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Adopting lean product development in new production system introduction process for sustainable operational performance

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Abstract:

This research explores adopting the lean product development (LPD) concept in the new production system introduction process (NPSIP) to achieve both pre-launching and post-launching operational performance considering sustainability aspects. An empirical study was conducted in a multinational pharmaceutical company, having lean practice for over a decade. Two case projects for launching the new production system were followed in retrospect, and data was collected by interviewing experts. In the case company, evidence were found regarding adoption of soft lean practices in the NPSIP, however, lack of adoption of hard lean practices. Several challenges were identified that hinder achieving both pre-launching and post-launching operational performance, which could be mitigated by adopting LPD practices. This paper contributes to the broad lean literature by expanding its implication within the NPSIP context. Additionally, a set of LPD principles and practices is proposed that could be adopted in the NPSIP context. Adopting the LPD principles and practices in the NPSIP, manufacturing companies can launch a new production system faster, and achieve target sustainable operational performance faster, resulting in additional competitive advantage.

Key words:

Lean product development, operational performance, manufacturing system design, sustainability, production system design process.

1. Introduction

At present, manufacturing companies worldwide are being pressurized to improve their operational performance addressing the triple bottom line (i.e., economic, environmental, and social aspects) of the sustainability perspective. However, a production system's operational performance depends on how the production system was designed during its introduction process (Islam et al., 2022). Manufacturing companies can introduce or launch a new production system for various reasons, such as to capture new markets, facilitate production of new products, increase the existing capacity, and change the existing operational processes to address stakeholders or legal requirements. Launching a new production system or transforming an existing production system is termed as 'Industrialization' or 'New Production System Introduction Process' (NPSIP) (Gobetto, 2014).

NPSIP consists of a number of phases including planning, designing, constructing, testing, and training with the new production system (see Figure 1) (Andersen et al., 2017; Bruch & Bellgran, 2013). An efficient and effective NPSIP can reduce the time-to-market of a new product by launching the new production system faster, and can facilitate fast ramp-up (Surbier et al., 2014). Latest research (Ahmad et al., 2018; Islam et al., 2022; Hagström et al., 2023) shows that inappropriate design specification and management of the NPSIP impacts a production system's overall equipment effectiveness (OEE). In addition, the study of Magnusson et al.

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(2023) in several manufacturing companies identified that around 70% of the corporate strategy related to environmental aspects could be addressed during the design stage of a production system. Hence, the operational performance impacted by managing the NPSIP could be classified into two categories:

- *Pre-launching operational performance*: performance related to managing the project of launching new production system (i.e., time-to-market, cost of launching new production system, etc.)
- *Post-launching operational performance:* performance of the newly launched production system while running operations (i.e., OEE, lead time, CO_2 emission, safety aspects, etc.)

Though an effective and efficient way of managing the NPSIP impacts both pre-launching and post-launching operational performance, mastering such excellence is still a challenge for manufacturing companies due to associated complexity (Battesini et al., 2021). NPSIP deals with several challenges, such as high uncertainty, multi-functional involvement, capturing holistic view rather sub-optimizing individual system, time pressure from top management (Rönnberg Sjödin et al., 2016; Ahlskog et al., 2019; Trolle et al., 2020).

Referring to the resource based view theory (Barney, 1991), considering production system as critical resource, managing the NPSIP could be viewed as company's resource deployment capability. Hence, having excellency in managing the NPSIP could be viewed as a means to achieve competitive advantage that is difficult for competitors to imitate (Netland & Aspelund, 2013, Bruch & Bellgran, 2013). Therefore, earlier research urged to develop a systematic way of managing NPSIP that would ensure both pre-launching and post-launching operational performance (Andersen et al., 2017; Rösiö & Bruch, 2018; Islam et al., 2022). However, such a systematic way of managing the NPSIP is scant in extant literature.

One of the potential ways to develop such a systematic way is by adopting the concept of lean philosophy in the NPSIP context. Adopting the concept of lean product development (LPD) in the new product introduction process results in less time-to-market and better customer satisfaction (Marodin et al., 2018; Salgado & Dekkers, 2018). Birkie et al. (2023) addressed that to design green production equipment, a vital element of production system, practices related to green product development need to be adopted. With the same analogy, considering the new production system as a product, it could be argued that adopting the LPD concept in the NPSIP could improve both pre-launching and post-launching operational performance of a production system.

According to Marodin et al. (2018) a company must adopt lean practices in every function to be a lean enterprise. However, the latest literature review articles on lean practices (Antony et al., 2021; Danese et al., 2018; Psomas & Antony, 2019) reveals that adoption of lean concept (including LPD) in the NPSIP context is rarely addressed that could be viewed as a research gap. Hence, this paper addresses two research gaps: 1) lack of systematic way of managing NPSIP considering both pre-launching and post-launching operational performance, 2) lack of adoption of lean practices when launching a new production system.

This paper intends to address these research gaps by exploring the applicability of adopting LPD concept to manage the NPSIP that could potentially assist in achieving sustainable operational performance. Hence, this paper addresses the following research questions.

RQ-1: Can adopting LPD in the NPSIP impact on achieving sustainable operational performance?

If so, RQ-2: How can practitioners adopt LPD to manage the NPSIP?

This paper contributes by adopting LPD concept in the NPSIP context which is first of its kind, as far author's knowledge.

2. Theoretical background

2.1. New production System introduction process

NPSIP can be viewed as a part of the production system lifecycle, which consists of several phases: planning, design, construction, ramp-up, operations, and upgradation or termination (Attri & Grover, 2012). Several researchers addressed the NPSIP as a series of activities, from identifying the requirements to fulfilling the requirements of the intended physical production system (Alves & Carmo-silva, 2009; Schuh et al., 2009; Marzouk et al., 2012). In literature, NPSIP is represented using other terms, such as "production system development process" (Bellgran & Säfsten, 2010), "design project" (Aurich & Barbian, 2004), "production system design process" (Islam et al., 2022).

Reviewing the literature (Andersen et al., 2017; Bruch & Bellgran, 2013; Rösiö & Bruch, 2018, Islam et al., 2022), it could be summarized that NPSIP is comprised of several phases: planning (creation of the project proposal of launching new production system), preliminary design (identifying systems requirements), detailed design (defining system solution with equipment or technology providers), constructing (physically built the production system) and finally testing and training with the new production system. Figure 1 represents a sample illustration of the NPSIP adopted from Anderssen et al. (2017) and Islam et al. (2022).

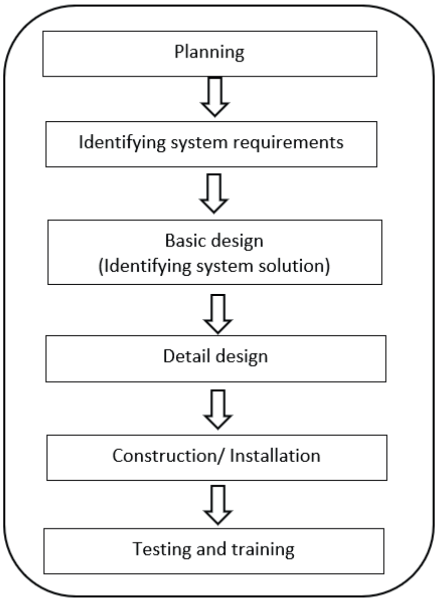

Figure 1. New production system introduction process adopted from Anderssen et al. (2017) and Islam et al. (2022).

2.2. Lean product development

Lean production (LP) focuses on increasing value and reducing waste. Theoretically, the LP concept includes different elements, such as principles, bundles, methods and tools. Methods and tools are also termed as lean practice. Bundles are an intermediate-level construct that connects the strategic level principles to implementation techniques at the tactical level (Birkie & Trucco, 2016). Lean bundles refer to interrelated and internally consistent practices supporting lean implementation (Pont et al., 2009).

The concept of lean product development (LPD) refers to adopting of lean techniques in the product development process (also referred to as product design or new product introduction processes) aiming to manage the product development process efficiently. Similar to LP, LPD focuses on the concept of value and waste. In LPD, Morgan & Liker (2020) addressed two types of wastes: process waste and design waste.

- *Process waste*: it refers to the eight types of waste addressed in LP literature, associated with the value generation in the product development process. This waste mainly impacts the pre-launching operational performance. Some of the practices to mitigate the process waste are process mapping using value stream mapping (VSM), 5S, standardization, etc.
- *Design waste*: it refers to the lack of capability to address the customer requirements fully within the product specification. This waste impacts on the post-launching operational performance. Examples of practices to mitigate the design waste could be quality deployment function (QFD), design for X (disassembly, remanufacturing) etc.

As like LP, Liker & Morgan (2011) proposed 13 principles for LPD. The practices relevant to the product development process (used in Toyota) are compiled and addressed within LPD. Some of the practices addressed in the LPD, such as set-based approach, concurrent engineering, and chief engineer system, were not mentioned in the LP because of their contextual irrelevancy. Hence, the term lean bundle is used in lean literature so that associated practices (i.e., methods and tools) could be added, removed, or customized based on the context of the application. Table 1 provides a list of LPD practices associated with relevant lean bundles.

2.3. Impact of LPD on sustainable operational performance

Earlier research provided empirical evidence that adopting LPD in the product development process reduces time-to-market by increasing product development process efficiency (Ferreira et al., 2023), and causes fewer defects in the manufacturing operations (Bubber et al., 2022). Hence, it is evident

Table 1. Practices within lean product development

Relevant lean bundles	Lean product design practice	References
Continuous improvement	War-room (pulse meeting)	(Johansson & Sundin, 2014)
	PDCA	(Liker & Morgan, 2011)
	Kaizen event	(Kumar et al., 2016)
	Genchi-Genbutsu (go and see)	(Morgan & Liker, 2020)
Supplier involvement	Integrate suppliers	(Agyabeng-Mensah et al., 2021)
Customer management	Customer focus	(Agyabeng-Mensah et al., 2021)
JIT	Kanban system	(Wang et al., 2011)
	Process mapping (VSM for product development process)	(Letens et al., 2011; Kumar et al., 2016)
	Detailed schedule	(Wang et al., 2011)
Standardization/processes	Standardization of processes	(Kumar et al., 2016; Marodin et al., 2018)
	Computer-aided design	(Liker & Morgan, 2011)
	Design for manufacture and assembly (DFMA)	(Dahmani et al., 2022)
	Set-based approach	(Marodin et al., 2018)
	Modularization	(Marodin et al., 2018)
	Concurrent engineering	(Marodin et al., 2018)
	Chief engineer's concept note	(Liker & Morgan, 2011)
TQM	Root cause analysis	(Johansson & Sundin, 2014)
	Design for Six Sigma	(Kumar et al., 2016; Dahmani et al., 2022)
	QFD (Quality Function Deployment)	(Johansson & Sundin, 2014)
Employee involvement	Assigning a chief engineer (product development leader having certain attrib-utes and responsibilities)	(Kumar et al., 2016)
	Cross-disciplinary teams	(Letens et al., 2011)
Visualization	5S	(Johansson & Sundin, 2014)
Training	Training of employees	(Kumar et al., 2016)

the positive impact of LPD on economic performance of an organization. However, the impact of LPD on environmental performance is still inconclusive. Johansson & Sundin (2014) compared LPD with green product development (GPD) practices, and concluded that adopting LPD might not always result in making the product environmental friendly and improving an organization´s environmental performance. The main reasoning was that LPD focuses on the early development process of a product, whereas GPD focuses on manufacturing operations and end-of-life processes of the product. The empirical study of Agyabeng-Mensah et al. (2021) shows that adopting LPD practices in product design significantly impacts the environmental operational performance of an organization. However, in that study, several GPD practices (i.e., designing products having less energy and resource consumption, less solid waste reduction during manufacturing operations) were considered as LPD practices.

Several research addressed that LPD assists in improving standardization, integrating customers and suppliers during the product development process, and fostering knowledge transfer between projects that assists in the GPD process ultimately improving environmental performance (Coutinho et al., 2019; Ferreira et al., 2023; Oliveira et al., 2022). In addition, improving product quality and reducing defects during the manufacturing (Bubber et al., 2022) saves associated energy and material consumption. Hence, the indirect impact of LPD on environmental performance could be argued. Finally, several research (Khan et al., 2015; Santos et al., 2020) considered environmental and social aspects of the product as customer value that need to be addressed by applying LPD practices.

2.4. Adoption of LPD in NPSIP context

Adopting the LPD concept to manage the whole NPSI is seldom addressed in the literature. However, the literature suggested several enablers, tactics and practices to manage different activities in the NPSI for achieving better operational performance that could be connected to the LPD practices. For instance, Rönnberg-Sjödin (2016) suggested involving the production team very early in the design stage when identifying the requirements of the new production system. Bellgran & Säfsten (2009) suggested involving multifunction personnel (i.e., experts in quality, safety, maintenance, production, and environmental aspects) to gather diverse perspectives when identifying requirements and generating solutions. Vilda et al. (2019) addressed involving shop-floor operators to understand their perspective. These practices could be linked to the employee involvement and/or customer focus aspects (considering that the company itself will use the new production system) of the lean bundles.

Moradlou et al. (2022) suggested developing close relationships with the equipment suppliers. Holgado & Macchi (2021) addressed that to achieve better operational performance, equipment suppliers must design and construct the production equipment with the company´s experts considering company´s existing facilities and uniqueness. This could be connected to the supplier integration of lean bundles. Islam et al. (2022) addressed developing internal technical competency to resolve technical issues after launching the production system and properly communicate the lesson learned from each project to internal resources. These practices could be linked to the training element within the lean bundle.

Earlier literature also proposed ways to design the new production system embedded with several aspects of different best manufacturing practices. For instance, Islam et al. (2020) and Slim et al. (2021) developed a method to incorporate lean, green and digitalization aspects of the new production system in the design stage. Anderssen et al. (2017) proposed a method for practitioners to design reconfigurable production system. These tactics could be linked to the design for X (lean, green, digitalization, reconfigurable) guideline as a standard practice addressed within lean literature.

Based on the evidence from the literature, it could be understood that earlier literature addressed several tactics or best practices to resolve the challenges within the NPSI that could be linked to lean practices. These lean practice practices, such as customer focus, employee involvement, training, supplier integration, standardization could be related to the soft lean practice. However, there is a lack of evidence in the literature to address hard lean practices, such as process mapping using the VSM (Value Stream Mapping) tool, detailed scheduling, workload leveling, identifying non-value adding activities, JIT (Just in Time), TQM (Total Quality Management), within the context of NPSI.

3. Method

A case study was conducted in a multi-national pharmaceutical company located in Europe. The pharma industry´s production system is strictly controlled by tight regulations (Januszek et al., 2023). Changes in the existing production system and the launching of a new product system need to go through a strict validation process that consumes time.

Pharmaceutical companies put a lot of investment in developing new medicines, and launching a new product faster in the market is important to retain market share early (Chavez et al., 2023). In addition, iteration in the newly launched production system may delay the product delivery due to the validation process. Hence, launching a new production system faster and having the ability of the intended production system to perform at desired operational performance is important for pharma industries. Therefore, the empirical study was conducted in a pharmaceutical company the importance of NPSIP for this industrial segment.

The purpose of the empirical study was not to implement the practices of LPD in actual new production system launching projects, considering the time required to do so, as such projects could last for several years. Rather, it was tried to identify improvement opportunities in the current NPSIP of the case company, and to extrapolate how adopting LPD practices could assist in improving their current practice.

The company has a single department (mainly formed by the project managers who lead different new production system launching projects) that coordinates the activities of NPSIP with multi-functional departments. Purchasing new equipment, transforming the existing production system into a new system, integrating new technology to improve operational performance, and launching new production system to increase capacity or to introduce new products, all of these are managed by the department. Hence, the activities within the NPSIP are very frequent. In addition, the case company adopted LP for more than 10 years. Therefore, the selected company is a suitable sample for collecting empirical data to identify: 1) if any LPD practices are currently adopted to manage the NPSIP, 2) challenges associated with the NPSIP process impacting sustainable operational performance that could be mitigated by adopting LPD practices, and finally, 3) how the case company can adopt LPD practice within their NPSIP process.

Two case projects (Project-A and Project-B) of launching a new production system were followed retrospectively. Data was collected by conducting semi-structured interviews of the eight personnel who were involved in the case projects. During the data collection time, both case projects were in the operational phase, so that activities in the NPSIP and their impact on the post-launching operational phase could be linked. In addition to interviews, project-related documents, such as project charter, project plan, equipment specifications, etc., were reviewed.

Furthermore, two additional project managers were interviewed to validate the findings and gather additional information. Interviews were conducted with the professionals independently, each interview lasting 40 to 60 minutes. All the interviewees worked for more than seven years during the data collection time, and were familiar with the LM. An overview of the interviews is presented in Table 2.

Table 2. Overview of interviews.

Title of interviewed experts	Number of interviewees
Case Project-A	
Project manager	1
Production manager during project	1
Line production manager	1
Case Project-B	
Project manager	1
Production manager during project	1
Lean expert (operational excellence)	1
Additional	
Project manager	2
Total	8

4. Empirical findings and analysis

4.1. Summary of the case projects

4.1.1. Case Project-A

Case Project-A was about launching a production system for a product that was used to be outsourced by the company. The project team was given a tight deadline to launch the new production system. Apart from the project manager, one personnel having experience as a production manager and two operators were appointed on a full-time basis to work dedicatedly on the project. The case company did not have any existing similar production system. The relationship with the equipment supplier chosen for this project was not strong. During the project, several dummy prototypes of the intended production system were built, incorporating lean, green and safety aspects. Finally, a suitable one was chosen. The project was finished on time; however, a lot of additional resources were allocated, which is very unusual in regular projects, according to the respondents.

After launching the production system, no significant changes were made in the production system. During the data collection time, it was found that company did not start to measure the operational performance of the newly launched production system yet. However, it was addressed by the line production manager that they were able to fulfill the delivery time of the products.

4.1.2. Case Project-B

The case Project-B was about launching a new production system for an existing product to increase the capacity. The case company had several production systems to manufacture the product during the initiation of the project. There was an addition of new technology for a particular process. The company had a strong relationship with all the equipment suppliers chosen for this project. No prototype of the whole production system was made, rather specifications were made from the existing production system incorporating several improvement suggestions from shop-floor. Project team members, except the project manager, were enrolled on a part-time basis.

The launch of new production system was delayed by around six months. The target operational performance was to reach 50% of OEE (overall equipment effectiveness) after six months of running production; however, it reached only 18% of OEE. Several reasons were identified for not achieving the target OEE, such as inappropriate equipment specification, insufficient time for testing, lack of opportunity to ensure quality of training, and equipment suppliers´ lack of understanding on shop-floor´s requirements. After conducting significant changes in the production system, OEE started to increase and reached 30% after one year of starting operation.

4.2. Lean practices in the NPSIP in the case company

The case company developed a stage-gate model to facilitate their NPSIP. The stage-gate model presents different documents required for each stage of the NPSIP and the responsible personnel for particular deliverables that allows the project manager to monitor and control the activities. The stage-gate model also allow them to check which document is yet to be completed before proceeding to the next stage. Hence, this stage-gate model could be considered as a standardized procedure within the NPSIP. For both case Project-A and B, stage-gate model were used.

It is a regular practice during NPSIP to involve multi-functional team members with different expertise, such as production, quality control, maintenance, processes, health & safety, to identify the systems´ requirements and define equipment specifications and system solutions. The operators are also involved in checking the ergonomic and safety issues of the equipment. These indicate a strong level of employees' involvement in the NPSIP.

The company has developed a strong relationship with some of the equipment suppliers over time. In most cases, after selecting the equipment suppliers, a detailed design of the equipment is developed jointly based on the system requirements. In the case projects, it was found that personnel having sufficient technical skill were appointed to do the necessary communication with the equipment suppliers. Furthermore, after installation internal technicians and equipment suppliers jointly tried to solve the root causes of technical disturbances. This indicates a strong level of collaboration with equipment suppliers throughout the NPSIP.

Interviewees addressed that, higher authorities were also involved in regular weekly meetings for quick decision making to resolve inconvenient issues. In the case project-A, it was found that when defining equipment specifications, lean and green aspects of the intended production line were considered during the design phase; for instance, designing the material flow using VSM, defining standard operating procedures considering less training time for operators, reusing heated water generated in the production system, etc.

Based on the above findings, it is evident that some of the lean practices addressed within LPD and LC literature are indirectly practiced in the case company. Table 3 provides a summary of lean practices adopted in the company indirectly during the NPSIP.

4.3. Challenges in the NPSIP and impact on operational performance

Respondents addressed that, in the case company, the NPSI projects often struggle to meet both pre-launching and post-launching operational performance. In most cases, the start of production of a new production system is usually delayed by six months to one year. In the case Project-B, the target post-launching operational performance was not achieved. It is common to perform modifications after installing the equipment, hampering regular production activities. Several challenges were identified that hamper achieving both pre-launching and post-launching operational performance.

It was found that there was a lack of standardization to manage the activities in the NPSIP, causing different projects´ team members to work in different ways. There are no standard methods or tools to identify system requirements and develop solutions and equipment specifications. This causes changing of equipment specifications frequently throughout the project, resulting in additional cost and time consumption. In addition, poor relationships with some of the equipment suppliers caused difficulties in incorporating any changes in later stages. Furthermore, respondents showed concern about changing team members throughout the project, which impacts the progress. Lack of information flow and utilization of lesson learning is another issue. Respondents addressed that it is very common to develop equipment specifications of the same equipment for multiple parallel projects separately due to a lack of information that could have been avoided. In addition, finding lesson-learned documents is an arduous task that hinders the utilization of lesson learnings from previous similar projects. These reasons impact the pre-launching operational performance, incurring extra costs and delaying project completion time.

Regarding achieving post-launching operational performance, several challenges are addressed. Firstly, at the initiation of the project, the post-launching operational performance is not set. Hence, attention remains launching the new production system within the allocated budget and timeline. In addition, project team members do not take responsibility if the new production system performs

Table 3. Empirical evidence of adoption of lean practices in NPSIP in the case company.

Lean bundles	Related lean practices	Empirical evidence in the NPSIP	Related Project(s)
Employee involvement	Assigning a chief engineer	Project manager has the authority to extract resources.	Project-A and B
	Multi-functionalities involvement	Different departments (production, quality, safety-health-environment, maintenance, processes) were involved in the project.	Project-A and B
	Early involvement of the production team	Production managers were assigned on a full-time (Project-A) or part-time basis (Project-B).	Project-A and B
	Involvement of operators	Operators are involved to perform mock-tests with the dummy equipment to resolve ergonomic and safety issues.	Project-A and B
	Specific person to communicate with equipment suppliers	Specific contact persons were appointed having sufficient technical knowledge to communicate with equipment suppliers.	Project-A and B
Training	Developing internal technical competence	Internal technical competence helped to solve defects after installation.	Project-A
Supplier involvement	Collaboration with equipment suppliers	Some of the equipment specification were developed having joint collaboration.	Project-A and B
Standardization	Systematic design process	A stage-gate model was developed to manage the activities in NPSI process.	Project-A and B
	Design for X (lean, green, etc.)	Equipment specifications were designed using VSM considering the cycle time, changeover time, etc.	Project-A
Continuous improvement	War room (pulse meetings)	Regular weekly meetings held where problems and solutions were addressed.	Project-A and B
	Genchi Genbutsu (go and see)	Project manager went to the supplier´s site in order to solve a problem addressed by the equipment supplier.	Project-A
	Kaizen event	When reviewing documents, team members should address not only what could be improved, rather how it could be improved in detail.	Project-A

poorly during regular production operations. Consequently, time is sacrificed for sufficient analysis to identify requirements, develop system solutions, and conduct testing and training with the new production system. As a result, the opportunity to gain better post-launching operational performance is lost. Finally, there is a lack of tools and methods that are required to conduct proper analysis to incorporate best manufacturing practices, such as lean, green, digitalization aspects during the early design stage of the new production system. Appendix 1 provides a list of challenges with empirical evidence that impact achieving pre-launching and post-launching operational performance.

5. Discussion

RQ-1: Can adoption of LPD in NPSIP impact on sustainable operational performance?

Empirical findings provide evidence of several LPD practices adopted (see Table 3) in the case company, limited to only soft-lean practices. Though adopting some of the soft-lean practices assisted in managing the NPSI process to some extent, there are still several challenges (see Appendix 1) that impact both pre-launching and post-launching operational performance of NPSI.

It was found that lack of standardization, lack of utilization of lesson learned, poor knowledge transfer system, weak relationship with equipment suppliers and frequent change of specifications impacted the overall completion time of the project (i.e., pre-launching operational performance). Several LPD practices, such as standardization, supplier integration, set-based approach, chief engineering´s concept paper, 5S, visualization and cross training could be adopted to mitigate these issues. The set-based approach and chief-engineers concept papers practice ensures identifying all the functional requirements analyzing possible solutions very early, avoiding changing requirements and conflicts in the later stages of the project (Araci et al., 2022; Morgan & Liker, 2020).

Regarding the utilization of lessons learned from previous projects, the adoption of lean practices, such 5S, standardization, visualization and cross-training facilitate transforming cognitive knowledge to tacit knowledge in a structured way during product development and construction projects (Lindlöf et al., 2013; Lindskog et al., 2017). Apart from these, adoption of hard-lean practices, such as process mapping using VSM, work-load leveling, identifying value adding and non-value adding activities could be used to reduce the time required to launch a new production system.

Regarding post-launching operational performance, several challenges were found. It was found that in the case company, post-launching operational performance is less prioritized, and attention remains completing the project on time within the allocated budget. In addition, the project team members do not take responsibility if the newly launched production system performs less than expected level. This indicates a lack of consideration of post-launching operational performance as value or a lack of understanding of the value associated with the NPSIP. One of the practices addressed in the LPD is the chief engineer system, where a chief engineer remains involved with the project from beginning to end and holds accountability for the product´s success or failure (Morgan & Liker, 2020).

In the case company, it was found that when defining the new production system's specifications, safety aspects are highly prioritized, whereas environmental aspects are less prioritized. Interviewees addressed that because of time pressure and lack of standard method, proper analysis regarding long term environmental impacts of identified feasible solutions is skipped. Adopting LPD practice in the NPSIP could augment practitioners´ understanding of value, ensuring incorporation of economic, social, and environmental performance as customer value that need to be addressed. Hence, this paper provides the following proposition. Figure 2 illustrates the proposition that requires further research to validate.

Proposition: Adopting LPD in the NPSIP improves sustainable operational performance.

RQ-2: How to adopt LPD within NPSIP?

The empirical study indicates that the case company adopted some of the LPD practices within the NPSIP in an ad-hoc manner. After 10+ years of lean journey of the case company, the question remains why there is still lack of adoption of lean practice in the NPSIP as it is within the intersection of production development and regular production operation functions. In the case company, the product development function does not get involved during the NPSIP. After developing a product, the temporary project management team aims to finish the project on time with the allocated budget, and does not take accountability for the operational performance of the intended production system. Hence, the product development function and production operation functions work in silo, rather than integrated fashion.

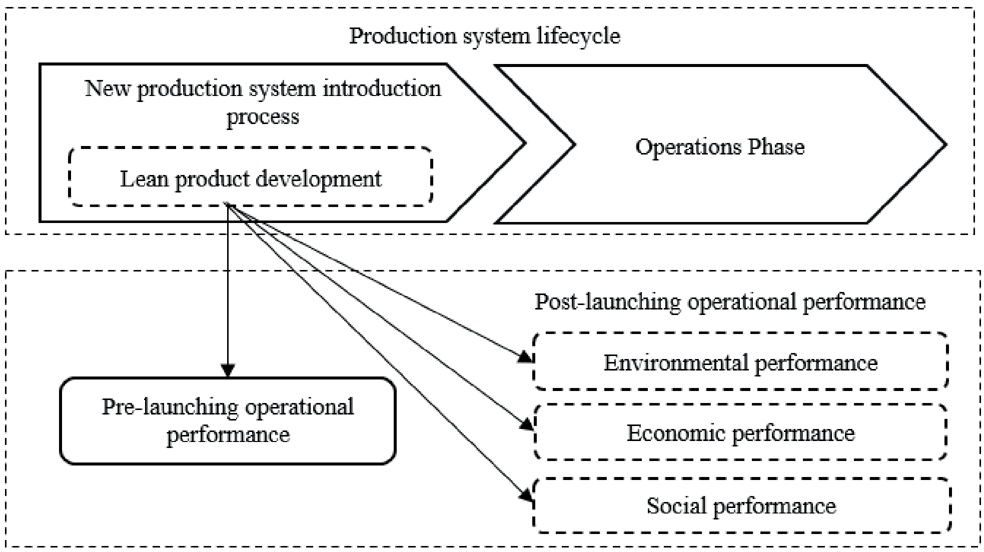

Figure 2. Proposition on impact of LPD in NPSIP on operational performance.

The similar issue was raised in earlier research by Bellgran & Säfsten (2009) and Rösiö & Bruch (2018). In addition, project members are involved on a part-time basis from different functionals for a short while. Hence, developing the NPSIP drew less attention throughout the organization despite being aware of its importance.

One of the possible solutions would be adopting different lean practices throughout the NPSIP. However, it was found that pre-launching operational performance was more prioritized than post-launching operational performance. In addition, environmental aspects are also less prioritized. This indicates a lack of understanding of value (Principle-1 of 13 principles of LPD), which is one of the reasons why lean implementation fails (Morgan & Liker, 2020). Hence, it is important for practitioners to adopt both LPD principles and practices simultaneously to get utmost long-term benefit.

Birkie et al. (2023) addressed that launching a new production system differs from launching a new product, as the new production system is used by the company itself, and operational performance is highly dependent on it. Hence, practices developed for new product development might not be suitable for NPSIP or might need to be modified due to contextual aspects. For instance, a new production system needs to be designed in such a way that it includes lean production, digitalization and green aspects that differs from traditional product development practices. Hence, a modified model of LPD needs to be modified in terms of the NPSIP context to facilitate its adoption by the practitioners. Therefore, this research elaborates the principles and practices of LPD according to NPSIP context.

Appendix 2 provides 13 principles of LPD elaborated in the NPSIP context, and Table 4 provides a list of LPD practices connected to lean bundles that could be adopted in the NPSIP.

6. Conclusion

This paper aimed at explore if lean philosophy could be adopted to manage the activities within the NPSIP in a systematic manner that can assist practitioners in achieving sustainable operational performance. The empirical study shows that in the case company some of the soft-lean practices were adopted in the

Table 4. Proposed LPD practices in NPSI context.

Lean bundles	Applicable practices in Lean PSDP
JIT	Detailed scheduling
	Process mapping (VSM for NPSIP)
	Heijunka (levelling)
TQM	QFD (quality function deployment)
	Root cause analysis
	Poka-yoke (stage-gate model)
Employee involvement	Assigning a chief engineer or project manager(s) that has certain attributes and responsibilities
	Multi-functionalities involvement
	Early involvement of the production team
	Involvement of operators and shop-floor employees
Supplier involvement	Collaboration with the equipment supplier (on developing specification, solutions)
	Knowledge transfer from supplier
Standardization	Systematic design process (stage-gate model)
	Design for X (lean, green, reconfigurable, etc.)
	Concurrent engineering
	Set based approach
	Chief engineer´s concept note
Continuous improvement	War room (daily meeting meeting)
	Genchi Genbutsu (go and see)
	Kaizen event
Visualization	5S
	Visual information management
Training	Developing internal technical competency
	Cross training

NPSIP in an ad-hoc manner that provided some benefits. However, several challenges were identified that impacted both pre-launching and post-launching operational performance. These challenges could be mitigated by adopting LPD practices. Hence, referring to RQ-1, adopting LPD practice in the NPSIP would assist in reducing the timeline associated with launching a new production system, and achieving target operational performance after commissioning the new production system.

In the case company, it was found that after 10+ years of lean journey, there is still a lack of adoption of lean practices in the NPSIP. In addition, there is a lack of prioritizing post-launching operational performance, especially environmental aspects as value. Adopting LPD practices in the NPSIP would augment practitioners understanding of value and decision taken in the NPSIP would be directed in favor of achieving post-launching operational performance, providing environmental performance equal importance. Referring to RQ-2, there is a contextual difference to apply LPD concept in the NPSIP from regular product development operations. Hence, a modified model of LPD is proposed containing principles (see Appendix 2) and practices (see Table 4) that could be suitable for practitioners to implement.

6.1. Theoretical and practical implications

This paper contributes to the broad lean literature by extending the implication of lean practices in the new production system introduction process context. Therefore, this research could be considered a foundation for adopting lean practices in the NPSIP that could guide further interest for researchers and practitioners. In addition, earlier research (Andersen et al., 2017; Islam et al., 2022; Rösiö & Bruch, 2018; Trolle et al., 2020) urged to develop a systematic way to manage the activities within the NPSIP to achieve both pre-launching and post-launching operational performance. From theoretical and empirical evidence, this research proposes that the adoption of LPD in the NPISP could act as a systematic way that could improve pre-launching and post-launching operational performance considering sustainability aspects.

Another theoretical contribution is that research implies resource-based-view theory in NPSIP context. Adopting LPD in NPSIP could enhance companies dynamic capability to acquire new production system that leads to further competitive advantage.

Regarding practical implications, to become a complete lean enterprise, organizations need to adopt lean philosophy within all functions (Marodin et al., 2018). Adopting the lean practices in the NPSIP could increase the maturity level of lean implementation within the organization. Furthermore, adopting lean practices in the NPSIP, companies can launch a new production system faster and attain expected operational performance from newly launched production system faster that could provide them additional competitive advantage.

6.2. Future research

As this paper could be viewed as a foundation of adopting lean concept in NPSIP context, this paper proposes following further research directions.

- Conducting empirical study to validate the proposition as addressed in Figure 2.
- Distinguish which lean practices require more attention in the NPSIP to attain pre-launching and post-launching operational performance respectively.
- Identifying success factors and barriers of adopting lean practices in the NPSIP context.
- Developing a framework for adopting lean practices in the NPSIP context.

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Appendix 1. Challenges to achieve pre-launching and post-launching operational performance in the case company

Impact/ Category	Challenges	Evidence
Pre-launching operational performance	Lack of standardization	"*its more difficult to work with it [existing stage-gate model]. I think we need to have more training on the model for all. My sponsor did not always appreciate when I tried to follow the model because they did not understand how the model works and that was quite difficult.*"
	Lack of utilizing lesson learned	"*the lesson learn is somewhere [in the data storage system], you should of course tag them as lesson learn, its quite difficult to find all the lesion learn.*"
	Changing specification frequently	"*one of the lesson learnings was that [equipment specification] was not really good because they had to add things over and over time.*" "*the [equipment specifications] was constantly changing, we had to stop it*".
	Poor relation with supplier	"*that's the company that we knew difficult to work with and they proved bit difficult to work with*" "*the project manager for the supplier had lot of other projects at the same time or something else, so it was low communication, low proceeding in the project.*"
	Poor knowledge transfer	"*when you are shifting people, Its always an overlapping knowledge, and its always hard to get all the knowledge from one person to another*"

Impact/ Category	Challenges	Evidence
Post-launching operational performance	Lack of target on post-launching operational performance	"*Right now we do not have any targets*." "*I think there was no analysis at all, why did they have the goal to reach 50% [of OEE]. I think they took a chance because they thought it's a new line and why should [there] be [a] problem with the new line…I know that there was no analysis behind [it] or I [could] say [regarding] the choice of reaching 50% OEE, they took a shot*."
	Lack of alignment of objective among team members	"*When something delays in the design process, training time is often compromised, which is not good*". "*For the project we cannot take responsibility of how trained the operators are, and how the standard way of working is. We can only take responsibility for the machines*". "*I have seen the same pattern where we started a project, we built a line, we [were] eager to get the commercial production, we stressed the training [that affects] the quality of the training*".
	Lack of tools to address functional requirements	"*Right now, there is [a] lot of copy [and] paste*." "*Just look at what we wrote in the other [equipment specifications], just copy it, that's good, just order it because we need to get that production going. But really! that's where you must stop and put the most effort, because that's [new production system] going [to] be with you forever*."
Post-launching operational performance	Lack of testing and training	"*When something delays in the design process, training time is often compromised, which is not good*". "*I have seen the same pattern where we started a project, we built a line, we [were] eager to get the commercial production, we stressed the training [that affects] the quality of the training*".
	Lack of responsibility by project team	"*For the project we cannot take responsibility of how trained the operators are, and how the standard way of working is. We can only take responsibility for the machines*".
	Suppliers lack of understanding on functional requirements	"*I am not sure that the supplier got the correct prerequisite to make the machine go on*"
	Lack of incorporation of best manufacturing practices in system solution	"*There was a lack of standards. There was no standards for change overs. If you had trained [operators] from standards, then they would have learned to do the things in the right way*." "*You cannot first build the machine, and then apply operators and ways of working. You need to have the requirements early, and you need to figure out [very early in the project] how you are going to work with the machines*."

Appendix 2. Elaboration on LPD Principles in NPSI context

Principles in LPD	Elaboration within the context of NPSI
1. Customer value	Enhancing customer value by reducing waste. Here, the customer refers to user of the production system (i.e. production team, company, stakeholders). Value: Pre-launching (i.e. cost, time-to-market) and post-launching operational performance (time-to-volume, OEE, quality, deliverability, safety, green, etc.) Waste types: Engineering design waste: not addressing properly the production system specifications and requirements (such as equipment specification, capacity, buffer size) Process-related waste: waste associated with activities to design the production system (i.e. specification development, supplier selection, testing, training, etc.)

Principles in LPD	Elaboration within the context of NPSI
2. Front-loading	Finding alternative solutions of the intended production system using a set-based approach and avoiding changes in the later stages. Variation of intended production system need to reduce by considering standardization (i.e. standardization of spare parts, control system) and modularization of in the specification of new production system.
3. Levelled development process	Achieving levelled flow using different tools, such as VSM, detailed scheduling of each activity, visual management in the activities associated with value generation process of the intended production system.
4. Rigorous standardization	Achieving standardization in the activities of value generation process by Design standardization (layout, equipment specification, material handling system, technology type, etc.) Process standardization (supplier selection, administrative task, documentation, testing of equipment, etc.) Engineering skills standardization (training employees)
5. End-to-end leadership of the process	Adopting the chief engineer system (or assigning project manager(s)) who should have the following attributes and responsibilities: Ability to challenge top management´s pressure and focus on standards System integration Lead the concept Sufficient technical expertise Taking responsibility for the project's success or failure
6. Cross-functional integration	Allocating the chief engineer or project manager sufficient authority to extract resources whenever required.
7. Towering technical competence	Developing internal technical competency within the organization to reduce the dependability on external vendors (i.e. equipment suppliers, technical solution providers, etc.)
8. Integrating suppliers	Developing close relationship with external vendors/equipment suppliers. Developing detailed solution and design specification of the production equipment/system together with the equipment suppliers/ external vendors.
9. Learning and continuous improvement	Learning as the project progresses and utilizing lessons learned from one project to another. Facilitating capturing lessons learned and transferring the knowledge and lesson throughout entire enterprise.
10. Supporting excellence and improvement	Developing a culture to support continuous improvement such as daily kaizen (team meeting), work ethics, accountability and responsibilities.
11. Fitting technology	Adapting technology that fits with the people, processes and organizational culture in the value generation process
12. Organizing visual communication	Facilitating communication among different functions, team members and stakeholders so that everyone are aware of the common goals, for instance, what requirements need to be addressed, what operational performance needs to be achieved from the newly launched production system and drive towards achieving it.
13. Tools for standardization and organizational learning	Facilitating standardization and organizational learning using different tools.