Investigating the Challenges and Opportunities for Production Planning and Control in Digital Lean Manufacturing

Daryl Powell[1,2]; Eirin Lodgaard[1] and Heidi Dreyer[2]

[1] SINTEF Manufacturing, Raufoss, Norway
[2] Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, Trondheim, Norway

{daryl.powell; eirin.lodgaard}@sintef.no
Heidi.c.dreyer@ntnu.no

Abstract. Digital Lean Manufacturing has emerged as a new approach to Lean Production, combining lean thinking and practice with the new opportunities presented by innovative digital technologies and Industry 4.0 concepts. However, this combined approach also raises certain challenges for the manufacturing industry. In this paper, we explore both the challenges and opportunities presented to manufacturers in light of digitalization *contra* Lean Manufacturing, with a specific focus on Production Planning and Control. Drawing on insights from four diverse explorative industrial cases studies, we identify the challenges and opportunities experienced by manufacturers embarking on a journey towards Digital Lean Manufacturing and highlight important avenues for further research.

Keywords: Lean Production, Digitalization, Production Planning and Control.

1 Introduction

A recent trend in operations management is digitalization and a shift towards Industry 4.0, which is set to dominate the next frontier of operational improvement in the manufacturing industry [1]. As such, this has created a so-called lean-digitalization paradox [2] and has even raised the question as to whether digitalization will replace lean [3]. Certainly, in some cases, digitalization may indeed begin to counteract the application of lean, for example when decision-making becomes more centralized in information systems, as opposed to the decentralized decision-making principle of lean thinking. However, current research has illustrated that lean thinking and practice is still very much here to stay as a dominant manufacturing concept contributing to efficiency and performance improvements, and that digitalization can behave as an enabler and catalyst for Lean Production [4]. An example is the application of digital algorithms on production planning decisions based on sensor technology and real time ordering data. This is, in fact, in line with previous research that investigated the role of information

technology (specifically enterprise resource planning (ERP) systems) in lean transformations [5].

The concept of Digital Lean Manufacturing (DLM) has emerged in response to this debate [6]. DLM is realized when traditional lean methods gain a new digitally-enabled edge [7, 8]. However, the integration of digitalization and lean thinking is a two-sided coin. Adopting a limited view of digitalizing lean practices in isolation rather than considering also the adoption and application of lean thinking to digital transformations, risks simply digitalizing unnecessary activities, leading to digital waste [7]. In this paper, we explore the challenges and opportunities that arise during the integration of Lean Production and digitalization with a particular focus on Production Planning and Control (PPC).

2 Theoretical Background: Beyond the Lean Vs. ICT Paradox – The Emergence of Digital Lean Manufacturing

Production planning and control is a key mechanism in lean manufacturing, since planning puts the organization in a position where future demand can be met with a lean approach to better utilize resources and capacity. Supported by digitalized planning solutions mitigates uncertainty by providing information for better decision-making. Although in some instances considered an enabler for lean production, planning is otherwise strongly challenged by lean principles, since lean makes rigid planning highly sensitive to disturbances [9, 10], in particular variability in supply and demand. For a competitive environment this contradiction is emergent and the role of digitalization in a lean manufacturing setting must be further explored.

Though earlier publications identified Lean- and ICT-based approaches to production planning and control as contradictory [11-13], the more recent scientific literature presents both (therein specifically the integration of) as enablers of competitive advantage since digitalization promises to positively impact on flexibility and capacity utilization [5, 14]. This is an important development in thinking with regards to the contemporary debates around the contradictory or complementary nature of lean and digitalization – and suggests that we must once again revisit the Lean-ICT Paradox [15] in order to exploit potential novel concepts from the paradox [16].

[17] posed the question as to whether lean and information technology (IT) were complementary or contradictory in nature. Exploring this challenging issue, [18, 19] explored the support functionality of Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) Systems for Lean Production, respectively. Exploring the concurrent application of lean and ERP through action research, [5] proposed an ERP-based Lean implementation process – suggesting that the ERP implementation acted as a catalyst for the case-company's lean transformation. [20] also explored the support functionality offered by ERP systems for pull production, using multiple case-study research.

Given the complementary nature of contemporary ICT solutions and Lean Production, [6, 7] proceed with presenting both conceptual and practical insights into the complementary nature of Lean and Digitalization – rather than dwelling on the debate as to

whether the two paradigms can co-exist or not. As such, [6] discusses Industry 4.0 technologies as enablers of leaner production, while [7] coins the term *Digital Lean Manufacturing*, and subsequently extends the focus beyond production planning and control to also include total quality management (TQM) functions, such as *Jidoka 4.0* [21] and *Quality Management (QM) 4.0* [22].

As a final theoretical discussion, [1] presents and discusses the managerial challenges associated with lean and digitalization, classifying the *Digital Lean Landscape* in terms of a set of paradoxes within organizational design, supply chain planning, decision systems and supplier relationships. As such, these important research themes represent the structure for this investigation.

3 Research Design

This paper presents preliminary results from the initial stage of a four-year research project. To fully understand and gain a deep insight into the production planning and control processes of the digital lean manufacturing concepts applied by manufacturing companies, the research design is based on a theory-building case study approach [23]. The unit of analysis is the production planning and control process at strategic, tactical and operational levels, which has been explored by the research question: *What are the challenges and opportunities for Production Planning and Control in Digital Lean Manufacturing?*

Given the what-type research question [24], we chose to adopt a multiple case study research design and to draw useful insights form the results of semi-structured interviews with representatives from four industrial case companies (for an overview, see Table 1.). In addition, information from two workshops with the four case companies has contributed to contextual insight about the planning and control process. Data from the interviews was compiled in a report and triangulated with other sources, such as company documentation and follow-up discussions.

Table 1. An overview of the case companies and interviewees.

Case	Industry	Interviewee
1	Automotive	Project manager – lean responsible
2	Oil and Gas	Chief Operations Officer (COO) – lean responsible
3	Construction	Human Resources (HR) manager – lean responsible
4	Aluminium	Project manager – lean responsible

3.1 Case 1: Automotive

PPC at Case 1 is largely driven by input from forecasted expectations of sales and market development as well as strategic priorities over a five-year horizon, which then provides the basis for making plans for production, distribution and procurement. In forecasting and planning, various digital planning tools are used, such as ERP and MES.

These systems support the planning processes of the various functions at different levels in the organization (strategic, tactical, operational).

Takt-time and capacity are important planning constraints. Planning meetings are conducted in order to consider available resources, equipment, and materials. One challenge in particular is that suppliers have different response times for different requirements – which also has an impact on inventory. Demands for reduction in inventory and varying response time from the suppliers lead to greater uncertainty in the planning environment and vulnerability in relation to the level of delivery precision. As a countermeasure, the Industrial Internet of Things (IIOT) and supply chain connectivity present an interesting opportunity for Case 1.

3.2 Case 2: Oil and Gas

Case 2 processes over 400,000 work orders through its base stations each year, for example for material supplies and maintenance equipment. Therefore, the planning and management of supply at base stations presents a grand challenge for Case 2 (the base stations are the central hubs of the value chain that link on-shore and off-shore operations). As such, the PPC task is complex, and the bases are required to coordinate both inbound and outbound material- and information flows from- and to its facilities off-shore, its external suppliers, and its logistics providers. In addition, the base stations serve as (intermediate) storage points for equipment and materials. Therefore, effective flow, interaction and coordination in and between base stations presents a key challenge, whereby digitalization can provide a solution in the form of more integrated digital planning.

3.3 Case 3: Construction

Case 3 is an engineer-to-order (ETO) / project-based producer, providing systems to the oil and gas industry. As such, the customer's product specifications intervene "deeply" into the company's upstream processes, i.e. in or before engineering. This creates a completely different planning environment to the one which is typically found in the traditional commodity manufacturing industry, where demand uncertainty is usually mitigated through the production and storage of standard products. The ETO environment is therefore surrounded by significantly greater uncertainty related to, among other things, lead times, delivery reliability, access to specialized expertise / capacity / resources, etc. This uncertainty also propagates further down the value chain to suppliers. Coordination, integration, planning / management of the processes in these types of organizations and the utilization / role that digitization can have, for example in connection with information capture, the sharing of information between decision steps and levels, product configurators / bill-of-materials / catalogs, organization, integration with suppliers and customers, etc., are critical elements that can greatly affect profitability and competitiveness.

3.4 Case 4: Aluminium

Case 4 has developed and implemented an advanced digital model to plan and allocate resources in relation to demand / order requirements. The model is mainly used for the European region and has an accuracy of about 80%, i.e. the inaccuracy of 20% is relatively significant, which in turn has implications for the quality of planning and a need to build capacity (storage, production, transport, etc.) to maintain a high level of delivery precision. The company could benefit further from an analysis of the digital model and its subsequent planning process, as well as the integration of a Big Data analytics module in order to uncover barriers and potential "digital waste" and mitigate uncertainty in Production Planning and Control.

4 Discussion

The aim of this paper was to investigate the research question: *What are the challenges and opportunities for Production Planning and Control in Digital Lean Manufacturing?* The what-type question guided us towards a multiple case-study research design where data was collected primarily through semi-structured interviews and further triangulated with company documentation and follow-up discussions with participants.

The research resulted in the identification of challenges and opportunities for PPC in DLM, specifically intra- and inter-organizational integration (with respect to material and information flows). Additionally, the cases identify the complexity and systemic component of the planning and control process as critical elements in DLM, but also the potential benefits and novelty coming from investigating the paradox of DLM. We consider this to represent both the fundamental challenge and opportunity for PPC in DLM – traditional lean supply chain practices can certainly be enhanced by novel digital solutions such as IIoT and Big Data analytics.

5 Conclusion

By considering the challenges and opportunities for PPC in DLM, it appears that lean paves the way for successful digital transformation and digitalization enriches lean practices. From the results of this investigation, it appears that the combination of lean with digital solutions certainly promises to enable lean thinking to be extended beyond company borders and out into the supply chain. As such, we suggest that further research should investigate *Digital Lean Supply Chains* in more detail.

Acknowledgements

The authors acknowledge the support of the Norwegian research project *Lean Digital* and the Norwegian research program *SFI Manufacturing*.

References

1. Ashrafian, A., Powell, D.J., Ingvaldsen, J.A., Dreyer, H.C., Holtskog, H., Schütz, P., Holmen, E., Pedersen, A.-C., Lodgaard, E.: Sketching the Landscape for Lean Digital Transformation. In: IFIP International Conference on Advances in Production Management Systems, pp. 29-36. Springer, (2019).
2. Lewis, M.W.,Smith, W.K.: Paradox as a metatheoretical perspective: Sharpening the focus and widening the scope. The Journal of Applied Behavioral Science 50(2), 127-149 (2014).
3. Lorenz, R., Buess, P., Macuvele, J., Friedli, T., Netland, T.H.: Lean and Digitalization—Contradictions or Complements? In: IFIP International Conference on Advances in Production Management Systems, pp. 77-84. Springer, (2019).
4. Meissner, A., Müller, M., Hermann, A., Metternich, J.: Digitalization as a catalyst for lean production: A learning factory approach for digital shop floor management. Procedia Manufacturing 23 81-86 (2018).
5. Powell, D., Alfnes, E., Strandhagen, J.O., Dreyer, H.: The concurrent application of lean production and ERP: Towards an ERP-based lean implementation process. Computers in Industry 64(3), 324-335 (2013).
6. Powell, D., Romero, D., Gaiardelli, P., Cimini, C., Cavalieri, S.: Towards digital lean cyber-physical production systems: industry 4.0 technologies as enablers of leaner production. In: IFIP International Conference on Advances in Production Management Systems, pp. 353-362. Springer, (2018).
7. Romero, D., Gaiardelli, P., Powell, D., Wuest, T., Thürer, M.: Digital Lean Cyber-Physical Production Systems: the Emergence of Digital Lean Manufacturing and the Significance of Digital Waste. In: IFIP International Conference on Advances in Production Management Systems, pp. 11-20. Springer, Heidelberg (2018).
8. Mora, E., Gaiardelli, P., Resta, B., Powell, D.: Exploiting lean benefits through smart manufacturing: A comprehensive perspective. In: IFIP International Conference on Advances in Production Management Systems, pp. 127-134. Springer, (2017).
9. Fisher, M.L.: What Is the Right Supply Chain for Your Product? Harvard Business Review 75(2), 105-116 (1997).
10. Copra, S.,Meidl, P.: Supply Chain Management Strategy, Planning, and Operations. Pearson Education Limited, Essex (2016).
11. Piszczalski, M. *Lean vs. Information Systems*. Automotive Manufacturing & Production, 2000. **2000**, 26-28.
12. Halgari, P., McHaney, R., Pei, Z.J., *ERP Systems Supporting Lean Manufacturing in SMEs*, in *Enterprise Information for Systems Business Integration in SMEs: Technological, Organizational, and Social Dimensions* M.M. Cruz-Cunha, Editor. 2011, IGI Global: Hershey, PA.
13. Sugimori, Y., Kusunoki, K., Cho, F., Uchikawa, S.: Toyota production system and Kanban system Materialization of just-in-time and respect-for-human system. International Journal of Production Research 15(6), 553 - 564 (1977).
14. Powell, D.: ERP Systems in Lean Production: New insights from a review of Lean and ERP literature. International Journal of Operations & Production Management 33(11/12), 1490-1510 (2013).

15.Powell, D.,Strandhagen, J.O.: Lean Production Vs. ERP Systems: An ICT Paradox? Operations Management 37(3), 31-36 (2011).
16.Hargrave, T.J.,Van de Ven, A.H.: Integrating dialectical and paradox perspectives on managing contradictions in organizations. Organization Studies 38(3-4), 319-339 (2017).
17.Riezebos, J., Klingenberg, W., Hicks, C.: Lean Production and information technology: Connection or contradiction? Computers in Industry 60 237-247 (2009).
18.Powell, D., Binder, A., Arica, E., *MES Support for Lean Production*, in *Competitive Manufacturing for Innovative Products and Services: Proceedings of the APMS 2012 Conference, Advances in Production Management Systems*, C. Emmanouilidis, M. Taisch, and D. Kiritsis, Editors. 2012, Springer Verlag: Berlin.
19.Powell, D., Alfnes, E., Strandhagen, J.O., Dreyer, H., *ERP support for lean production*, in *Advances in Production Management Systems. Value Networks: Innovation, Technologies, and Management. Proceedings of the IFIP WG 5.7 International Conference, APMS 2011, Stavanger, Norway. 26-28 September 2011*, J. Frick and B. Laugen, Editors. 2011, Springer.
20.Powell, D., Riezebos, J., Strandhagen, J.O.: Lean production and ERP systems in SMEs: ERP support for pull production. International Journal of Production Research 51(2), 395-409 (2013).
21.Romero, D., Gaiardelli, P., Powell, D., Wuest, T., Thürer, M.: Rethinking Jidoka Systems under Automation & Learning Perspectives in the Digital Lean Manufacturing World. IFAC-PapersOnLine 52(13), 899-903 (2019).
22.Romero, D., Gaiardelli, P., Powell, D., Wuest, T., Thürer, M.: Total Quality Management and Quality Circles in the Digital Lean Manufacturing World. In: IFIP International Conference on Advances in Production Management Systems, pp. 3-11. Springer, (2019).
23.Yin, R.K.: Case study research: design and methods. 4th ed. Sage Publications, Thousand Oaks, California (2009).
24.Karlsson, C.: Researching operations management. Routledge, New York (2009).