Not lean by default

Ziengs, Nick

Summary

Lean manufacturing has been widely adopted by manufacturers in an effort to improve quality, reduce throughput times, and reduce costs. The application of lean manufacturing principles, however, is often met with various degrees of success. To improve our understanding of how lean manufacturing affects performance, it is helpful to characterize lean manufacturing as a philosophy implemented by a set of interrelated manufacturing practices which are, in turn, supported by a large number of tools and techniques. Based on this classification, two general research objectives, presented in **chapter 1**, were identified. The first research objective stipulates the need to understand how lean manufacturing practices jointly affect performance. The second research objective expresses the need to understand how the design of lean manufacturing practices affects performance by studying the underlying mechanisms that drive performance. The chapters, presented in this dissertation, therefore address lean manufacturing practices and their design.

The study, presented in **chapter 2**, addresses the role core and infrastructural quality management practices play in achieving quality, operational, and business performance. Quality management practices are a subset of lean manufacturing practices. Previous studies considered, either implicitly or explicitly, one of the following three perspectives. The first perspective suggests that core and infrastructural quality management practices are distinct and directly related to performance. The second perspective suggests that core and

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infrastructural quality management practices are also distinct and that infrastructural quality management practices are indirectly related to performance. The third perspective suggests that core and quality management practices are not distinct and that quality management practices taken together directly and jointly relate to performance. The aim of this study is to determine whether or not quality management practices are distinct and to determine how core and infrastructural quality management practices affect performance.

To address the aims, a combination of meta-analytical and structural equation modeling techniques was used. Meta-analytical techniques were used to determine the degree to which practices relate to other practices and performance. In addition, the meta-analytical techniques were also used to assess the degree of heterogeneity present within these relations. The meta-analytically derived correlation matrix served as the input for the confirmatory factor and structural equation modeling analysis. The confirmatory factor analysis was used to determine if quality management are distinct. The structural equation modeling analysis was used to determine whether or not core and infrastructural quality management practices affect performance.

There are four main findings. First, the results of the meta-analysis shows that core and infrastructural quality management practices are positively related to each other and to quality, operational, and business performance. Second, the results of the meta-analysis also show that these relations are all subject to considerable heterogeneity. Third, the results of the confirmatory factor analysis revealed that, overall, core and infrastructural quality management practices are not distinct. Finally, the results of the structural equation model show that quality management practices positively impact quality, operational, and business performance.

The study furthers the debate on the role of core and infrastructural quality management practices in a number of ways. First, the study shows that the third perspective provides the best explanation. Overall, core and infrastructural quality management practices are indistinct and, together, positively impact quality, operational, and business performance. Second, the study highlights the importance of carefully considering differences between studies. The degree of heterogeneity observed emphasizes the need to consider possible moderators in future research. Finally, the study shows how a combination of meta-analytical techniques and structural equation modeling can be used to evaluate different theoretical perspectives. In conclusion, the study furthers our understanding of the roles core and infrastructural quality management play with respect to improved performance thereby adding to our understanding of how lean manufacturing practices jointly affect performance.

The study, presented in **chapter 3**, addresses how the placement of work-in-progress restrictions enables effective workload balancing capability in unit-based pull production systems. Effective workload balancing aids in achieving shorter and more reliable shop floor throughput times. Previous studies have demonstrated that unit-based pull production systems are able to create a balanced distribution of work on the shop floor by passing on information related to the availability of capacity within a route to upstream workstations in order to prioritize orders for which capacity is or is likely to become available. The placement of work-in-progress restrictions determines how such route-specific information is passed upstream. The aim of this study is to determine how the placement of route-specific work-in-progress restrictions affect the effective workload balancing capability of unit-based pull production systems.

To address the aim, discrete-event simulation was used. A three- and a four-stage divergent shop floor topology was used. The divergent topologies were used because they allow the workload to be balanced at each stage. A four-stage topology was used, in addition to a three-stage topology, because it enables the exploration of the placement of additional work-in-progress restrictions. POLCA was used to control the flow of orders on the shop floor because it is able to pass route-specific information upstream and relies on multiple work-in-progress restrictions.

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There are four main findings. First, work-in-progress restrictions placed in second to last stages of the shop floor topology are most effective in both the three-stage and four-stage shop floor topologies. Second, in the four-stage shop floor topology additional work-in-progress restrictions placed in the first stage of the shop floor topology increase the effective workload balancing capability. Third, the effective workload balancing capability on the shop floor is hindered by adding consecutive work-in-progress restrictions. Fourth, the effective workload balancing capability of a unit-based pull production system improves when utilization and/or batch size increases. The improvement, however, is more pronounced when a work-in-progress restriction is placed in the first stage of the shop floor topology. Finally, processing time variability erodes the workload balancing capability of unit-based pull systems.

The study furthers our understanding of the design of pull production systems in the following ways. First, the study demonstrates that the design of a pull production system affects the effective workload balancing capability. The study shows that carefully considering the placement of work-in-progress restrictions makes it possible to outperform the traditional placement of work-in-progress restrictions of a POLCA system. Second, the study highlights the limitations of unit-based pull production systems when it comes to effectively balancing the workload, especially in make-to-order manufacturing environments. In conclusion, the study furthers our understanding of how the placement of work-in-progress restrictions affects throughput time performance thereby adding to our understanding of how the design of lean manufacturing practices determine performance.

The study, presented in **chapter 4**, addresses the role work-in-progress restrictions play in facilitating motivation gains and losses. Previous studies showed that individuals in work-in-progress restricted production lines were motivated to avoid idle time. As a consequence, more severe work-in-progress restrictions do not necessarily result in reduced throughput. Social comparison and social indispensability theories offer an explanation for the observed behavior. The aim of this study is to identify to what degree these two mechanisms – social comparison and social indispensability – determine the behavior of the individual in work-in-progress restricted production lines.

To address the aim, an experiment was used. In the experiment, participants worked on the assembly of printed circuit boards. The experiment allowed us to vary the working condition to isolate the relative importance of the social comparison and social indispensability mechanisms.

There are four main findings. First, social comparison results in motivation gains by facilitating the development of productivity norms. Second, the task structure inherent in serial production lines results in motivation losses. Third, more severe work-in-progress restrictions mitigate the aforementioned motivation losses by making the contribution of the slowest individual more indispensable. Mitigation of motivation losses, however, is accompanied by coordination losses. Finally, motivation gains or losses vary considerably from one individual to the next.

The study furthers our understanding of the design of pull production systems in the following ways. First, the study demonstrates the importance of considering not only coordination losses but also motivation gains and losses. Second, the study underlines the importance of using theory from reference disciplines, such as organizational behavior, industrial psychology, social psychology, or cognitive psychology to inform pull production system design. In conclusion, the study furthers our understanding of how the work-in-progress restrictions of pull production systems affect performance by facilitating motivation gains or losses thereby adding to our understanding of how the design of lean manufacturing practices affects performance.

The three studies, presented in this dissertation, address lean manufacturing practices and their design. Together, these studies demonstrate the need to study lean manufacturing on different levels of abstraction thereby shedding new light on how lean manufacturing practices jointly affect performance and furthering our understanding of what the underlying mechanisms are by which these practices affect performance. There are a number of promising directions for future research as presented in **chapter 5**. To further the first research objective, how lean manufacturing practices jointly affect performance, future research should consider how lean manufacturing practices jointly develop over time. To further the second research objective, how the design of lean manufacturing practices affects performance, future research should consider incorporating theory from other disciplines. Taken together, these studies show that a holistic yet tailored approach to lean manufacturing is required.