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A K-Chart Based Implementation Framework to Attain Lean & Agile Manufacturing

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Abstract: Lean manufacturing has always ensured production optimization by eliminating wastes, and its implementation has helped in improving the operational performance of the organization since it eliminates the bottlenecks from the processes, thus making them efficient. In lean scenarios, the focus is on "waste" elimination, but in agile manufacturing, the focus is on the ability of comprehension of changing market dynamics and the resilience. One of the major factors in the combined implementation of lean and agile approaches is inadequate planning, monitoring and lack of awareness regarding changing market trends, and this can be countered by utilizing the effective tool of K-Chart. Through a systematic literature review, the authors establish the requirement of effective planning and monitoring in the implementation of integrated lean and agile approach, concluding that K-Chart is a handy tool to adopt for their effective implementation. The result provides a new vision of lean implementation through K-Chart, whereas it provides clarity to practitioners by presenting a K-chart based implementation framework for achieving favourable results. Being a literature review the research work can be validated through a case study approach in future through a comparative analysis between various implementation techniques and K-Chart.

Key words: K-Chart, lean manufacturing, agile manufacturing, operational excellence.

1. Introduction

Lean Manufacturing is vital in the elimination of wastes and improvement of the operational efficiency, in addition to optimized production (Khodeir & Othman, 2016; Moyano-Fuentes et al., 2012). Every industry is using lean for improvements in its process since long (Koskela, 1992). Lean manufacturing minimizes the hurdles that occur in processing and improves the production rate (Bhamu & Singh Sangwan, 2014; Rafique et al., 2017). Lean principles have been successfully applied on the systems in which lead times and operational efficiency were improved (Matt & Rauch, 2013). On the contrary, many industries adopt lean system but usually falter in its implementation, which is not a straightforward task. This complexity of lean has produced awareness in manufacturers and researchers of the whole world to apply such tools that are beneficial for lean in the system (Swank, 2003), to acquire the best results like improve lead times, customers demand and controlling cost and quality (Goldsby, Griffis, & Roath, 2006; Rafique, Ab Rahman, Saibani, Arsad, & Saadat, 2016). In order to do so, the lean tool of value stream mapping is beneficial since it categorizes the process to value added and non-value added times, laying groundwork for improvements (Christian & Zimmers, 1999). Lean can be considered as a philosophy which helps to make the system effective and efficient for industries. The cost of labours, customers satisfaction, reduce lead time, reduce wastes can be minimized with the help of lean and agile (Fagerholm et al., 2015). Leanness eliminates the wastes and the process becomes more

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efficient. Lean manufacturing is used to control the production according to its environment and company's demand (Maqbool et al., 2019; Naslund, 2008). Responding to, and taking advantage of changes through strategic utilization of managerial and manufacturing methods and tools are the pivotal concepts of agile manufacturing (Sharifi & Zhang, 2001). Diversification and product individuality are the backbones of agile manufacturing, whilst being able to swiftly responding to market change (Waters, 2007). The success of agility lies in making through a turbulent and a period of uncertainty, and striving for excellence by prospering in a competitive environment, thus setting the foundations for organizational success (Yauch, 2011). It was deduced by McCullen and Towill (2001) that lean manufacturing can be considered a sub category of agile manufacturing.

In order to ensure smooth implementation of lean and agile manufacturing, it is imperative to have an efficient tool for its implementation that facilitates the change. Cause & Effect, Fishbone Diagram, Pareto Chart are a few important techniques, but do not cater to the requirement of simultaneous planning and monitoring. In this scenario, the objective of this research is to introduce a novel technique for planning, monitoring and implementation of lean, known as K-Chart (Abdullah et al., 2006). The research introduces a new concept of K-Chart in manufacturing context that will provide a new direction to researchers. In addition to that, it will provide clarity to practitioners regarding the use of K-Chart in implementation of lean and agile techniques for improving the production process.

The paper is structured in the following manner; research methodology will be is discussed in Section 2, section 3 comprises of the literature review, results are in section 4. In the 5th section, the conclusions are drawn along with discussion on the limitation of research and future implications.

2. Research Methodology

In order to achieve a robust research methodology, it is imperative to designate a clear research context. Therefore, the research onion strategy was developed by M. Saunders, Lewis, and Thornhill (2009) and M. N. Saunders (2011).Nesensohn (2014) further explains that division of research onion into four distinct layers in order to achieve favorable results. A research onion comprises of the following layers:

- Research Philosophies (Ontology, Epistemology)
- Research Logics (Inductive & Deductive)
- Research Purposes (Explanatory, Exploratory & Descriptive)
- Research Approaches (Qualitative & Quantitative)
- Research Strategies (Survey, Case Study, Phenomenology, Ethnography)
- Research Techniques (Data Collection, Procedures)

Research philosophy being the outermost layer of research onion specifies the starting point of the research work (Nesensohn, 2014; Saunders, 2011). It is subdivided into ontology, epistemology and axiology (Elnadi, 2015; Srichuachom, 2015). It can be seen that quantitative research is attributed to positivism philosophy, whereas qualitative research is associated with the concept of interpretivism.

After selection of positivism philosophy, the next task was the study of data collection techniques for the subject matter since it is of paramount importance in every research. From numerous data collection procedures, the authors selected the literature review philosophy. The literature review suggests reviewing the data available in literature (Elnadi, 2015; Robson & McCartan, 2016). The literature reviews inclusive of previous researches and findings, which are gathered from previous publications, journal papers, articles, conference papers, books and other previous reviews. According to Robson and McCartan (2016) the leading reason to conduct literature review are:

- To comprehend the research topic and to acquire research knowledge
- Classifying previous works and examining them to attain results
- Realizing gaps in previous research
- Evading mistakes and limitations of previous research
- Circumventing inadequate work

After selection of literature review as research methodology, the authors developed a comprehensive search and selection criteria for lean manufacturing, agile manufacturing & K-Chart.

This has culminated in development of a roadmap that helped in arriving at the most pertinent research works in line with the subject matter.

The designed search and selection criteria has helped in selection of the most relevant journals and research works, which have been cited in the succeeding section. The authors were careful in

Table 1. Search & Selection Criteria.

Study material	Implementation of lean manufacturing, implementation of agile manufacturing, importance of k-chart, modern planning & monitoring techniques
Period covered	1997–2020
Data used from sites	Emerald, Science Direct, Springer, Scopus, Taylor and Francis Online
Keywords used to search from Database	Lean Manufacturing, Agile Manufacturing, Planning & Monitoring, K-Chart, Implementation Framework

selecting the research works based on the relevance, coherence and relationship to the manuscript aims. The literature was collected from high impact factor and eminent journals in the field of manufacturing, production and their management. In addition to that, credible conference papers were also used in the literature review. It was aimed that the selection criteria returns those articles that carry the most impact in their relevant field, and are in line with the research aims. Using the ScienceDirect database, the research works for the period 1997-2020 were selected, with primary focus on works from 2013-2020 The initial search resulted in 134 papers on lean manufacturing, and 138 articles on agile and lean-agile manufacturing. 19 papers related to lean manufacturing were selected after careful consideration; and for agile manufacturing domain 18 papers were selected The papers related to supply chain domain were excluded, and the manufacturing domain was considered only. There was no such criterion of selection of research method from the selected articles, the authors included case studies, surveys, conceptual models, mathematical models, etc. so that the core message for both approaches in conveyed.

3. Literature Review

3.1. Lean Manufacturing

The very first instance of introducing the manufacturing sector to lean was in 1990, when James P. Womack wrote the book *The Machine That Changed the World*. The transition from mass production to lean became a necessity since it presented an efficient and economical solution to the manufacturing industry (Sabbagh et al., 2016; Womack et al., 1990). The era of mass production came to a halt in 1980s and was duly replaced by agile or flexible production, which marked the beginnings of revolution in industrial management (Duguay et al., 1997). This led to the conclusion that lean manufacturing enables industries to walk towards a path of business excellence (Mamat et al., 2015; Mejabi, 2003). Koskela (1992) indicated that the major categorization of lean philosophy can be done by segregating the processes in production systems to conversion activities and flow activities,

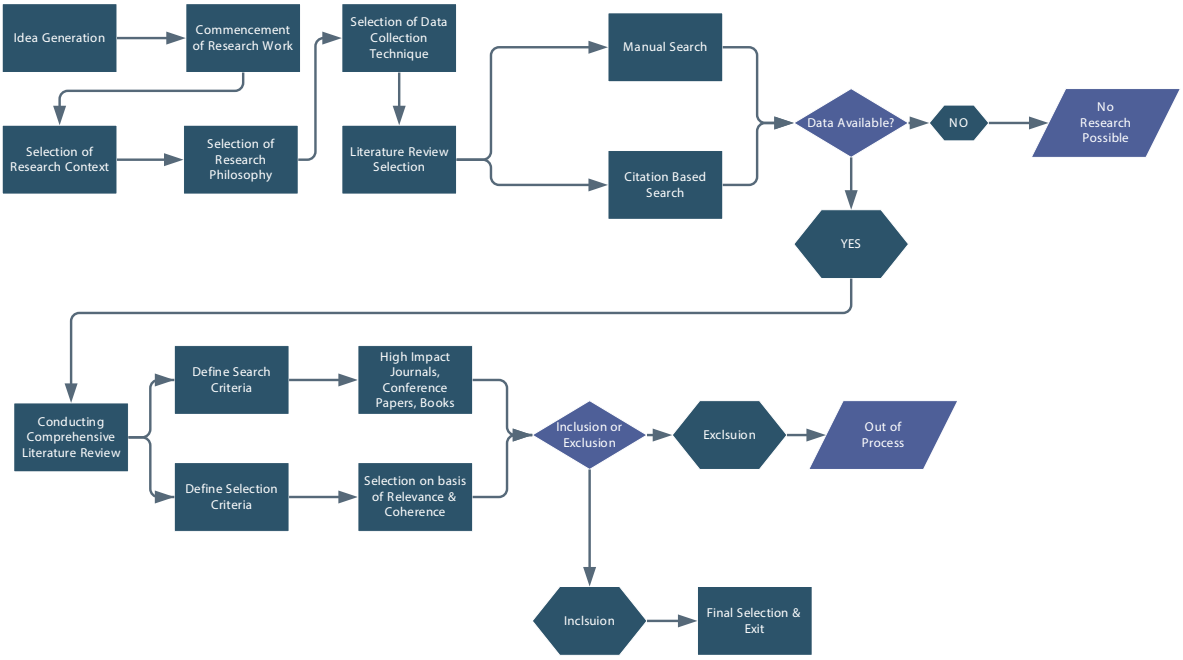

Figure 1. Search & Selection Criteria.

the former being value adding and the latter being time and consuming, while adding no value to the product. Lean was further defined in following steps by (Womack et al., 1990) that included:

- Explicitly define the end customer need which in in turn define the value
- Eliminate wastes and map each process for each product
- Make the processes flow by continuously making sure that there is no waste, waiting and no downtime
- Introducing a pull system
- Design, production and delivery should be a function of customer need
- Following the philosophy of "Continuous Improvement

Lean manufacturing is not just a fancy term thrown everywhere, it's a philosophy (Bhasin & Burcher, 2006) that enables industries to do better by employing the principles of continuous improvement and changing the organizational culture. Moreover, lean manufacturing helps in waste reduction (Bhamu & Singh Sangwan, 2014; Sahwan et al., 2012) thus causing an increase in quality and quickly responding to customer demand The universality of lean is such that its concepts and tools were developed in the services sector (Swank, 2003) and the implications can be clearly seen in the better business and operational performance of the organization (Nawanir et al., 2013; Nordin et al., 2012). The facet of Just-In-Time manufacturing has a significant impact on the operational performance (Rahman et al., 2010; Rehman et al., 2018)

Implementation of lean manufacturing principles considerably reduces the production time (Rahani & al-Ashraf, 2012), regardless of the size of the organization (Matt & Rauch, 2013). It has been observed that for achieving long term strategic goals and objectives, it is necessary to implement lean manufacturing techniques to reduce waste and providing detailed guidelines to the management for process improvement (Sundar et al., 2014). By basing their work on implementation of lean strategies, (Anvari et al., 2011) concluded that it improved productivity and increased competitiveness. However, it was seen that the attitude of workers and complete understanding of the concepts are of primary importance in effective implementation of lean system (Nordin et al., 2010). A coalescence of Just-In-Time & Total Quality Management is necessary for increased employee involvement, increased productivity levels and higher quality standards (Sriparavastu & Gupta, 1997). By using Kanban model, industries can reduce operational costs and can make their workstations more flexible. (Rahman et al., 2013). An organization that desires to reduce the lead time, escalate the product quality, increase the flexibility and lower the costs must adopt lean production techniques (Martínez Sánchez & Pérez Pérez, 2001). An inverse relation has been observed between the inventory and the extent of leanness, irrespective of the organizational volume – thus reducing the logistics charges over the course of time (Chun Wu, 2003). LM can affect organizational performance, not only at the operations level but also at the business level. By demonstrating the existence of direct and indirect effects of LM practices on BP (Nawanir et al., 2013) provide clear evidence that LM implementation is important to enhance companies' performance.

3.2. Agile Manufacturing

In lean environment, the focus is on "waste" elimination, but in agile environment, the focus is on the ability of understanding the market changes and responding to them. An important difference is that lean supply is associated with level scheduling, whereas agile supply means reserving capacity to cope with volatile demand.(Martin & Towill, 2000). Supply chains, supply chain management change, and evolve mainly under the pressure of the competition. Generally, the existing activities of supply chain management aim at the cost reduction by using instruments for their leanness (lean management concept) or at higher service level by higher flexibility (agile management concept) (Konecka, 2010). Agility has four underlying principles: delivering value to the customers; being ready for change; valuing human knowledge and skills; and forming virtual partnerships (Gunasekaran, 1999) The main characteristics of agile manufacturing summarized by Yusuf, Sarhadi, and Gunasekaran (1999) are given as follows:

- High end customization of products without compromising on quality
- Manufacturing products and offering services with value added content
- Increased responsiveness to shifting paradigms, uncertain conditions and environmental issues
- Amalgamation of diverse technologies

Agile manufacturing was termed to be of supreme importance in the survival and prosperity of organizations with the volatile business climate

Table 2. Literature Review on Lean Manufacturing.

Author Name & Year	Methodology	Findings(Authors' points of view)
Womack and Jones (1996)	Case Study	The following five steps are effective to ensure leanness: - Defining the customer value - Defining value stream - Subjecting the value stream to a flow - Introducing a pull system - Continuous determination towards achieving excellence:
Martínez Sánchez and Pérez Pérez (2001)	Survey	Lean indicators can be classified into six groups: - Elimination of non-value added activities - Continuous Improvement - Just-In-Time Production & Delivery - Teamwork - Integration of Suppliers - Flexible Information Systems
Abdulmalek and Rajgopal (2007)	Case Study	A simulation model was run it was concluded that application of lean manufacturing principles significantly reduces production lead time by reducing WIP inventory, using hybrid production system and introduction total productive maintenance.
Anand and Kodali (2010)	Literature Review	The ten levels of implementation framework are given as follows: - Evaluate - Prepare organization for LM implementation - Defining value - Identification of value stream - Creating a process flow - Process Improvement using SPC, Pokayoke etc. - Stabilizing Improvements - Advancing by letting the customer pull - Establishing the use of philosophies such as TPM, TM, Six Sigma etc. - Pursue Perfection
Losonci et al. (2011)	Case Study & Survey	It was identified that the critical intrinsic factors (commitment, belief) and external factors (lean work method, communication) affect the success of the lean implementation from workers' point of view. The stereotypical gender values can intensify the impact of factors related to the particular process type
Rahani & Al-Ashraf (2012)	Case Study	Reduction of waiting time, economic impact of time improvement and lower rejection rates.
Matt and Rauch (2013)	Case Study	Lean Production principles can be conveniently applied to SMEs resulting in productivity improvement.
Metternich et al. (2013)	Case Study	The number of operators and number of machine tools can be adjusted to suit the production demand, thus accounting for customer volatility.
Nawanir et al. (2013)	Case Study & Survey	The author suggest that business performance and lean practices have a direct relationship, resulting in increased productivity.
Bhamu and Singh Sangwan (2014)	Literature Review	External support is required to enhance adoption of LM in SMEs. One of the critical implementation factors of LM is simultaneous adoption of leanness in supply chain
Sundar et al. (2014)	Literature Review	A roadmap was proposed for implementation of LM techniques such as Every Product Every Interval & Continuous Improvement.
Rohani and Zahraee (2015)	Case Study	The authors applied the approach of value stream mapping in a color factory to achieve lead time and value added time reduction.
Salonitis and Tsinopoulos (2016)	Survey	The authors conducted a survey for Greek manufacturing sector and concluded that organizational culture is of paramount importance when it comes to the successful implementation of lean manufacturing.
Botti et al. (2017)	Case Study	The authors developed a mathematical relationship between lean manufacturing and workplace ergonomics, which was then applied to an Italian manufacturing firm. The results indicate that hybrid assembly lines are beneficial for maximum productivity.
Sartal et al. (2017)	Hypotheses Testing	The authors developed various hypotheses regarding the integration of lean manufacturing with green practices and IT approaches to conclude that the developed conceptual model suggests that IT approaches are incumbent for achieving manufacturing excellence.
Marodin et al. (2018)	Survey	The authors use a survey approach to develop a relationship between the lean product development and lean manufacturing, and conclude that the aforesaid interact in a positive manner.
Ghobadian et al. (2018)	Literature Review	The authors discuss the case of various industries and propose that lean manufacturing concepts can be extended to sustainability and posit that additive manufacturing is of vital importance in sustainability.
Abu et al. (2019)	Literature Review & Survey	The authors discuss the barriers in the implementation of lean manufacturing in various Malaysian industries ad suggest that 5S, employee training and quality control are essential for harnessing the lean benefits.
Yadav et al. (2020)	Case Study/ Survey	The authors developed a framework for lean manufacturing implementation in developing economies using the hybrid-fuzzy mathematical modeling tools.

(Sharifi & Zhang, 2001) achieved by astute utilization of the resources. Being a strategic process, agile manufacturing breeds winners – ranging from suppliers to end user customer by using the integration of core components (Jin-Hai et al., 2003). The core components, as described Yusuf et al. (1999) are given as follows:

- Core competence management
- Value driven enterprise
- Capability for reconfiguration
- Virtual driven enterprise

Agile philosophy improves the capability of the supply chain to respond towards customer's requirements by the virtue of flexibility. Thus, the product/service quality is increased, lead times are shortened despite variation in volume, customer satisfaction is increased and the products are delivered on time. The aforementioned qualities lead to increase in productivity and profitability (Carvalho et al., 2012; Tao & Zhang, 2017).

Table 3. Literature Review on Agile Manufacturing.

Author Name & Year	Methodology	Findings(Authors' points of view)
Gunasekaran (1998)	Conceptual Model	The author suggests that lean manufacturing techniques in conjunction with digital technologies can help in achieving agility.
Yusuf et al. (2004)	Conceptual Model/ Case Study	The authors suggest that lean and agile practices can be integrated in a harmonious manner to achieve improved business performance.
Baker (2006)	Survey/Case Study	Design of distribution centers is a critical part of communication and visibility improvement in agile supply chains.
Iskanius et al. (2006)	Survey/Case Study	To achieve agility, the flexibility should be focused on operations as opposed to human capital. Process integration in supply chain requires switching the mindset.
Ismail and Sharifi (2006)	Literature Review	Supply chain design interacts with market, supply chain, business environment, technology to support the dynamic characteristics of Agile Supply Chain.
Vonderembse et al. (2006)	Case Study & Conceptual Framework	The authors considered product lifecycle in which it was concluded that earlier phase requires agile practices, whereas maturity and decline phases require lean principles.
Baramichai et al. (2007)	Case Study & Conceptual Framework	The authors developed a conceptual framework which helps in improving the business performance through agile means, focusing on supply chain reconfiguration.
Gunasekaran et al. (2008)	Framework/ Case Study	For achieving agility in manufacturing, integration with IT is necessary for smart working.
Inman et al. (2011)	Survey / Conceptual Framework	The authors suggested that lean practice of JIT has positive relationship with agile principles in which the operational and marketing performances are improved.
Costantino et al. (2012)	Case Study	The authors discussed the role of decision making in manufacturing systems and suggest that agile practices are necessary to achieve efficient performance.
Constantinescu et al. (2014)	Literature Review	The authors identified the drivers and antecedents of agile manufacturing, and conclude that pragmatic usability applicability and mass customization are of extreme importance in agile manufacturing environment.
Pawlowski and Pawlowski (2015)	Survey	The authors surveyed the Polish manufacturing industry to conclude that mass customization, organizational shrewdness and resource flexibility are of vital importance in agile manufacturing.
Leite and Braz (2016)	Survey & Case Study	The authors suggest that agile manufacturing practices contribute positively to financial performance of the industry, however it remains a relatively unknown approach.
Sindhwani and Malhotra (2017)	Structural Modeling	The authors have discussed the enablers of agile manufacturing and suggest that top management commitment, organizational support and IT integration are extremely important for agile manufacturing implementation.
Gunasekaran et al. (2018)	Case Study	The authors shared the results of four UK based companies and suggested that agile manufacturing needs to be integrated with BigData business analytics in order to achieve manufacturing excellence.
Ghobakhloo and Azar (2018)	Survey	The authors conducted a survey with Iranian manufacturing companies, developed hypotheses and used structural equation modelling to suggest that lean manufacturing is a precursor to implementation of agile manufacturing, where the former improves financial performance.
Gunasekaran et al. (2019)	Literature Review	The authors suggest that the five major agile competencies include transparent customization supply chains of agile nature, automation, employee empowerment and technology integration.
Khalfallah and Lakhal (2020)	Survey	The authors took responses from 205 Tunisian manufacturing companies and suggest that lean approaches supplement the agile practices except for JIT delivery, whereas agile manufacturing practices add towards improved operational performance.

4. Results & Discussion

K-Chart was introduced by Abdullah et al. (2006) as a simplistic research planning and monitoring technique. It shows the scope, methodologies, key findings/results and timelines by giving them in shape of ladder or tree; thus a detailed micro level layout can be developed through K-chart (Abdullah et al.). It should not be confused with the mathematical modelling technique used for statistical process control (Gani & Limam, 2013; Kumar et al., 2006). K chart plays an important role in planning and monitoring through tree diagram. Without using K chart, errors such as like delays, incorrect monitoring and inadequate utilization of resources can be encountered. In addition to this, K chart assists in cost reduction, interlink between the whole processes of the system. The main role of K chart depends on layers and each layer describes itself (Abdullah et al.). The uses of K-Chart found through literature are in Table 4.

The results in the Table 4 indicate that K-Chart is an excellent tool for planning and monitoring, but has only been employed in research works and a singular instance of supply chain management. Therefore, the authors have used this technique for lean implementation. Rafique et al. (2017) have introduced an excellent implementation framework for lean but it does not cater to the requirements of controlling and monitoring.

The tool, Pareto charts, Ishikawa/Fish bone/Cause and Effect, Flow Chart and Gantt chart (Jasiulewicz-Kaczmarek, 2013) are common tools, which can't provide the clear structure of the system, Hence, a new tool is introduced named K chart, which is a useful tool for any research and industry to become sustainable. It provides the clear picture of research scope, explanation of expected and ongoing results and issues, stepwise methodology for any research planning. It is clear that, K chart is a useful tool, which distinguish the different layers and its corresponding outcomes on micro level. A K-chart consists of Issues, Methodologies, Results and Time line. A K-chart basically organizes the issues from the broad ones to the specific ones within the area under study. The broader issues are placed at the higher branches of the tree diagram and dissected into various specific issues (sub-issues) underneath it. The issues are then designated into general, complementary and focused issues.

4.1. Using Lean Tool of Value Stream Mapping

kLean Manufacturing has always been at the forefront of improving production performance of an organization; doing so by introducing various tools and techniques to curb the losses. Out of the lean tools of VSM, 5S, Kanban, Andon, TPM etc. VSM (Value Stream Mapping) is of significant importance in which the processes are mapped to evaluate the performance and identify the bottlenecks in the production (Rother & Shook, 2003). It is proposed that current state map of the process is drawn and checked for areas for improvement (Singh et al., 2011). The tool of VSM carries such universality that it does not only cater to the production process, but the services as well (Keyte & Locher, 2004). The lead times, cycle times and changeover times are calculated, in which the value added activities and non-value added activities are differentiated

Table 4. Literature Review on K-Chart.

Author Name & Year	Research Focused Area	Findings
Abdullah et al. (2006)	Research Planning & Monitoring	The authors introduced the techniuque of K-Chart for efficient planning and monitoring of research, by using a layered approach in which processes are divided into sub issues and methodologies, enabling the user to achieve time based monitoring.
Alfaris et al. (2019)	Enterprise Resource Planning	The authors have performed a literature review in which they have described the importance of K-Chart in research planning and monitoring, exhibiting its importance by applying it to their case study based research where the use of K-Chart has provided clarity regarding the planning and execution of research.
Yahaya (2016)	Power Systems	The author has used the K-Chart technique in planning and monitoring the research work in which the research was divided into various subgroups and subsystems for efficient working and delivery.
Yen (2013)	Electronics	The author has used K-Chart for planning and stringent monitoring of the research work in order to create an electronics based alert system.
Ter Ji-Xi (2013)	Electronics	In order to perform a project on object monitoring for people suffering with dementia, the authors employed K-Chart technique to achieve favourable results.
Immawan et al. (2015)	Supply Chain Management	The authors have developed a framework to assess the supply chain performance of Indonesian industries by employing K-Chart technique for planning and monitoring of research.

(Serrano Lasa et al., 2008; Seth & Gupta, 2005). It is advised to simulate the values for validation through power software tool (Lian & Van Landeghem, 2007) so that the issues in data collection are identified and addressed. By answering the eight questions suggested by Rother and Shook (2003), a future state map is drawn in which the lean wastes of DOWNTIME (defects, overproduction, waiting, non-utilized resources, transport, inventory, motion and extra processing) are eliminated and cycle times are reduced (Seth & Gupta, 2005). The future state map gives a direction regarding the changes in production process or production layout (Hines & Rich, 1997; Rahani & Al-Ashraf, 2012). The tool of value stream mapping can be applied to any industry regardless of its size or production quantum (Chen et al., 2010; Grewal, 2008).

4.2. Using Agile Tool of Technological Unification

In case of agile manufacturing, the authors have suggested the use of technological unification in which the processes would be automated, and highly stressful laborious processes would be replaced by technologically intensive processes. Agile systems seem provide rapid and cost-effective response to new (unplanned) product model introductions and dynamic capacity allocation to meet unpredictable demand (Elkins et al., 2004). In order to achieve the aforesaid, the driving force behind the concept of agile manufacturing pivots on the following points, as described by Yusuf et al. (1999):

- Eliminating human error by using automation
- Broadening the customer segment and ensuring the highest quality standards
- Ever-competitive manufacturing climate
- Proactive manufacturing – thinking one step ahead from customers
- Coalescence of manufacturing and management best practices

It is a well-known fact that holistic lean manufacturing implementation requires 3-5 years, and requires top management commitment, employee training and embracing the lean thinking approach. Similarly, the literature review suggested that in case of agile manufacturing, the successful implementation is incumbent upon the top management commitment to achieve higher operational performance (Khalfallah & Lakhal, 2020). Therefore, a conscious effort should be made towards integrated implementation of both approaches for optimized manufacturing and operational performances. In the current literature, there exists a paucity of approaches that involve implementation of said approaches on system and sub-system levels, divided into various layers (Abu et al., 2019; Ghobakhloo & Azar, 2018).

In this regard, K-Chart serves as an effective tool due to its strong monitoring capability (Abdullah et al., 2006). It involves, problem identification, objective setting, definition of deliverables and setting various milestones. The drivers of lean and agile manufacturing are the independent variables which correspond to the results such as improved production performance, financial gains, operational efficiency, reduced lead times, etc. In comparison to the conventional methods of Fishbone diagram, Ishikawa, Pareto chart, etc. the K-chart takes a holistic view of the implementation of the said approaches. In the case of lean and agile manufacturing implementation, the sub-issues included operational issues, strategic issues and methodology for implementation. Consequently, the following layer of the sub issues encompassed manufacturing, organizational nature and production philosophies. This is followed by the methodology layer in which technical and experimental approaches are discussed; in which the former explains the antecedents whereas the latter discusses the dependent variables and the tools used. After successful experimentation, the production optimization process is commenced using lean and agile tools of value stream mapping and technological unification, validated through rigorous simulations. Concomitant to that, the real time improvements include lead time reduction, non-value-added time reduction, reduction in excessive operations and workforce, and improved value-added time.

Therefore, it can be stated that the implementation of K-Chart based approach helps immensely in smooth implementation of desired manufacturing approaches and carries the ability to meticulously plan and monitor the progress. The use of K-Chart can be extended to project management, program management, research tracking, etc.

5. Conclusion

Through a systematic literature review, the authors have discussed the implementation of K-Chart in combined implementation of lean and agile

manufacturing, using the tools of Value Stream Mapping and technological unification respectively. A K-Chart has been drawn which is divided into various layers and sub-layers, eventually culminating in the production optimization. As per the K-Chart given in Figure 2, the system level is defined which caters to manufacturing, which is divided into three sub issues of operational, methodology based and

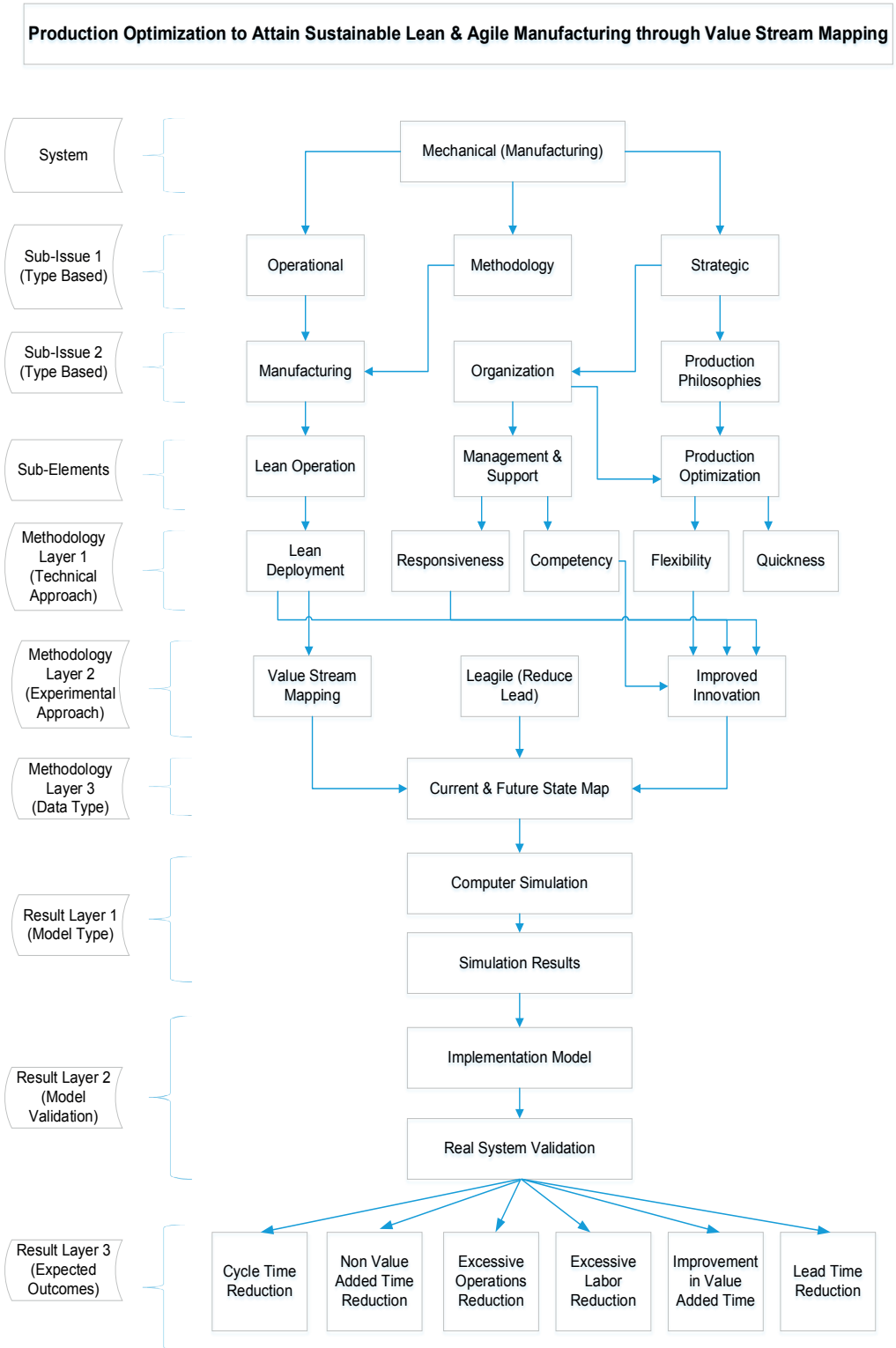

Figure 2. K-Chart Based Lean & Agile Implementation.

strategic, which have been further divided into manufacturing, organizational and production paradigms. The sub-elements succeed the sub-issues, which have been further divided into three methodology layers. The results layers follow which are divided into three tiers as well, helping in arriving at the most pertinent results. With the increased level of planning and monitoring, the research introduces a new concept of K-Chart in manufacturing context that will provide a new direction to researchers. In addition to that, it will provide clarity to practitioners regarding the use of K-Chart in implementation of lean and agile techniques for improving the production process. However, the proposed idea requires validation through a case study that is the obvious limitation of this research work. Building on this limitation, the future research works can be case study based and a comparative analysis between various implementation techniques and K-Chart to provide a clear picture of its efficacy.

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