Quantifying the impact of digitalization in a power generation company

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Topic Areas: Manufacturing, Strategy, Metrics

Summary:

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KEY INSIGHTS

1. Manufacturing SC becomes increasingly important with implementation of digital concepts such as Industry 4.0 or Smart Manufacturing. Though, quantitative research on the improvement by digitalization has not yet been done.

2. The impact of digital initiatives such as visualization of information on the shop floor shall be measured toward the expected boost in productivity and availability of assets.

3. In the precedent case, the visualization on the shop floor increased the operation time of the machines and the planned maintenance. However, the reduction of unplanned machine downtime could not be confirmed.

Introduction

Industrial digitalization concepts such as Industry 4.0 or Smart Manufacturing are currently of great interest in academia and among industrial players. These concepts are expected to boost companies' manufacturing supply chain performance factors such as availability and productivity of assets on the shop floor. For instance, greater availability of operational machines based on reduced breakdown rate makes the product flow more predictable and smooth, thus reducing the necessity for high inventory. Higher productivity due to increase in production or effective predictive maintenance increases inventory turnover or reduces lead time for customer orders.

<u>Digital concepts</u>

Technological progress generated a number of innovative tools and approaches which can be used for industrial digitalization: Internet of Things (IoT), cloud services, 3D printing, sensors, to name a few. Looking for the best way to combine these tools and approaches in one system, one would mostly find the concepts named "Industry 4.0" and "Smart Manufacturing". Industry 4.0 was originally initiated in Germany in 2011, but quickly gained international attention. The high-level Industry 4.0 concept pillars are Cyber-physical systems, Internet of Things, Internet of Services and Smart Factory. In many academic sources these pillars are overlapping. Cyber-physical flows are interconnected by interface devices such as sensors, RFID or barcodes. Digitally linked assets, systems and devices build the Internet of Things. Large amount of data accumulates in the clouds creating the so called Big Data. The Big Data is processed and analyzed mostly using internal application such as Enterprise Resource Planning or Manufacturing Execution Systems connected to the cloud services. These applications and systems are increasingly offered virtually thus building an own domain - the Internet of Services. The Smart Factory is an entire digitally interconnected manufacturing system and includes autonomous manufacturing processes, robots and 3D printing. The U.S. model of industrial digitalization, so called Smart Manufacturing is similar to Industry 4.0.

<u>Research gap</u>

Based on the review of the academic sources and qualitative interviews with subject matter experts in the power generation industry, several problems could be identified. Academia and industry lack a common understanding of the industrial digitalization concept. The fast technological progress creates large asymmetries between proposed frameworks – not everyone can keep the pace. Furthermore, the industrial digitalization was hardly observed from the logistics perspective. The manufacturing supply chain still lacks the proper focus. The main gap is the absence of the quantitative proof that digital initiatives influence the performance development in industrial manufacturing positively. The assumptions are based on the interviews with industrial subject matter experts. However, no common methods for measurement could be identified.

The gap can be addressed by introducing a data-based method of quantitative analysis and examination of the effectivity of selected digital initiatives. This study observes the impact of the *Visualization* on the performance factors *unplanned machine downtime, machine utilization* and the *planned maintenance*. The term Visualization is used for the system of interactive whiteboards, dashboards, tablets, displays and usage of Tableau on the manufacturing shop floor, which is implemented as a part of digitalization concept.

This analysis can be conducted in the first step by simple testing of the assumptions made in the academia and given by the experts. The assumptions can be tested by using an appropriate hypothesis test. The inferential statistics offer a broad range of hypothesis tests. A preliminary data sample assessment is needed to determine which one is the right test. This way such initiatives as visualization, paperless manufacturing, digital quality control and many more can be tested regarding the assumptions made by the managers in the industry before implementation or identified in the literature. The general framework of the research is shown in Figure 1. For academia, this can be a step toward quantitative analysis of digitalization in industrial areas.

Showcase and data

The qualitative interviews and the data were collected from a factory which belongs to a large power equipment manufacturer. The showcase factory produces gas and diesel engines for power generation. In 2015, the enterprise decided to become a Smart Factory model and to roll out a full program of digital innovations. Starting in 2016, the company changed to paperless manufacturing introducing digital WIP jobs, started with digital quality control, and cloud based energy management. Furthermore, the factory installed vibration sensors on machines for predictive maintenance, integrated visual analysis on the working desks and on the shop floor. The serial 3D printing of a complex component is planned to be launched in 2018. All systems, such as Enterprise Resource Planning, Manufacturing Execution System, Computer-Aided Design, digital quality systems and some of the company's own tools, equipment and resources databases are interconnected via Digital Thread and exchange data on the protected factory server. The connection to the company's own Industrial Internet of Things platform is launched and partially used.

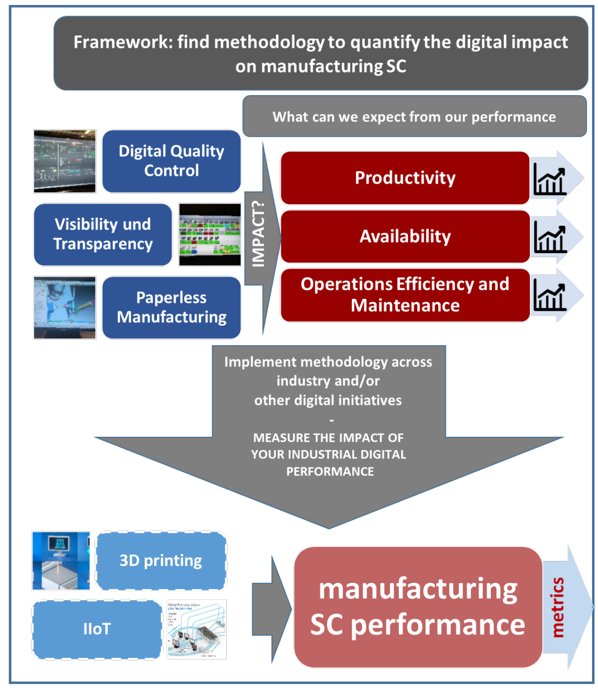

Figure 1: Research objective

The case data is collected from the Manufacturing Execution System of the showcase factory and extracted via Tableau. Since 2011, the system records machine signals which are categorized according to various machine conditions such as production, planned downtime, downtime for maintenance, downtime caused by tools and material absence etc. The manufacturing shop floor can be clustered in 13 machine groups. The data is collected and cumulated for each machine group. The sample pairs are signals taken before and after the implementation of visualization. Here, it is important to observe the duration of a certain machine conditions. The number of signals is irrelevant since these are changing instantly and multiple times a day for the same condition. The Figure 2 exhibits the historical pattern of the machine records for the conditions *unplanned downtime, planned maintenance*, and *machine utilization*. The implementation of visual tools for information and data analysis with integrated user interface on the shop floor impacts human perception and decision making.

The resulting employee activities are expected to increase machine utilization and early-stage planned maintenance, and decrease unplanned machine downtime (Figure 3). These factors increase productivity and availability of assets in the manufacturing supply chain.

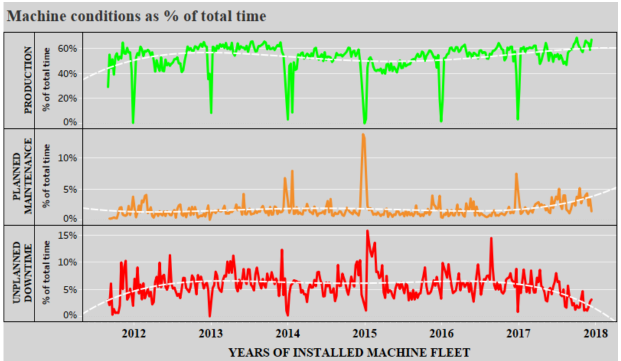

Figure 2: Pattern of machine utilization, planned maintenance and unplanned machine downtime. Data from Manufacturing Execution System evaluated in Tableau

Methodology

For the analysis of the visualization-driven changes, the machines "behavior" on the shop floor before the implementation and after the implementation must be assessed. Hypothesis test is applied to assess changes in performance.

To identify the appropriate hypothesis test, the normality of data distribution must be evaluated. This can be done by graphical (histogram, quantile-quantile plot), numerical (kurtosis, skewness) and formal methods (Shapiro-Wilk test). For normally distributed data samples, the most common hypotheses test is the t-test. However, the showcase data samples proved to be non-normal. Furthermore, the data samples are dependent data-pairs (before-after) for 13 machine clusters. The Wilcoxon Signed-Rank test is the most appropriate non-parametric hypotheses test for the analysis. This test examines the impact of the visualization as dependent variable on the independent variables: unplanned downtime, planned maintenance and machine utilization.

Results

The results indicate a significant increase in machine utilization (p-value = 0.0199 < 0.05) and planned maintenance (p-value = 0.002319 < 0.01). However, unplanned machine downtime was not significantly reduced, although the result shows an approximation toward statistically significant change (p-value = 0.2274 > 0.05). The importance of frequent analysis becomes obvious. Future tests are necessary to study the development in later stages of implementation of Visualization. The reduction in downtime could become significant and the planned maintenance should stop increasing and start decreasing over time. The proposed method serves as a step toward academic quantitative analysis of industrial digitalization.

Conclusion

Every initiative which can be proved as effective can be converted into directly related financial benefits for the company: manufacturing SC performance leads to a boost in the overall SC performance, which results in cost savings and higher revenues due to customer satisfaction. The initiatives, which would not show a significant result, are subjects for further analysis and observations, which can lead to early identification of issues and on-time corrective actions. The awareness to strive for a structural digital implementation approach could help the industrial players to overcome the reluctance to collaborate with external experts and lead to more research projects between companies and research institutes.
Industry 4.0 and related industrial digitalization concepts are progressing promising a new era of performance in heavy industry. The step toward quantification of these development in academia is a step toward close collaboration with the industry. The endeavor to prove the academic assumption and to quantify the digital progress generates a win-win situation for both: academia and industry, helping the industrial decision makers to develop the right digital

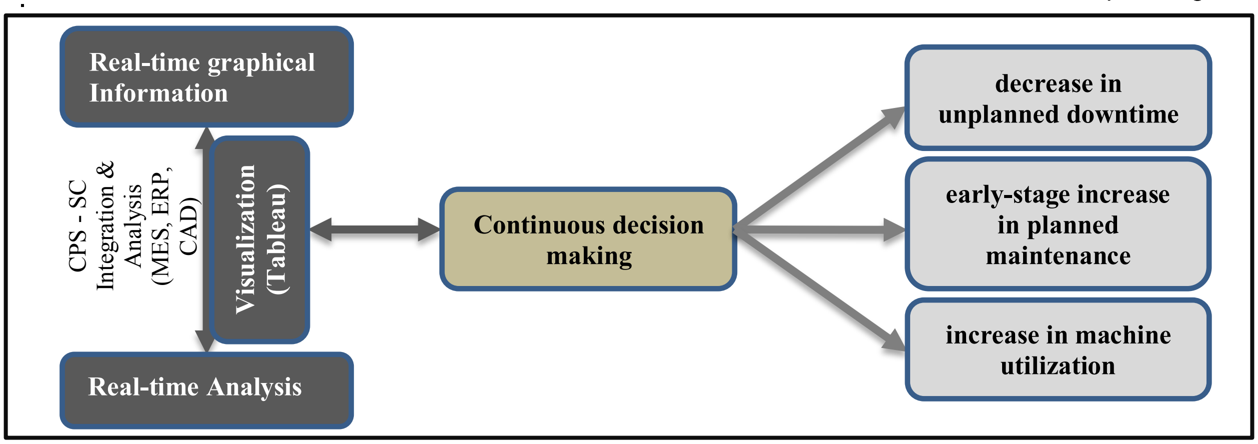

Figure 3: Expected impact of Visualization on manufacturing SC performance factors

mind-set and giving the researchers the proof for their studies. This is a simple concept of measurement of digital initiatives which can be the first step toward convergence between academia and the power equipment manufacturing industry.