Effect of Supply Chain Digitalization on Lean Waste Reduction as Mediated by Lean Operations

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Abstract - The lean operation aims for a continuous cycle with a just-in-time supply of raw materials, efficient production completion, and on-time delivery to customers. However, the pandemic made sustaining lean more challenging with parts shortages. Digitalizing Supply Chain is an agile tool that can improve production and inventory control to achieve and sustain lean manufacturing. Applying digital trends can benefit real-time data, immediate resolution, and faster turnaround time. An innovative, shorter, and more accurate process cycle promotes a circular supply chain, reduces lean waste, and supports building sustainable cities and communities. This research conducted a study on the effect of supply chain digitalization on the reduction of manufacturing lean waste as mediated by lean operations. A survey of 60 respondents from experts in supply chain and lean operations was made within the manufacturing companies in Calabarzon. Cronbach alpha initially tested the validity of the constructs in the questionnaires of the pilot study. The application of supply chain technology recorded the frequency to assess the level of digital trends adopted. Five-point Likert scale was used to determine the level of lean operations. Lastly, Baron and Kenny with regression tested the effect of the adoption of digital trends on the reduction of eight lean wastes in manufacturing examining the mediation of the level of lean operations. The study revealed a significant effect of technological adoption mediated by lean operation in the reduction of the eight lean wastes.

Keywords: Digital Supply Chain, Lean Operation, Manufacturing Lean Wastes, Downtime, Supply Chain Management 4.0

I. INTRODUCTION

The global pandemic and series of natural disasters experienced by the world inflicted turmoil on many industries, including supply chains. Considering these, supply chain trends denote a need for more resilient management (Scott, 2021). It is practical if accurate information is visible to start with. With this, information on what is on hand will provide vital information and is crucial for production planning and inventory control. This will ensure producing what is only necessary at the right time.

The lean production principle commits to just-in-time (JIT) delivery. This equates to excess stocks and unnecessary use of resources, thus, reducing operational costs and environmental impact. Lean operation adheres to the elimination of waste and non-value-added processes. This promotes continuous improvement, better visual control, and autonomation or early detection. But implementation requires precision of order management and critical production control to reduce waste, redundancy of work, and accrual of errors (Hyder, 2021). Hence, the disruption of global manufacturing, the shift of policies, and logistics barriers create supply chain abnormalities and corporate instability. Furthermore, the world market for electronic components is now having a scarcity of supply affected highly by shipping problems caused by the lockdown (CNN, 2020). The argument for the small buffer stocks then posed the question of how one can become lean in this challenging time (Heston, 2020).

With the current condition, it is rational to seek innovation and process improvements in the supply chain to adjust to the new demands of lean manufacturing. Digitalization can provide supply chains with real-time data and automated processes. This gives significant records that are useful in management decisions. Automation can minimize manual processes, offering valuable time to respond to other operational problems (Bendis, 2020). The digitization of the supply chain will also lessen the excessive use of resources, reduce lean waste, and promote green practices. Reduction of the end-to-end process through these helpful technologies is vital to contribute towards a sustainable community. This research is working towards goal 9 of SDG build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation (United Nations, 2020). Also, this supports goal 11, sustainable cities and communities (United Nations, 2020). This study aims to determine the effect of supply chain digitalization in the reduction of lean waste mediated by lean operations in manufacturing companies.

The progress of digital technology is modernizing supply chain management. Seven trends in digital technology are transforming the supply chain world (Hadud & Khare, 2020). These are the Internet of Things (IoT), social media, Mobile Technology (RFID, GPS, and other wireless technology), Big Data, Cloud Computing, Predictive Analytics, and 3D Printing.

Lean aims for continuous flow from raw materials supply to production lines to finished goods delivery using Visual Management (VM) as its communication tool. VM also demonstrates quality requirements that are visible to all. The process promotes kaizen or continuous improvement and supports Total Productive Maintenance (TPM) and quality improvement through early detection with the aid of autonomation and Poka-Yoke. Lean operation reduces waste, fosters faster cycles, increases productivity, and improves quality.

The application of lean principles aims to reduce, if not eliminate, the eight wastes in manufacturing to improve productivity and quality. Toyota JIT has defined seven wastes of lean, but as this model was applied globally, the waste of "non-utilized talent" was added. Defect is a lean waste that adds on cost and also impacts customer trust. When leaked, it becomes a market claim and can tarnish the company's reputation. Overproduction is prone to excess and obsolete. This happens with low inventory accuracy. Waiting is time lost. Unable to supply parts or sub-assembly for continuous manufacturing is a loss in capacity. Non-utilized talents happen when a process takes a long time to perform an activity. Automation reduces cycle time and allows the utilization of people to perform other tasks that they can excel in. Transportation is unnecessary when we order the wrong raw material and when we must make special trips due to urgent deliveries caused by incorrect information. The inventory itself, when excess, needs additional warehousing space. Obsolete and expired materials are tangible wastes that will be subject to disposal. Motion is a waste when there are unnecessary movements. Extra processing occurs when we have to add processes to meet customer requirements. Ensuring that materials arrive just in time will reduce lean waste.

A. Conceptual Framework

The study Digitalizing Supply Chains' Impact on Waste in Lean Manufacturing (Hadud and Khare, 2020) provided insights into developing this study. The research assessed the impact of the supply chain digitalization trends on the level of lean manufacturing waste. The adoption of one or more technologies is the dependent variable of the study. The level of lean operations adoption is a mediating variable in this research, while the level of lean manufacturing wastes is a dependent variable. The data in this study was gathered through online surveys as the primary source. The questionnaires derived from the journal were secondary data. Figure 1 shows the research model of this study.

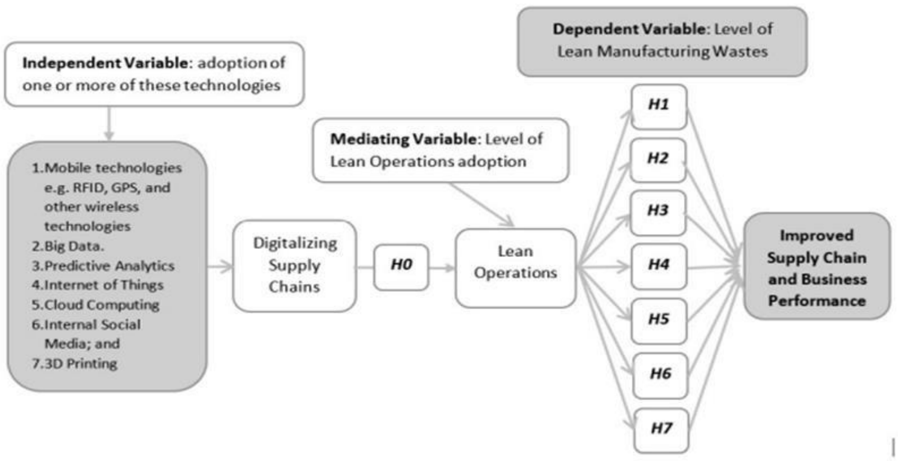


***Figure 1.* The Research Model**

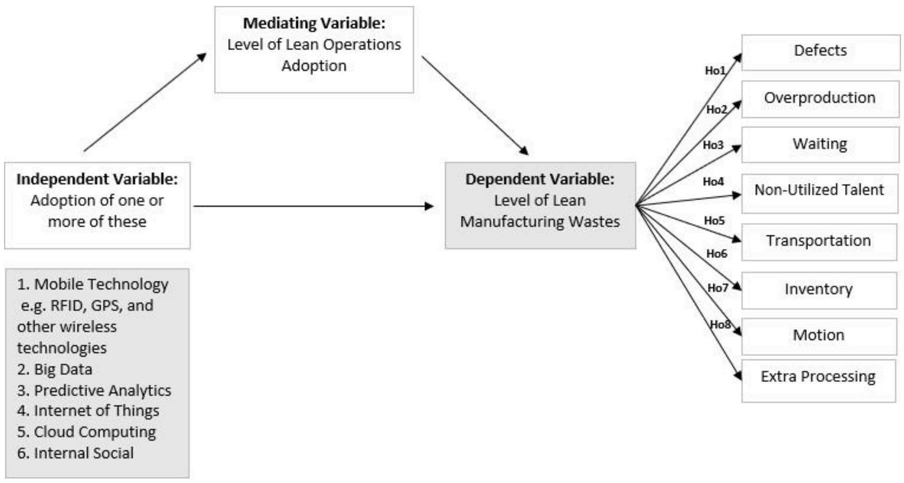
Source: Digitalizing Supply Chains Impact on Waste in Lean Manufacturing

The Hadud and Kare study tested 35 potential impacts on the seven lean wastes, which resulted in 32 out of 35 constructs supporting the acceptance of five out of seven examined hypotheses. The potential impacts of supply chain digitalization on lean wastes were significant on overproduction, waiting, inventory, motion, and defects. Hypotheses on the impacts of the two lean wastes on transportation and extra processing were partially accepted. Examined lean manufacturing wastes with impacts from possible adopted technologies were identified in the study.

B. Operational Framework

While the study of Hadud and Khare (2020), was conducted in the United States; this research, was performed in the Philippines, specifically, in the industrial manufacturing sectors in Calabarzon. The Hadud and Khare (2020) study's respondents were majority from the academic sector, while this study gathered data from firsthand industrial managers with experience in actual technology interface. This research evaluated the digitalization of the supply chain effect with the reduction of lean waste mediated by lean operations in manufacturing companies. The number of adopted technologies from the seven digital trends was used in this study as the independent variable. Lean operations use probable tools that can increase the level of lean and reduce lean waste. With this, lean operations stand as the mediating variable. The original seven lean wastes from Toyota were updated to eight lean wastes with the global acceptance of lean manufacturing (Cunningham, 2020). Thus, this study updated the lean wastes from seven to eight, which served as the dependent variable of the study. Figure 2 shows the operational framework of this study.

Figure 2. Operational Framework



C. Objectives

This research was conducted mainly to examine the effect of supply chain digitalization on the reduction of lean waste mediated by lean operations to achieve an improved sustainable supply chain and better business performance. Specifically, this study aims to:

1. To determine the effect of the supply chain digitalization mediated by lean operations on the reduction of lean manufacturing wastes on defects.

2. To test the effect of the supply chain digitalization mediated by lean operations on the reduction of lean manufacturing wastes on overproduction.
3. To observe the effect of the supply chain digitalization mediated by lean operations on the reduction of lean manufacturing wastes on waiting.
4. To analyze the effect of the supply chain digitalization mediated by lean operations on the reduction of lean manufacturing wastes on non-utilized talent.
5. To evaluate the effect of the supply chain digitalization mediated by lean operations on the reduction of lean manufacturing wastes on transportation.
6. To assess the effect of the supply chain digitalization mediated by lean operations on the reduction of lean manufacturing wastes on inventory.
7. To measure the effect of the supply chain digitalization mediated by lean operations on the reduction of lean manufacturing wastes on the motion.
8. To examine the effect of the supply chain digitalization mediated by lean operations on the reduction of lean manufacturing wastes on extra processing.

D. Hypotheses:

To address the need of the study, the following hypotheses will be tested:

Ho1: Adoption of Supply Chain digitalization has no significant effect on the reduction of defects as mediated by lean operations.

Ho2: Adoption of Supply Chain digitalization has no significant effect on the reduction of overproduction as mediated by lean operations.

Ho3: Adoption of Supply Chain digitalization has no significant effect on the reduction of waiting time as mediated by lean operations.

Ho4: Adoption of Supply Chain digitalization has no significant effect on the reduction of non-utilized talent as mediated by lean operations.

Ho5: Adoption of Supply Chain digitalization has no significant effect on the reduction of transportation as mediated by lean operations.

Ho6: Adoption of Supply Chain digitalization has no significant effect on the reduction of inventory as mediated by lean operations.

Ho7: Adoption of Supply Chain digitalization has no significant effect on the reduction of motion as mediated by lean operations.

Ho8: Adoption of Supply Chain digitalization has no significant effect on the reduction of extra processing as mediated by lean operations.

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II. METHODOLOGY

A. Research Design

The study used a quantitative research approach and observed the descriptive research design. The study considered digital technology adoption in the supply chain as the independent variable. The research observed the effect of the digital trends' adoption with the reduction of eight lean wastes as the dependent variable. While the level of lean operations served as the mediating variable studied through a causal analysis.

The sample size of this study was 60 respondents based on a GPower of 15% effect size, 5% error probability, 80% Actual Power, and 1 predictor gathered through non-random probability, purposive sampling. The respondents of this research included supply chain and operations professionals of managerial level per organization in Calabarzon region, top value output producer in the Philippines, with a 43.3% share and consisting of 1548 companies (Philippine Statistics Authority, 2020).

This paper was prepared in conformity with the research ethics norms and the codes and practices. The primary data collection of this paper was gathered through online and printed form surveys. The questionnaire was adopted from the study of Hadud and Kare (2020) entitled "Digitalizing Supply Chains' Impact on Waste in Lean Manufacturing". A pilot test examined the reliability of the survey questionnaires from 22 responses from non-Calabarzon manufacturing companies collected from February to March 2023. Cronbach alpha tested the validity and consistency of the survey constructs. A five-point Likert scale was used to gather the respondents' perceptions by gauging the influence of SCM digitizing on lean operations and the reduction of lean waste. The lowest scale of one does not influence at all, while the highest scale of five is noted as highly influential. IBM's Statistical Package for the Social Sciences (SPSS) version 24 was used to evaluate the retrieved data.

A total of 60 respondents answered the survey questionnaires from March to April 2023. There were four parts to the questionnaire. First is the descriptive analysis of the respondents' profiles. Second, the descriptive analysis for the identified adoption of supply chain digitalization trends. A check sheet was used to test the frequency of technological trends. Third is the descriptive analysis of the effect of these adopted technologies on the eight wastes of lean with the mediation of lean operations. The Baron and Kenny with regression were used to test the effects on the variables.

III. RESULTS AND DISCUSSION

Descriptive Statistics

Table 1 shows that out of 60 respondents, 15 respondents, or 25% are adopting three digital technologies in their respective companies. While, 14 respondents, or 24%, use four digital technologies in their supply chain. The average of three to four technology adopted is 48% combined or 29 of the total respondents.

Table 1. Number of Technology Adopted by Respondents

Adopted Technology	Respondents	Percent
1	5	8%
2	6	10%
3	15	25%
4	14	23%
5	10	17%
6	7	12%
7	3	5%
	60	100%

Identified in Table 2 are the top four trends that the respondents are adopting in their supply chains. These are the Internet of Things at 23.2%. Followed by Big Data at 17.2%, Mobile Technology at 15.3%, and Predictive Analytics at 13.7%.

Table 2. Adopted Technology Frequency

		Responses		
		N	**Percent**	**Rank**
Adoption of Digital Technology	Mobile Technology	38	16.3%	3
	Big Data	40	17.2%	2
	Predictive Analytics	32	13.7%	4
	Internet of Things	54	23.2%	1
	Cloud Computing	31	13.3%	5
	Social Media	24	10.3%	6
	3D Printing	14	6.0%	7
Total		233	100.0%	

Table 3 contains the analysis of the five-point Likert scale for the level of lean operation of the chosen respondents. The data revealed that all seven digital trends adoption entailed the highest level of lean operation with a ratio of 0.95. On the other hand, having only one technology adoption has the lowest rating, with a ratio of 0.66. The ratio of the level of lean operation increases as the number of implemented technologies also increases. The result indicates that the more technology applied, the higher support is available to increase the lean operation level.

Table 3. Level of Lean Operations

No of Technology Adopted	Respondents per level of Technological Adoption	Assumption of Full Adoption Lean Operation	Actual Respondent's Level of Lean Operations	Ratio
1	5	25	16.4	0.66
2	6	30	20.2	0.67
3	15	75	50	0.67
4	14	70	50.6	0.72
5	10	50	38.2	0.76
6	7	35	30	0.86
7	3	15	14.2	0.95

Table 4. Effect of digital adoption on reduction of Defects as mediated by lean operations

Model	R	R square	Factors	Unstandardized Beta	Std. Error	Standardized Beta	t-value	p-value	Interpretation
1	.505[a]	.255	(Constant)	2.833	.235		12.041	.000	Significant
			Adoption	.250	.056	.505	4.457	.000	Significant
			*** *F value = 19.864*		**** *p-value = .000[b]*				
2 - Lean Operations	.705[b]	.498	(Constant)	1.282	.354		3.619	.001	
			Adoption	.120	.053	.242	2.275	.027	Partial Mediation
			Level of Lean Op	.563	.107	.558	5.245	.000	Significant
			*** *F value = 28.224*		**** *p-value = .000[c]*				

Results show that the level of digitalization of supply chain adoption has a standard coefficient of .242 and p-value of .027 and implies partial mediation with Lean Operation on the reduction of defects. The adoption of digital technology reveals a significant effect on the reduction of lean waste of defects with β =.558, p < .000. This implies that the digital supply chain contributes to better quality control with the network view at every stage. Immediate identification of issues enables faster response. This can lead to early reject detection (Salesforce UK, 2021).

Table 5. Effect of digital adoption on Reduction of Overproduction as Mediated by lean operations

Model	R	R square	Factors	Unstandardized Beta	Std. Error	Standardized Beta	t-value	p-value	Interpretation
1	.505[a]	.255	(Constant)	2.833	.235		12.041	.000	Significant
			Adoption	.250	.056	.505	4.457	.000	Significant
			*** *F value = 19.864*		**** *p-value = .000*[b]				
2 - Lean Operations	.682[b]	.465	(Constant)	1.284	.401		3.206	.002	
			Adoption	.149	.060	.275	2.500	.015	Partial Mediation
			Level of Lean Op	.561	.121	.508	4.619	.000	Significant
			*** *F value = 24.721*		**** *p-value = .000*[c]				

Data indicates that the adoption of digital SCM has partial mediation with lean operations with β =.275, $p < .000$. Also, the application of the technologies has a significant effect on the reduction of overproduction with β =.275, $p < .015$. Visualizing the status of these units helps drive the depletion of hold units that are waiting for disposition. Thus, in the study of Belatis et al. (2021), it was determined that connectivity and digital traceability can promote productivity and understanding of the manufacturing lead times and bottlenecks.

Table 6. Effect of digital adoption on reduction of Waiting as mediated by lean operations

Model	R	R square	Factors	Unstandardized Beta	Std. Error	Standardized Beta	t-value	p-value	Interpretation
1	.463[a]	.215	(Constant)	3.120	.253		12.315	.000	Significant
			Adoption	.240	.060	.463	3.981	.000	Significant
			*** *F value = 19.864*		**** *p-value = .000*[b]				
2 - Lean Operations	.728[b]	.530	(Constant)	1.266	.359		3.523	.001	
			Adoption	.085	.053	.163	1.588	.118	Full Mediation
			Level of Lean Op	.673	.109	.636	6.180	.000	Significant

*** *F value = 32.104* **** *p-value = .000*[c]

Data generated indicates that the adoption of digital SCM has a full mediation with lean operations with β =.163, p < .118 and that the digital adoption has a significant effect on the reduction of waiting time with β =.636, p < .000. The automation process reduces the takt time of supply chain activity (Hand, 2022). The reduced end-to-end process contributes to a circular and green supply chain (Banker, 2021). In addition, ensuring the availability of materials demonstrates the elimination of downtime and unproductive period. Availability is part of the six big losses that affect the overall equipment effectiveness or OEE (Lean Production, 2023).

Table 7. Effect of digital adoption on Reduction of Non-Utilized Talent as Mediated by lean operations

Model	R	R square	Factors	Unstandardized Beta	Std. Error	Standardized Beta	t-value	p-value	Interpretation
1	.525[a]	.276	(Constant)	2.838	.252		11.268	.000	Significant
			Adoption	.282	.060	.525	4.702	.000	Significant
			*** *F value = 22.104*		**** *p-value = .000*[b]				
2 - Lean Operations	.664[b]	.441	(Constant)	1.448	.406		3.570	.001	
			Adoption	.166	.060	.308	2.746	.008	Partial Mediation
			Level of Lean Op	.504	.123	.461	4.103	.000	Significant
			*** *F value = 22.486*		**** *p-value = .000*[c]				

The table shows that the digital SCM application has a partial mediation with lean operations with a beta coefficient of .2746, a *p-value of* .008, and that this technological trend implementation has a significant effect on the reduction of non-utilized talent with β =.461, p < .000. The automation methods reduce the end-to-end processing time. With this, employees have available time to attend not just to regular operational issues but also to strategic matters. These maximize the talent of people and develop high performance in improving daily operational activities (Fearn, 2021). Available time derived through computerization, autonomation, and "poka-yoke" enables people's development with strategic and critical thinking, rather than focusing only on daily operational activities.

Table 8. Effect of digital on reduction of Transportation as mediated by lean operations

Model	R	R square	Factors	Unstandardized Beta	Std. Error	Standardized Beta	t-value	p-value	Interpretation
1	.469[a]	.220	(Constant)	3.086	.241		12.809	.000	Significant
			Adoption	.232	.057	.469	4.042	.000	Significant
			*** *F value = 16.338*		**** *p-value = .000[b]*				
2 - Lean Operations	.741[b]	.548	(Constant)	1.279	.336		3.808	.000	
			Adoption	.080	.050	.163	1.612	.113	Full Mediation
			Level of Lean Op	.656	.102	.650	6.440	.000	Significant
			*** *F value = 34.607*		**** *p-value = .000[c]*				

The data can be interpreted that the adoption of digital SCM has a full mediation with lean operations with a betta coefficient of.163 and with a *p-value of* .113, and the implementation of technological trends has a significant effect on the reduction of waste in transportation (β =.650, $p < .000$). Network visibility improves delivery management. This supports the generation of correct transport schedules, which can improve traffic and logistics activities (Tech Insight, 2020). For raw materials, generating the correct purchase order reduces air shipment, especially if the original mode of shipment is by sea. Purchase errors can lead to emergency orders and be considered additional shipments. Realized production plan without material shortages, will ensure just-in-time delivery to customers.

Table 9. Effect of digital adoption on reduction of Inventory as mediated by lean operations

Model	R	R square	Factors	Unstandardized Beta	Std. Error	Standardized Beta	t-value	p-value	Interpretation
1	.429[a]	.184	(Constant)	3.156	.257		12.278	.000	Significant
			Adoption	.222	.061	.429	3.617	.001	Significant
			*** *F value = 13.084*		**** *p-value = .000[b]*				
2 - Lean Operations	.405[a]	.164	(Constant)	1.312	.369		3.552	.001	
			Adoption	.067	.055	.129	1.218	.228	Full Mediation

			Level of Lean Op	.669	.112	.636	5.980	.000	Significant
			*** *F value = 28.343*		**** *p-value = .000*[c]				

The result indicates that the adoption of digital SCM has full mediation with lean operations with a beta coefficient equal to .129 and a *p-value data of* .228. Moreover, digital innovation adoption has a significant effect on the reduction of inventory (β =.636, p < .000). Accuracy and real-time data of count can generate correct orders and promotes the small buffer and small lead time buy, thus reducing stocks and improving cash flow (Global Supply Chain Institute, 2020). Accurate stock-taking improves the order management system to ensure correct purchases and eliminate excess and obsolete parts. Moreover, long-time stocking can lead to the expiration of materials and deterioration of units, which leads to scrappage and unwanted physical wastes for disposal. Expired chemicals, oils, and grease can add harm to the environment. In the study of Negi and Khare (2021), quality problems are attributes of the increase in inventory.

Table 10. Effect of digital adoption on reduction of Motion as mediated by lean operations

Model	R	R square	Factors	Unstandardized Beta	Std. Error	Standardized Beta	t-value	p-value	Interpretation
1	.687[b]	.472	(Constant)	3.048	.276		11.037	.000	Significant
			Adoption	.222	.066	.405	3.372	.001	Significant
			*** *F value = 11.372*		**** *p-value = .000*[b]				
2 - Lean Operations	.706[b]	.499	(Constant)	1.110	.402		2.760	.008	
			Adoption	.059	.060	.108	.993	.325	Full Mediation
			Level of Lean Op	.703	.122	.630	5.771	.000	Significant
			*** *F value = 25.504*		**** *p-value = .000*[c]				

The results gathered showed the adoption of digital SCM has full mediation with lean operations (β =.108, p < .325) and adoption of digital technology has a significant effect on the reduction of motion (β =.630, p < .000). The elimination of the manual process reduces movement in the process which shortens cycle closure (Singh, 2023). Mobile technology, such as RFID, scans units from a distance, while the Internet of Things can allow the availability of data that we use anywhere, anytime, thus, reducing extra travel. The shortening of cycle time promotes productivity to increase output conversion. In the study of Taifa and Vhora (2021), it was shown that manufacturing companies need to develop production flexibility to shorten the lead time to deliver to customers. Digitalization can offer shorter cycles than can be a value add to reducing motion and tact time.

Table 11. Effect of digital adoption on reduction of Extra Processing as mediated by lean operations

Model	R	R square	Factors	Unstandardized Beta	Std. Error	Standardized Beta	t-value	p-value	Interpretation
1	.424ᵃ	.179	(Constant)	3.086	.232		13.304	.000	Significant
			Adoption	.197	.055	.424	3.561	.001	Significant
			*** *F value = 12.682*		**** *p-value = .000ᵇ*				
2 - Lean Operations	.712ᵇ	.507	(Constant)	1.392	.329		4.224	.000	
			Adoption	.055	.049	.118	1.118	.268	Full Mediation
			Level of Lean Op	.615	.100	.649	6.157	.000	Significant
			*** *F value = 29.334*		**** *p-value = .000ᶜ*				

The table proves that the adoption of digital SCM has full mediation with lean operations (β =.118, $p < .268$) and that the adoption of digital technology has a significant effect on the reduction of extra processing (β =.649, $p < .000$). Creating correct purchases reduces excess stocking, handling, and obsolete parts that can trigger the requirement for rework additional handling and treatment (McCue, 2020). Likewise, wrong production planning brought by inventory mistakes can lead to a longer turnover of units. Prolonged storage and additional handling can cause defects that will later need restoration to good units or even disposal. The study of Forero and Sisodia (2020), discussed Total Quality Management with visual control will help preserve quality.

IV. CONCLUSION

This study aims to identify the effect of supply chain digitalization with the reduction of eight lean manufacturing wastes as mediated with lean operations. The level of digital technology adoption is the independent variable (IV), which tested the mediation of the level of lean operation. There were five constructs, tested per potential effect, totaling forty examined effects on the reduction of manufacturing lean wastes, which is the direct variable (DV). These determined the acceptance of full mediation between supply chain digitalization and lean operation on hypotheses of reduction of lean wastes on waiting time, transportation, inventory, motion, and extra processing. These pass all tests and IV is not significant upon entry of the mediator, therefore, H_O3 (Waiting), H_O5 (transportation), H_O6 (Inventory), H_O7 (Motion), and H_O8 (Extra processing) hypotheses were rejected. On the other hand, hypotheses on the mediation of digital trend adoption with the lean operation have acceptance of partial mediation with the reduction of lean manufacturing waste on the defect, overproduction, and non-utilized talent. These also pass all tests and IV is still significant upon entry of mediation, therefore, H_O1 (Defect), H_O2 (Over Production), and H_O4 (Non-Utilized Talent) hypotheses were partially rejected.

V. RECOMMENDATION

The output of the study recommends the digitalization of the Supply Chain through the adoption of the digital trends available in the market. Based on the gathered data, a company with an average of three to four digital adoption shows a significant effect on lean operation, thus, reducing lean waste. The Internet of Things, Big Data, and Mobile Technology were derived as the most applied trend in manufacturing industries to support lean operations. These are proposed start-up technology for emerging companies to invest in. However, the study also shows that the more technology is adopted, the level of lean operation increases. Moreover, data shows that if the enterprise has a high occurrence of defects, overproduction, and non-utilized talent; it is recommended to increase the level of digital adoption to more than the average and maximize adoption of all seven technology. Furthermore, for companies that have already adopted these technologies, it is recommended to gear towards SCM 4.0 and interconnect with Industry 4.0. Integration optimization of these technologies will develop the realization of SCM 4.0 and create value-add for smart manufacturing. Networking of adopted digital trends and investment in specialized training creates a readiness to innovate in cyberspace. Careful planning and execution are vital (Hadavi, 2021). Industry 4.0 and SCM 4.0 synchronization to potentially leverage the organization for a more resilient supply chain is being recommended for further study.

A. Limitations

This study presented seven digital trends available in the market for supply chain digitalization. However, technology emerges continuously, and each company's lean operations may differ from the respondent's application and level. This study can serve as an insight, into the effect of applied technology to lean operations and lean wastes. Future study is also being recommended to further define each technology effect and its impact per lean waste, as this will entail a longer time to complete.

B. CAPSTONE

Title: Optimization of Digital Supply Chain Management of Company A for SCM 4.0 Application

Company A is an Electronics Manufacturing Services (EMS) multi-plant that produces Printed Circuit Board Assembly (PCBA) and Box Build Assembly (BBA). As part of the global supply chain, the organization is committed to continuous improvement. Currently, Company A is adopting mobile technology, big data, cloud computing, the Internet of Things, and 3D printing. Integration of these digital technologies is being proposed to optimize value and gear towards SCM 4.0. With this SCM 4.0 ready, networking it with Industry 4.0 will enable operational management flow better. This is key to sustaining market lead and contributing to economic growth.

This project aims to improve the Supply Chain Process of Company A through technology upgrades and the interconnection of stand-alone innovations adopted in each section. The goal is to optimize the benefits of available technology to further elevate business conditions.

The project proposes a five-step program to innovate mobile technology and interlink it with the existing technology and system. First, will be the application of RFID to the warehouse and linking it with the Warehouse Management System (WMS). The second will be on planning improvement with Work Order Implementation connection with the Operational Management (OM) System. This will require the interconnection of the existing Enterprise Resource Planning (ERP) with the Smart Factory and further linked with the Card Assembly Traceability System (CATS). The Big Data from all these systems will use Cloud Computing as servers and interlinked via the Internet of Things. The third step will be the improvement of WIP inventory, turn-around, and depletion through RFID application. This will be integrated with the step two Work Order as a production carrier. The fourth step will be the material allocation using the generated inventory in Material Resource Planning. The final step will be the Work Order linking also with Master Production Scheduling to ensure the completion of customer PO. Having all the processes interconnected and developed to step up to Predictive Analytics use will complete the SCM 4.0 adoption.

Evidence of success will be through Gantt chart monitoring of plan versus actual activity referred to in Appendix B. Review of process flow and loopholes for improvement will gauge target output versus actual output. Also, conducts of regular audits will ensure the implementation of desired targets. The project implementation effect on business process improvements will be measured through KPI achievement referred to in Appendix C.

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