Industry 4.0 and Lean based Operational Performance Improvement Approach: A Conceptual Framework for the Banking Sector

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Abstract

With the advancement of technology, Industry 4.0 concepts have been thrived up to a state where the applications can be utilized in a wide variety of industries with the focus of improving operational performance. In order to gain market share, as well as to sustain in the economic crisis, operational performance improvement is highly crucial to the banking sector. This study is concerned with the application of industry 4.0 technologies in a lean based environment within the banking sector of Sri Lanka. When considering banking processes, the main question that arises is, the inefficiencies occurred at different stages of conducting business. Hence, the **application of lean tools is a viable solution to address these inefficiencies.** Banking **processes can be streamlined in order to improve resource utilisation with the elimination of wasteful practices while shortening time and cost to serve, thereby improving the productivity.**With some degree of modifications, concepts and technologies comprised in industry 4.0, can be applied to service sectors such as banking. Combining these advanced technologies with lean principles, may result a better operational performance than application of these concepts distinctly. Therefore, integration of industry 4.0 technologies within a lean based environment can be proposed as a viable solution to improve operational performance of the banking sector. This scrutiny presents findings of a comprehensive and systematic review of literature based on the areas of operational performance improvement, industry 4.0, lean management and banking sector. The article will offer an insight to current state of knowledge available in the corresponding areas and will suggest the path for future research.

Keywords: Industry 4.0, Lean Management, Operational Performance Improvement, Banking Sector

INTRODUCTION

In order to succeed in the new business environment while ensuring sustainable profitability, banks are focusing on adapting new management strategies that provide more efficient and cost effective services without reducing quality from the customer perspective (Santos and Cabrita, 2016). Banks deliver their value to customers and stakeholders through operational processes. Therefore, enhancement of operational performance is significant for banks to achieve operational excellence. When considering banking operations, several loop holes can be identified such as physical dispersion of information, rework, process loopbacks, excessive verification points, duplicationof information and etc. Lean can be considered as a significant approach in addressing these challenges. Streamlined banking processes can improve operational efficiency by reducing costs and wastes.

The basic idea behind lean management is the elimination of waste from a process to maximise amount of gain while utilizing least amount of capital or other investments through continuous improvement (Nordin et al., 2016). Manufacturers have applied lean concepts to their manufacturing processes to reduce operational complexity and to improve performance, they can be treated as a basis for operational excellence by standardizing processes while eliminating non value adding activities. However, these concepts were suggested as possible applications for service industries as well.

For the last few decades, technological advancements have been thrived up to a state where the applications can be utilized in a wide variety of industriesto achieve operational excellence. Technology evolves from first industrial revolution as steam power, water power and mechanization to mass production, assembly line and electricity. Then it evolves as third industrial revolution, the introduction of computerization and automation, though the fourth is the move towards digitization(Deloitte, 2015). Industry 4.0 is the concept of automation and data exchange in the manufacturing technologies, which enables the use of Internet of Things (IoT), Cyber-Physical Systems (CPS), big data analytics, cloud computing and cognitive computing to move towards a smart world (Hercko and Hnat, 2015).

A successful integration of industry 4.0 technologies in to the business processes are vital to gain competitive advantage in any business. Even though to integrate these technologies to business processes it is significant that the processes are streamlined in advance to reduce additional resource consumption and reduce costs. Industry 4.0 can be applied to service sectors

such as banking with a certain degree of modifications in its concepts and technologies. With the risen expectations of the customers, banking sector is focusing on adapting new technological solutions to automate processes in order to offer a better service.Hence to get optimal output from the investment of industry 4.0 technologies it is important that processes are streamlined with lean tools with the aim of improving operational performance. Therefore, the objective of this study is to comprehensively and systematically analyze the literature published in the context of industry 4.0, lean management and operational performance of banking sector to identify theoretical research gaps in the above context.

The remainder of this paper is organized as follows: the methodology applied for this study, an overview of research approaches used in the examined articles, the results of the systematic literature review, closure of the paper by offering conclusions and an attempt to provide some perspectives on future research.

METHODOLOGY

Content analysis is the approach employed to capture the state of knowledge in the classified areas that explicit sequence of steps methodically and organize the elements of texts. Thus it enables an investigator to meaningfully interpret and make inferences about the patterns in the content of the overall study (Bowen and Bowen, 2008). The initial step of this study is to collect the articles related to the areas of Industry 4.0, Lean Management and Operational Performance of the Banking sector. The accumulated articles were screened according to title and abstract and further referred which resulted in 26 articles. The full text of each paper was reviewed with the aim of eliminating the articles which are not within the scope of the study. Incongruities were discussed by researchers and 24articles were considered for the review by removing duplications. Hence, in total of 24 articles were included in this study. The selection process of the study is shown in the Figure 1. The list of references listed at the end of this paper comprises all studied articles. It is believed that the selected and screened articles for this study involves a reasonable representative of the broad body of research work accomplished in this area. A comprehensive literature review was conducted with the purpose of acknowledging the effect of industry 4.0 and lean management on the operational performance of the banking sectorthus revealing the research gap in the corresponding area. The contemporary articles which have been published within the years of 1990 and 2018 were chosen for the review. The contents of the articles were classified based on the factors that have been studied by the researchers and suggested models / frameworks also analysed.

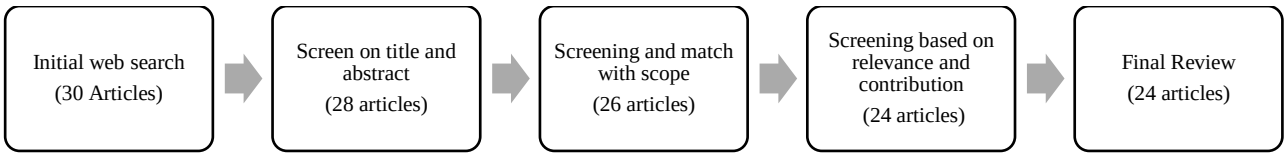

Figure 7: Literature screening process

MAIN RESULTS OF THE REVIEWED STUDIES

This section provides an insight into the current state of knowledge.(Refer Table 1 for the summary of the reviewed studies)

The phenomenon of industry 4.0 was first introduced in 2011 in Germany thus it is based on the concepts and technologies namely: cyber-physical systems, Internet of Things, and Internet of services, Industrial Internet of Things, Big Data analytics and etc. These concepts enhance perpetual communication via internet which allows a continuous interaction and exchange of information not only between humans, human and machineand the machines themselves (Roblek et al., 2016).Hercko and Hnat (2015), argues the concept of industry 4.0 creates a new orientation for theproduction companies. The successful implementation of this strategy depends on the use of the principles of the concept. Industry 4.0 is based on six basic principles: Interoperability (CPS and people connected viaIoTand IoS), Virtualization (creates a copy of the physical world in a virtual environment), Decentralization (decentralized control systems), Capacities in real time (collect data in real time), Service orientation (CPS and people are available through IoS), Modularity and re-configurability (modular systems adapt to changing requirements).

As Schumacher et al. (2016) argued, manufacturing companies focussed on adapting industry 4.0 to increase their operational performance while being competitive. Thus it is important for them to measure their industry 4.0 maturity to identify and improve competing factors. Schumacher et al. (2016), proposed a model to assess industry 4.0 maturity of an enterprise in the domain of discrete manufacturing based on nine dimensions. Even though the concept of industry 4.0 firstly limited to manufacturing sector thus it started to evolve in service sectors as well. As modern customer expectations have risen with the technology improvements, they value relationship centric experience that hinges on trust and personalization while receiving unlimited accessibility, convenience and speed of service. So it is significant for the service sector to integrate these technologies to offer a better customer satisfaction.

The main question arise in this context is that, the investment of industry 4.0 applications to the service sector actually returns optimal output if the processes are not properly streamlined. There are several process inefficiencies can be identified in banking sector such as physical dispersion of information, rework, process loopbacks, excessive verification points, duplicate of information and etc. (Santos and Cabrita, 2016). Thus lean tools are a significant solution to identify process loopholes and to streamline processes while reducing wastages. Santos and Cabrita (2016) mentioned, lean is a beholding paradigm which creates more value for customers using less resources. Thus lean aims to minimize waste, along value streams to provide products with greater quality and variety at lower costs and shorter lead times by incorporating a collection of principles, concepts and tools into business processes.

Karlsson and Ahlstrom (1996) proposed nine determinants in lean management such as elimination of waste, continuous improvement, zero defects, just in time, pull instead of push, multifunctional teams, decentralized responsibilities, integrated functions and vertical information systems. According to the authors the nine determinants can be used to streamline processes.

Shah and Ward (2007) developed a conceptual framework to assess lean based performance of an organisation which consists of ten dimensions. As Tortorella et al. (2016) said, there are three bundles of lean management practices that used to measure the level of lean implementation such as JIT, TQM, and TPM. According to Putri et al. (2018), Lean Six Sigma is a methodology that focuses on quality management and business process improvement by managing customer requirements.

Nordin et al. (2016) developed a framework to measure lean based performance of a manufacturing plant. Themodel assesses behaviour of five lean aspects against the waste elimination. According to Leite and Vieira **(**2013),lean manufacturing philosophy is based on the principles that guide the "lean thinking", namely: value specification, value stream mapping, flow optimization, pull production system and perfection or continuous improvement.

Therefore, according to the literature, lean tools is significant in streamlining business processes. Thus streamlined business processes can be automated using advanced technologies to improve performance. Hence some studies focus on integrating industry 4.0 technologies to lean optimised business processes. Kolberg and Zuhlke (2015), mentioned industry 4.0 is a

networking approach where components and machines are becoming smart and a part of a standardized network based on the well proven internet standards. The integration of Just in time or Kanban systems with industry 4.0 is called as lean automation. TortorellaandFettermann (2018) conducted a study to examine the relationship between lean production practices and the implementation of industry 4.0 in Brazilian manufacturing companies. The results indicate, lean practices are positively associated with industry 4.0 technologies and their concurrent implementation leads to large performance improvements in any organisation.As Ward and Zhou (2006) mentioned, firms who have integrate information technology in lean/just-in-time manufacturing practices have been succeeded in improving their operational performance as exampled in North America.

Lean IT is a new approach for optimizing IT-enabled business processes with the focus on quality improvement, waste elimination, reduce lead time and cost. According to Jeong and Yoon (2016), IT firms can apply value stream mapping to standardize its processes as a Lean-IT approach. Jackson et al. (2011) investigates the requirements and possible solutions in lean to increase the efficient use of automation in the Swedish manufacturing industry as a lean-automation approach.

Buer et al. (2018) carried a study which reveals four aspects of research streams, such as industry 4.0 supports lean manufacturing, lean manufacturing supports industry 4.0, performance implications of an industry 4.0 and lean integration, and effect of environmental factors on industry 4.0 and lean manufacturing integration. According to Rauch et al. (2016),Lean Product Development and an industry 4.0 oriented Smart Product Development are not contrarily, but go hand in hand. Thus both shares the advantages.

Although the studies published in the area of integrating industry 4.0 into lean based environment were mainly focussed on the manufacturing process automation thus limited studies focussed on integrating this concept to service sectors such as banking. There were several studies published revealing knowledge areas of industry 4.0 applicability in the banking sector. KPMG Banking Systems Survey (2018), Ratings direct (2018), Deloitte (2015), Hyman (Fintech Focus) are studies which discloses the applicability of new advance technologies comes under industry 4.0 to banking systems.

Hyman (Fintech Focus), discusses about digital banking experience that modern customer demanded today. Innovation leads to easier customer satisfaction through fully digital reimagining and digitizing banking operations and processes, and improvement in core

infrastructure. The concepts of personalization, frictionless, accessible and consistent across devices, connected to customer life events, and enabling intelligent data-driven decision making are achieved through digitalisation.

KPMG Banking Systems Survey (2018), talks about the concept of open banking which is known as *Payment Service Directive II*. It facilitates bank to share customer transaction and account data with third parties, including, retailers, telco providers, payments services and financial account aggregators. PSD2 is a trigger to open up the current banking landscape to new players in financial arena. Ratings direct (2018) reveals of the usage of new concepts like *cryptocurrency* in Banking. Cryptocurrencies are digital currencies that use encryption techniques to regulate the generation of units of currency and verify the transfer of funds.

Biometric technology improves the user experience of banking customers, by providing a simple process to verify existing customers or to enhance KYC (Know Your Customer) on-boarding methods. Customers can create their own set of biometric credentials and then use a combination of these biometrics to log in, verify their accounts and authenticate transactions (Cook, 2017).

Mobile wallet is another new concept of industry 4.0, which enables electronic payment transfer from customer-to-customer, linking the citizens' identity (ID) and mobile phone numbers to bank accounts. This provides a convenient mode for the customers to transfer and receive funds through the use of citizen ID numbers and mobile phone numbers instead of bank account numbers (Wonglimpiyarat, 2017).

Hence published studies distinctly reveals the relationship between lean banking and industry 4.0 banking,thus it is important to investigate the linkage within the areas of industry 4.0 and lean for the banking sector for better operational performance improvement. Based on the results of the study lean automation in the banking sector can be identified as a viable solution to improve its performance.

Even though to improve industry 4.0 performance some studies suggest that training and knowledge is a considerable factor. According to Wilkesmann and Wilkesmann (2017), designers of Industry 4.0 have to take responsibility for underlying results of digitalized work. Hence, to achieve successful transformation to digitisation,professional, vocational and academic training will be a key factor. Training and performance measures requiredto take up

the theoretical aspects of industry 4.0 thus to link with practical aspects of complextechnologies.

Table 45:Findings of the reviewed studies

Reference	Design Method/s	Key findings
(Roblek et al., 2016)	Literature review	Analysis about the concepts of industry 4.0 such as cyber-physical systems, the Internet of things (IoT), and the Internet of services, Industrial Internet of Things (IIoT), Big Data analytics. The importance and influence of internet connected technologies for the creation of value added for organizations and society was highlighted.
(Wilkesmann and Wilkesmann, 2017)	Conceptual framework	Emphasizes on the factors affecting to the success of digital transformation of an organisation such as the designer's responsibility for underlying results of digitalized work into account and must jointly find socially acceptable solutions. To achieve successful transformation to digitisation, professional, vocational and academic training will be a key factor.
(Hercko and Hnat, 2015)	Literature review	Analysis of the basic principles of Industry 4.0; Interoperability, Virtualization, Decentralization, Service orientation, Modularity and re-configurability.
(Schumacher et al., 2016)	Model	Proposed a model to assess industry 4.0 maturity of an industrial enterprise in the domain of discrete manufacturing based on nine dimensions. The dimensions such as products, customers, operations and technology have been created to assess the basic

		enablers. Additionally, the dimensions like strategy, leadership, governance, culture and people allow for including organizational aspects into the assessment.
(Deloitte, 2015)	Analysis	Introduction to industry 4.0, history, knowledge areas and new innovations in financial sector.
(KPMG Banking Systems Survey, 2018)	Report	Introduction to the concept of Payment Services Directive II (PSD2) where banks will now share customer transaction and account data with third parties, including, retailers, telco providers, payments services and financial account aggregators.
(Ratings direct, 2018)	Report	Introduction to cryptocurrencies. Cryptocurrencies are digital currencies that use encryption techniques to regulate the generation of units of currency and verify the transfer of funds. Cryptocurrencies are independent from central banks, and the risk of them penetrating the traditional financial systems
(Hyman, Fintech Focus)	Report	Digital banking experience enhanced by Artificial Intelligence (AI). Digital banking offers application of behavioural economics, predictive analytics, artificial intelligence (AI) and machine learning to anticipate customer needs and get smarter over time about what to offer them rather than being an elegant, consistent interface to customer accounts.
(Cook, 2017)	Report	Biometric technology helps to improve the user experience of banking customers, by providing a simple process to verify existing customers or to enhance KYC (Know Your Customer) on-boarding methods. Customers can create their own set of biometric

		credentials and then use a combination of these biometrics to log in, verify their accounts and authenticate transactions.
(Wonglimpiyarat, 2017)	Case study	Evaluation of new technologies developed by FinTech. Explained the concept of mobile wallet which enables electronic payment transfer for customer-to-customer (C2C), linking the citizens' identity (ID) and mobile phone numbers to the customers' bank accounts. This provides a convenient mode for the customers to transfer and receive funds through the use of citizen ID numbers and mobile phone numbers instead of bank account numbers.
(Karlsson and Ahlstrom, 1996)	Model	A model which contains nine measurable determinants for lean assessment. The proposed nine determinants are elimination of waste, continuous improvement, zero defects, just in time, pull instead of push, multifunctional teams, decentralized responsibilities, integrated functions and vertical information systems.
(Santos and Cabrita, 2016)	Case study	Application of lean principles to banking services and its critical success factors. Introduce five lean principles that can be applied to banking sector such as specifying value from customers' perspective, understanding the value stream, improving the flow, producing based on customers' pull and striving for perfection.
(Shah and Ward, 2007)	Conceptual framework	Measure relationships between lean production and firm performance through a framework that recognises most noticeable ten dimensions in lean implementation such as flow, total preventive maintenance, employee involvement, customer involvement,

		setup time reduction, statistical process control, pull production systems, JIT delivery by suppliers, suppliers feedback, and supplier development.
(Tortorella et al., 2016)	Empirical analysis	Introduce three bundles of LM practices that used to measure the level of LM implementation such as JIT, TQM, and TPM. JIT practices are related to the improvement of material and information flow efficiency, TPM includes practices that are focused on creating basic stability for the production processes, TQM stand for practices that aim to improve and mitigate quality issues by consistently problem-solving activities.
(Putri et al., 2018)	Empirical analysis	Application of lean six sigma into front line processes of a bank. Provide analysis of the two six sigma concepts DMAIC (Define, Measure, Analyse, Improve, Control) and DMADV (Define, Measure, Analyse, Design, Verify). DMAIC is used to improve current business process, whereas DMADV is used to design the process of new product to deliver zero defects performance.
(Nordin et al. 2016)	Framework	Assessment of lean manufacturing (LM) practices in a production plant. Investigation of the concepts of process improvement models such as Just in Time (JIT), Total Productive Maintenance (TPM), Total Quality Management (TQM), Lean Six Sigma (LSS)
(Leite and Vieira, 2013)	Literature review	Lean principles and its applicability in service sector. Emphasize on five main principles of lean manufacturing, namely: value specification, value stream mapping, flow optimization, pull production system and perfection or continuous improvement.

(Kolberg and Zuhlke, 2015)	Literature review	Analysis of lean automation practices in manufacturing sector. Lean Automation refers to the combination of automation technology with Lean Production. With the term Low Cost Intelligent Automation, the applications for automation should be developed with easy to realize instruments. Standardized, cost-efficient solutions should be favoured over individualized solutions.
(Tortorella and Fettermann, 2018)	Empirical analysis	Assess the relationship between lean production and implementation of industry 4.0 in Brazilian manufacturing companies.
(Ward and Zhou, 2006)	Empirical analysis	Integration of lean / JIT practices with IT tools to improve lead time performance in the manufacturing companies. The concept was tested using North American manufacturing companies.
(Jeong and Yoon, 2016)	Case study	Application of value stream mapping to an IT firm as a Lean-IT approach resulted performance improvement. Value Stream mapping (VSM) is a significant Lean tool to identifying waste and improvement areas and it is a standardized way of documenting the process steps and flow of work items, and then applying a systematic way to analyse these processes to develop an improvement plan.
(Jackson et al., 2011)	Case study	Analyse requirements and possible solutions for efficient use of automation in the Swedish manufacturing industry. Investigate about the requirements on automation

		solutions within small and medium-sized manufacturing companies and possible solutions for increased flexibility and re-configurability of robotic systems.
(Buer et al., 2018)	Literature review	Analyse the link between industry 4.0 and lean manufacturing. Results of the study indicate positive relationship between the two areas and operational performance of a manufacturing firm.
(Rauch et al., 2016)	Analysis	Smart Product Development provides better results in cost and quality when it integrates with Lean Product Development. Lean Product Development is mainly focussing on reducing wastes in the product development process and to concentrate on value adding activities.

DISCUSSION

The categorization of factors studied in the selected articles are discussed in the following sections of impact of industry 4.0 on banking, impact of lean on banking, integration of industry 4.0 and lean and other factors.

Impact of industry 4.0 on Banking

Under this category, studies focused on the impact of industry 4.0 on Banking sector. These impacts can be a competitive advantage for the banks while sometimes having implications in the practical context such as requirement of a higher investment, resources and need for process changes.

The fourth industrial revolution, creates new stage in organizing and managing the entire value chain more efficiently. Thus it addresses highly personalized customer requirements while satisfying customers via associated services. The availability of the real time information establishes a basement for value creation, by networking of all related entities in to a single platform with optimal value flow at any time. Association between people, objects, real-time and self-organizing systems affected by the facts of cost, availability and resource consumption (Wilkesmann and Wilkesmann, 2017).

Industry 4.0 consists of the concepts of cyber-physical systems, Internet of things (IoT), and the Internet of services. Perpetual communication via internet is important to allow continuous interaction and exchange of information between human, human and machine and machines themselves (Roblek et al. 2016). Industry 4.0 is mainly based on six basic principles such as Interoperability, Virtualization, Decentralization, Capacities in real time, Service orientation, Modularity and re-configurability (Herko and Hnat, 2015).

In today, digital banking considered to be a popular concept as customer expectations have risen with the technological advancements and they are more depend on technical devices. According to Hyman (Fintech Focus), innovation leads to easier customer satisfaction through digital reimagining and digitizing banking operations and processes, and improvement in core infrastructure. Thus it offers application of behavioural economics, predictive analytics, artificial intelligence (AI) and machine learning to anticipate customer needs and get smarter over time about what to offer them rather than being an elegant, consistent interface to customer accounts.

For the past decades, banks made heavy investments in technology and attempts to improve the efficiency of financial services. There are several new innovations in banking landscape like electronic fund transfer at the point-of-sale, ATM cash dispenser, internet banking, international electronic fund transfer, Electronic Data Interchange, mobile banking, Bitcoin wallet, Blockchain banking, crowd funding to improve customer satisfaction as well as to be competitive(Wonglimpiyarat, 2017).

As Cook (2017) said, biometric technology helps to improve the user experience of banking customers, by providing a simple process to verify existing customers or to enhance KYC (Know Your Customer) on-boarding methods. This will eliminate the use of passbooks, passwords in login or identification purposes in banking system. Customers can create their own set of biometric credentials to log in, verify their accounts and authenticate transactions.

KPMG Banking Systems Survey (2018) introduce Payment Services Directive II (PSD2) as a new concept of industry 4.0, which facilitates 'Open Banking' where, banks will share customer transaction and account data with third parties, including, retailers, telco providers, payments services and financial account aggregators. PSD2 will be a trigger to open up the current banking landscape to new players in financial arena, with moving towards new customer experiences, bringing possible disruption to banks.

According to the literature the concepts and technologies of industry 4.0 such as Payment Services Directive II, biometric identification, internet banking, international electronic fund transfer, Electronic Data Interchange, mobile banking, Bitcoin wallet, Blockchain banking, crowd funding,predictive analytics, artificial intelligence (AI) and machine learning, cryptocurrencies could be incorporated with banking processes to improve efficiency. Even though the investment to apply these concepts is really high, it is important to get optimal output for the investment. If the existing processes are not properly streamlined, application of these concepts distinctly may not result actual performance improvement. Hence these advance technical applications can be integrated to streamlined banking processes to reduce lead time, improve customer satisfaction and as a competitive advantage to survive.

Table 46:Impact of Industry 4.0 on Banking

Study	Competitive advantage for the user organization	Issues and difficulties in practical application	Relevance for Banking sector	Industry 4.0 application for Banking	Key findings
(Wilkesmann and Wilkesmann, 2017)	*		*	Intelligent adaptive assistance systems	Mobile integrated system to assist employee work.
(Herko and Hnat, 2015)	*	*	*	-	Industry 4.0 concepts such as CPS, IoT, IoS, Smart Factory
Hyman (Fintech Focus)	*	*	*	Use of artificial intelligence (AI)	Use of AI to analyse behavioural economics, predictive analytics and machine learning to anticipate customer needs
(Wonglimpiyarat, 2017)	*	*	*	EFTPOS, ATM , Internet banking, Interbank Telecommunication ,International electronic fund transfer, EDI, mobile banking, Bitcoin wallet, crowd funding	Facilitates banking operations and provide extensive customer satisfaction.
Cook (2017)	*	*	*	Biometric technology	Used to verify existing customers or to enhance Know Your Customer on-boarding methods

KPMG Banking Systems Survey (2018)	*	*	*	Payment Services Directive II	share customer information with third parties to personalising its service offerings

Impact of Lean Management on Banking

Under this category, studies focused on the impact of lean management on the Banking sector.

Lean banking is significant approach in addressing operational performance. Lean applicability is important to minimise wastages in banking processes like delay/waiting, duplication and over processing, unnecessary movement, unclear communication, incorrect inventory, lost opportunity, and defects in service.Putri et al. (2018) conducted a study to implement lean Six Sigma in banking processes which delivers recommendations to minimize the seven wastes.

Santos and Cabrita (2016), mentioned five lean improvement areas of banking sector such as working method, technology, bureaucracy, innovation and quality. The study suggests ten critical success factors for holistic lean implementation in banking. Karlsson and Ahlstrom (1996) proposed nine determinants in lean management, such as elimination of waste, continuous improvement, zero defects, just in time, pull instead of push, multifunctional teams, decentralized responsibilities, integrated functions and vertical information systems which used as a tool to follow progress in an effort to introduce lean production.

According to Leite and Vieira (2013), there are five main principles of lean manufacturing, namely: value specification, value stream mapping, flow optimization, pull production system and perfection or continuous improvement.Thus lean does not have a single model of tools or practices and standards for services. Shah and Ward (2007) suggested a framework that recognises ten dimensions in lean implementation in an organisation such as flow, TPM, employee and customer involvement, setup time reduction, statistical process control, pull production systems, JIT delivery by suppliers, suppliers feedback and development.

According to Tortorella et al. (2016), there are three bundles of Lean practices such as JIT, TQM, and TPM. JIT is related to the improvement of material and information flow efficiency, TPM focuses on creating basic stability for the production processes, as zero defects, quality assurance, product and process quality planning and TQM aims to improve and mitigate quality issues by consistently problem-solving activities, such as maintenance systems, workplace organization and etc.

The selected studies focus on different lean management tools as possible solutions to streamline banking processes while reducing wastes along value stream to improve performance. Hence technology can be incorporate with these lean tools for better performance

improvement as lean automation approach. Thus lean automation can be applied to service sectors such as banking.

Table 47:Impact of Lean Management on Banking

Study	Applied Industry			Key Findings
	Banking	Other services	Production	
(Putri et al., 2018)	*			Lean banking is significant in addressing operational performancewhileimproving quality at lower cost.
Santos and Cabrita (2016)	*			Mentioned five lean improvement areas of banking sector such as working method, technology, bureaucracy, innovation and quality.
Karlsson and Ahlstrom (1996)			*	Proposed nine determinants in lean management to assess changes towards lean implementation.
Leite and Vieira (2013)		*		Five main principles of lean manufacturing : value specification, value stream mapping, flow optimization, pull production system and continuous improvement.
Shah and Ward (2007)		*	*	Ten dimensions that affects lean implementation.
Tortorella et al. (2016)			*	Three bundles of Lean implementation practices such as JIT, TQM, TPM

Integration of Industry 4.0 and Lean

Literature suggest that integration of industry 4.0 and lean will result actual performance improvement than application of these concepts distinctly. In this section the study focus on integration of industry 4.0 and lean concepts.

Lean Automation refers to the combination of automation technology with Lean Production. However, according to the context of Industry 4.0, new solutions are available for combining automation technology with Lean Production. With the term Low Cost Intelligent Automation, the applications for automation should be developed with easy to realize instruments. Standardized, cost-efficient solutions should be favoured over individualized solutions (Kolberg and Zuhlke ,2015).

Lean IT is a new approach for optimizing IT-enabled business processes with the focus on quality improvement, waste elimination, reduce lead time and cost. Value Stream mapping is a useful lean tool to document the process steps and flow of work items, to analyse the processes and bottlenecksto develop an improvement plan. Even though the visualization of the process flow, increases the visibility of identifying waste and other limits on value chain (Jeong and Yoon, 2016).

Ward and Zou (2006) examines the relationships among inter-firm IT integration, intrafirm IT integration, lean/JIT practices, and lead-time performance using data from real world application through a case study. The results of the study show two main considerations such as implementing lean/JIT practices significantly reduces lead time and lean/JIT practices mediate the influence of IT integration on lead-time performance.

Tortorellaand Fettermann (2017) carried-out a study to implementindustry 4.0 and lean production in Brazilian manufacturing companies. Findings of the study indicate that lean production practices are positively associated with industry 4.0 technologies and their concurrent implementation leads to larger performance improvements in manufacturing sector. Although lean production is claimed as a socio-technical and low-tech continuous improvement approach, its benefits can be enhanced if digital technologies are properly incorporated. According to Jackson et al. (2011), European manufacturing industry is focussing on increasing the level of automation and use of industrial robotics. However, robot automation investments are expensive and too technically advanced, Jackson et al. investigates the requirements and possible solutions to overcome the challenges. Results from the study

indicated that automation through lean implementation will results cost and waste reduction in manufacturing sector.

Buer et al. (2018) presents an insight into the available knowledge on the areas of industry 4.0 and lean manufacturing. The results of the study indicate positive relationships between the two areas and operational performance of a manufacturing firm.

As the literature suggests there is a positive impact on operational performance of a manufacturing organisation when incorporating the concepts of lean automation to its business processes. Therefore, these concepts can be identified as a viable solution to service sectors as well. Even though lean can support to minimise wastages in banking processes like delay/waiting, duplication and over processing, unnecessary movement, unclear communication, incorrect inventory, lost opportunity, and defects in service, thus lean tools can be used to identify process inefficiencies in order to streamline the processes. Hence application of technical solutions to streamlined business processes give better operational performance improvement in banking sector.

Table 48: Integration of Industry 4.0 with Lean Management

Study	Applied industry			Key findings
	Banking	Other services	Production	
(Kolberg and Zuhlke ,2015)			*	Combination of automation technology with Lean Production
(Jeong and Yoon, 2016)		*		Lean IT approach for optimizing IT-enabled business processes with the focus on quality improvement, waste elimination, reduce lead time and cost
(Ward and Zou, 2006)			*	Integration of IT with JIT manufacturing practices
(Tortorellaand Fettermann, 2017)			*	Integration of industry 4.0 in lean manufacturing paradigms

(Jackson et al., 2011)			*	Integration of lean to automotive robotics technology.
(Buer et al., 2018)			*	There are positive relationships between the industry 4.0, lean management and operational performance of a manufacturing firm

Other Factors

According to the literature there are some other factors that influence on the implementation of lean and industry 4.0 in a firm.

Schumacher et al. (2016) consider external and internal factors that affect the assessment of industry 4.0 maturity such as Leadership, customers, culture, people, governance and etc. Deloitte (2015), mentioned there are challenges in implementing industry 4.0 in an organisation such as data security, integrating customers, IT infrastructure requirements and expertise knowledge. As to the changing expectations of the customers with the risen technological developments, the existing technology should be up to date with latest versions. Wilkesmann and Wilkesmann (2017),Roblek et al. (2016) mentioned the requirement of expertise knowledge and empowerment of employees to take independent decisions in implementing industry 4.0. As Cook (2017) mentioned, there is a risk of security in associating with open banking concept. Cook suggested the use of biometric technologies to overcome such challenges.

Karlsson and Ahlstrom (1996) identifies the importance of multifunctional teams when implementing lean management in a manufacturing firm. Leite and Vieira (2013),Putriet al. (2018) identifies the human factor is more important in lean implementation to provide better customer service.

Even though as literature suggests the factors like leadership of the organisation, customers, culture, people, governance, data security, IT infrastructure requirements, expertise knowledge, empowerment of employees, resources are critical when implementing industry 4.0 and lean in an organisation. Hence these factors should be considered in transforming to lean automation, unless it could result process inefficiencies.

Table 49:Other factors affecting lean and industry 4.0 implementation

Study	Focussed Factors
(Schumacher et al., 2016)	Leadership, customers, culture, people, governance
(Deloitte, 2015)	Data security, integrating customers, IT infrastructure requirements, expertise knowledge
(Wilkesmann and Wilkesmann, 2017), (Roblek et al., 2016)	expertise knowledge, empowerment of employees
(Cook, 2017)	Security concerns
(Karlsson and Ahlstrom, 1996), (Leite and Vieira, 2013) and (Putri et al., 2018)	Human factors

MODELS/FRAMEWORKS

Models and frameworks presented in the selected articles are discussed under this section (Refer to the Table 6). The developed conceptual framework is further discussed in this section of the study.

Wilkesmann and Wilkesmann (2017) suggested a framework which describes an organizing continuum for analysing digitalized work in the context of industry 4.0 from reproducing and improving routines (exploitation) against enabling inventions and innovations (exploration).

Schumacher et al. (2016) developed a maturity model to assess industry 4.0 maturity in manufacturing enterprises. The model assesses industry 4.0 maturity, based on nine dimensions, such as products, customers, operations, technology, strategy, leadership, governance, culture and people.

Karlsson and Ahlstrom (1996) proposed a new operationalise model to asses lean based performance of an organisation. The model consists of nine determinants in lean management such as elimination of waste, continuous improvement, zero defects, just in time, pull instead of push, multifunctional teams, decentralized responsibilities, integrated functions and vertical information systems.

Shah and Ward (2007) suggested a framework that recognises ten dimensions in lean implementation such as flow, total preventive maintenance, employee and customer involvement, setup time reduction, statistical process control, pull production systems, JIT delivery by suppliers, suppliers feedback and development. The framework is used to assess lean based performance improvement of an organisation.Nordin et al. (2016) developed a framework to measure waste elimination factor of a manufacturing plant against five criteria such as process and equipment enhancement, production rules and discipline, workforce engagement, suppliers' integration, customer focus.

Wonglimpiyarat (2017) developeda systemic innovation model that provides a better understanding on the systemic characteristics, progress and pattern of technology development and diffusion. This research study provides useful applications of technologies to supportbanking industry,developed by FinTech. Table 6 gives and overview of the models and frameworks found in the literature.

Table 50: Models / Frameworks

Reference	Model/Framework	Applied Field of Study			Advantages/ Uses
		Industry 4.0	Lean	Banking	
(Wilkesmann and Wilkesmann, 2017)	Framework to analyse digitalized work in a firm	*			Analyse connection betweenreproducing and improving routines and enabling inventions and innovations of industry 4.0.
(Schumacher et al.,2016)	Model to assess the industry 4.0 maturity of enterprises	*			Assessing industry 4.0 maturity of an organisation based on nine dimensions.
(Karlsson and Ahlstrom, 1996)	Model to asses lean based performance of an organisation.		*		Assessinglean performance of a manufacturing firm using nine determinants.
(Shah and Ward, 2007)	Framework to measure relationships between lean production and firm performance		*		Assessing lean based performance of an organisation under ten dimensions.
(Nordin et al., 2016)	Conceptual framework to assess lean performance.		*		Measure waste elimination against five lean aspects of a manufacturing plant.
(Wonglimpiyarat, 2017)	Model to assess the success of industry 4.0 innovation and market diffusion.	*		*	Provides an understanding on systemic characteristics and progress pattern of technology development and diffusion

According to the literature, a positive relationship can be identified in between operational performance and implementation of advance technologies in a lean based environment of an

organisation. Thus authors developed following framework to summarised the key findings of the study.

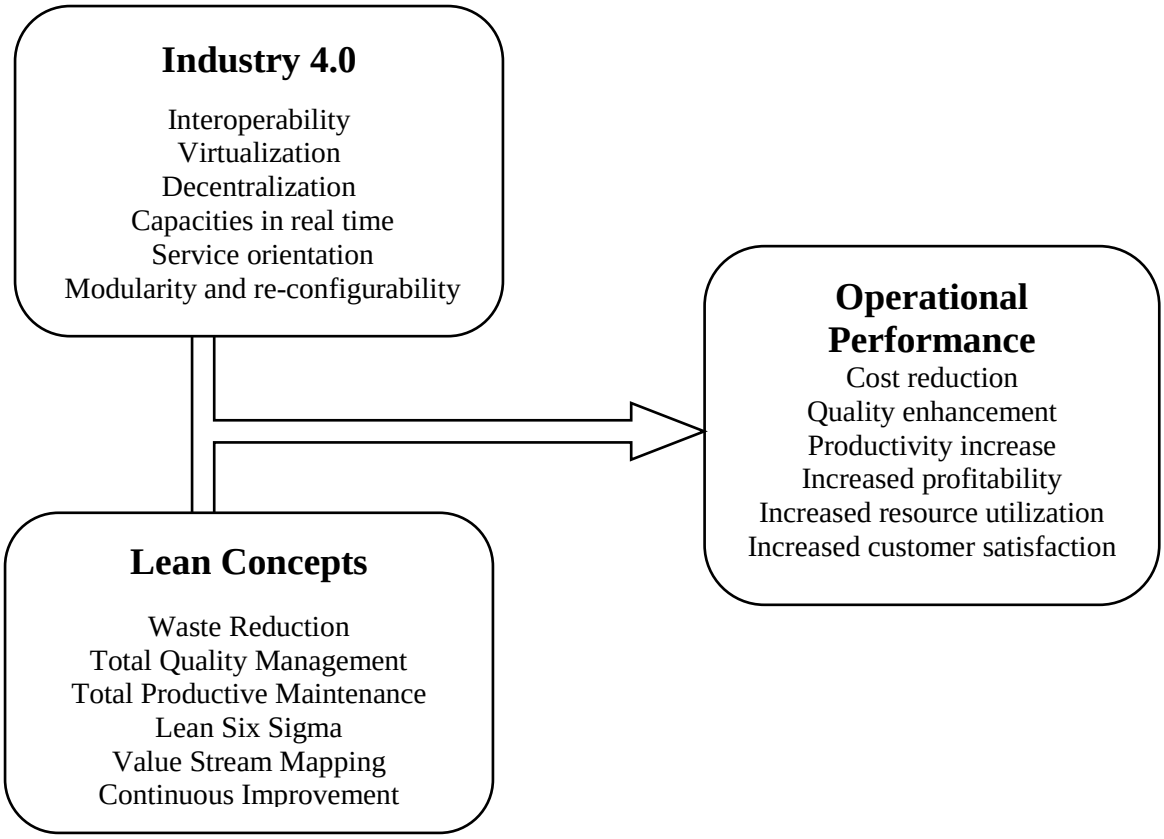

Figure 16: Conceptual Framework

Figure 2 presents the developed framework by integrating lean concepts with industry 4.0 principles in order to improve operational performance of an organisation in the aspects of cost reduction, quality enhancement, productivity increase, increased profitability, increased resource utilization and increased customer satisfaction. Industry 4.0 consists of six main principles such asInteroperability, Virtualization, Decentralization, Capacities in real time, Service orientation, Modularity and re-configurability. These principles were resulted through application of industry 4.0 technologies. There are several approaches to implement lean in an organisation thus a combination of these lean approaches with industry 4.0 technologies will result actual performance improvement in any organisation.

CONCLUSION

Lean is a beholding paradigm which has a potential to create more value for customers using less resources. Thus lean aims to minimize waste, along value streams to provide products/services with greater quality and variety at lower costs and shorter lead times while improving performance. According to literature there are several studies that assess lean based performance of organisations(Karlsson and Ahlstrom (1996),Shah and Ward (2007), Nordinet al. (2016)). Literature suggest several approaches to implement lean in an organisation such as Total Quality Management, Total Productive Maintenance, Lean Six Sigma, Value Stream Mapping, Continuous Improvement, JIT, wastes elimination and etc. (Santos and Cabrita (2016), Karlsson and Ahlstrom (1996), Shah and Ward (2007), Tortorella et al. (2016)).

For the past few decades, vast transformations of the technology hascreated massive changes in the way of industries performing their operations. Industry 4.0 is a concept whichenables the use of advance technologies namely: Internet of Things, Cyber-Physical Systems, big data analytics, cloud computing and cognitive computing to move towards a smart world. These concepts were previously limited to manufacturing sector, but now it evolves to service sector as well. According to the literature, industry 4.0 technologies have created massive development in financial sector as well. There are new concepts emerging in the financial sector such as Open Banking, Mobile Wallet, Cryptocurrencies, Biometric Technologies, Artificial Intelligence an etc. (Deloitte (2015), Cook (2017) KPMG Banking Systems Survey (2018), Ratings direct (2018), Hyman (Fintech Focus)).

Even though implementation of these concepts of industry 4.0, doesn't result actual performance improvement due to reasons like process inefficiencies, improper resource utilisation, lack of organisational change, wasteful processes, lack of knowledge and expertise and etc. Hence, lean management is a viable solution to address these inefficiencies. According to the literature it is evident that firms who have implemented industry 4.0 concepts within a lean based environment has been succeeded. Lean tools can be used to eliminate all kinds of waste in the processes by identifying unnecessary activities, streamlining the process, and creating standardised routines. Therefore, implementing industry 4.0 concepts to standardised and streamlined processes will reduce wastes and unnecessary investments. The concept of integrating lean and industry 4.0 technologies is still new to service sector thus very limited applications in the banking sector. Hence, this study focusses on identifying the gap of knowledge exists in the areas of integrating lean and industry 4.0 technologies in the banking sector. The developed conceptual framework described the relationship between lean and

industry 4.0 concepts with the operational performance of an organisation in different aspects. Though the implementation of the principles of industry 4.0 can be strengthen by incorporating lean tools to streamline the processes.

According to the literature there are few other factors that affect the implementation of industry 4.0 such as requirement of higher investment, IT infrastructure requirement, expertise knowledge and human resources, security concerns and etc. Human factor is considered as important in implementing lean as well.

Though there are only few studies which were conducted to analyse and evaluate industry 4.0 and lean based performance of an organisation and there are limited studies to apply these concepts to banking sector. So it is important to analyse and assess lean and industry 4.0 based performance improvement of the banking sector.

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