

DIGITAL SHOPFLOOR MANAGEMENT IN CONSTRUCTION – A CASE STUDY

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ABSTRACT

Lean Management is considered a very promising approach to improving productivity in the construction industry. Shopfloor Management (SFM) is receiving increasing attention in theory and practice, as it has an impact on daily routines of all organizational levels. This paper presents over two years of experience in adopting and implementing SFM at a general contractor, which focuses on industrial and custom new buildings. The underlying company is following a clear and organizationally manifested approach toward Lean Management since the mid-2000s. Hence, the SFM methodology needed to be embedded in the already existing methods conceptually, before it could be rolled out. After two years of implementation, rollout to over 80 projects with an equivalent of approx. 1 billion € volume was achieved. Also, a consistent cascade from the construction site to top management was established, i.e. all levels of the organization have transitioned to the new way of working (and leading) inherent to SFM. In parallel, under the application of a strictly agile approach, the SFM cascade was digitized with a special focus on data reuse and integration of systems to ensure consistency, accuracy, and up-to-date information. The overall impact of SFM in the company underlying this case study to date is positive, and an initial approach is proposed to measure the impact in this paper.

KEYWORDS

Lean construction, collaboration, benefits realization, shopfloor management, digitization.

INTRODUCTION

The company underlying this case study is a general contractor with a regional footprint and with the majority of projects creating new buildings for non-residential usage. Some of its ten business units attempt to gain efficiencies through reuse, but the majority of buildings are customer-specific and produced on-site (no prefabrication) by subcontractors. Lean Management is being implemented since the mid-2000s when a dedicated team was created to drive and support the lean journey.

The main goals of implementing Lean Construction (strategically) in this case can be described from company, project, and people perspectives:

1. *Company* - establish a culture of continuous improvement based on standards and project-overarching build-up of best-practice knowledge, leading to an increase in revenue and margin through productivity gains.
2. *Project* - achieve project objectives as committed to customers (e.g. completion date), and reduce the lead time of projects to improve competitiveness.
3. *People* - achieve a sustainable, motivating, and performing work environment.

The company sees itself to be a pioneer regarding Lean Management implementation in the construction industry, but as described in the problem statement later in this paper, the impact

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of Lean Management remained behind expectations. Hence, the company analyzed other enterprises outside the construction industry for further inspiration on Lean Management and discovered the concept of SFM. Starting in 2018, a team continued to investigate SFM and received the mandate to adapt and implement SFM. In this paper, a full view of the adaptation, implementation, and impact review of SFM is presented. The author acknowledges, that various other general contractors are also implementing SFM, and hopes that those companies might contribute to this research as well based on their experience.

LITERATURE REVIEW

The term shopfloor management (SFM) as it is used in this paper refers to a broader methodological approach that builds on the understanding of lean leadership as described by Liker & Convis (2012) or Suzaki (1993), as opposed to a narrower understanding of operational techniques and mechanisms to plan and control production activities (e.g. production scheduling, shift capacity planning). The word shopfloor itself refers to a focus on the teams that work mostly in direct production (Grütter et al, 2002). Bertagnolli (2018) further defines SFM to consist of the four structural elements communication, visualization of key performance indicators (KPIs), problem-solving, and process control. Hertle et al. (2017) describe SFM as a procedural model. The structural and procedural definitions align with the understanding used in this paper. Beyond literature from within the lean management domain, it is important to review publications from adjacent domains such as operations management. Dombrowski et al. (2018) present case studies in which work team performance has been improved by concepts similar to SFM. Also, less associated with the domain of lean management, but rather performance management is the article by De Leeuw & Berg (2011). In it, the effect of SFM-like interventions on productivity and motivation has been investigated. A survey of approximately 100 companies from various industries and sizes created the insight that 71% of respondents confirm productivity gains from introducing a performance management system. Regarding the digitization of SFM in general, an overview of publications is provided by Jelínková & Prochazkova (2023), showing a strong increase between 2015 and 2020. Meißner et al. (2020) developed a target state for digital SFM (not construction-specific), defining what improvements should result from digitization in the categories of identification of deviations, shopfloor meetings, problem-solving, as well as standardization and stabilization. Publications on SFM adaptation to construction reach back to 2010 (Hofacker et al., 2010), with a pure focus on the production process on-site. Lootz (2018) describes the application of SFM to a ship-building context, integrating more processes (e.g. engineering) and also covering all levels of the organization (i.e. an SFM cascade). Romano (2022) describes the practical experience of the implementation of a digitized version of SFM in a large construction company. Binniger, M & Wolfbeiß, O. (2018) present specific implementation experience from a construction company in Germany using a special pen to digitize information.

Based on the literature review in total, the author believes SFM is a necessary element on any lean journey, and that the method should not only be seen as a set of KPI boards, but as a shift towards lean leadership with the corresponding behaviors and values.

PROBLEM STATEMENT & SOLUTION CONCEPT

After a brief outline of the problem statement, differentiated into the three perspectives *company*, *project*, and *people*, the approach to SFM as a solution will be explained in detail.

PROBLEM STATEMENT

From a *company perspective*, revenue was increasing slightly year-over-year, but the margin was stagnating at a market average level for multiple years. A key problem was that losses from a few projects led to a significant negative impact on the margin of all projects and thus on the

entire company over several years. Management usually received information about negative deviations in projects at a time when there was no more possibility to influence the impact. Also, comparing business units showed strong deviations in the stability of both revenue and margin, even though the business models were identical (only differing by region).

At the same time, from a *project perspective*, the company was lacking quantification of project performance in a holistic sense. The financial outcome was available as a metric, but timeliness, quality, or customer satisfaction were not quantified.

From a *people perspective*, individuals invested considerable time in meetings and reporting to ensure information flow to (a) subcontractors, (b) within the project team, and (c) to higher management levels. Typically, the time consumed to communicate and coordinate was so high, that other required processes were not feasible with the team's capacity. For example, preventive quality assurance was either not existent or executed at a minimum in most projects. In general, for all management roles, it was not possible to receive a holistic view with up-to-date and actionable items within the roles' range of responsibilities. A management role (e.g. project leader, business unit head) had to first compile information from various sources (e.g. Customer Relationship Management system, financial controlling, procurement systems, systems to manage drawings, comparing milestone schedules with Last-Planner, etc.). This information was then used to conduct meetings, in order to create a full picture through a time-consuming dialogue. Often, by the time conclusions were made, the situation was outdated. In the best case the problem was resolved, in the worst-case the problem could not be mitigated anymore and/or has become worse.

Summarizing the problem statement, the company's general management approach can be described as lagging, and there was a chronic state of unsatisfying information even though time invested in information processing and communication was significant.

SOLUTION CONCEPT

The SFM methodology was selected as a solution concept because it seemed to address many aspects of the problem statement and at the same time was consistent with the company's overall goals of implementing Lean. SFM would replace traditional ways of communication and reporting with a short-cyclic, dialogue- and metric-oriented, standardized management routine which was claimed to be very efficient by strongly increasing the relevance of and reducing time spent on communication on all levels of the organization simultaneously (Bertagnolli, 2018). This effect has been recently also confirmed by research (Wester & Hitka, 2022), based on an SFM implementation in a company in Germany (steel industry).

In total, it was expected that SFM would reduce the negative impact of loss projects from a company perspective, help achieve committed goals from a project perspective, and at the same time free up time and reduce stress by decreasing interruptions from a people's perspective. The key elements of the solution concept are as follows:

- Stand-ups with a weekly cadence were defined internally on all levels of the organization to form a SFM cascade (like on page 359 in Fiedler, 2019). Stand-ups with contractors (on-site) were executed daily. The structure of stand-ups is displayed in table 1. The stand-ups were executed in person, hybrid, or virtually.
- The duration of the stand-ups was planned to be 15-20 minutes, focusing the dialogue on the main issues and not attempting to solve them during the stand-ups.
- The contents of the stand-ups were structured in advance by means of SFM boards with topics and KPIs. An overview of the contents is given in tables 2 and 3.
- The SFM boards were defined for four roles initially: on-site leader, project leader, business area leader, and managing director. In this paper, the focus will be on the boards for on-site and project leaders, as these are most relevant to the shopfloor.

In case deviations on the SFM boards of the on-site and project leaders exceeded a predefined threshold, the issue was escalated to the next level. A choice could be made if the escalation is informative, or required action by the higher management level.

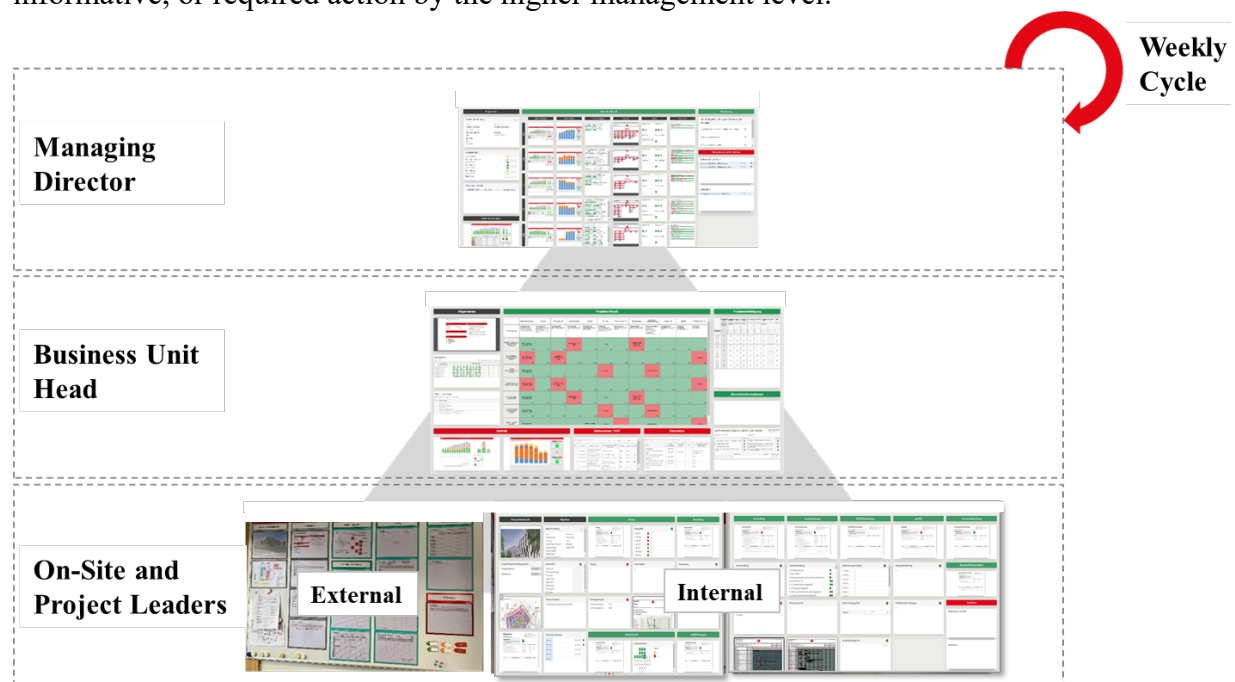


Figure 1: SFM Cascade

The following table shows how the stand-ups were synchronized to ensure up-to-date information throughout the organization. Conceptually, a cascade fully synchronized on a single day would have maximized the timeliness of information, but due to central functions that participate in multiple stand-ups on the project level (especially procurement), a second day was also required for project-level stand-ups.

Table 1: Schedule for SFM Stand-Ups

Stand-up type	Weekday		
	Mon-Wed	Thursday	Friday
Internal	no stand-ups	any time: project leaders	08:00-10:00: project leaders 10:00-11:00: business unit heads 11:00-12:00: managing directors
External	on-site leaders: preferably in the early morning (daily)		

From the view of a project leader, the 15-20-minute stand-up can be executed on Thursday, or Friday before 10:00. Between 10:00-11:00, all project leaders participate in the stand-up of their respective business unit head which is expected to take up to one hour (some business units have 15 projects running in parallel, others 5). Consecutively the business units' heads participate in the stand-up of their managing director. Also, the duration can be up to 1 hour depending on the number of business unit heads per managing director. It is conceptually clear that not only the proportion of organizational units (e.g. number of projects per business unit head) is a driver for the duration of stand-ups, but also the number and severity of issues, as well as the communication behavior of the participants.

The contents on both SFM boards can be distinguished into actual KPIs versus topics that are a useful basis for communication. This is not strictly in line with SFM theory but was

thought sufficient to still achieve the desired impact by posting topics on a board that regularly are the cause of phone calls or multiple emails per day.

The following tables 2 and 3 depict the KPIs / topics which were used for the on-site and project leaders. Each line item was a sheet of paper (or later a digital tile) on the SFM boards.

Table 2: Contents of SFM Board for on-site leaders

No.	Title	KPI / topic
1	Health & Safety	# days since the last incident
2	Logistics (1)	One-week calendar to enter planned events (e.g. use of crane)
3	Logistics (2)	List of materials to be supplied by general contractor
4	Planning	List of plans and their revision for the current week
5	Production	# of people on-site planned vs. actual and deviation per trade
6	Quality	Rework overdue by more than one day
7	KAIZEN	Lessons learned for continuous improvement
8	Actions & escalations	List of actions and escalations if a threshold is exceeded

The SFM board for on-site leaders was typically located in a container accessible to contractors. As mentioned above, daily stand-ups were executed in the morning to assess each of the KPIs / topics.

Table 3: Contents of SFM Board for project leaders

No.	Title	KPI / topic
1	Health & Safety	# days since the last incident
2	Sampling	Overdue sampling
3	Planning (1)	Risks identified per planning partner
4	Planning (2)	Overdue drawings
5	Planning (3)	Evaluation of performance per planning partner
6	Tender (1)	Requests for proposals overdue
7	Tender (2)	Contracts pending overdue or over budget
8	Production	Milestone status (planned vs. expected / actual date)
9	Quality	Status of preventive quality plans per trade
10	KAIZEN	Lessons learned for continuous improvement
11	Actions & escalations	List of actions and escalations resulting from deviations
12	Process Map	List of work packages and their status

The SFM Board for project leaders was initially located either in a container on-site or in the office of the project leader. The location of the SFM board for project leaders was an issue, because project leaders typically worked both from the construction site, but also from the office. The participants of the stand-ups were also split into those that worked on-site, and those that worked from the office (e.g. procurement).

OVERALL LEAN CONCEPT WITH SFM

SFM needed to be integrated into the existing Lean concept, which has evolved since the mid-2000s. For this purpose, a short overview of the existing Lean concept is given in table 4.

Table 4: Levels of existing Lean concept

Level	Main elements of the Lean concept
Company	<ul style="list-style-type: none"> • Retrospective after each project (approx. ½ day in the project team) • In-depth analysis of loss projects • Idea Management
Project	<ul style="list-style-type: none"> • Process Map • Project Team-Meeting (discontinued with SFM) • Project Reporting (discontinued with SFM)
On-site	<ul style="list-style-type: none"> • Last-Planner-System • Logistics (in- and out-bound) • Quality (preventive and reactive)

The first level, *company*, is a level that is often missing from the author's view when implementing Lean Construction. Its objective is to manifest and accelerate a learning curve across the entire company and project portfolio. To achieve this objective, the approach is to make ways of working transparent and to exchange lessons learned in a systematic way. It was expected that SFM supports this level because the recurring process of exchanging lessons learned was integrated into SFM.

The second level, the *project*, was implemented by means of a standardized Process Map, which contains a work breakdown structure in combination with quality gates. The Process Map is digitally provided to the teams quoting or executing a project as a guideline to complete the required work. Each work package is scheduled and executed by the responsible person in the team. The completion is tracked in the digital tool and aggregated to the project leaders. In regular intervals of two weeks, the project team and the leadership met to review the progress of the work packages. After the review, a one-page report containing KPI and potential escalations was created by the team, which was intended for review by higher management.

SFM conceptually overlaps with the second level in three areas. (1) the weekly stand-up and the bi-monthly team meeting. (2) the use of KPI, and (3) the function to escalate. It was decided to replace the bi-monthly team meeting with the weekly stand-up, reducing the planned time spent on this process from 4 hours per month to 2 hours per month. To keep track of the work package progress in the Process Map, information on the degree of completion of work packages was included in the SFM board of the project leader (automatically generated). The report containing KPI was also replaced by the SFM boards. With SFM, a more sophisticated set of KPIs was defined by differentiating by organization level (previously not the case). Potentially the most impactful decision concerning (3) was to replace the existing reporting with stand-up meetings also for higher management (i.e. cascade) and to define thresholds for each KPI and organizational level.

The third level, *on-site*, was based on the Last-Planner-System with the corresponding tools and meeting structure. According to Hofacker et al. (2010), SFM conceptually is an addition to the Last-Planner-System by providing a daily routine with multiple topics relevant to short-term production management (e.g. materials required, staff on site). It was intended that communication otherwise happening during the day and leading to interruptions would be combined in the daily stand-up, creating an efficiency gain and leading to smoother communication patterns.

The following picture illustrates the three levels with the main elements relevant to SFM:

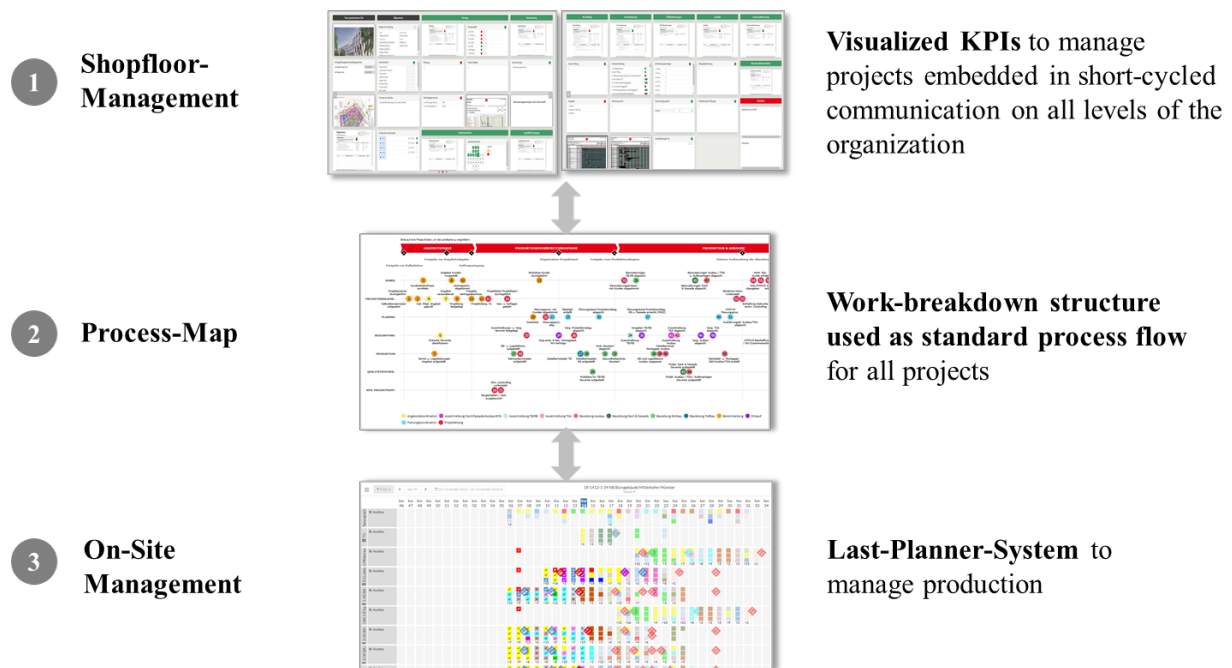


Figure 2: Extract of Lean concept relevant to SFM

IMPLEMENTATION APPROACH

After an explanation of the general approach to introduce SFM, the digitization approach is elaborated in more detail due to its high relevance from the view of the author.

GENERAL IMPLEMENTATION APPROACH

With regard to change management, the planned approach was to proceed in four steps:

1. *Conceptualize* with stakeholders from two of ten business units, and thereof representatives of all organizational levels. The stakeholders started with external benchmark visits before conducting internal workshops.
2. *Pilot and Refine* – after piloting one project from each of the two business units with the close involvement of leadership, the methodology was refined based on the outcomes and experience of the pilots.
3. *Rollout* to all new projects while applying a just-in-time training for each project team individually. In parallel, the so-called cascade for the business area leads and managing directors was built-up (equaling three conceptual levels of SFM).
4. *Review* the maturity of implementation of SFM on a per-project level regularly, make the maturity assessment transparent to the project leader, and give advice on how to improve and integrate it into regular reporting to managing directors.

A duration of two years was planned from the start of conceptualization to the start of rollout. The introduction of SFM was managed by a person with strong experience in lean management.

DIGITIZATION APPROACH

The company decided to implement a custom-developed digital solution following a strictly agile / SCRUM-based approach as outlined in Brenner (2019), p. 141 - 143 based on the following key principles:

- a usable version of SFM had to be available within three months, to not deviate too strongly from the overall timeline to rollout SFM to all new projects.
- the digital version had to be an identical copy of the paper-based version to reduce the complexity of two SFM versions – in terms of the contents - in parallel.
- the SFM board had to be optimized for large touch screen use, to maintain the “look and feel” of a physical SFM board.

The development teams were in a near-shore location managed by a consultant in Germany. Weekly calls were set up to prioritize scope with a fixed budget and monthly release cycles. For each of the contents on the SFM boards, three data integration steps were differentiated and implemented in an incremental approach:

(1) It is possible to access the underlying data with a maximum of one click. This was achieved by the simple linking of documents. (2) It is possible to reuse data values from other systems and display them on the SFM boards. (3) The SFM board displays the result of a computation, hence actually assisting in the interpretation of data. As an example, the system would compare the dates of actual drawing delivery (from a cloud-based platform) with the scheduled and thus expected delivery dates (in a specialized scheduling software), and deliver a key performance indicator such as weekly schedule adherence in percent.

DISCUSSION

To date, there is no literature specifically attempting to quantify the impact of SFM on the KPI of construction companies. Hence, the following measurement approach is a proposal subject to adaptation based on further research and feedback.

The business impact from a *company perspective* is considered to be lagging and a direct correlation to SFM difficult to prove. Still, an attempt was made by tracking the total (negative) earnings impact from loss projects. The measurement showed a clear reduction of this KPI, as shown in table 5. The revenue of the company was more or less the same at the two points of measurement.

With respect to the *project perspective*, an analysis of on-time completion was conducted. Measurement of on-time completion was not measured previously in the company. As a consequence, data first had to be collected and cleaned for example by analyzing causes of prolonged construction in detail: if the customer added scope to the project, the target completion date was deferred, hence the project was on-time if the deferred date was met. As table 5 shows, also a clear improvement could be observed. One must note, that this improvement might have been influenced by factors (external/internal) beyond SFM. There was no ex-ante prolongation of schedules to improve on-time completion.

From a *people perspective*, time savings in combination with better information quality were positive impacts. To explain in more detail, this perspective will be further differentiated into individual, project team, and management (business unit heads and managing directors):

For *individuals*, it was estimated that the time previously spent to process information required to fulfill one's management role (independent of level) was at least 2-5 hours per week. Example tasks are: reviewing information in systems, lists, or reports, fetching information by email or personal interaction, or conducting meetings. Because this value strongly depends on the working style and organizational performance level, it varies strongly. With SFM there is a range of 30-60 minutes per week to achieve at least the same information level. Also, SFM led to a reduction of interruptions because the stand-ups offered a structure for communication instead of the multitude of people involved in a construction project communicating with each other. This reduction of interruptions has not yet been quantified.

For *project teams*, an average of 30 minutes (vs. 15-20 minutes as expected) is required per week, hence 2 hours per month, for the project leader's stand-up compared to the previous 4

hours per month for team meetings. Only these figures from the people perspective were included in table 5, since they have less variance than the figures for individuals. Feedback was clear that the information shared during a stand-up led to a much better result in terms of all team members being synchronized. Ideas to solve problems were shared in the team much more dynamically, which is expected to benefit the project-level mid-term.

Also, *management* reflected uniformly that the quality of information (i.e. the value resulting from the time spent sharing information) was better than before. The information was more complete, up-to-date, and accurate than previously. As another clear impact, the relevance of issues communicated was higher (due to thresholds defined uniformly in the company). If the negative impact of an issue did not exceed the threshold, the team continued to solve the issue without investing time in communication with the next hierarchy level.

The impact on all levels needs further investigation. The author recommends companies aiming at introducing SFM, invest more in baseline quantification and in keeping track of the impact on a regular basis.

Table 5: Overview of indicators to evaluate impact of SFM

Perspective / Indicator	First quantification	Second quantification	Change	Hypothesis on cause-effect logic
<i>Company</i> sum of negative earnings from loss projects	100 points (as indexed baseline; end 2020)	37 points (mid-2022)	-63%	By recognizing deviations earlier and creating more effective solutions
<i>Projects</i> on-time completion of projects	100 points (as indexed baseline; 2020; n=53)	126 points (2021; n=45)	+26%	Higher awareness of schedule deviations (target / actual) compared to Last-Planner alone
<i>People</i> time spent in project meetings	4 hrs/month (2 x 2 hrs)	2 hrs/month (4 x 0.5 hrs)	-50%	Efficiency of stand-ups due to structured communication

With respect to the *contents* of the SFM boards, the general agreement was that all topics are relevant to successfully manage from the view of the respective role. At the same time, especially from the group of project leaders, it was noted that the SFM board contained too many elements to be handled efficiently. Also, major feedback was that the project leaders claimed to already know most of the information that was written on the SFM boards. The response to this was two-fold: (1) after multiple discussions with project leaders during refinement / continuous improvement of the SFM methodology, the outcome remained to be that all topics on the SFM boards are required for their management role. Regarding the feedback of already existing knowledge, an assessment showed that the change in communication behavior (resulting from SFM) was not fully achieved on an individual level: it is ineffective to continue the communication/information processing approach applied over years and apply SFM in parallel. The project leaders need to change the communication approach by regarding the SFM stand-up as the primary source of information, and ask the team members to provide their information not ad-hoc during the week, but instead during the stand-up (except for very time-critical issues). This change was underestimated and is a learning which may help other companies in the adoption of SFM.

The next learning concerns the *digitization* approach. The agile / SCRUM-based approach was very positive regarding flexibility and output. But the decision to implement a paper-based version on the project level before digitizing should be critically reviewed. The majority of negative feedback received was that the paper-based version was not only inefficient (writing by hand data that is available in systems and then feeding the issues over the threshold into the

management cascade), but also created paper waste that can be avoided, and caused limitations to involve the full team during stand-ups. Team members concerned with the planning and procurement process could not be well integrated into a stand-up unless it was conducted in the office. This is not the intention of SFM, because the stand-up should take place on the construction site. Using a digital board allows the entire team to access it, independent of location (and time). Due to the SCRUM approach applied in software development, a usable version of the digital SFM board was available after only three months. With respect to the overall timeline of two years from the start concept to the start rollout, it is recommended to build the digitization into the timeline and start with the digital version earlier. This is contrary to the recommendation given on page 120 by Leyendecker & Pötters (2020). A relevant difference may be, that the company underlying this case study had a strong history in Lean. From an IT equipment perspective, the pilot projects showed that a very large touch-screen was not required for SFM. A regular (non-touch) screen on-site was fully sufficient to execute a stand-up. Because all sites were already equipped with a screen and a team meeting area, no additional investment was required.

In total, the expected positive effects of digitization outweighed the potential risks outlined by Clausen et al. (2020), with the exception of on-site leaders. Digitization of the boards for external stand-ups was discontinued, because on-site leaders gave feedback that the digital version was considered a too high barrier and culturally incompatible.

CONCLUSIONS

Over 2 years of implementation have created valuable experience regarding the adaptation of SFM to the construction industry. The results presented show measurable positive impact from all the perspectives (company, projects, people). Given the benefits outlined in this paper, the author expects a strong increase in SFM implementations in construction in the next years. Further research is required regarding the measurement of the impact created by SFM. The indicators presented in this paper are the first proposals, which should be further discussed. Also, it will remain a challenge to separate the causes leading to changes in such indicators aside from SFM, to isolate as much as possible the pure impact of SFM.

The paper shows that early adoption of a digital SFM system will increase acceptance and hence facilitate rollout. As the availability of technology to process large amounts of data advances, more intelligent features can be included in such a digital SFM system. This is positive and critical alike because it should be well understood that SFM is – at the core – a fundamental management approach, not just a set of boards or an IT tool showing numbers on a display. Companies seeking to embrace SFM should be aware that its successful implementation will strongly depend on the readiness to create teams that are more autonomous than in traditional hierarchical and functional setups, and that the teams are motivated to not only solve issues in the individual project but also to identify root causes of issues in the sense of company level continuous improvement and learning.

ACKNOWLEDGMENTS

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