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The role of maintenance in company-specific production systems

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Abstract

Company-Specific Production Systems (XPS) are in use in several manufacturing companies around the globe, as a reference to variations of the Toyota Production System. XPS is a continuous improvement program responsible for increasing the general performance of companies. Maintenance has an important contribution to XPS by delivering technical availability at a rational cost. However, the connections between all the elements of the XPS and the corresponding contributions from maintenance are not crystal clear. Providing such clarity could increase the focus on improvements that would create real benefits for the company. The current study aims to bridge the XPS literature to maintenance applications, thereby substantiating the role of maintenance in XPS. Firstly, a theoretical framework of XPS is created and explained based on previous literature. The framework outlines three core elements of an XPS: content, management, and outcomes. Also, it presents the interconnections between the elements. Secondly, the framework acts as a guide to an empirical study at an automotive company in Sweden. The study maps the role of maintenance and its contribution to the XPS in place. For each of the XPS elements, a maintenance correspondent was selected and connected to the XPS framework. Thirdly, based on the results of the empirical study, the paper proposes a set of critical research directions, both guiding the design and execution of future research studies and supporting the long-term competitiveness of the company.

Keywords: Maintenance; Manufacturing; Company-Specific Production Systems; XPS.

1. Introduction

A relentless pursuit for improving productivity has been forcing companies all over the world to reduce waste and cost, decrease non-value-added activities, and by that, make an important contribution to the overall performance of the company. Additionally, the threat of knowledge loss and the ever-accelerating wave of digitalization enhance the challenge that organizations need to overcome by avoiding being behind the competition. Indeed, the journey of improvement is no longer optional, it is the essence of survival in the modern business ecosystem.

Given the importance of improvements, systematizing a Continuous Improvement Process (CIP) is needed for companies, especially for a multi-site corporation competing globally. In prior research, such a movement is often referred to as XPS (Company-Specific Production Systems), where X usually relates to the initial letter of the company's name [1]. XPS are lean programs adapted from the Toyota Production System (TPS), and they differ from conventional improvement projects in their intention of being permanent and impacting the culture of the company.

The focus of XPS is on implementing methods by employees themselves, considering they should be applied in place of the value-added process and require employees to always think about their actions so that a CIP takes place [2].

Maintenance is responsible for ensuring availability in the production processes and should play an important role in the XPS for two key reasons. Firstly, maintenance accounts for a substantial portion of the manufacturing costs, which must be

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addressed and controlled. Secondly, maintenance supports productivity by assuring high machine availability, performance, and quality.

However, in the XPS literature, almost no mention of maintenance is present, and when it appears that is superficially. The opposite also holds, where there is no recognition of XPS as a way of systematizing maintenance improvements across plants. Therefore, this study aims to bridge the research streams of XPS and industrial maintenance by explicating the role of maintenance in XPS and bringing the XPS perspective into maintenance applications.

2. Company-specific production systems

The way to improve processes in lean manufacturing companies is related to improving efficiency, optimizing processes, and eliminating wastes during the value-added activities which reduces the lead time of the materials in the process flow [3]. Rewers *et al.* [4] point to seven types of waste: (1) overproduction, (2) inventory, (3) mistakes & quality defects, (4) waiting, (5) over-processing, (6) unnecessary transport, and (7) unnecessary movement.

An additional eighth waste is also known as underutilized people which relates to not taking advantage of people's creativity [5]. This is the foundation of the XPS; a production improvement program developed specifically for the company [6] that seeks to adopt or adapt to the TPS [7]. Therefore, while all XPS take their main inspiration from TPS, every company develops its own XPS by strategically selecting and implementing specific principles tailored to its own company [7].

To structure and synthesize the existing literature on XPS as well as guide the present empirical study, we developed a theoretical framework for XPS based on previous literature (Fig 1.). Three XPS elements were mapped and named *content*, *management*, and *outcomes*, and a closed loop interconnects all three elements. The XPS content is intended to be diligently implemented to produce the desired XPS outcomes. This process is controlled by the XPS management, who also hold responsibilities for assessing feedback from the outcomes and accordingly devise improvements to the content.

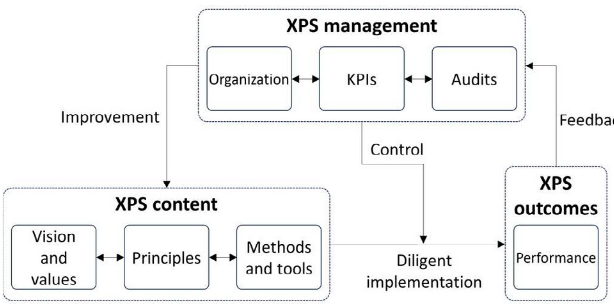

Fig. 1. The XPS elements and connections.

Within the XPS content, the guidelines and the structure of the production system are stated, where the *vision and values* (or objectives) of lean manufacturing are to eliminate waste and to develop customer value [3]. The *principles* that come next are considered the organizational concepts that support the vision and values [8], and the strategic selection of the principles results in the structuring of the company's XPS [7]. The extant literature classifies the principles in different ways.

According to Netland [6], 32 principles are found in the literature, however with some divergences among authors. Arlbjørn and Freytag [3] state that there are five principles: (1) value creation, (2) Value Stream Mapping (VSM), (3) stability, (4) pull system, and (5) continuous improvement. Patil and Lakshmanan [9] propose teamwork, process stability, built-in quality, just-in-time, and continuous improvement as core principles. The differences among authors may be explained by the classification criteria used to define them as either principles or methods and tools, the latter positioned as a third element inside the XPS content in this article.

Methods and tools (also named techniques) are the standard procedures applied at the place of the value-added process by the employees [2]. According to Rewers *et al.* [4] they are VSM, 5S, Single digit Minute Exchange of Die (SMED), kanban, jidoka, hoshin kanri, heijunka, standardized work, poka yoke, kamishibai and kaizen. Other variations are also mentioned in the literature, such as pull production, group layout, tact time, Total Productive Maintenance (TPM), bottleneck & constraint management, information boards, performance management, cause & effect as well as Overall Equipment Effectiveness (OEE) [3]. Similarly, Patil and Lakshmanan [9] presented 24 methods and tools linked to the principles.

The next subgroup, XPS management refers to the way of managing the XPS implementation. It includes the *organization* in place to coordinate the XPS program, so as to influence important company characteristics such as culture, size, roles and responsibilities, and maturity level [6]. The focus is on implementing methods by employees themselves, which requires employees to always think about their actions so that a CIP takes place [2].

Successful CIP requires an approach to measurement and evaluation. For this purpose, *Key Performance Indicators* (KPIs) are used to measure, directly or indirectly, the XPS implementation, thereby allowing the company to evaluate if the actions taken are improving the trend. Here, Neely and Bourne [10] state that the trick is to measure as little as possible but to ensure that you are measuring the things that matter.

Audits, not only on the KPI level but also on the organization's way of working, are important both to control the XPS implementation as well as to guide the necessary and focused improvements. Netland and Aspelund [11] state that audits act as a control system, where the XPS assessment regime aims to measure each plant's maturity in the execution and thereby drive performance.

The expected XPS outcomes are reflected in increased *performance*. Evaluating performance allows for highlighting opportunities for improvement, detecting problems, and helping find solutions [12]. It can be characterized by three different levels where the first measures, in the sample area the efficacy of the methodology application, then the effectiveness, when widespread to similar or correlated areas, ending in efficiency, the core focus, where the more efficient use of resources is considered. Measuring performance is essential in any business according to Kumar *et al.* [13], and lean maturity has been shown to positively influence performance [14].

A closed loop connecting all the XPS elements allows this framework to perform as a CIP. The XPS outcomes have an important role in providing feedback to the XPS management, where focused reactions are expected from the audit system to guide the proper selection of the methods and tools, ensure a focus on prioritized KPIs, as well as adjusting or challenging the way of working of the organization itself. Two outputs are expected from the XPS management. On one hand, controlling the implementation of the XPS content, and on the other hand, proposing improvements, updates, and proper selection of the methods and tools, aiming to attain the principles that guide the vision and values of the organization.

3. Methodology

3.1. Research approach

Previous XPS literature is largely based on Scandinavian, global automotive companies [3, 7]. To enable the continuation of previous research streams on XPS and improve the conditions for establishing an accumulated knowledge base on maintenance in XPS, the choice was taken to study maintenance in XPS within the same region. Thus, an empirical study within a Swedish automotive company was conducted.

3.2. Data collection

The company granted access to the internal systems where all relevant XPS-related documents are stored. It is a collection of 7 files, all of which have a PowerPoint format. The content of these documents includes a general description of the XPS and its latest updates, the Professional Maintenance (PM) Methodology and Workshop, a summary of the PM Methodology, and the PM Audit Criteria. Table 1 presents a summary of the collected data.

Table 1. Summary of data collected.

Description	Pages
General description of the XPS	337
Recent updates of the XPS	12
PM Methodology in detail	279
PM Workshop in detail	120
Summary of PM Methodology	21
PM Detailed Audit Criteria	27
Summary of PM Audit	6
Total	802

3.3. Data analysis

Four different steps were clearly defined for the data analysis, inspired by the coding procedures in Kendall [15]. Firstly, a full reading of all the material was conducted to provide a general understanding of the full XPS and PM methodology as well as links to other areas. Secondly, open coding was applied to identify distinct conceptual entities [16]. Thirdly, axial coding was applied that focused on identifying and categorizing the entities into emergent themes.

Finally, selective coding was used to integrate the categories of organized data in cohesive and meaning-filled expressions, specifically by interpreting the themes vis-à-vis the developed XPS framework in Fig 1. This facilitated the construction of theoretical meaning from the empirical findings [15].

A clear connection between this company's XPS material and the XPS proposed framework was identified. Additionally, the role of maintenance in the XPS was mapped, fitting all the elements presented in the framework, where maintenance plays a crucial contribution to achieving the performance that guides the company towards excellence.

4. Findings

The specific and relevant aspects of PM and its links to the general XPS are presented in the following sections, thereby explicating the PM contributions to each of the XPS elements.

4.1. PM-focused XPS content

As part of the content under PM responsibility, the vision and value are to secure the correct level of technical availability for each production equipment based on its needs (safety, quality, delivery, cost, environment, and people). Methodologically, World Class Manufacturing (WCM) is in use at the company, which has dedicated one of ten technical pillars in the temple to PM. Although PM has close ties with Autonomous Activities (or Maintenance - AM), PM is the only focus of this study.

The vision and values are anchored in the principles of PM. The PM principles are: (1) to maintain, restore, and improve production equipment by effectively and efficiently reacting on breakdowns, preventively utilizing present process knowledge and proactively foreseeing future breakdowns to eliminate occurrences of future breakdowns; and (2) secure critical spare-part availability and managing improvement projects towards equipment and secure performance excellence in new equipment.

The method in use has two different approaches inside the PM pillar that are complementary: (1) the 7 steps approach, where the machine is in focus; and (2) the application (rollout or spread) level, where the focus is the coverage area of PM, i.e., the number of machines and devices under the PM responsibility. As a result, a score, or maturity level from 0 (no application) to 5 (high maturity) is possible.

As resources in maintenance are usually scarce, an analysis on prioritization is suggested to understand which machines are to be prioritized to receive the 7 steps approach first. It starts with one model machine (or model area) where the initial deployment of the methodology, tryout, adjusts, corrections, and tentative standards are incentivized.

- Step 1 (reactive): eliminating and preventing deterioration of equipment. This can be achieved by restoring to default states and preserving an environment that prevents the possibility of deterioration.

- Step 2 (preventive): focuses on reverse deterioration consisting of activities performed to prevent identical errors from occurring again.
- Step 3 (preventive): maintenance standards are established. This facilitates the work with the prevention of errors through, for example, planned time intervals.
- Step 4 (preventive): develop countermeasures to be able to identify weaknesses in equipment to extend the service life.
- Step 5 (preventive): creation of periodic maintenance system.
- Step 6 (proactive): develop a maintenance system with a focus on proactivity to enable the prediction of errors that will occur further.
- Step 7 (proactive): deals with maintenance cost management and focuses on establishing a planned maintenance system.

Fig. 2 presents the objectives of each step visually.

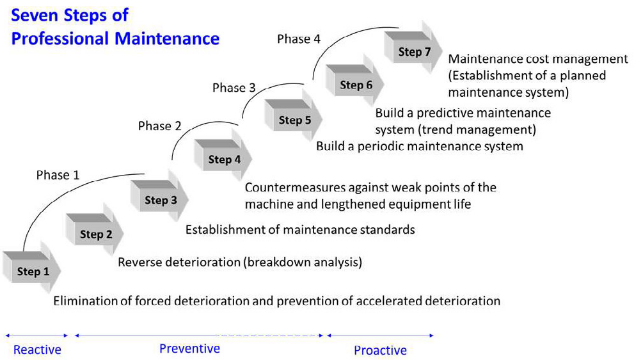

Fig. 2: The 7-step approach to PM.

In addition to the 7-step approach, the PM methodology describes important tools and techniques, consisting of the 7 WCM basic tools: (1) prioritization; (2) logic, systematic and detailed deployment of objectives; (3) problem description with sketches; (4) problem description with 5W+1H; (5) 5 whys; (6) phenomena description with sketches; and (7) The Way To Teach People (TWTTP).

The methods take into consideration the number of machines and equipment in the coverage area, so a prioritization of machines into AA (most critical), A, B and C (less critical) occurs in the three different stages (reactive, preventive, and proactive). The kickoff for PM implementation demands breakdown data to be recorded, for instance, via a Computerized Maintenance Management System (CMMS). This also allows Cost Deployment (CD) to be used to properly classify the machines under the coverage area by maintenance-related losses (including mainly maintenance human hours, spare parts, and production losses). This is the reactive classification.

The 50/20/20/10 rule is applied next, as shown in Fig. 3, where machines addressed to 50% of the breakdown losses are classified as AA machines, the next 20% of breakdown losses receive A classification, the next 20%, B, and the last 10%, C.

Good practices suggest addressing (mainly) Real Time Condition Based Maintenance (RTCBM) for AA Machines, recurrent Condition Based Maintenance (CBM) for A Machines, Time-Based Maintenance (TBM) and Inspection & Replacement (IR) for B Machines and Breakdown Maintenance (BM) for C Machines. This is called reactive classification.

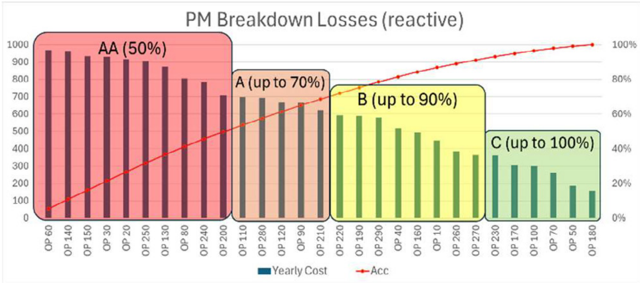

Fig. 3: Reactive machine classification using 50/20/20/10 criteria.

There is also a similar classification called preventive classification, where human hour and spare part costs are summed and presented in a similar Pareto distribution. This is an important source of information for steps 4, 5, and 6, and finally, a proactive classification, for step 7, where factors such as the impact on production, quality, cost, delivery, safety & environment, and people's morale are considered.

Reactive machine classification, PM core team training, 5S, and maintenance KPIs selection, are considered prerequisites. They should be available before starting the implementation, also known as step 0.

On the next or first real step, number 1, the machine should be fragmented into equipment (machine), unit (system), subunit (sub-system), and finally component. The assumption that a machine does not break but components do, gives importance to this functional structure. The effect on the machine due to the malfunction at the component level classifies them into three different possibilities:

- A: when the component breaks down the equipment stops, with high impact on production losses.
- B: when the component breaks down the impact on equipment is limited, with medium impact on production losses.
- C: when the component breaks down the equipment has minor stops, with minimal impact on production losses.

The criteria that support this classification are the impact of the component in other components or subunits, the impact on Mean Time To Repair (MTTR), Mean Time Between Failures (MTBF), and the degree to which component breakdowns can be detected before their occurrence. Based on component classification and prioritization, supported by the Focus Improvement (FI) pillar, improvements are launched to restore the basic condition of use of the components as well as a machine ledger in combination with an AM Calendar (A components, maybe B).

Step 2 focuses on avoiding the reoccurrence of the same or similar breakdown at the component level, in the same or similar machine. This uses a problem-solving tool specific to the M of machine on the 4Ms, called Emergency Work Order (EWO). A visual breakdown map is suggested to help share the information. Countermeasures are addressed and followed.

In the next step, number 3, the PM calendar in combination with the machine ledger is created. For A components, maybe some B, Standard Maintenance Procedures (SMP) are created to standardize the recurrent preventive maintenance activities on the components aiming to avoid their breakdown. Once A components do not present any breakdown (except for human error) for at least three months, it triggers the next step, number 4. A good reminder is that any recently purchased machine should be delivered at least in this step.

Step 4 supposes no breakdown occurrences on A components and turns the focus from reactive to preventive costs using the second machine classification. On prioritized machines, a preventive, yearly based cost at component level classification is performed, considering human hours and spare part costs. Using technical knowledge in partnership with the FI pillar, suggestions to improve components' life cycle are launched and validated, aiming to reach at least 30% preventive cost reduction per machine.

The last preventive step, number 5, focuses on applying ECRS (Eliminate unnecessary work, Combine operations, Rearrange sequence of operations, and Simplify the necessary operations). For instance, it includes eliminating unnecessary preventive activity, combining frequency among electric, mechanic and lubrication activities, rearranging different activities in the same component to be executed together, and simplifying activities in such a way that they can be executed by the machine operator, transferring the activity from PM to AM.

Another example could be associated with replacing a TBM with an IR activity, as visualized in Fig. 4, thereby reducing its costs. Another 20% in preventive cost reduction is the target per machine.

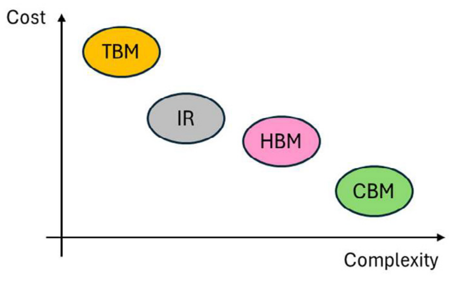

Fig. 4: Costs versus complexity of distinct types of maintenance.

The first proactive step, number 6, is based on the updated Pareto Diagram about preventive costs after step 5. It consists of selecting or developing some kind of CBM, sample or real-time, to replace high-cost TBM, IR, or Hit Based Maintenance (HBM). Updating the PM calendar and at least 10% preventive cost reduction are the expected outputs of this step.

Finally, step number 7 should be considered a "true north", i.e., something to strive for but which is close to impossible to reach. Cost-driven, i.e., a constant search for maintenance cost reduction, is the aim of this step. A factory-wide approach to control and improve overall effectiveness is required. In a continuous product line manufacturing system, OEE, a lagging indicator, supports maintenance management in the measurement of equipment availability and planning rate. Another lagging indicator for Equipment Performance is Availability (results from a combination of MTBF and MTTR).

OEE is best suited to environments of high-volume process-based manufacturing where capacity utilization is of a high priority, and stoppages and disruptions are expensive in terms of lost capacity. The most important objective of OEE is not to get an optimum measure but to get a simpler measure that indicates potential areas for improvement.

Some additional indicators are also mentioned. The first is the total number of maintenance employees, blue and white collar, over the total number of the site employees. There is no target here. Next comes the total number of machines in the coverage area per maintenance employee, sub-grouped by blue and white collar, with no target as well. For both, trend analysis over the years and a correlation to the cost are to be evaluated.

4.2. PM-focused XPS management

The organization in place has a standardized way to assess the KPIs via yearly audits. Auditors are employed by the company in a global department and follow one standardized audit criteria where a set of questions is composed for the 5 different levels of maturity.

Answers to the questions are split between fulfilled or not fulfilled criteria, and all of them make the same contribution to the level result. A set of 19 questions composes level 1; 12 for level 2; 13 for level 3; 12 for level 4; and 13 for level 5. Here, level 0 means no application, and level 5 means high maturity level. This examination of the maintenance system verifies that the maintenance management is following its mission, meeting its goals and objectives, adhering to proper procedures, and managing resources efficiently and effectively. Fig. 5 shows the six colored areas that define the maturity level or score.

Score 1 (in red) is characterized by moving from a reactive to a preventive approach, which demands the knowledge of some basic data of maintenance. Score 2 (in vermillion) means a preventive approach focused on the model machine/area. Score 3 (in orange) is a similar preventive approach for the major areas. Score 4 (in yellow) means a proactive approach focused on the model machine/area. Score 5 (in green) means a proactive approach for the major areas.

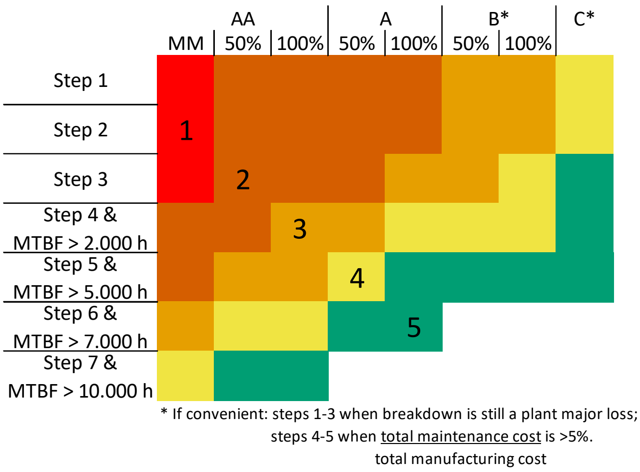

Fig. 5: Scores according to step depth implementation and expansion.

Recommendations derived from the yearly assessment of the steps evolution per machine and maturity level at the coverage area will provide input to the maintenance strategic plan for the next year.

4.3. PM-focused XPS outcomes

The expectations from implementing the XPS content and management focused on PM, are to reach some desired outcomes, here named PM Performance. The two most important of them are (1) maintenance costs, measured as a percentage of manufacturing cost (targeting 5%), and (2) cost per equivalent unit produced (there is no target instead it evaluates the trend over the years), reflecting how maintenance contributes to the company's profitability.

5. Discussion and future research directions

This study bridges the XPS and literature to maintenance applications by developing a theoretical framework of XPS (Fig 1.) and using it as a guidance for an empirical study at an automotive company in Sweden.

The vision and values in the XPS content ensure that maintenance plays a crucial role in manufacturing companies since having the knowledge to avoid breakdowns and lengthening the components' life span leads to availability and cost contention. The maintenance principles mapped in this study will influence the availability of production facilities, the volume, quality, and cost of production, as well as the safety of the operation. This, in turn, will contribute to the profitability of the firm [17]. The mapped methods and tools, mainly the seven-step approach to PM [18], are to be used properly and contribute to ensuring machine availability. This is aligned with the conventional view that the maintenance function primarily repairs equipment [19]. The most important KPI to be considered is OEE, known as best suited for high-volume process-based production environments where capacity utilization is of high priority and stops and interruptions are costly in terms of lost capacity. However, the objective of OEE or any other indicator is not to get an optimum measure but to get a simpler measure that indicates the areas for improvement [20, 21]. The goal of achieving an 85% OEE is a classic and well-known ambition within WCM [22]. Within maintenance-related XPS management, auditing is a necessary attribute. It is the way to assess the maintenance system to verify that the maintenance management is following its mission, meeting its goals and objectives, adhering to proper procedures, and managing resources efficiently and effectively [13]. Systematizing a continuous improvement program that targets increased performance builds a strong path and serves as a way of strengthening the company culture. It helps to embrace most of the employees and take advantage of people's knowledge and willingness to contribute to the general result of the company. Also, the spread of several local improvements to the entire global organization increases the speed of change.

The competitiveness of global organizations benefits from such a systematic approach to maintenance improvements since the existent production system requires maintenance and investments to stay competitive [23]. By keeping employees' morale high and considering their contribution towards the performance journey, the organization is capable of increasing the speed in reverting losses, minimizing non-added value activities, reducing cost, and increasing the overall performance. According to Pałucha [24], WCM is a never-ending process. Cost-driven, a constant search for maintenance cost reduction is the aim of the methodology.

Based on the findings from this study, we call for more research on the role of maintenance in XPS and specifically propose six relevant future research directions:

1. *Local adaption*. For multi-site companies, the XPS program seeks to roll out the PM methodology as a global standard. However, research is needed to understand how local contingencies influence the PM elements as well as how individual sites can flexibly adapt the XPS program to their unique conditions.
2. *Performance relationships*. The logic of XPS implementation hinges on the presumption that as long as the XPS content is diligently implemented according to the standard, performance will increase. However, this is a proposition that still lack empirical evidence. Therefore, future research is needed to truly uncover the relationship between the different maturity levels of PM implementation and measurable performance.
3. *Implementation paths.* XPS implementation is not linear but rather follows an S-shaped pattern that differentiates between the initial, intermediate, and later stages of PM implementation. Understanding the expected performance outcomes across the three stages can guide the selection of the proper approach and resources necessary to overcome barriers and challenges to XPS success.
4. *Audit systems.* The current XPS audit criteria and assessment approach aims to link the main indicators of the PM methodology to maintenance cost. Yet, more research is needed to thoroughly evaluate and potentially improve the validity and reliability of the XPS scoring systems.
5. *Digitalization*. The advancements within industrial digitalization offer immense opportunities for maintenance improvements. Therefore, research efforts need to uncover how digitalization can be effectively grounded, included, and scaled in XPS programs to achieve Smart Maintenance, e.g., by specifying necessary updates to the PM methodology.
6. *Sustainability*. The maintenance function plays a key role in improving sustainability by optimizing the use of natural resources and lengthening the component's life span. More research is needed to expand and systematize the focus on maintenance-related sustainability outcomes within XPS.

6. Conclusion

This study substantiates the role of maintenance in XPS through a synthesis of the existing XPS literature, the development of a theoretical XPS framework, and an empirical study in automotive manufacturing. This effectively bridges the XPS literature to maintenance by clarifying both how maintenance contributes to XPS as well as how XPS can help systematize maintenance improvements.

Deployed from the XPS, the maintenance contributions cover all the elements in the content (vision and values, principles, and methods and tools), management (organization, KPIs, and audits), and outcomes (performance), highlighting the need for a systematic approach that ensures the importance and alignment of maintenance in the production system.

The use of an XPS can contribute to standardized maintenance ways of working that support the company's strategy across the sites, where several departments need to work aligned. An isolated department will not be able to achieve any strategic and stable results.

The XPS vision and values are supported by the principles and ensured by using standardized methods and tools in the XPS content. This results in a diligent implementation of the PM, which is presumed to positively impact desired performance as reflected in the XPS outcomes. The feedback to the XPS Management is necessary to challenge the organization, the KPIs, as well as the audit system in place. This supports both improvements to the XPS content as well as control of the implementation, ultimately ending in higher machine availability and maintenance cost reduction.

As part of a CIP that aims to impact the culture of the company, XPS implementation is important to drive an increase in the maturity level and consequently improve the company's competitiveness over the years.

To increase the attention to research on the role of maintenance in XPS, this study also proposes six directions for future research: (1) local adaption, (2) performance relationships, (3) implementation paths, (4) audit systems, (5) digitalization, and (6) sustainability.

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References

[1] Baudin, M., & Netland, T. (2022). Introduction to manufacturing: An industrial engineering and management perspective. Taylor & Francis.
[2] Prinz, C., Kreggenfeld, N., & Kuhlenkötter, B. (2018). Lean meets Industrie 4.0–a practical approach to interlink the method world and the cyber-physical world. Procedia Manufacturing, 23, 21-26.
[3] Arlbjørn, J. S., & Freytag, P. V. (2013). Evidence of lean: A review of international peer-reviewed journal articles. European Business Review, 25(2), 174-205.
[4] Rewers, P., Trojanowska, J., & Chabowski, P. (2016, June). Tools and methods of Lean Manufacturing: a literature review. In Proceedings of 7th International Technical Conference Technological Forum (pp. 28-30).
[5] Wahab, A. N. A., Mukhtar, M., & Sulaiman, R. (2013). A conceptual model of lean manufacturing dimensions. Procedia Technology, 11, 1292-1298.
[6] Netland, T. (2013b). Exploring the phenomenon of company-specific production systems: one-best-way or own-best-way? International Journal of Production Research, 51(4), 1084-1097.
[7] Netland, T. H. (2013a). Company-specific production systems: Managing production improvement in global firms.
[8] Hekneby, T., Ingvaldsen, J. A., & Benders, J. (2022). Orchestrated learning: creating a company-specific production system (XPS). International Journal of Lean Six Sigma, 13(2), 361-381.
[9] Patil, S.J., & Lakshmanan, P. (2015). IMPLEMENTATION OF LEAN TECHNIQUE THROUGH VOLVO PRODUCTION SYSTEM ATTRIBUTE IN EXCAVATOR ASSEMBLY LINE.
[10] Neely, A., & Bourne, M. (2000). Why measurement initiatives fail. Measuring business excellence, 4(4), 3-7.
[11] H. Netland, T., & Aspelund, A. (2013). Company-specific production systems and competitive advantage: a resource-based view on the Volvo production system. International Journal of Operations & Production Management, 33(11/12), 1511-1531.
[12] Wireman, T. (2005). Developing performance indicators for managing maintenance. Industrial Press Inc.
[13] Kumar, U., Galar, D., Parida, A., Stenström, C., & Berges, L. (2013). Maintenance performance metrics: a state-of-the-art review. Journal of Quality in Maintenance Engineering, 19(3), 233-277.
[14] Hekneby, T., & Powell, D. J. (2023). The financial implications of XPS: an organizational learning perspective. International Journal of Lean Six Sigma, (ahead-of-print).
[15] Kendall, J. (1999). Axial coding and the grounded theory controversy. Western journal of nursing research, 21(6), 743-757.
[16] Williams, M., & Moser, T. (2019). The art of coding and thematic exploration in qualitative research. International management review, 15(1), 45-55.
[17] Tsang, A. H. (2002). Strategic dimensions of maintenance management. Journal of Quality in Maintenance Engineering, 8(1), 7-39.
[18] Kalaiarasan, R., & San Giliyana, A. (2015). Underhållsstrategi enligt Professional Maintenance metodiken som en del av World Class Manufacturing.
[19] Lundgren, C., Bokrantz, J., & Skoogh, A. (2021). Performance indicators for measuring the effects of Smart Maintenance. International Journal of Productivity and Performance Management, 70(6), 1291-1316.
[20] Jonsson, P., & Lesshammar, M. (1999). Evaluation and improvement of manufacturing performance measurement systems-the role of OEE. International Journal of Operations & Production Management, 19(1), 55-78.
[21] Dal, B., Tugwell, P., & Greatbanks, R. (2000). Overall equipment effectiveness as a measure of operational improvement–a practical analysis. International journal of operations & production management, 20(12), 1488-1502.
[22] Nakajima, S. (1988). Introduction to total productive maintenance (TPM) (productivity press).
[23] Söderberg, V., Tomkowski, R., Chen, D., & Archenti, A. (2023). The effect of technology development on components machined in the current production system used by the OEMs in the truck industry. Procedia CIRP, 120, 1588-1593.
[24] Pałucha, K. (2012). World Class Manufacturing model in production management. Archives of Materials Science and Engineering, 58(2), 227-234.