benefits. Further, they point out four common characteristics of those VM tools: (1) the information that is visualized is presented to create information fields in the workplace, from which the information freely can be pulled in a self-service manner; (2) it uses a pre-emptive approach for the information need that is determined in advance to prevent information deficiencies; (3) the information display is placed in the direct interface between the employee and process elements, i.e. it is easy-to-reach and easy-to-see; and (4) it promotes simple communication and relies little on or not at all on textual or verbal information.

The previous mentioned general classification according to Galsworth (1997) of the VM tools, i.e. information giving; signalling; guaranteeing; and controlling, may create confusion in the employees understanding of what tools should be used for what (Tenzel, Koskela, Tzortzopoulos, 2016). Hence, Tenzel, Koskela and Tzortzopoulos (2016) presents a summary with classifications of the commonly used VM tools with definitions, roles and practical implications. One group of VM tools brought up are the centres and rooms, e.g. an Obeya, where visual performance figures, process information and Key Performance Indicators (KPIs) are grouped in a designated location in the workplace used in communication settings, i.e. meetings. These Visual tools take a supportive role in Performance management and create greater focus and efficiency in meetings, i.e. reduce meeting durations (waste). Further, these types of tools are known for facilitating group discussion, coordination, and problem-solving as well as easing the identification of improvement opportunities. (Tenzel, Koskela, Tzortzopoulos, 2016). In addition, it has proven to improve information processing capability and support communication between individuals (Lindlöf, 2014). Visualization has shown to have a positive relationship towards cognitive ability, collaboration and emotional abilities which in turn supports team communication and collective understanding (Alassaar, 2017).

Another VM tool methodology is the Pulse methodology, introduced by Scania in 2003 which is widely used in lean product development in Swedish organisations. While it shares Lean thinking with

Obeya, it focuses uppermost on managerial understanding of the organizational status by utilizing a visualisation (pulse board) to identify potential deviations in product development. Pulses has shown to increase transparency, synchronization between employees, resource allocation and time spent in meetings. (Kaya, Stenholm, Catic & Bergsjo, 2014)

Organizational Performance and Visual Management

To meet current and future challenges, the right product development methodologies have to be used to successfully innovate and work efficiently. However, existing methods are often too complex and time consuming (Binz et al., 2011). According Keller and Binz (2009) critical requirements of a good methodology include, inter alia: (1) it provides a structure for complex tasks and problems; (2) it's comprehensible; (3) it's compatible with different environments; and (4) it provides flexibility for the designer using degrees of freedom when applying the methodology.

These are requirements that VM tools, mentioned in the previous section, seem to meet. Also, according to Šramková and Ridziková (2020), the individual elements of VM can affect how high or low the employees are encouraged to perform in the workplace, hence having an effect on organizational performance.

However, no, or very little, research seems to have been performed about the effect of VM on innovation in particular. Regardless of that, practitioners seem to see VM as an appropriate tool for generating innovation. Although, according to Eppler and Burkhard (2004) knowledge visualization offers great potential for the creation of new knowledge in groups, thus enabling innovation. Knowledge visualization is the use of visual representations to improve the transfer and creation of knowledge between multiple individuals (Burkhard, 2005). Thus, it can be argued that VM can have a positive effect on innovation, if used for the transfer and creation of knowledge between multiple individuals.

King (2019) presented that VM supports frequent employee communication, something that Söderholm (2008) points out as a solution to the challenges that managers face when working with product development as discussed by Munthe et al. (2014). In addition, by increasing the alignment of organizational goals with work processes by utilizing VM (Suski, 2019), employees will have a greater chance to do "things right" as mentioned by Binz et al. (2011). Further, as the employees are actively taking part in VM meetings, it can be proposed that they get the possibility to assess their work process, hence creating the ability for self-improving. Thus, it can be argued that VM can have a positive effect on efficiency if the factors mentioned above are enabled.

Qualitative Study with Visual Management Experts and Practitioners

As mentioned earlier, the VM principles have mostly been developed and established by practitioners, therefore a qualitative study was performed with experts and practitioners working with facilitating or implementing VM. Deeply knowledgeable experts and practitioners were found in VM networks, theses, academic articles, and news articles. 13 practitioners were selected for further interviews where rich data about the interviewees' experiences with VM were gathered. This method was used since it is an appropriate method to use when exploring topics in a depth and breadth, which is often harder to achieve with fully structured interviews (Lazar, Feng, Hochheiser, 2017). The main benefit of using unstructured interviews was that the interviewees could focus on the topics, concerns, issues, and problem that they found most important.

Conducting unstructured interviews are known to be challenging (Wilson, 2014). Therefore, before conducting the interviews, common pitfalls, such as: using leading questions or prompts (Dumas & Redish, 1999); talking too much; not listening enough to the participant; and trying too hard to get answers to each general topic or questions (Wilson, 2014) were investigated to ensure they were avoided.

Knowing some of the terms of the interviewees can enhance the interviewer's credibility (Wilson, 2014). Therefore, technical terms and phrases that were part of the language of the investigated group of people were investigated beforehand to be able to incorporate that language into the unstructured aspect of the interviews.

Following the guidelines on goals for unstructured interviews (Wilson, 2014), the main goals of the qualitative unstructured interviews were to; explore VM from the practitioners' point of view; understand how VM processes work; understand the functions of VM; understand how particular groups in organizations work together with VM; and develop, test and confirm (or disconfirm) the preliminary research model and hypotheses the literature study resulted in.

An interview guide that listed general topics and questions to cover in the unconstructed interviews was used. Following guidelines on how to conduct unstructured interviews (Wilson, 2014), the interviews began with a brief introduction, followed by some warm-up questions that were easy, non-threatening, and relevant. During the main part of the interviews, the topics brought up in the interview guide were explored. Lastly, in the "cool-off" period (Robson, 2002) a few final questions that were relatively easy to answer were asked followed by signalling a clear end of the interview by thanking the participants.

The interviews were arranged to last about an hour, however many of the interviewees were dedicated and willing to give up more of their time. The interviewees lasted from 45 to 120 minutes, which follows the general guidelines of unstructured interviews (Wilson, 2014). If too short, it can be hard to establish rapport and cover the topic in sufficient depth, and if too long, the pool of qualified participants may be reduced since they do not want to give up valuable work or leisure time (Wilson, 2014).

Research Model and Hypotheses

To conclude the exposition of theory, it is safe to say that some of the activities in VM and its structure should have a positive effect on the employees innovative and efficient behaviours as well as efficient- and innovation performance. Given previous reasoning and knowledge about VM in product development, the following research model, see *Figure 1,* and hypotheses is suggested.

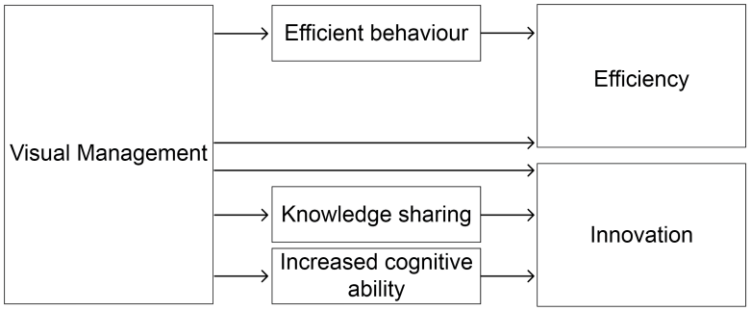

Figure 1. Research model

The findings from the explorative literature study have served as the primary input in the construction of the research model and the formulation of hypotheses for the hypothesis-testing research that this paper builds upon. However, the findings from the qualitative study, i.e. the unstructured interviews with experts and practitioners, have served as important input as well, see *Appendix A*. By combining knowledge from academia and practice in an early stage makes the hypotheses testing to be relevant for both fields. Further, Eisenhardt (1989) argues that when using multiple data collection methods, it provides stronger substantiation of hypotheses.

After having reviewed and discussed existing VM literature and related research, the overall purpose presented in the introduction section was further delineated with more specific formulations. This was done in the form of five hypotheses, which were the following:

H1a: The use of VM has a direct positive effect on Efficiency

H1b: The use of VM has an indirect positive effect on Efficiency, mediated by employees' Efficient Behaviour

H2a: The use of VM has a direct positive effect on Innovation

H2b: The use of VM has an indirect positive effect on Innovation, mediated by Knowledge sharing Behaviour

H2c: The use of VM has an indirect positive effect on Innovation, mediated by the employees' increased Cognitive Ability.

The research model and the hypotheses were formulated successively throughout the literature study, and the structure of the model and the formulation of the hypotheses have been modified over time. According to Eisenhardt (1989), prior formulations of hypotheses are helpful, but they are typically considered tentative. Further, Eisenhardt argues that for theory to be strong, the process of building theory involves constant iteration backward and forward between steps, which e.g. includes sharpening and redefining hypotheses when new evidence is brought up to light.

Research Design and Methodology

Previous researchers have proposed several theories on how VM affect organizational performance, increase individual's ability to perform in the workplace, and how it can be utilized as a place for teams to communicate and align objectives. However, many of these theories derive from anecdotal observations and qualitative studies but generally lack quantitative testing. Therefore, it is suitable to test presented hypotheses by conducting a quantitative hypothesis-testing in a comparative study with statistical analysis.

In this section, the research design and methodology are described more in detail. The sampling of organisations participating in the study is presented, followed by method for data collection, definition of variables and methodology of analysis. The study was executed during the first half of year 2020 and can broadly be divided into two stages, see *Figure 2*. Information seeking was conducted through a comprehensive literature study and interviews with scholars and practitioners knowledgeable in VM. Followed was the executive phase of the study where the quantitative hypothesis-testing was carried out.

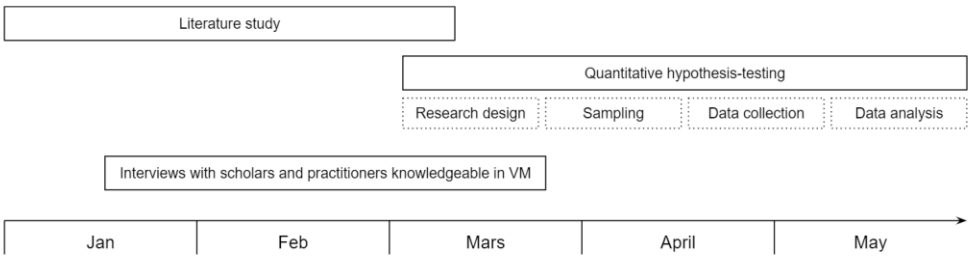

Figure 2. Timeline for the research process

Sampling

According to Eisenhardt (1989), the selection of population to include in a hypothesis-testing research is a crucial aspect since it defines the set of entities from which the research sample is to be drawn. Discussions, workshops, and interviews with 13 practitioners and scholars with expertise in Lean methodology and VM were performed to find and select appropriate organizations, departments, and teams. This resulted in referrals to suitable organisations. The single most important selection criterion was that visual tools were utilized on a management or team level on a weekly basis. Another important criterion was the access to the object, which in this case was the utilized visual tool. This includes being able to review the visual tool and receive knowledge of how the visual tool was used. The last, but nonetheless important, criterion was the access to interviewees knowledgeable in the company's VM procedure.

Based on the criterions above, it resulted in 12 departments or teams utilizing a VM approach participating in the comparative study. These were all utilizing visual tools and were distributed over four organizations in six countries. All organisations are considered large and VM management is utilized at some stage of product development. Organisation 3 is the only organisation in the study not being a Swedish company and only acting in the Netherlands. Remaining organisations are Swedish and operating internationally. Organisation 1 manufactures and delivers security solutions. Organisation 2 offers financial advice and banking services. Organisation 3 deliver telecommunication services. Organisation 4 delivers infrastructural solutions for communication.

Data Collection

Since its start, the research study has been performed in close collaboration with the organizations. By performing some pre-observations and qualitative semi-structured interviews with at least one individual

knowledgeable in the procedure of VM in each department, new insight was given regarding their VM designs and processes, which has shaped the research process and development of the model.

Empirical data was primarily collected through online surveys with employees utilizing VM. The individual knowledgeable in the procedure of VM was responsible for identifying suitable respondents and distributing the survey. The survey was sent to 370 number of suitable respondents and was submitted by 144 individuals, resulting in a response-rate of 38.9%.

Survey Design

The survey was created to be distributed digitally to respondents. The respondents answered the questions by grading their perceived experience against statements with a 7-point Likert scale. The 7-point scale was used because it produces the biggest variance, while not exceeding the point where the accuracy of answers reduces (Johns, 2010). The survey was modified for each department to align with the vocabulary the respondents would be familiar with, minimizing the risk for misinterpretation. In *Appendix B*, the general survey is presented, which the modified versions were created from.

The survey's composition was determined by balancing the wish for having the most crucial questions as early as possible and having questions following each other to be about adjacent topics. The survey resulted in several variables that were used in the statistical analysis and presented below. A list of all utilized variables is shown in *Appendix C*.

Dependent Variables

This study follows previous research of measurement of organizational performance presented by Farooq (2014): efficiency and effectiveness. However, since it is measured in a setting of product development the broad and generalizable definition presented by Farooq was further concretized and defined as the two following variables.

Efficiency was measured in the survey by having the respondents self-report the outcome on previous deliveries by answering six questions. Three of which were considering the outcome of previous work measured to what degree their deliveries were on time, within budget, and with wishful outcome in terms of functionality and quality. These measurements are often used when considering efficiency and can be seen in other research papers (Rothaermel & Hess, 2007). Further, product development is challenging and complex which is previously discussed (Siriam, 2002; Duffy, Andreasen, Donnell, 1999). Therefore, the three remaining questions were considering the respondents' teams ability to; identify challenges, communicate changes in demand of resources, and handle changes in a successful way.

In line with Crossen and Apaydin's (2010) definition of innovation, mentioned in the section *Exposition of Theory*, both the innovation outcome, innovation activities, and innovation process was measured. *Innovation* was, like *efficiency,* measured by respondents self-reporting their team's ability to innovate by answering three questions regarding; generated new innovative ideas, successfully developed new solutions to identified problems and developed innovative technology, product or process. The main performance indicator for measuring innovation with surveys as to whether the respondents' firms have produced a product, process, or other innovation regarding organization or marketing during a set period of time, often three years (Lhuillery et al., 2015). Due to VM being self-improving and therefore changing over time (Galsworth, 1997), innovation was measured over a shorter time period of six months. In addition, since the study is performed in a product development setting, innovation is considered regarding technology, product, and processes.

Independent Variables

Independent variables describing the design and procedure of the respective VM were collected from the interviews and surveys. Items deriving from the interviews were binary and classified with a value

of zero or one, where a one represented that the VM utilized a type of tool or procedure. Items used in the final model were:

- KPI's are visualized
- All team members were collocated during VM meetings
- One person is setting the pace and structure of VM meetings
- Analog boards are utilized
- All participants in VM meeting are physically interactive with visualized material

To further collect data regarding the procedure and to increase potential variety of measured design and procedure of respective VM, the surveys were utilized which were measured on a seven-step scale. The respondents answered questions regarding to what degree the VM meetings were used for:

- Collective problem solving
- Reporting of progress status
- Information sharing
- Asking for and receiving help
- Individual task allocation

Mediating Variables

Mediating variables were included to see if the VM itself was directly increasing organizational performance or if affected behaviours and capabilities that in turn affected the performance. All mediating variables were self-reported by the respondents and relating to what degree VM supported different abilities or behaviours. *Efficient behaviour* was the mean value of the respondent's perceived ability to assess and improve their work process, understand and prioritize their work, and align their work with organizational goals, due to the use of VM. *Increased cognitive ability* was the mean value of the respondent's perceived ability to identify, understand and find solutions to challenges. *Knowledge sharing behaviour* was the mean value of the respondent's perceived increased level of communication within the team and with other teams, as well as understanding received knowledge.

Control Variables

Several control variables were included to absorb the potential effect it has on dependent variables which are not interesting for the study. This is done to measure more precise correlations between independent and dependent variables. Included control variables were the gender, age and education of respondents and what organisation the respondents were affiliated with.

Data Analysis

Responses from the survey were manually excluded if they were identified to have a high frequency of repetitive values and/or missing answers. This resulted in excluding six responses and using the remaining 138 responses for further analysis. Interviews were thematically analysed and translated into empirical data on key aspects of the design and procedure. Empirical data from the surveys were linked to the data gathered and codified from the interviews. Variables were created and analysed using the statistical software SPSS (2019).

Since the survey is self-reported, some variance can be attributed to the used measurement method created from respondents being biased towards positive answers and being the source for dependent and, to a limited degree, independent variables (Chang et al., 2010) . To investigate to what degree the variance in the dataset can be described by used measurement method, it was tested with one of the most widely used techniques used by researchers to address the issue of common method variance, called Harman's single factor test. It includes all items of the study into a factor analysis to determine

whether the majority of the variance can be accounted for by one general factor, i.e. if a cumulative percentage of total variance more than 50% has to be accounted for.

Further, items designed to measure the same phenomena were tested for the degree of internal consistency using Cronbach Alfa. DeVellis (2017) states that a statistical reliability coefficient of .70 is considered respectable, and its mean value can be used for further analysis. It was tested if statistical reliability could be increased by excluding any items from the test, which would lead to excluding them from computed mean value.

The research model was tested using multiple linear regression analysis. Independent variables and control variables were initially modelling for mediating variables to identify existing correlations. Followed, dependent variables were modelled for with independent and control variables to identify possible mediating effects absorbed by the mediating variables as they were included.

The models were checked for multicollinearity using collinearity statistics. A variance inflation factor (VIF) value of >1 and <4 was considered to be acceptable (Hair et al., 2010). Independent variables were excluded from the model if a VIF value outside of the accepted interval was identified. Modelling for an acceptable VIF value was done to improve the ability to more precise analyse correlation coefficients.

Results and Data Analysis

In this section results of the statistical results are presented together with analysis. First, the reliability and simplification of gathered data is presented, followed by the result of conducted multiple linear regressions.

Reliability of Dataset and Simplifications

Harman's single factor test of the survey responses resulted in a cumulative variance of 31.491%, see *Table 1*. It was determined that the dataset could be used for further analysis as there appeared to be no significant common method bias since calculated variance was below 50%.

Table 1. Harman's single factor of the dataset

				Total variance explained		
	Standardized Coefficients			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	23.619	31.491	31.491	23.619	31.491	31.491

Internal consistency was tested for all items designed to describe the same phenomena, see *Table 2*. Cronbach's Alfa was conducted on respective items describing efficiency, innovation, efficient behaviour, knowledge sharing behaviour and increased cognitive ability. All tests resulted in a score of >.80, which according to DeVellis (2017) is considered to be very good. This resulted in a low enough level of internal consistency to further analyse the respective factor on an aggregated level, generated by the mean of the items.

Table 2. Internal consistency using Cronbach's Alfa

		Reliability Statistics
Independent Variables	Cronbach's Alpha	N of items
Efficiency performance	.871	6
Innovation performance	.874	3
Efficient behaviour	.889	6
Knowledge sharing behaviour	.890	7
Increased cognitive ability	.859	3

While conducting multiple linear regression analysis, the models were investigated for correlation and redundancy of independent variables by measuring the VIF. All VIF values, which are shown in *Appendix D-H* were >1 and <4, determining that there was not a problem with multicollinearity (Hair et al., 2010)

Effects of Visual Management on Efficiency

In this subsection the result and analysis of two multiple linear regressions will be presented regarding efficiency. First, the correlation of independent variables on the mediating variable efficient behaviour. Following, the correlation of independent variables and mediating on dependent variable efficiency.

Efficient Behaviours are Supported by Activities Linked to Visual Management

A multiple linear regression was conducted modelled with the mediating variable efficiency behaviour defined as dependent variable. *Table 3* consists of the relevant coefficients. For comprehensive statistical results see *Appendix D*. The model explains almost half of the variance (R Square = 0.499) and the Anova test showed that the accumulated model was highly significant (.000). Reporting of progress status as an activity was shown to have the biggest impact by being highly significant and have a high positive correlation coefficient to efficient behaviour. Alignment between teams and collective problem solving as activities had a similar effect but with a lower significance and correlation coefficient.

Table 3. Selection of relevant correlation coefficients of multiple linear regression of the efficient behaviour

	Model 1	
Independent variables:	Coeff.	Sig.
Pur_1_Probsolving	0.153	**0.014**
Pur_2_Report	0.293	**0.000**
Pur_6_Align	0.133	**0.045**

Efficiency is Primarily Affected by Efficient Behaviour Rather Than the Utilization of Visual Management

Efficiency is defined as dependent variables. *Table 4* consists of relevant coefficients. For comprehensive statistical results see *Appendix E*. Model 1 includes all control variables and variables describing the VM's design and procedure while model 2 also includes mediating variable efficient behaviour. Both model 1 and 2 are significant and describe respectively 46.8% and 57.6% of the variance where the increased value can be attributed to the explanatory property that efficient behaviours have on the dependent variable. Efficient behaviour is highly significant and has a high positive correlation coefficient, highlighting that efficient behaviour is the most prominent factor of efficiency.

Visualisation of KPIs is the only variable exhibiting a negative correlation coefficient. The significance remains the same and the changed value of correlation coefficient is negligible, showing only a direct effect. Reporting of progress status indicates that there is a direct positive correlation towards dependent variable. Further, it is shown that the significance and correlation is decreasing in model 2 compared to model 1, revealing that efficient behaviour is mediating a great portion of the effect. Similarly, utilization of analog boards, asking for and receiving help, and alignment between teams also indicates a positive correlation to dependent variables; effects that are most probably mediated by efficient behaviour.

Table 4. Selection of relevant correlation coefficients of multiple linear regression of efficiency

	Model 1		Model 2	
Independent variables:	Coeff.	Sig.	Coeff.	Sig.
Input_4_KPI	-0.587	**0.031**	-0.527	**0.031**
Input_13_Analog	0.504	**0.072**	0.386	0.124
Pur_2_Report	0.256	**0.001**	0.134	**0.054**
Pur_4_Help	0.163	**0.062**	0.099	0.208
Pur_6_Align	0.101	**0.097**	0.045	0.409
Efficient_Behaviour			0.415	**0.000**

Effects of Visual Management on Innovation

In this subsection the result and analysis of three multiple linear regressions will be presented regarding innovation. First, the correlation of independent variables on the two mediating variable cognitive ability and knowledge sharing behaviour. Following, the correlation of independent and mediating variables on dependent variable innovation.

Visual Management Increase Individuals Cognitive Ability and Knowledge Sharing Behaviour

Two multiple linear regression is conducted with dependent variables defined as the level of increased individual cognitive abilities, see *Table 5*, and increased level of knowledge sharing, see *Table 6*. For comprehensive statistical results see *Appendix F* and *G*. Both models are highly significant and explain over 50% of the variance of dependent variables.

Table 5 identifies four variables to have a significance value of <.05. Collective problem solving and reporting of progress status exhibit the highest positive effect on cognitive ability together with a high significance. Asking for and receiving help also show a positive effect while it, together with level of significance, is slightly lower. Interestingly, the control variable that indicate the gender of the respondent exhibit an effect on dependent variable, where women are labelled with a zero and men labelled with a one, showing that women report a higher degree of increased cognitive ability due to the use of VM than men. In addition, there are two variables that show a smaller significance, indicating an effect: visualisation of KPI's and information sharing where the first mentioned exhibit a negative correlating factor and the second a positive.

Table 5. Selected coefficients of multiple linear regression of increased cognitive ability

	Model 1	
Independent variables:	Coeff.	Sig.
Ctrl_Gend	-0.492	**0.017**
Input_4_KPI	-0.487	**0.085**
Pur_1_Probsolving	0.233	**0.000**
Pur_2_Report	0.234	**0.003**
Pur_3_Infosharing	0.129	**0.089**
Pur_4_Help	0.197	**0.031**

In *Table 6*, two independent variables can be identified having a high significance to knowledge sharing behaviour; collective problem solving and information sharing as an activity during VM meetings, both of which have a positive correlation towards knowledge sharing behaviour. In addition, there are three variables having slightly less significance: asking for and receiving help, collocation during VM meetings and having all participants physically interactive with visualised material. Collocation has a negative coefficient while the remaining two variables exhibit a positive correlation.

Table 6. Coefficients of multiple linear regression of knowledge sharing behaviour

	Model 1	
Independent variables:	Coeff.	Sig.
Input_10_Together	-0.676	**0.005**
Input_15_Interactive	0.442	**0.080**
Pur_1_Probsolving	0.239	**0.000**
Pur_3_Infosharing	0.254	**0.001**
Pur_4_Help	0.156	**0.073**

Innovation is Primarily Affected by Individuals Increased Cognitive Ability due to the Use of Visual Management

A multiple linear regression is run with independent variables defined as innovation performance. *Table 7* consists of relevant coefficients. For comprehensive statistical results see *Appendix H*. Model 1 includes independent and control variables, model 2 and 3 includes knowledge sharing behaviour and level of increased cognitive ability respectively while model 4 includes both. All models are significant (.000) and describe 39.3%, 41.5%, 43.6% and 44.0% of the variance of innovation performance respectively.

Looking at model 4 in *Table 7,* two variables can be seen that exhibit a significant positive effect on the dependent variable: the control variable for organisation 1 and the level of increased cognitive ability. Interestingly, the defined mediating variable knowledge sharing behaviour goes from significant to non-significant from model 2 to model 4, showing that increased cognitive ability mediates the relationship. Collective problem solving is highly significant in model 1 and decreasing in all other models, showing that the effect is mediated by both knowledge sharing behaviour and increased cognitive ability. Analysing reporting of progress status in a similar way a slight decrease of significance from model 1 to model 2 and a bigger decrease to model 3 and 4 can be seen, indicating a small mediating effect from knowledge sharing behaviour and a bigger mediating effect from the increased cognitive ability.

Table 7. Selected coefficients and significances of multiple linear regression of Innovation performance

	Model 1		Model 2		Model 3		Model 4	
Independent variables:	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Ctrl_Org_1	1.340	**0.055**	1.415	**0.039**	1.268	**0.059**	1.314	**0.051**
Pur_1_Probsolving	0.156	**0.039**	0.096	0.231	0.077	0.321	0.062	0.437
Pur_2_Report	0.238	**0.216**	0.216	**0.025**	0.158	0.105	0.161	0.101
Knowledge_Sharing			0.252	**0.042**			0.110	0.420
Cognitive_Ability					0.339	**0.004**	0.289	**0.028**

Discussion

Figure 3 and *Figure 4* in the following sections visualises the results from the previous section regarding statistical results and analysis. Solid arrows symbolize significance level of ≤.05 while dotted arrows symbolize a significance that is more uncertain (.05< and <.10), highlighting a possible relationship.

Efficiency Performance in Project Development is Mostly Affected by Individuals' Behaviour, Which Mediates the Effect of Activities Related to Visual Management Meetings

Looking at *Figure 3,* it shows that VM exhibits a direct as well as an indirect effect on efficiency, somewhat contradicting previous research stating that managerial tools and techniques at best have an indirect effect (Nohria, Joyce, Roberson, 2003). The direct effect derives from the negative impact the use of visualized KPIs have. Surprising since organisations often use performance measurements to ensure that they are on the right track, something that should be aligned with an efficient performance. However, the negative effect visualized KPIs have on reported efficiency can possibly be described by the increased understanding individuals have of their situation when they are actively measuring and evaluating their work, as well as more critical since they are already analysing their ways of working. Arguing for that there is no significant direct effect of VM on efficiency, resulting in an indirect effect mediated by efficient behaviour.

Results show that alignment between teams is positively correlated to efficient behaviour which is partly measured by to what degree an individual's assignment is aligned with organizational goals. It can be argued that to have individuals to work towards the same goal alignment at a higher degree must also exist, in this paper referred to as teams, which would explain the correlation between the variable alignment between teams and efficient behaviour. Its effect on efficiency performance is also described by Suski (2019) where VM is portrayed as a tool that aligns organizational objectives to increase performance.

Working with reporting of progress status on a regular basis will improve the team's ability to track and follow the progress of their work against decided time-frame and budget whilst aligning the team's effort, minimizing the risk of bottlenecks, which is directly supportive of efficiency. While the study only finds a possible correlation to efficiency, the mediated effect on efficient behaviour is far more significant. The study shows that regular debriefs of the progress status is one of the most crucial activities during VM meetings related to efficiency. Interviewees often witnessed that team members focused on challenges during reporting of progress status, opening up for the possibility of collective problem solving. The authors believe that the combination of regular debriefs, the quick addressing of problems, and collectively solving those problems is the key activity that supports organizational efficiency when utilizing VM meetings.

Further, the study finds that analog visualization indicated to support efficiency performance more than digital boards and storage on digital platforms. This is line with the statements from the interviews with experts, stating that analog boards involve employees to a higher degree, and is more efficient to update than virtual equivalent. However, it can also be explained by virtual VM being a newer phenomenon, and therefore not reached the same level of maturity as physical Visual tools.

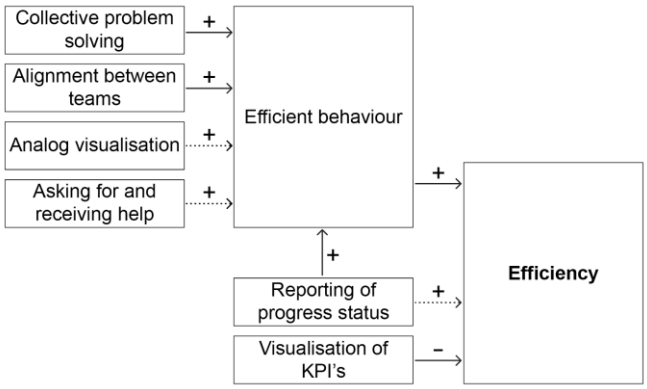

Figure 3. Relationship from statistical analysis of VM, Efficient behaviour and Efficiency performance

Activities in Visual Management Meetings Can Increase Individuals' Cognitive Ability, a Key Factor for Innovation Performance

Figure 4 shows that the design and procedure of VM have no direct influence on innovation performance, which is in line with previous research (Nohria, Joyce, Roberson, 2003). Rather we see that VM is mediated by other variables, e.g. individual's cognitive ability is affected by the design and procedure of VM and thereby have a positive effect on innovation performance. This is in line with previous research, which shows that VM increases individuals cognitive ability (Lindlöf, 2014), and a company's intellectual human capital, i.e. the individuals' capabilities, has a positive effect on innovation performance (Frank et al., 2007)

Further, results show that knowledge sharing behaviour is not directly an explanatory factor of innovation performance, which was believed in the initial research model, rather highlighting that knowledge sharing is required to increase individuals cognitive ability, mediating the impact on innovation performance. However, results show that depending on the procedure of VM meetings, it can be used to increase knowledge sharing behaviour, something that is in line with Bazáns et al. (2019) view of how VM can be utilized. In addition, the results show that innovation also is affected by organisational differences, arguing that the variance of innovation performance amongst different organisations is naturally occurring, and cannot be fully accounted for by measured variables.

This paper has defined increased cognitive ability as the individual's ability to identify, understands and find solutions to challenges. It can be argued that several activities that are positively affecting individuals' cognitive ability is practicing just those measured abilities: collective problem solving; understanding and finding solutions to identified challenges: asking for and receiving help; understanding identified challenges: and reporting of progress status; early on identify when challenges occur. Their positive impact on cognitive ability might be explained by the repetitive practice individuals receive while participating in VM meetings.

Collocation during VM meetings is a negative factor of knowledge sharing behaviour. One can argue that it is because of the lack of informal knowledge flow that naturally can occur when people are collocated, and therefore more prominently is utilized during VM meetings as a way to facilitate knowledge sharing behaviour that geographically distanced teams require.

The remaining activities that indicate, or more strongly highlight, an impact on knowledge sharing behaviour can be explained by the nature of the activities themself. They are based on some level of knowledge sharing behaviour. Collective problem solving requires that all individuals are understood with the problem, demanding some level of knowledge sharing behaviour which logically explains the correlation. Reporting of progress status and the activity asking for and receiving help is similarly requiring individuals to share knowledge about the situation. Whether information sharing activities have a positive

impact on knowledge sharing behaviour or if the relationship is inverted is challenging to determine, while its correlation is logically obvious.

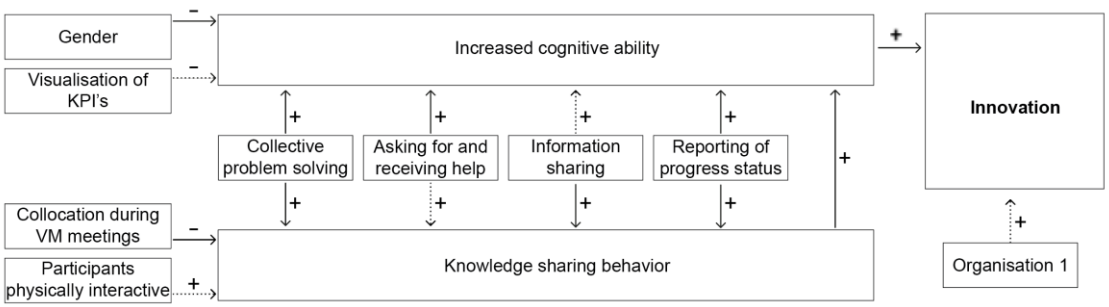

Figure 4. Relationship from statistical analysis of VM, Increased cognitive ability, Knowledge sharing behaviour and Innovation

Conclusions

After assessing statistical significance and logical reasoning, the findings of the study are visualized in *Figure 5*. VM has no direct effect on organizational performance in terms of efficiency or innovation in a product development setting, showing no support for hypothesis *H1a* and *H2a*. Rather it is mediated through individual's behaviour and abilities. The use of VM has an indirect positive effect on efficiency, mediated by employees' efficient behaviour, which is supporting hypothesis *H1b*. In addition, the use of VM has an indirect positive effect on innovation, mediated by the increased cognitive ability amongst the employees, which supports hypothesis *H2c*. However, VM effect knowledge sharing behaviour, but its effect is mediated through employees increased cognitive ability, which is partly supporting hypothesis *H2b*.

Reporting of progress status and collective problem solving is the most significant and impactful activity, since it is supportive of all mediating variables investigated in this study, therefore by extension, both efficiency and innovation. Alignment between teams and asking for and receiving help is respectively indirectly supportive of efficiency and innovation.

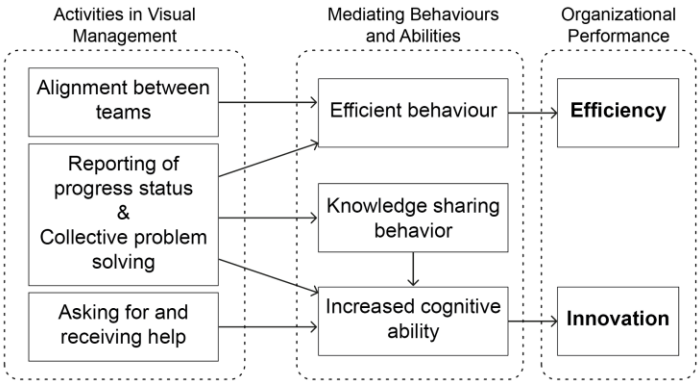

Figure 5. Proposed framework highlighting the mediated effect of Activities in Visual Management on Organizational Performance in Product Development

Implications for Theory

This paper contributes to the understanding of VM's impact on organizational performance. By statistical analysis it highlights previous research stating that managerial tools and processes indirectly has an effect on organizational outcomes, while identifying some of the mediating elements when VM is utilized. Proposed framework is a beginning of visualizing the complex relationship between VM and organizational performance in a product development setting.

Implications for Practice

Depending on desired outcome, the finding from this study can act as a guidance in defining the procedure of VM meetings, by highlighting certain activities. By combining previous knowledge and the findings from this research study, the authors urge practitioners to take a few aspects into account when implementing VM. These are highlighted in the following sections.

Align Team by Defining Objectives and Goals

Regardless of organizational structure or team configuration it is important to align team-members and other inter-dependent parts of an organization to make sure that everyone works in the same direction. This is done by establish a common understanding of a delivery's objectives and goals, and preferably how it benefits the organization as a whole. This can be realized by visualizing organizational goals and going

through how it is linked to current delivery while visualizing the end goal of the delivery. In addition, it can support the team's ability to weigh options against each other in decision making.

Maintain a Successful Task Allocation

Teams should visualize current and future assignments that is interdependent to minimize risks of unfinished assignments hindering other to be successfully conducted. The assignments should also be colour-coded by the responsible person, showing the status of its progress. Green, yellow and red is normally used and indicates that the assignment: is progressing as planned, have minor challenges but is believed to be handled, or have major challenges that require further assistance.

By visualizing assignments, the vertical alignment is increased since managers get the possibility to track progress and course correct early, without creating a hostile environment where individuals must "come clean" with their failures.

Frequent Update of Progress Status, Identification of Challenges and Collective Problem Solving

The main activity in VM meetings should be to discuss the progress of the work by going through the color-coded assignments, identify immediate or upcoming challenges, and collectively find solutions to those challenges. Each responsible person should go through current assignments and the status of the progress, which will maximize the number of active individuals. The focus should be to shed light on current or emerging challenges and collectively find the best solution. This can improve general problem solving, while increase individual's perception of ownership, belonging and support, as well as minimize the risk of harmful corporate politics. Further, by collectively practicing at identifying challenges the individuals can become better equips to find them in the future.

Evaluation of team accepted KPI's of behaviours and abilities

Evaluation of conducted work should be done with KPIs, which should be established together with the team members to ensure the acceptance of the measurement. Rather than focusing solely on the outcome, the focus should be on things closer to what is possible to change; the behaviours and abilities of team-members. By analysing the current behaviour and making sure that individuals are supported in the best way possible to solve challenges, the results should be achieved. Measuring results can be included but should not be addressed primarily since correct behaviours and an environment that support the team members ability to solve problems should result in successful achievements. However, it excludes contextual factors effecting the outcome.

Limitations and Future Research

The authors fail to identify key design aspects of VM but rather highlight activities that during VM meetings have an indirect effect on organizational performance. Due to the emergent crisis of the COVID-19 virus that emerged during the study, the ability to observe VM meetings amongst the participating organizations was limited, and thereof the authors ability to observe detailed design aspects or subtle procedures.

In addition, many of the teams were working from other locations than normal, forcing the organisations to alter their use of VM. Typically, it was a transition from analog visualized material to simplified digital versions. The normal state of used VM was analysed since the change was recent, there would not have been enough time for individuals to assess the new way of working. The abnormal situation can have an effect on the respondents, and by extension the collected data set.

Further, the situation with COVID-19 forced many organisations to reprioritize and cancelled their participation in the study, greatly reducing the sampling pool of the study. It would be interesting to see further research like the conducted study, but with a greater sampling pool. It could open up possibilities to identify and measure the moderating effects employee engagement and organizational culture have on VM's effect on organizational performance, something the study failed to identify.

In addition, further investigation of the impact analog boards have compared to virtual boards should be performed. Experts states that implementing virtual boards a normal next step in the development of an organization's VM, which is already happening at different firms. This makes it crucial for organizations to understand advantages and limitations of respective VM design and procedure.

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APPENDIX A: Compilation of key input from practitioners and experts

Expert	*VM is supported by:*	*VM supports:*	*Other notes:*
1	• Involved employees • Good leadership •	• Structure • Vertical alignment • Efficiency • Feeling of ownership	• Good leadership is often what is missing. Management must drive the implementation and support individuals in the use of VM. • Digital transformation of VM is interesting and is going to happen.
2		• Good communication • Transparency • Good corporate culture • Feeling of control	• Individuals thinks it is fun and engaging to work visually. • There is a difference when VM is used to facilitate team communication or strategy planning.
3	• Engagement • Trust • Determination to making VM work	• Individuals ability to perform • Communicate task-allocation	• It is challenging it visualize the right amount. There is a battle of making it easy to understand and making it cover enough. • There is no “one size fits all”
4	• Trust • Open-minded • Accept transparency • Supporting leaders	• Efficiency • Autonomous teams	
5		• Efficient communication • Organizational alignment	
6	• Good norms • Good values	• Efficiency coordination • Quick problem solving	
7	• Supportive management • Motivation • Inspiration	• Motivation and inspiration	• Management needs to create the wishful culture • Without managerial support VM falls apart.
8		• Alignment • Communication	• There is a big potential when different distances are connected, something VM can facilitate.
9	• A clear goal and reason for the implementation		• Virtual VM takes longer to implement • Virtual VM is at best half as time effective.
10			• There are different versions of VM; one to follow projects and one for managerial level.
11		• Spread information • Drive projects	
12			• There is a great potential for virtual VM for aligning parts of an organization that are separated.
13			• Virtual VM is better suited for material that is seldomly updated

Survey - Visual Management

This survey is for you who is working with [The VM TOOL] at [COMPANY]. The collected data will only be analyzed on an aggregated level, and no answers will be traced back to a single individual. Your answers are confidential and will not be shared internally in your organization or to any external third-party.

Collected data will be used for a research project and master thesis at the Royal Institute of Technology. Thank you for taking the time to answer these questions!

1. Enter your gender

Tick all that apply.

- [ ] Woman
- [ ] Man
- [ ] Other
- [ ] Prefer not to answer

2. Enter your highest education

Tick all that apply.

- [ ] High School / Gymnasium / Upper secondary school
- [ ] Bachelor
- [ ] Master
- [ ] PhD

3. Enter your age

_____

4. Enter the number of initiated years you have worked at [COMPANY]

_____

5. Enter your position

Tick all that apply.

- [ ] Team member
- [ ] Project manager
- [ ] Product owner
- [ ] Management

6. Specify which project team you belong to

_____

In order to deliver value, your team has during the last 6 months:

7. identified challenges early

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

8. communicated changes in demand of resources in time

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

9. handled changes in a successful way

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

10. generated new innovative ideas

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

11. successfully developed new solutions to identified problems

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

12. developed innovative technology/product/process

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

During the last 6 months your [team's]/[project's] deliveries have been delivered:

13. on time

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

14. within budget

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

15. with the wishful outcome, in terms of functionality and quality

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

In your workplace:

16. you interact a lot with other teams

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

17. you are collocated with your team

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

18. you can affect your work process

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

[The VM TOOL] makes:

19. your work to be set in line with the organization's business plan

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

20. you notice when you don't work towards the organization's business plan

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

21. you able to assess your work process

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

22. you able to improve your work process to increase your efficiency

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

[The VM TOOL] increases your ability to:

23. identify challenges earlier than your otherwise would

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

24. communicate challenges to [TEAM]/[PROJECT] members and/or right stakeholder(s)

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

25. understand identified challenges

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

26. find solutions to identified challenges

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

Your understanding of [The VM TOOL] is that it shall uppermost support:

27. collective problem-solving

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

28. reporting project status

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

29. information sharing

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

30. asking for and receiving help

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

31. individual task allocation

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

32. align priorities between different teams

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

You experience that [The VM TOOL]:

33. supports your understanding of your assignments/responsibilities

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

34. supports you to prioritize your assignments/responsibilities

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

35. is used as a knowledge sharing tool within your [TEAM]

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

36. increase your ability to share knowledge to [TEAM/PROJECT] members

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

37. increase your ability to understand received knowledge from [TEAM/PROJECT] members

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

38. increase your interaction with other teams

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

39. increase your ability to understand other teams' work and challenges

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

40. increase your ability to share knowledge with other teams

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

41. increase your ability to understand knowledge from other teams

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

You feel full support in your work from:

42. team members

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

43. project manager(s)

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

44. line manager

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

45. management team

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

[The VM TOOL] makes you feel an increased level of support from:

46. team members

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

47. project manager(s)

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

48. line manager

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

49. management team

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

You perceive [The VM TOOL] as:

50. an effective tool in your work

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

51. something you feel personally responsible for

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

52. something you feel fully engaged in using

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

53. something you have adequate education in, or experience of, to fully utlilize in your work

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

You perceive:

54. the organization's problems as your own

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

55. that you put a great deal of effort beyond what's expected for the success of the company

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

56. that your values and the organization's values are similar

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

In [the VM TOOL] you feel completely confident in

57. presenting project status

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

58. presenting project challenges

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

59. proposing solutions to other's challenges

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

60. proposing new ways of working

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

61. taking on new identified challenges

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

62. asking questions when you don't fully understand what's discussed

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

You experience the norm at [COMPANY] that employees are expected to

63. actively seek new knowledge

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

64. give time and space for exchanging knowledge

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

65. give time and space to reflect and learn new things

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

66. see failures as possibilities to learn

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

67. actively seek opportunities to improve products and services

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

68. actively seek opportunities to improve ways of working

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

69. actively propose novel ideas

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

70. take initiative to new projects even if the outcome is uncertain

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

71. experiment with novel ideas and seek new opportunities

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

72. affirm individual risk-taking and team autonomy

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

73. constructively handle differences of opinions

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

74. challenge status quo

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

75. actively participate in discussions and joint problem-solving

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	◯	◯	◯	◯	◯	◯	◯	Strongly agree

In your [team]/[Project team], what tool/process/occasion is uppermost used

76. when sharing and seeking new knowledge

_____

77. for assigning tasks and responsibilities

_____

78. for interaction with other teams

_____

79. for discussion and joint problem-solving

_____

80. to evaluate the work process

_____

81. to ensure that your work is in line with the organization's strategy

_____

APPENDIX C: Variables

List of all utilized variables in the research study

Type	Name of variable	Description	Source
Control variable.	Ctrl_Org_1	Specifies which organisation respondents belong to.	Interviews
	Ctrl_Org_2		
	Ctrl_Org_3		
	Ctrl_Org_3		
	Ctrl_Gend	Gender of respondent.	
	Ctrl_Edu	Educational level of respondent.	
	Ctrl_Age	Age of respondent.	
Independent variable from interviews. Value of 0 or 1.	Input_4_KPI	Visualisation of KPIs.	
	Input_10_Together	Collocation of participants during VM meetings.	
	Input_12_Leader	One person is leading the VM meeting, Setting the pace and structure.	
	Input_13_Analog	Analog boards are utilized.	
	Input_15_Interactive	All participants are physically interactive with visualised material.	
Independent variables from survey. Value of 1-7	Pur_1_Probsolving	VM meetings are uppermost used for collective problem solving.	Survey: 27
	Pur_2_Report	VM meetings are uppermost used for reporting of progress status.	Survey: 28
	Pur_3_Infoshar	VM meetings are uppermost used for information sharing.	Survey: 29
	Pur_4_Help	VM meetings are uppermost used for asking for and receiving help.	Survey: 30
	Pur_5_Taskallo	VM meetings are uppermost used for individual task allocation.	Survey: 31
	Pur_6_Align	VM meetings are uppermost used for alignment between teams.	Survey: 32
Mediating variables Value of 1-7	Effecient_Behaviour	Individuals increased ability to assess and improve work process, understand and prioritize, and align assignments with organizational goals	Survey: 19, 20, 21, 22, 33, 34
	Knowledge_Sharing	Individuals increased level of knowledge sharing within and between teams, as well as understanding received knowledge.	Survey: 24, 36, 37, 38, 39, 40, 41
	Cognitive_Ability	Individuals increased ability to identify, understand and find solutions to challenges.	Survey: 23, 25, 26
Dependent variables Value of 1-7	Efficiency	Team has delivered on time, within budget, and with a wishful outcome. Teams ability to identify challenges, communicate changes in demand of resources, handle changes in a successful way.	Survey: 7, 8, 9, 13, 14, 15
	Innovation	Teams performance of innovative ideas, successfully developed solutions to identified problems and new innovative technology/product/process.	Survey: 10, 11, 12

APPENDIX D: Regression Effective Behaviour

Model summary of multiple linear regression of Effective behaviour

MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.706a	**0.499**	0.424	0.94261

Anova test of multiple linear regression of Efficiency behaviour

ANOVA

Model	Cronbach's Alpha	Sum of squares	df	Mean Square	F	Sig.
1	Regression	100.764	17	5.927	6.671	**0 .000**
	Residual	101.291	114	0.889		
	Total	202.054	131			

Coefficients of multiple linear regression of Efficiency behaviour

COEFFICIENTS

		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	1.723	1.089		1.583	0.116		
	Ctrl_Org_1	-0.434	0.565	-0.088	-0.767	0.445	0.331	3.018
	Ctrl_Org_2	0.046	0.564	0.010	0.082	0.935	0.277	3.608
	Ctrl_Org_3	0.526	0.452	0.127	1.163	0.247	0.370	2.701
	Ctrl_Gend	-0.189	0.212	-0.065	-0.891	0.375	0.834	1.198
	Ctrl_Edu	-0.075	0.124	-0.046	-0.610	0.543	0.775	1.290
	Ctrl_Age	-0.009	0.011	-0.060	-0.799	0.426	0.790	1.265
	Input_4_KPI	-0.144	0.293	-0.058	-0.493	0.623	0.315	3.178
	Input_10_Together	-0.295	0.260	-0.115	-1.137	0.258	0.427	2.343
	Input_12_Leader	-0.294	0.340	-0.071	-0.863	0.390	0.656	1.525
	Input_13_Analog	0.283	0.302	0.115	0.939	0.350	0.296	3.381
	Input_15_Interactive	-0.057	0.273	-0.023	-0.209	0.835	0.361	2.771
	Pur_1_Probsolving	0.153	0.062	0.213	2.484	**0.014**	0.598	1.673
	Pur_2_Report	0.293	0.079	0.292	3.696	**0.000**	0.705	1.419
	Pur_3_Infoshar	-0.003	0.079	-0.004	-0.044	0.965	0.569	1.758
	Pur_4_Help	0.154	0.094	0.126	1.636	0.105	0.739	1.353
	Pur_5_Taskallo	0.088	0.064	0.135	1.378	0.171	0.461	2.171
	Pur_6_Align	0.133	0.065	0.170	2.031	**0.045**	0.628	1.592

APPENDIX E: Regression Efficiency Performance

Model summary of multiple linear regression of efficiency performance

MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.684	**0.468**	0.388	0.86612
2	.759	**0.576**	0.509	0.77616

Anova test of multiple linear regression of efficiency performance

ANOVA

Model	Cronbach's Alpha	Sum of squares	df	Mean Square	F	Sig.
1	Regression	75.138	17	4.420	5.892	**0.000**
	Residual	85.519	114	0.750		
	Total	160.657	131			
2	Regression	92.584	18	5.144	8.538	**0.000**
	Residual	68.074	113	0.602		
	Total	160.657	131			

Coefficients of multiple linear regression of efficiency performance

COEFFICIENTS

		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	2.128	1		2.128	0.036		
	Ctrl_Org_1	0.571	0.520	0.13	1.099	0.274	0.331	3.018
	Ctrl_Org_2	0.580	0.518	0.145	1.119	0.265	0.277	3.608
	Ctrl_Org_3	0.609	0.416	0.164	1.464	0.146	0.370	2.701
	Ctrl_Gend	0.207	0.195	0.079	1.062	0.291	0.834	1.198
	Ctrl_Edu	-0.025	0.114	-0.017	-0.22	0.826	0.775	1.290
	Ctrl_Age	-0.007	0.010	-0.050	-0.648	0.518	0.790	1.265
	Input_4_KPI	-0.587	0.269	-0.266	-2.183	**0.031**	0.315	3.178
	Input_10_Together	-0.253	0.239	-0.111	-1.059	0.292	0.427	2.343
	Input_12_Leader	-0.153	0.312	-0.041	-0.488	0.626	0.656	1.525
	Input_13_Analog	0.504	0.277	0.228	1.817	**0.072**	0.296	3.381
	Input_15_Interactive	-0.062	0.251	-0.028	-0.247	0.806	0.361	2.771
	Pur_1_Probsolving	-0.001	0.057	-0.001	-0.009	0.993	0.598	1.673
	Pur_2_Report	0.256	0.073	0.286	3.513	**0.001**	0.705	1.419
	Pur_3_Infosharing	0.061	0.072	0.077	0.848	0.398	0.569	1.758
	Pur_4_Help	0.163	0.087	0.15	1.886	**0.062**	0.739	1.353

	Pur_5_Taskallo	0.035	0.059	0.061	0.601	0.549	0.461	2.171
	Pur_6_Align	0.101	0.060	0.144	1.674	**0.097**	0.628	1.592
2	(Constant)	1.413	0.906		1.559	0.122		
	Ctrl_Org_1	0.751	0.467	0.172	1.609	0.110	0.330	3.034
	Ctrl_Org_2	0.561	0.464	0.140	1.208	0.230	0.277	3.608
	Ctrl_Org_3	0.390	0.375	0.105	1.041	0.300	0.366	2.733
	Ctrl_Gend	0.285	0.175	0.110	1.628	0.106	0.829	1.207
	Ctrl_Edu	0.006	0.102	0.004	0.062	0.951	0.773	1.294
	Ctrl_Age	-0.003	0.009	-0.022	-0.320	0.750	0.786	1.272
	Input_4_KPI	-0.527	0.241	-0.239	-2.185	**0.031**	0.314	3.185
	Input_10_Together	-0.130	0.215	-0.057	-0.605	0.546	0.422	2.370
	Input_12_Leader	-0.031	0.281	-0.008	-0.109	0.913	0.651	1.535
	Input_13_Analog	0.386	0.249	0.175	1.548	0.124	0.293	3.408
	Input_15_Interactive	-0.038	0.225	-0.017	-0.170	0.865	0.361	2.772
	Pur_1_Probsolving	-0.064	0.052	-0.100	-1.229	0.222	0.567	1.763
	Pur_2_Report	0.134	0.069	0.150	1.945	**0.054**	0.629	1.589
	Pur_3_Infosharing	0.063	0.065	0.079	0.969	0.335	0.569	1.758
	Pur_4_Help	0.099	0.078	0.091	1.265	0.208	0.722	1.384
	Pur_5_Taskallo	-0.001	0.053	-0.002	-0.023	0.982	0.453	2.208
	Pur_6_Align	0.045	0.055	0.065	0.829	0.409	0.606	1.650
	Effecient_Behavior	0.415	0.077	0.465	5.381	**0.000**	0.501	1.995

APPENDIX F: Regression Cognitive Ability

Model summary of multiple linear regression of increased cognitive ability

MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.743	**0.552**	0.485	0.90170

Anova test of multiple linear regression of increased cognitive abilities

ANOVA

Model	Cronbach's Alpha	Sum of squares	df	Mean Square	F	Sig.
1	Regression	104.007	17	6.706	8.248	**.000**
	Residual	92.689	114	0.813		
	Total	206.696	131			

Coefficients of multiple linear regression of increased cognitive abilities

COEFFICIENTS

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	0.776	1.041		0.745	0.458		
	Ctrl_Org_1	0.184	0.541	0.037	0.339	0.735	0.331	3.018
	Ctrl_Org_2	-0.083	0.539	-0.018	-0.154	0.878	0.277	3.608
	Ctrl_Org_3	0.070	0.433	0.017	0.162	0.871	0.370	2.701
	Ctrl_Gend	-0.492	0.203	-0.167	-2.429	**0.017**	0.834	1.198
	Ctrl_Edu	0.142	0.118	0.085	1.197	0.234	0.775	1.290
	Ctrl_Age	-0.008	0.010	-0.051	-0.721	0.472	0.790	1.265
	Input_4_KPI	-0.487	0.280	-0.195	-1.740	**0.085**	0.315	3.178
	Input_10_Together	0.124	0.249	0.048	0.499	0.619	0.427	2.343
	Input_12_Leader	-0.047	0.325	-0.011	-0.143	0.887	0.656	1.525
	Input_13_Analog	0.113	0.289	0.045	0.391	0.696	0.296	3.381
	Input_15_Interactive	0.270	0.261	0.108	1.031	0.305	0.361	2.771
	Pur_1_Probsolving	0.233	0.059	0.320	3.950	**0.000**	0.598	1.673
	Pur_2_Report	0.234	0.076	0.230	3.082	**0.003**	0.705	1.419
	Pur_3_Infosharing	0.129	0.075	0.143	1.717	**0.089**	0.569	1.758
	Pur_4_Help	0.197	0.090	0.159	2.183	**0.031**	0.739	1.353
	Pur_5_Taskallo	0.030	0.061	0.045	0.490	0.625	0.461	2.171
	Pur_6_Align	0.048	0.063	0.061	0.767	0.445	0.628	1.592

APPENDIX G: Regression Knowledge Sharing Behaviour

Model summary of multiple linear regression of knowledge sharing behaviour

MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.733	**0.538**	0.469	0.86107

Anova test of multiple linear regression of knowledge sharing behaviour

ANOVA

Model	Cronbach's Alpha	Sum of squares	df	Mean Square	F	Sig.
1	Regression	98.420	17	5.789	7.808	**0.000**
	Residual	84.525	114	0.741		
	Total	182.945	131			

Coefficients of multiple linear regression of knowledge sharing behaviour

COEFFICIENTS

		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	0.365	0.994		0.367	0.714		
	Ctrl_Org_1	-0.339	0.517	-0.073	-0.656	0.513	0.331	3.018
	Ctrl_Org_2	0.307	0.515	0.072	0.595	0.553	0.277	3.608
	Ctrl_Org_3	0.083	0.413	0.021	0.200	0.842	0.370	2.701
	Ctrl_Gend	0.018	0.194	0.006	0.092	0.927	0.834	1.198
	Ctrl_Edu	0.144	0.113	0.092	1.276	0.205	0.775	1.290
	Ctrl_Age	0.008	0.010	0.058	0.808	0.421	0.790	1.265
	Input_4_KPI	0.255	0.267	0.108	0.953	0.343	0.315	3.178
	Input_10_Together	-0.676	0.237	-0.277	-2.846	**0.005**	0.427	2.343
	Input_12_Leader	-0.301	0.311	-0.076	-0.970	0.334	0.656	1.525
	Input_13_Analog	-0.109	0.276	-0.046	-0.395	0.694	0.296	3.381
	Input_15_Interactive	0.442	0.250	0.187	1.769	**0.080**	0.361	2.771
	Pur_1_Probsolving	0.239	0.056	0.349	4.244	**0.000**	0.598	1.673
	Pur_2_Report	0.085	0.072	0.089	1.175	0.242	0.705	1.419
	Pur_3_Infosharing	0.254	0.072	0.298	3.525	**0.001**	0.569	1.758
	Pur 4 Help	0.156	0.086	0.134	1.812	**0.073**	0.739	1.353
	Pur_5_Taskallo	-0.006	0.058	-0.009	-0.099	0.921	0.461	2.171
	Pur_6_Align	0.094	0.060	0.126	1.574	0.118	0.628	1.592

APPENDIX H: Regression Innovation Performance

Model 1 is conducted with control variables and VM variables. Model 2 includes knowledge sharing behaviour. Model 3 includes cognitive ability without knowledge sharing behaviour. Model 4 includes all above mentioned variables.

Model Summary of multiple linear regression of Innovation performance

MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.627	**0.393**	0.303	1.143228
2	0.644	**0.415**	0.322	1.12747
3	0.661	**0.436**	0.347	1.10661
4	0.663	**0.440**	0.345	1.10830

Anova test of multiple linear regression of Innovation Performance.

ANOVA

Model	Cronbach's Alpha	Sum of squares	df	Mean Square	F	Sig.
1	Regression	96.514	17	5.677	4.343	**0.000**
	Residual	149.007	114	1.307		
	Total	245.521	131			
2	Regression	101.877	18	5.660	4.452	**0.000**
	Residual	143.643	113	1.271		
	Total	245.521	131			
3	Regression	107.143	18	5.952	4.861	**0.000**
	Residual	138.378	113	1.225		
	Total	245.521	131			
4	Regression	107.949	19	5.682	4.625	**0.000**
	Residual	137.572	112	1.228		
	Total	245.521	131			

Coefficients of multiple linear regression of Innovation Performance

COEFFICIENTS

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	0.174	1.320		0.132	0.895		
	Ctrl_Org_1	1.330	0.686	0.246	1.939	**0.055**	0.331	3.018
	Ctrl_Org_2	0.931	0.684	0.189	1.361	0.176	0.277	3.608
	Ctrl_Org_3	0.625	0.549	0.136	1.138	0.257	0.370	2.701
	Ctrl_Gend	0.072	0.257	0.022	0.281	0.780	0.834	1.198

	Ctrl_Edu	0.011	0.150	0.006	0.072	0.943	0.775	1.290
	Ctrl_Age	0.009	0.013	0.056	0.679	0.499	0.790	1.265
	Input_4_KPI	-0.337	0.355	-0.124	-0.950	0.344	0.315	3.178
	Input_10_Together	0.114	0.315	0.041	0.363	0.717	0.427	2.343
	Input_12_Leader	-0.320	0.412	-0.070	-0.776	0.439	0.656	1.525
	Input_13_Analog	0.308	0.366	0.113	0.841	0.402	0.296	3.381
	Input_15_Interactive	-0.069	0.331	-0.025	-0.210	0.834	0.361	2.771
	Pur_1_Probsolving	0.156	0.075	0.197	2.084	**0.039**	0.598	1.673
	Pur_2_Report	0.238	0.096	0.215	2.470	**0.015**	0.705	1.419
	Pur_3_Infosharing	0.159	0.095	0.161	1.661	0.100	0.569	1.758
	Pur_4_Help	0.035	0.114	0.026	0.307	0.760	0.739	1.353
	Pur_5_Taskallo	0.092	0.077	0.128	1.189	0.237	0.461	2.171
	Pur_6_Align	0.089	0.079	0.104	1.124	0.263	0.628	1.592
2	(Constant)	0.082	1.303		0.063	0.950		
	Ctrl_Org_1	1.415	0.678	0.262	2.089	**0.039**	0.330	3.029
	Ctrl_Org_2	0.853	0.676	0.173	1.263	0.209	0.276	3.620
	Ctrl_Org_3	0.604	0.541	0.132	1.115	0.267	0.370	2.702
	Ctrl_Gend	0.068	0.253	0.021	0.267	0.790	0.834	1.199
	Ctrl_Edu	-0.026	0.149	-0.014	-0.171	0.864	0.764	1.308
	Ctrl_Age	0.007	0.013	0.043	0.531	0.596	0.786	1.272
	Input_4_KPI	-0.402	0.352	-0.147	-1.142	0.256	0.312	3.203
	Input_10_Together	0.285	0.322	0.101	0.885	0.378	0.398	2.510
	Input_12_Leader	-0.244	0.408	-0.053	-0.598	0.551	0.650	1.538
	Input_13_Analog	0.335	0.361	0.123	0.928	0.355	0.295	3.386
	Input_15_Interactive	-0.181	0.331	-0.066	-0.545	0.587	0.351	2.847
	Pur_1_Probsolving	0.096	0.079	0.121	1.205	0.231	0.516	1.937
	Pur_2_Report	0.216	0.095	0.195	2.265	**0.025**	0.696	1.436
	Pur_3_Infosharing	0.095	0.099	0.096	0.955	0.342	0.513	1.950
	Pur_4_Help	-0.004	0.114	-0.003	-0.037	0.971	0.719	1.392
	Pur_5_Taskallo	0.094	0.076	0.130	1.225	0.223	0.461	2.172
	Pur_6_Align	0.066	0.079	0.076	0.828	0.409	0.615	1.627
	Knowledge_Sharing	0.252	0.123	0.217	2.054	**0.042**	0.462	2.164
3	(Constant)	-0.089	1.281		-0.069	0.945		
	Ctrl_Org_1	1.268	0.664	0.234	1.909	**0.059**	0.331	3.021
	Ctrl_Org_2	0.959	0.662	0.194	1.448	0.150	0.277	3.609
	Ctrl_Org_3	0.601	0.531	0.131	1.131	0.260	0.370	2.701
	Ctrl_Gend	0.239	0.255	0.074	0.936	0.351	0.793	1.260
	Ctrl_Edu	-0.037	0.146	-0.021	-0.255	0.799	0.766	1.306
	Ctrl_Age	0.012	0.013	0.072	0.898	0.371	0.787	1.271
	Input_4_KPI	-0.172	0.348	-0.063	-0.495	0.622	0.307	3.262
	Input_10_Together	0.072	0.306	0.026	0.237	0.813	0.426	2.349
	Input_12_Leader	-0.304	0.399	-0.067	-0.762	0.447	0.655	1.526

	Input_13_Analog	0.270	0.355	0.099	0.76	0.449	0.295	3.386
	Input_15_Interactive	-0.161	0.322	-0.059	-0.499	0.619	0.357	2.797
	Pur_1_Probsolving	0.077	0.077	0.097	0.997	0.321	0.526	1.901
	Pur_2_Report	0.158	0.097	0.143	1.634	0.105	0.651	1.537
	Pur_3_Infosharing	0.115	0.094	0.116	1.226	0.223	0.554	1.804
	Pur_4_Help	-0.032	0.113	-0.023	-0.279	0.780	0.710	1.409
	Pur_5_Taskallo	0.082	0.075	0.114	1.092	0.277	0.460	2.176
	Pur_6_Align	0.073	0.077	0.085	0.947	0.345	0.625	1.601
	Cognitive_Ability	0.339	0.115	0.311	2.946	**0.004**	0.448	2.230
4	(Constant)	-0.091	1.283		-0.071	0.944		
	Ctrl_Org_1	1.314	0.668	0.243	1.969	**0.051**	0.329	3.043
	Ctrl_Org_2	0.921	0.665	0.187	1.385	0.169	0.276	3.627
	Ctrl_Org_3	0.595	0.532	0.130	1.118	0.266	0.370	2.702
	Ctrl_Gend	0.213	0.258	0.066	0.826	0.411	0.781	1.281
	Ctrl_Edu	-0.046	0.147	-0.025	-0.315	0.754	0.761	1.313
	Ctrl_Age	0.010	0.013	0.064	0.793	0.429	0.775	1.289
	Input_4_KPI	-0.225	0.355	-0.082	-0.633	0.528	0.296	3.373
	Input_10_Together	0.153	0.322	0.054	0.476	0.635	0.385	2.598
	Input_12_Leader	-0.273	0.402	-0.06	-0.681	0.497	0.649	1.540
	Input_13_Analog	0.287	0.356	0.105	0.807	0.421	0.294	3.399
	Input_15_Interactive	-0.196	0.326	-0.072	-0.602	0.548	0.351	2.849
	Pur_1_Probsolving	0.062	0.079	0.078	0.780	0.437	0.498	2.010
	Pur_2_Report	0.161	0.097	0.145	1.653	0.101	0.65	1.538
	Pur_3_Infosharing	0.093	0.097	0.094	0.956	0.341	0.513	1.950
	Pur_4_Help	-0.039	0.113	-0.029	-0.345	0.731	0.705	1.419
	Pur_5_Taskallo	0.084	0.075	0.117	1.118	0.266	0.459	2.179
	Pur_6_Align	0.065	0.078	0.075	0.835	0.405	0.615	1.627
	Cognitive_Ability	0.289	0.130	0.266	2.223	**0.028**	0.351	2.852
	Knowledge_Sharing	0.110	0.136	0.095	0.81	0.420	0.361	2.768

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