UNIVERSITY OF VAASA
SCHOOL OF TECHNOLOGY AND INNOVATIONS
INDUSTRIAL SYSTEMS ANALYTICS

Yadav Suryakant

DIGITALIZATION OF SUPPLIER COLLABORATION IN SCM

Thesis Writing in
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LIST OF ABBREVIATIONS

EPC – Engineering, procurement, and commissioning

KPI – key performance indicator

SC – Supplier Collaboration

SCM – Supply Chain Management

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UNIVERSITY OF VAASA
School of Technology and Innovations

Author:	Suryakant Yadav
Topic of the Master's Thesis:	Digitalization of supplier collaboration in SCM
Supervisor:	Petri Helo
Degree:	Master of Science in Technology
Major subject:	Industrial Systems Analytics
Year of Entering the University:	2017
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ABSTRACT:
The supply chain is a complex system where supplier collaboration is not fully or partially integrated and optimized that makes it difficult to properly manage it. Taking in consideration previous research on this topic and insights from data collected from 16 suppliers, the analysis of results suggest that the digitalization of supplier collaboration process is a means to achieve such integration and optimization to enhance transparency, visibility and communication throughout the supply chain network. Hence, a company requires a roadmap for businesses to initiate a digitization-based collaboration with their suppliers, critical success factors to assess the digitization progress and KPIs to measure the performance of the digitization for successful digitized supplier collaboration.

A case study in conjunction with the survey is used as the research methodology for this thesis. Additionally, 2 simulation models: three-point estimation and Monte Carlo simulation have been presented to measure the reliability of delivery time, resources and workforce needed for a company respectively. This thesis is concluded with suggestions for the company along with possibilities for future research.

KEYWORDS
Digitization, Supplier collaboration, Digitization roadmap, Digitization success factor, Key performance indicator, three-point estimation model, Monte Carlo simulation model.

1. INTRODUCTION

Supply chain management is considered as an integral part of most businesses and is vital to company success and customer satisfaction. It delights customers by delivering correct product assortment and quantity, providing the product at the right location and time, and supporting after sales services. Similarly, it reduces operating costs by decreasing the total supply chain cost through an efficient supply chain network. In addition to that, it helps to improve financial position by increasing profit leverage through proper control and reduce of supply chain costs, diminishing fixed assists, and increasing overall cash flow (CSCMP, 2018).

Supply chain management (SCM) is an interdisciplinary area which comprises different functions within and between organizations such as purchasing, logistics, Information technology etc (Fayezi et al., 2015) and deals with planning, implementing and controlling the operations of the supply chain. SCM covers all movements and storage of raw materials, work-in-process inventory, and finished goods from the point-of-origin to the point-of-consumption. Previous studies have focused mainly on an element of the supply chain rather than treating them as a complete system (Jula & Leachman, 2011). This makes SCM complex and challenging task for managers to implement it successfully as functional silos increases.

Successful supply chain implementation calls for effective supply chain communication and trust between manufacturer and supplier. However, it has been noticed in many cases that the relationship is confrontational, where

purchaser holds the upper hand that hinders commitment and trust from all parties involved resulting in poor supply chain performance and ineffective supply chain management. Similarly, research in this field shows that most of the supply chain networks are not integrated with any information technology systems within and between suppliers in fundamental areas such as forecasting and demand management. In addition to that, they lack consistency in a core process such as sales and operations planning and reverse logistics and rely too much on siloed and functional metrics which limit the ability to see the big picture of the supply chain. Thus, one can conclude that the information flow and communication are not continuous which obstruct visibility and transparency in the supply chain. Above all, supply chain network is considered to be an enormously complex system where sales and operations planning workflows are done by hand which are not aligned with how subcontractors and suppliers work (Plex, 2016). Therefore, it can be argued that both manufacturers and suppliers need a greater level of integration to properly manage a supply chain network. Hence, integrating, and optimising supply chain network can enhance collaboration among manufacturers and suppliers to drop down the cost of quality and reduce time - to – market, increase the performance of supply chain, and gain a competitive advantage in the market (Gattorna, 2009; Cole, 2014; Plex, 2016).

One way to achieve such an integrated and optimized supply chain network that reinforce transparency and visibility to gain a competitive advantage in the marketplace is through adopting digitization in the supply chain (Berttram, P. & Schrauf, S., 2016). Traditionally, the supply chain in any organization is a series of largely discrete and siloed steps taken through marketing, product development, manufacturing, distribution, and customers. An initiation of

digitization, on the other hand, helps to create an integrated supply chain by shrinking down that wall, which is transparent to all the members involved – from suppliers of all kind, manufacturers, to the transporter and distributors, and finally customers (Berttram, P. & Schrauf, S., 2016).

However, research shows that 95% of companies haven't seen any benefit from digitization considering they are still suffering from a lack of proper implementation of digitization in the organisation. Patrick in his article also suggests that companies still don't *have the necessary resources and workforce to implement it efficiently and effectively* (Patrick, 2018). Furthermore, interview conducted by PwC's Strategy& in 2018 states that only 10% of the world's companies have truly engaged in digitization and achieved a competitive advantage in the market thoroughly. This also suggests that there is a great impact of digitizing supply chain in an organization (Geissbauer et al, 2018) and so much can be accomplished by implementing it.

1.1. Purpose of the study

Most of the organizations today operating in a digital age and would like to investigate whether the alignment of supplier collaboration (SC) through the adoption of digital technology and digitized or native data in the supply chain will add value to the organization. Therefore, this study is conducted with the purpose to digitalize a company's supplier collaboration in the supply chain that will ensure the optimal operations throughout the supply chain and thus enhance a company's pre-determined chosen capabilities.

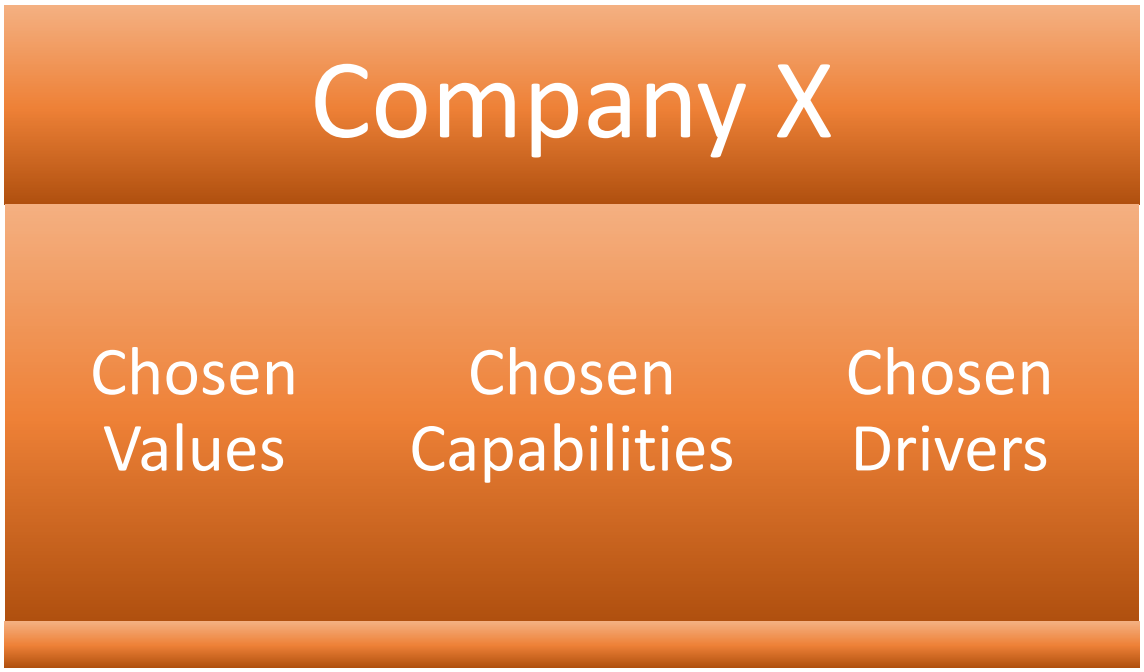


Figure 1. *company X's capabilities (Adopted from Material provided by Company X)*

1.2. The scope and delimitation of the research

The thesis will examine whether embracing digitalization in supplier collaboration increases the effectiveness of a company's SCM. On the grounds that supply chain includes suppliers from point of origin to the distributor, and finally the end consumer as shown in the figure below, the thesis, investigates only suppliers, in this case, engineering partners, outsourced manufacturing and project partners involved with company X and leaves out all other processes and networks involved in supply chain as shown in the diagram below which is one of the delimitation of this thesis. Similarly, this thesis will further outline a roadmap that a company can adopt to digitize supplier collaboration activities. In addition to that, the thesis will also highlight critical success factors to assess the digitization progress and KPIs to measure the performance of the digitization

for successful digitized supplier collaboration. The author will forecast the necessary resources and workforce needed to implement the digitization of supplier collaboration efficiently and effectively in a company. This thesis will also develop a tool for the supplier as outlined in the figure below to increase the reliability of a company's delivery time estimation. Furthermore, the research will focus on creating a framework for suppliers and company X on how to collaborate through a digital platform.

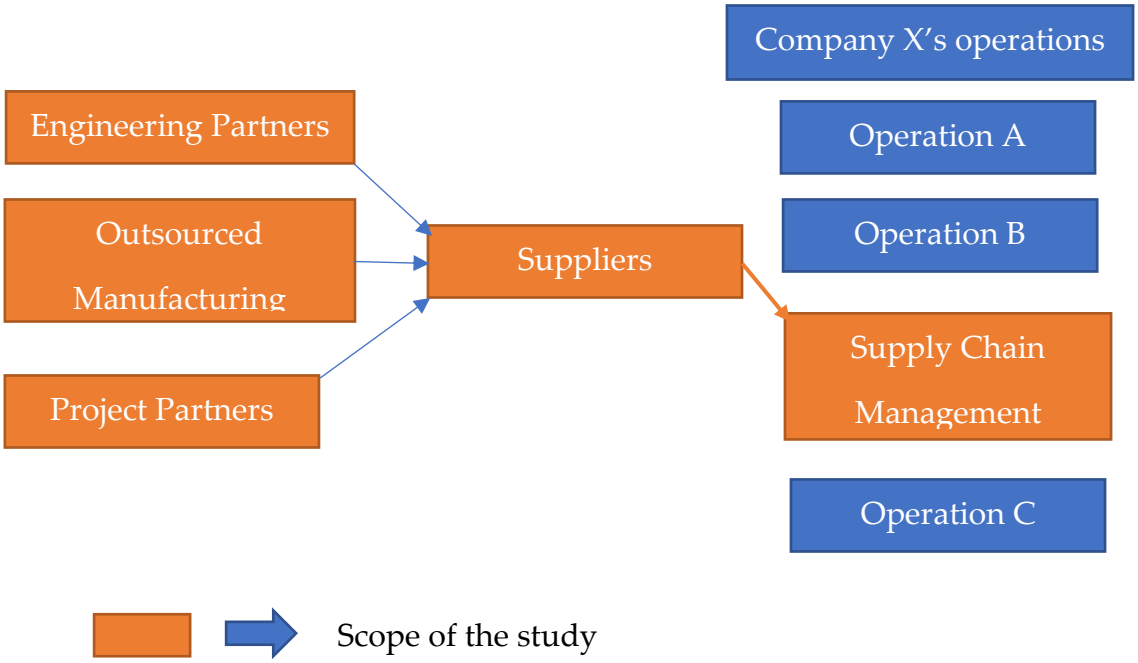


Figure 2. *Scope of the thesis*

1.3. Research questions

In the light of above-mentioned purpose and scope of the research, the following questions will be addressed throughout the research.

1. How does the adoption of digitization in supplier collaboration enhance the effectiveness of supply chain management?
    a) What are the deciding factors which predict improved performance through digitization of supplier collaboration?
    b) What are the most beneficial SCM KPIs when taking also into account the digitization of supplier collaboration?
    c) How can the reliability of a company's delivery time be measured through the use of KPIs?

2. How do a company measure necessary resources (time & cost) and workforce required to implement digitization successfully?
3. How can the implementation of the digitization in supplier collaboration be realized in the supply chain?

1.4. Research method

The nature of this research is exploratory that combines two research approaches: qualitative and analytical research methods.

1.4.1. Qualitative research approach

The primary focus of qualitative research is to provide a complete, detailed description of the research topic. This method is utilized to study an overall view of the subject. In qualitative research, the researcher acts as a primary data gathering instrument. The writer can employ various data-gathering strategies

depending upon the research approach and thrust adopted by the researcher (Explorable.com, 2009).

The research strategy adopted here is a case study considering the research questions and aim of the research. A case study is an in-depth study of a particular situation while investigating empirical events (Schell, 1992; Explorable.com, 2009). According to Schell (1992), a case study is an empirical inquiry which:

I. *investigates a contemporary phenomenon within its real-life context: when*
II. *the boundaries between phenomenon and context are not clearly evident; and in which*
III. *multiple sources of evidence are used (*Schell, 1992*).*

The benefits of using case study are not only to have access to historian's primary and secondary documentation as resources but can add direct observations and systematic interviewing: the case study's strength is thus its ability to cover a wide range of evidence – documentation, artifacts, interviews, and observations *(*Schell, 1992; Salo, 2006*).*

1.4.2. Analytical research approach

The analytical approach is a method of finding an appropriate process to breakdown a problem into the smaller pieces to solve it. This further requires *structuring* one's analysis in a way that separates the constituent elements of a problem (Jones, 1995; Thwink.org, 2018).

Considering the questions outlined above for the research and scope of the research, the author has chosen the Monte Carlo Simulation and 3-Point-Estimation as an appropriate process to answer the questions.

Monte Carlo Simulation is a computerized mathematical technique used by professionals to assess risks by providing with a range of possible outcomes and the probabilities they will occur for any choice of action to decision-makers (PALISADE, 2018).

Three-Point estimation is a mathematical process of identifying the best estimate point, also referred to as average. For any given variable, three different values are assigned such as optimistic, most likely, and pessimistic. Three-Point estimation can be calculated in three steps: first, identify positive and negative risks involved in a project; second, assign each risk three different estimates - optimistic, most likely, and pessimistic; third, use mathematical equations to calculate weighted mean and standard deviation as shown below (PMBOK, 2013; Singh, 2015).

(O + 4 ML + P) ÷ 6= the weighted mean ***Equation 1***

P-O/6 = the standard deviation ***Equation 2***

1.5. Structure of the thesis

The first part of the thesis, introduction, reveals the background of the thesis. It outlines the scope and delimitations of the research. It further directs attention to

research questions that shall guide the thesis and method adopted to answer research questions.

The second section discusses the literature on supplier collaboration in the supply chain. It brings the work of different scholars at a place to emphasize the importance of collaboration, elements of collaboration, and what is the current state of collaboration in a supply chain.

Section three connects literature presents on the digitization of supplier collaboration with the emphasis on how traditional form of collaboration is shifting towards digitized form. It further demonstrates the impact of digitizing supplier collaboration in the supply chain and how it brings value to all involved parties. In addition to that, it also presents author original work, a road map that a company can adopt to achieve this goal including the principle of digitization.

Section four outlines the importance of having a measurement system to ensure the effectiveness of a process. It goes deeper into details of how to develop KPIs based on the SCM framework and how not to dwell on measures that are not of the prime importance.

Section five demonstrated the survey conducted among suppliers to demystify the impact of digitization in supplier collaboration; check the awareness of the concept itself; know the importance of having mutually agreed KPIs and commitment in a business relationship, and understand the need for standardization and common foundations for digitization. Furthermore, it outlines two simulation models developed during the thesis writing that measures the reliability of delivery time for company's procurement and

required resources (time & money) and workforce needed to complete a successful digitized supplier collaboration project respectively.

Section six summarizes the whole thesis and propose a set of plans that can be deployed to enhance the effectiveness of the digitized supplier collaboration.

The last section, appendices include all the documents that were used to complete the thesis as well as framework and tool for the digitization that a company can use to make the digitization process better.

Figure 3. *Structure of the thesis*

2. SUPPLIER COLLABORATION IN SUPPLY CHAIN

Collaboration is an immense concept and when it is implanted into the supply chain it needs further elaboration to grasp the actual meaning behind it. Barratt (2004) posits that supplier collaboration is a mutuality of benefits, rewards and risk sharing together with the exchange of information as the foundation. He further adds that in order to achieve success in such collaboration one needs to understand why one is collaborating, with whom and wherein the supply chain one can collaborate, and over what activities (Barratt, 2004).

Similarly, supplier collaboration can also be defined as the process of decision making among different parties involved in the collaboration. It involves joint ownership of decisions and collective responsibility for outcomes (Daugherty & Stank, 2001). Schrage (1990) defines it as "*an effective, volitional, mutually shared process where two or more departments work together, have mutual understanding, have a common vision, share resources, and achieve collective goals*." Key elements in SC are; a cross-department (or organization) scope, a commitment to working together, and some common bond or goal (Daugherty & Stank, 2001).

Additionally, Simatupang and Sriradhan (2002) outline "*supply chain collaboration as two or more independent firm working together to align their supply chain processes in order to create value to the end customers and stakeholders with better growth and success than working individually*." (Simatupang & Sriradhan, 2002).

2.1. Importance of collaboration

When supplier and customer operate together as a single enterprise, they share scarce resources and relish benefits produce by that. Mathew & Mee (2008) posit that collaboration ***enhances performance*** significantly through increased profitability, operational efficiency, and joint decision making. As supplier and customer collaborate for a long-term, their commitment and improved relationship help one another to reduce the costs of development, manufacturing, delivery and marketing, and thus, increase the overall profit. In similar manner, working together and looking for joint sensemaking remove bottlenecks from the processes and create efficient processes.

Similarly, Slone et al. (2010) claim that collaboration boosts ***innovation*** through the availability of information and scarce knowledge which when combined together build stronger and deeper capabilities (Ferrer et al., 2008) and thus generate not only more insights for product/service innovation but also help to achieve them (Ferrer et al., 2008; Slone et al., 2010).

Cao et al. (2010) concluded that collaboration results in competitive advantage as the performance of involved parties over time improves. Further elaborated, it also produces innovations that place an organization on the top in customers eyes due to the introduction of a new product/service and improved quality of product and/or service.

Furthermore, it can be concluded that it helps an organization, and/or all members involved in collaboration grow rapidly in the existing market due to increase in customer satisfaction through improved quality of product and

service. Moreover, in times companies create a completely new market by launching disruptive product/service (Ferrer et al., 2008; Mathew & Mee, 2008; Slone et al., 2010).

2.2. Elements of collaboration

Scholars have suggested different elements of collaboration in and around supply chain management, however, Barratt (2004) has proposed a comprehensive framework which covers elements of the supply chain on a broader level as shown in the diagram below.

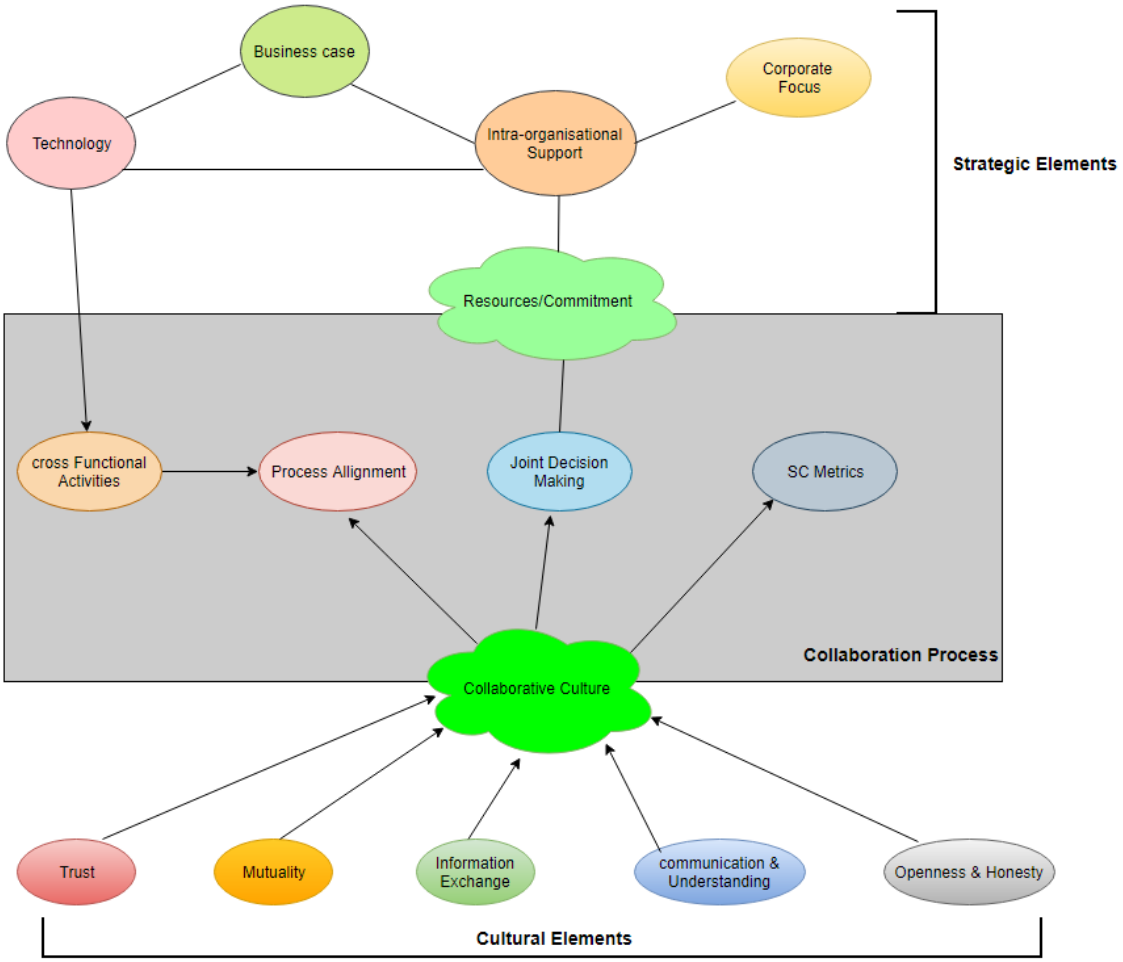


Figure 4. *Elements of Collaboration*

2.3. The current state of Supplier collaboration in supply chain management

The current supply chain is comprised of many tiers and thus supplier collaboration in supply chain involves the same characteristics and complexity (Barratt, 2004) as depicted in the picture below. Therefore, when the number of tires increased in the supply chain, the complexity in collaboration also increases. Furthermore, most organizations use email and/or EDI as the main technology

for communication and information exchange (Yen & Ng, 2003; Wei-His et al., 2014; Puhtila, 2018). Such technologies further make collaboration onerous due to lack of visibility and traceability through such technologies. This introduces barriers in many forms such as inadequate information exchange and/or loss of information, hard to align the process for all tiers, and having common supply chain metrics etcetera.

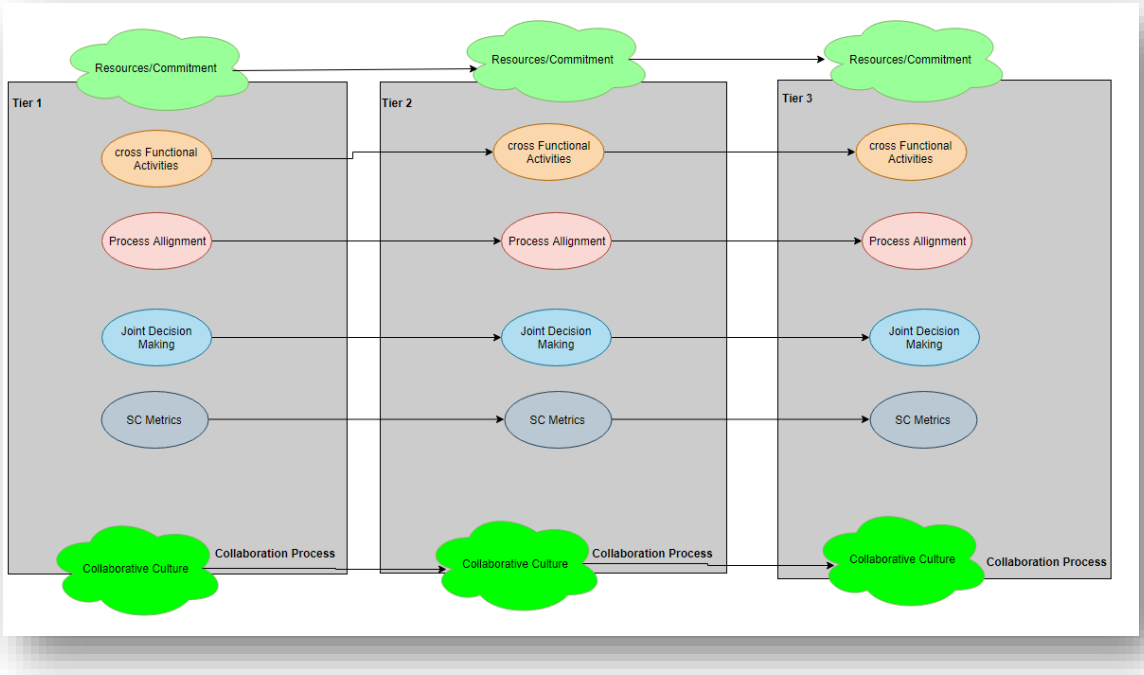


Figure 5. *Supply chain collaboration process (adopted from Barratt, 2004)*

As many writers have sought that digitalization is the solution for such onerous and complex process (Yen & Ng, 2003; Wei-His et al., 2014; Berttram & Schrauf, 2016; Bienhaus & Haddud, 2018; Geissbauer et al., 2018; Puhtila, 2018). Digitalization will provide complete visibility and transparency regardless of the number of tires involved in a supply chain and thus enhance the effectiveness of supply chain management.

3. DIGITALIZING SUPPLIER COLLABORATION IN SUPPLY CHAIN

Digitalization is a concept of industry 4.0 vision. The aim of the digitalization is to create a connected, smart, and highly efficient supply chain ecosystem. Thus, it can be concluded that digitalization of supplier collaboration means creating an ecosystem where all elements of collaboration (as described in the previous section) are connected in a seamless manner to achieve desired results and/or goals. Hence, the aim will be to have full visibility into the collaboration network where the needs and challenges of all members are easily seen and addressed. Furthermore, the digitalization of supplier collaboration will increase transparency of the collaborative network which will enable companies to overcome supplier collaboration barriers, react quickly to disruptions and foresee them, model the network, create future scenarios, and adjust suppliers' operation quickly as situations change (Berttram & Schrauf, 2016; Geissbauer et al., 2018).

Similarly, the goal of the digitalized supplier collaboration must be aligned with the vision of industry 4.0 – which could be creating a new kind of supplier collaborated network that is both resilient and responsive. However, if organizations dream of making such a collaborative ecosystem, developing technologies, building capabilities, finding the right people with matching skills, and managing the cultural change inside an organization are crucial. In other words, this is the vision which requires a complete transformation in an organization (Berttram & Schrauf, 2016).

3.1. The transition from traditional to the digitized supplier collaboration process

As described before, collaboration brings people with diverse interests and background together to achieve a common goal or solve a common problem. An example of a typical collaboration process for procurement in a company is presented below.

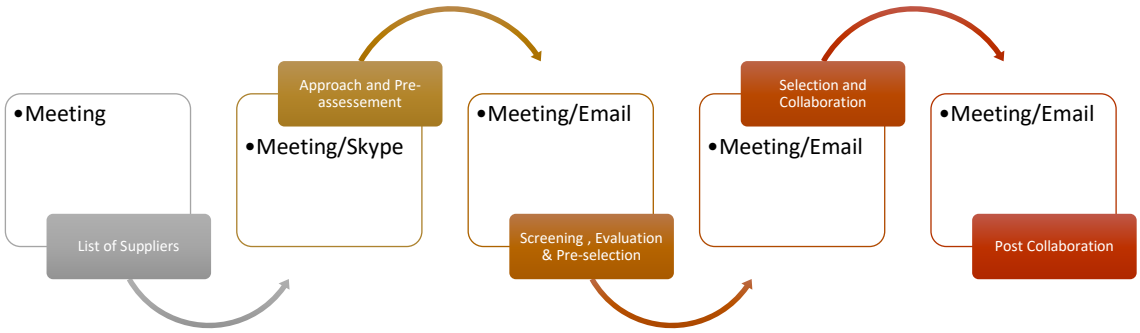


Figure 6. *Traditional Supplier collaboration method (own interpretation).*

The diagram above shows that the traditional collaboration process is linear (outer layer) and facilitated by either meeting or technologies (inner layer) such as emails, Skype, phone and tools of such. Wei-His et al. (2014) cite traditional collaboration methods have brought enough increase in transaction specifity, switching costs and uncertainty, and a lack of flexibility in collaboration. They further add such traditional methods were used to establish only linear links

between one buyer and one supplier. In other words, they were creating two black boxes which are not traceable and hinder information flow, currency to the sustainable development of any organization.

This process is time-consuming and it clearly lacks visibility and transparency which hinders collaboration process (Berttram & Schrauf, 2016). Furthermore, Puhtila (2018) described that such linear collaboration method and use of basic technologies such as emails, Skype, and mobile phone have not contributed in achieving any excellence in collaboration but rather brought barriers in collaboration process as list below:

- lack of collaborative strategic planning,
- inadequate and inaccurate information sharing,
- customers' unwillingness to share risks and rewards and
- inadequate and inconsistent performance metrics (Puhtila, 2018).

Puhtila (2018) further adds that having an advanced collaborative platform will allow supplier and customer to overcome those barriers and create more value and enhance their competitiveness. Similarly, it will provide more traceability and clarity into collaboration and hence increase productivity, efficiency, and overall effectiveness. Therefore, keeping the shortcomings of traditional linear method and unfolding scopes of digitization in the account, a figure is constructed below that depicts the depleted structure for a digitized supplier collaboration process.

3.2. Principles of digitization

Digitization is the process of converting information into the digital (i.e. computer-readable) form. In short, digital is the representation of data in digital, especially, numerical form through binary coding; binary is a process of depicting characteristics or numerical values using a two-state coding scheme, which is 0 and 1. Therefore, digitizing supplier collaboration can be defined as the process of automating traditional collaboration activities, that is, exchanges of information, offerings, and other business activities into digital form. In other words, digitization is a process of adopting technology and/or tools to automate manual work into digital form. Therefore, this research demystifies the concept of using digitalization and digitization interchangeably and establishes the focus on digitization process considering an organization has already set up digitalization strategies to become digital (Salo, 2014; ERNST & YOUNG Ltd., 2018).

The studies have shown that businesses are adopting digital tool/system to digitize their supplier collaboration (Yen & Ng, 2003; Salo, 2006; Wei-His et al.,2014; Florian & Abubaker, 2017). Digital tool/system is the combination of computer, software, hardware, web channels, and telecommunication networks (Salo, 2006). Some examples of means of digitizing supplier collaboration, in other words, digital tools are ERP, EDI, web-based collation tool (e.g. Teamcenter). Organizations are free to choose among digital tools in the market to digitize their collaboration and/or develop their own. Once the right digital tool has been found or developed, it's the time to know how to proceed towards digitization. Therefore, the author has constructed the steps in principles of digitizing supplier collaboration based on Salo (2006) work below considering an

organization has chosen supplier (s) with whom they would like to collaborate and hence digitize the collaboration process to again effectiveness in the supply chain. However, an organization must comprehend that supplier (s) is also willing to adopt a digital tool and eager to invest necessary time and capital, otherwise, all efforts will be wasted.

a) Design: Successful collaboration is rooted in an understanding of collaboration elements, needs and challenges. This principle begins with understanding what you are designing for through observation, mutual conversation, and co-creation (Principles of digital development, 2018). It seeks to answer the following questions:

   I. Why does an organization digitize supplier collaboration?
   II. What are the resources and capabilities that an organization will need?
   III. What are the risks involved considering current and future drawbacks?

b) Map: This principle seeks to understand the existing ecosystem among collaborators. Ecosystems are defined by the organization's culture, norms, values, technological infrastructure, knowledge and skills, and external environment that can affect an organization's ability to access and use a technology (Principles of digital development, 2018). This further illustrates the existing point of differences among collaborators. The following points need to be considered here:

I. What kind of information will flow?
II. What types of the transaction will be done?
III. How process among collaborators should be aligned?

IV. How performance should be measured and What should be performance measurement metrics?

c) Initiate: This principle is concerned about the action, that is, digital activities are executed based on analysis and evaluation of the previous principle.

I. What should be the digital activities?
II. What kind of data needs to be collected?
III. How to collect data (methods and techniques) and finally how to analyse and utilize them?

d) Iterate: the purpose of it is to see if everything that has developed and nurtured before are in calibration. Further, it aims for continuous learning and improvement through:

I. Are there more activities needed or not?
II. How the digitization can be sustained?
III. What kind of innovation and investment are necessary?

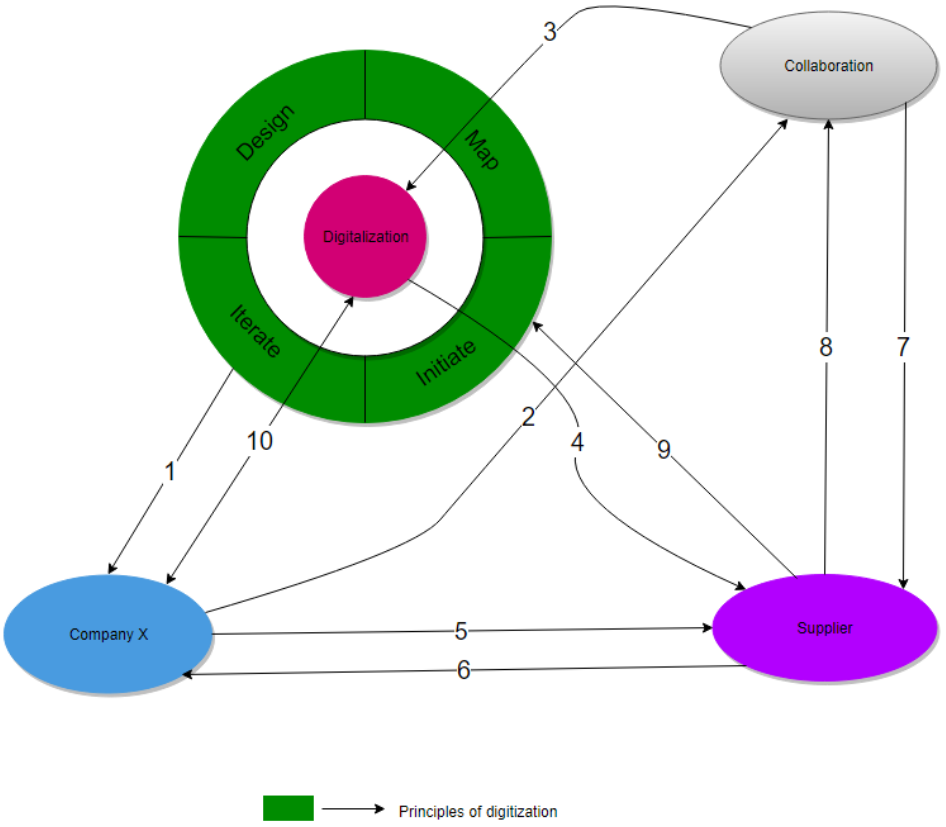


Figure 7. *Digitization of supplier collaboration process. (own interpretation).*

The diagram above is comprised of 10 different paths and digitization principle. The name of each path and its function has been described in the table below and then principle of digitization has been outlined.

Table 1. Path names and functions

Path	Name				
		Definition	Lists of pre-requisites	Strategic objectives	Strategic purpose
1 And 2	Pre-requisite for digitization	It is defined as the factors that need to be there before the digitization is initiated.	1. Level of trust and commitment, 2. A close business relationship, 3. Astuteness towards new technologies and the willingness to adopt them (Salo, 2006).	1. Enforce the dependency between involved parties. 2. Increase transparency in business practices. 3. Maximize collaboration performance.	1. Enhance efficiency and effectiveness. 2. Increase business performance and maximize results. 3. Creating a working culture that is based on sustaining innovation.
3 and 4	Barriers in digitization	Definition	Lists of barriers	Strategy to overcome the barriers	
		Barriers in digitization are defined as factors that hinder the adoption of a digital tool/platform.	1) Radical organizational and environmental changes, 2) Security matters, 3) Lack of trust and commitment from one and/or all involved sides,	a) Shared incentives, b) Upper management support c) Addressing technology and security issues, d) Visibility and commitment,	

			4) Missing mutual benefits, 5) Lack of talent and skills (Sumner, 2005; Salo, 2006; Bienhaus & Haddud, 2017)	e) Openness and communication, f) Training and support, g) Compatibility between existing and adopted practices (Sumner, 2005; Salo, 2006; Bienhaus & Haddud, 2017)
5 and 6	Contract Management	Definition	Process	
		"Contract management is the process which ensures that both the buyer and contractor fully meet their respective obligations as efficiently and effectively as possible, so as to meet the business and operational objectives required from the contract" (Baumann & Smith, 2011).	A. Plan: This phase outlines business needs, establish corporate goals, set expectations and define risks involved B. Execute: This stage includes a bidding process, development of a suitable form of contract, and negotiations C. Monitor and control: This phase comprises of actions and approaches needed to ensure successful implementation and management of the signed agreement considering sensible change management as situation demands (Cummins et al., 2011; Paulsen, 2017).	
7 and 8	Barriers in collaboration	Lists of barriers	Strategic counteract	
		1. Lack of collaborative strategic planning, 2. Inadequate and inaccurate information sharing,	A. Strategic collaboration, B. Involvement of top management, C. Communicate the value of collaboration downwards effectively and encourage collaborative initiative behaviour (Bannerjee et al., 2016).	

		3. Customers' unwillingness to share risks and rewards and 4. Inadequate and inconsistent performance metrics. (Puhtila, 2018).	
9	Contributions	List	Value adding
		1) Professionalism (e.g. skills, competence, and expertise), 2) R & D expenditure, 3) Specialization, 4) Collaborative attitude, 5) Engagement in development program (Pulles et al., 2014).	1. Creates a new knowledge base, 2. Enhance product/service innovation and sustain them, 3. Boost collaboration performance, 4. Improves collaboration practices (Yang, 2013; Pulles et al., 2014).
10	Digitization of SC	Roadmap for the digitization of SC	
		1. Perform an internal assessment and define growth possibilities, 2. Create a vision and value proposition, 3. Set up collaboration governance, investment, and decision board, 4. Build capabilities, 5. Harvest the value of collaboration and sustain it (Geissbauer et al., 2018; Lorentz & Srai, 2018)	

3.3. Impact of digitized supplier collaboration

Mcavoy (2016) quotes digitizing SC in the supply chain as *"the process of using technology advancements linked with physical and digital assets to redefine and reimagine current business practices to create a significant competitive advantage."* Digitizing supplier collaboration can have an impact on two different levels; organizational and inter-organizational level. At inter-organizational level, the implementation of SC digital tool can allow companies to build an environment where information can be shared effectively and mutual adjustment between themselves and supplier can be simplified to gain agility. Mutual adjustments are the way inter-organizational activities are coordinated. At the organizational level, the implementation of an SC digital tool enables companies to automate their collaboration process, and re-engineer their internal processes, thereby enhancing organizational performance (Wei-His et al., 2014).

Additionally, digitizing SC can have operational and strategic benefits. The operational benefits embrace the ability to reduce overall transaction costs and the improved audit of each transaction within the collaboration process. The strategic benefits comprise of superior influence and control over expenditures (Yen & Ng, 2003). Moreover, Srai & Lorentz (2018) have further broken down the opportunities and benefits that digitization can bring into organizations are as follow:

- Coordination and control,
- Supplier capability assessment,

- Relationship management,
- Aligned category management,
- Innovation. (Srai & Lorentz, 2018)

4. CRITICAL SUCCESS FACTORS OF DIGITIZED SUPPLIER COLLABORATION

Critical success factors are referred as factors that help organizations deciding on what is working and what is not. It further depicts the path for organizations that leads to success and growth. The deciding factors have been divided into three categories to access the effectiveness of digitized supply chain management as described below;

Strategic factors

- Set strategic goal and objective(s) are met.
- The number of business case formulation has increased
- Upper management involvement and support increase
- Innovativeness
- The high degree of mutual adjustment
- Improved project management and maintenance
- Increased shared resources and commitment
- High strategic collaborative planning and execution
- Increased SCM performance
- New knowledge creation
- Continuous improvement of digital tool/technology
- Aligning digital tool initiatives with a business goal
- The enlarged pool of suppliers (Yen & Ng, 2003; Barratt, 2004; Loh & Koh, 2004; X.-H. Lu et al., 2006; Salo, 2006; E. W. T. Ngai et al., 2007; Wei-His et al., 2014; Ab Talib et al., 2015; Kwin, & Park, 2017; Korn Ferry Institute, 2018; Puhtila, 2018; Srai & Lorentz, 2018).

Operational factors

- Increased process and operation efficiency
- Education and training
- Reduced pre-sourcing time
- Flexible and customizable Procurement quotation
- Less time devoted to Negotiation
- Optimized Order placement
- Improved transaction process and optimized transaction cost
- Improved quality
- JIT Post-delivery
- Increased joint decision making
- Reduced administrative time in monitoring and controlling the process
- Decreased in time-to-market cycle time (Yen & Ng, 2003; Barratt, 2004; Salo, 2006; E. W. T. Ngai et al., 2007; Wei-His et al., 2014; Wautelet, 2017).

Cultural factors

- Increased openness and honesty
- Enhanced communication and understanding
- Increased in trust level
- Increase in mutuality contributions
- Increased information sharing
- Motivation (Yen & Ng, 2003; Barratt, 2004; Salo, 2006; X.-H. Lu et al., 2006; E. W. T. Ngai et al., 2007; Wei-His et al., 2014; Puhtila, 2018).

5. SUPPLIER COLLABORATION PERFORMANCE MEASUREMENT

A company uses different sorts of indicators to measure the performance of the organization such as sales and revenue figures, produced goods which show previous performance, expected market growth and demand (Jyrälä, 2011). This section presents performance measurement for supplier collaboration considering digitalization into account.

5.1. Performance Measurement

Parmenter (2007) posits that many organizations have adopted wrong measures which are incorrectly termed as key performance indicators (KPI). He proposed three distinct performance measures; (a) key result indicators (KRIs), (b) performance indicators (PIs), and (c) key performance indicators (KPIs) as shown in the figure below.

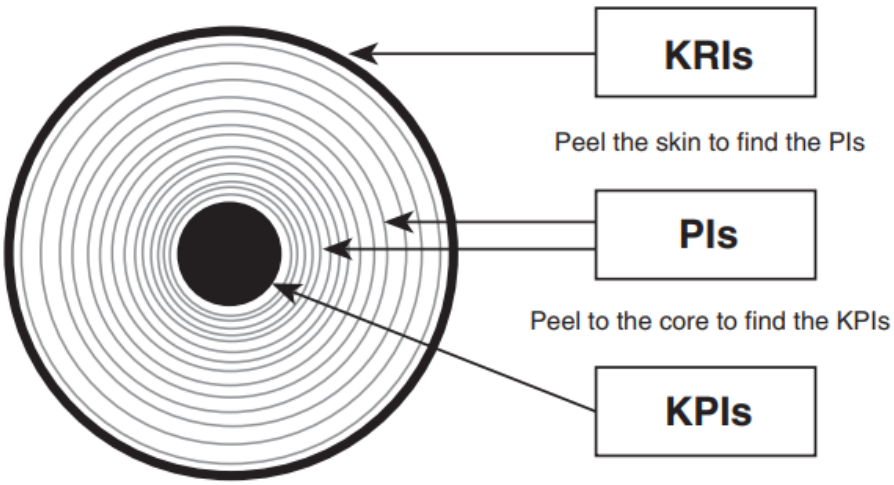


Figure 8. *Three types of performance measurement (adopted from Parmenter, 2007, p.2)*

KRIs are the measures of actions taken in the past which indicates whether the company is moving in the right direction. PIs are the more precise and definite measures of a given context that justify corporate events. They are measured over time and reviewed monthly or quarterly. Whereas, KPIs are defined as a set of measures that has a significant impact on the organization's current and future success and growth. KPIs are measured on a daily or weekly basis (Parmenter, 2007; Jyrälä, 2011).

Therefore, distinguishing KRIs, PIs, and KPIs from one another are not only essential but unavoidable as an emphasis on wrong and/or misleading measures can have a detrimental effect on business (Parmenter, 2007; Jyrälä, 2011). Parmenter (2007) recommends the 10/80/10 guideline for identifying, generating, and implementing performance measures inside the company as shown in the diagram below:

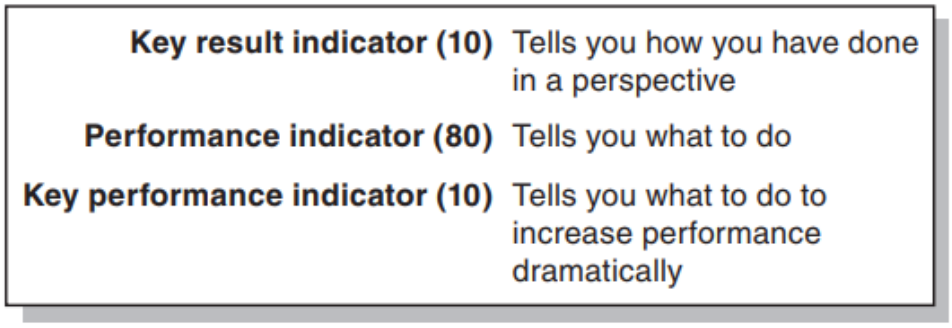


Figure 9. *10/80/10 rule (Adopted from Parmenter, 2007)*

5.2. Setting KPIs for supplier collaboration

5.2.1. Supply chain management

The supply chain is defined as "*a group of inter-connected participating parties that add value to a stream of transformed inputs from their source of origin to the end products or services that are demanded by the designated end-consumer*" (Lu, 2011). Hence supply chain is a sequence of processes (decision making and execution) and (material, information, and money) flows that aims to add value to end customer that exists within and outside of an organization. The supply chain includes suppliers and distributors as well as transporters, warehouse, retails, and consumers themselves. In addition to that, it also includes new product development, marketing, operations, finance etc. (Van der Vorst, 2004; Fayezi & Zomorrodi, (2015).

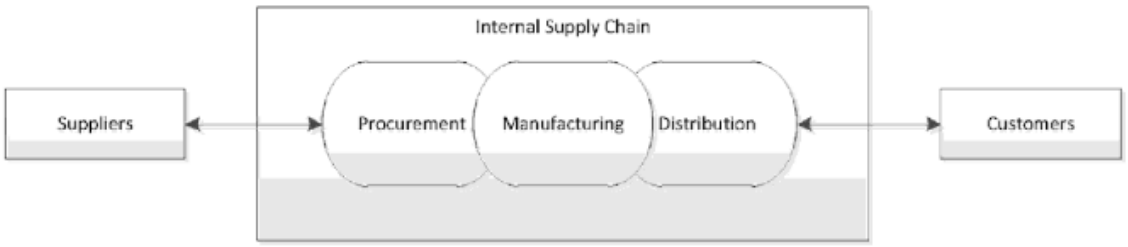


Figure 10. *A company's supply chain (adopted from Chen and Pulraj, 2004, p.120)*

5.2.2. Supply chain management framework

Scholars diverse knowledge and exploration have led to the existence of dozens of SCM framework including operational, network, strategic, and behavioural etc. (Fayezi & Zomorrodi, 2015), however, this thesis uses SCOR model developed by Supply Chain Council (SCC) as depicted below in the figure.

Figure 11. *SCOR SCM Framework (adopted from SCC)*

The Supply Chain Operations Reference model (SCOR®) is the product of Supply Chain Council, Inc. (SCC) which is designed to provide a framework for companies to evaluate and further developed their supply chain and manage it successfully. It comprises six major management processes: Plan, Source, Make, Deliver, Return and Enable as shown in figure 2. By using these process building blocks, the supply chain can be described at many echelons such as process type (scope), process categories (configuration), and process elements (steps) which are simple and complex. It spans, for example, customer interactions such as order entry, all physical material transactions such as supplier's supplier to customer's customer, including equipment, supplies, spare parts, bulk product, software, etc. and all market interactions such as from the understanding of aggregate demand to the fulfilment of each order. The model, however, doesn't seek to outline every business process or activity such as demand generation, product development, research and development, and some elements of post-delivery customer support. (SCC, 2012).

The purpose of the SCOR model is to depict process architecture in a way which is understandable and adds value to business partners. The SCOR structure consists of 4 major sections:

- *Performance: Standard metrics to describe process performance and define strategic goals*
- *Processes: Standard descriptions of management processes and process relationships*
- *Practices: Management practices that produce significantly better process performance*
- *People: Standard definitions for skills required to perform supply chain processes.* (SCC, 2012).

The section, however, will mainly concentrate on the performance segment where the aim would be to outline the KPIs for digitized supplier collaboration. The table below shows the performance attributes and KPIs for the respective attribute.

Table 2. *Setting KPIs for supplier collaboration (adopted and modified from SCC, 2012)*

Performance Attribute	KPIs	Description
Reliability	I. Rate at which milestone(s) are met. II. Number of agreed product/services delivered. III. Number of unmet goal(s).	I. Milestones are completed on Deadline. II. Discussed product/service(s) are provided. III. Unfulfilled goals.
Responsiveness	I. Order fulfilment cycle time (SCC, 2012). II. Source lead time (Caridi et al., 2014). III. Handling rate	I. The average actual cycle time achieved constantly to fulfil order starting from the order receipt to

		acceptance of the order (SCC, 2012). II. How much time it takes to source. III. How fast one handles orders, complaints, and other strategic issues.
Flexibility	a) Dimension variability (Dharmawarda et al., 2015). b) New product development (Dharmawardana et al., 2015). c) Deliverability (Gregory et al., 2005). d) Modification (Gregory et al., 2005).	a. Supplier's response to changes in product technical data. b. Adaptability in new product/service innovation. c. Product punctuality. d. Rate at which changes are met.
Innovation	I. Innovativeness. II. The resources allocated for innovation. III. Rate of innovation. IV. Revenues from New Products (Lijun et al., 2009).	i. Number of ideas proposed, and number of ideas initiated and executed. ii. Companies' resources involved in sustaining innovation. iii. Number of successful innovations during a certain timeframe. iv. Increase in profitability from new products.

6. EMPIRICAL STUDY

6.1. Research methodology

A survey is conducted to verify the previous findings in theory. The survey questionnaire is designed in a way that it covers the different aspects of digitization in supplier collaboration with a focus on how it impacts the effectiveness of the SCM.

6.1.1. Data collection and data analysis method

The survey questionnaire was sent to 22 different suppliers of company X where respondents replied to each statement from a general perspective and were not limited to their job, position, or organization. Based on these responses, it is possible to analyse the impact of digitizing supplier collaboration on the effectiveness of the SCM.

In total, 16 data were collected out of 22 participants who were operating in the field of SCM, procurement, or other business functions. The participants of the survey are in different parts of the world. Since company X is in modular power plants business, it is assumed that most of the respondents were from the same industry with different offerings considering the author was not involved in selecting participants. The list of suppliers was provided by company X and the author was responsible for sending a survey questionnaire to collect data without the influence of company X.

The descriptive analyses were used to calculate frequency, mean, and percentage of each item. Finally, the standard deviation per question was calculated to determine the range of the values or the variance of the values. The standard deviation allows measuring the deviation of responses from the mean. The lower standard deviation shows that the answers are closer to the mean and thus the responses are more consistent among the respondents (Bienhaus & Haddud, 2017).

6.1.2. Results

6.1.2.1. *Suppliers awareness in digitization.*

The first question was constructed to examine the supplier's awareness of digitization, which comprises of three options. The respondents were asked to choose between the three alternatives; very = highly aware, moderate = aware, and low = poorly aware. The frequency distribution of the three alternatives in the figure below shows that suppliers are somehow aware of digitization and how it is going to impact collaboration and organizations.

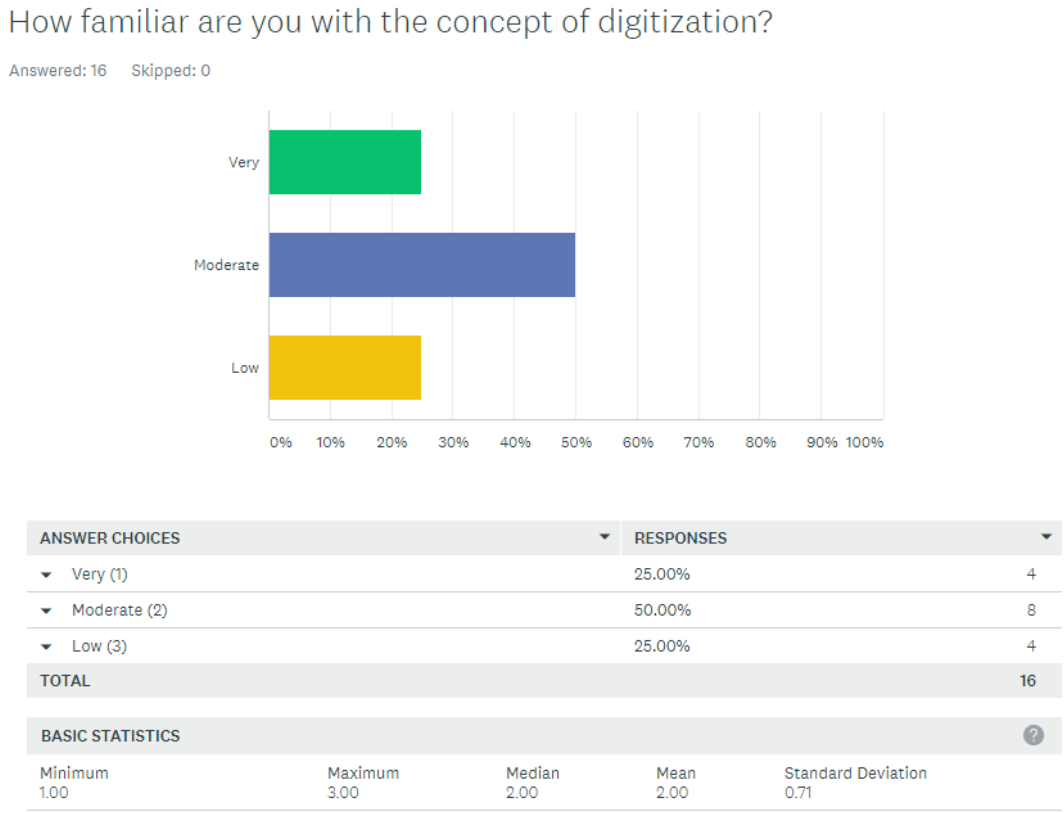
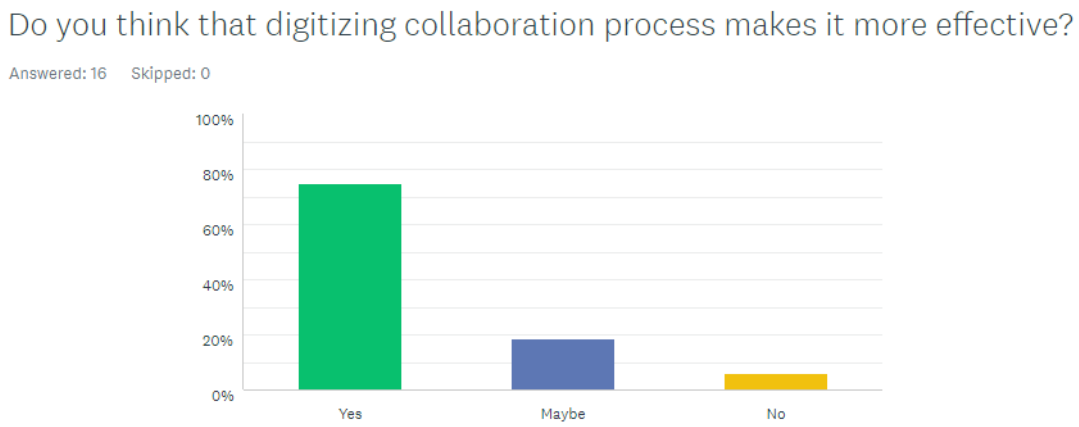


Figure 12. *Supplier's awareness in digitization*

6.1.2.2. *Impact of digitization on supplier collaboration*

The second question was constructed to examine the impact of digitization on supplier collaboration, which comprises of three options. The respondents were asked to choose between the three alternatives; Yes = digitization increases the effectiveness of the supplier collaboration, maybe = unsure of the impact of digitization, and No = digitization doesn't increase the effectiveness.

Digitizing supplier collaboration enhances the effectiveness of the SCM in an organization and this statement has been supported by the survey result as 75% of respondents agreed on the first choice.



ANSWER CHOICES	RESPONSES	
Yes (1)	75.00%	12
Maybe (2)	18.75%	3
No (3)	6.25%	1
TOTAL		16

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
1.00	3.00	1.00	1.31	0.58

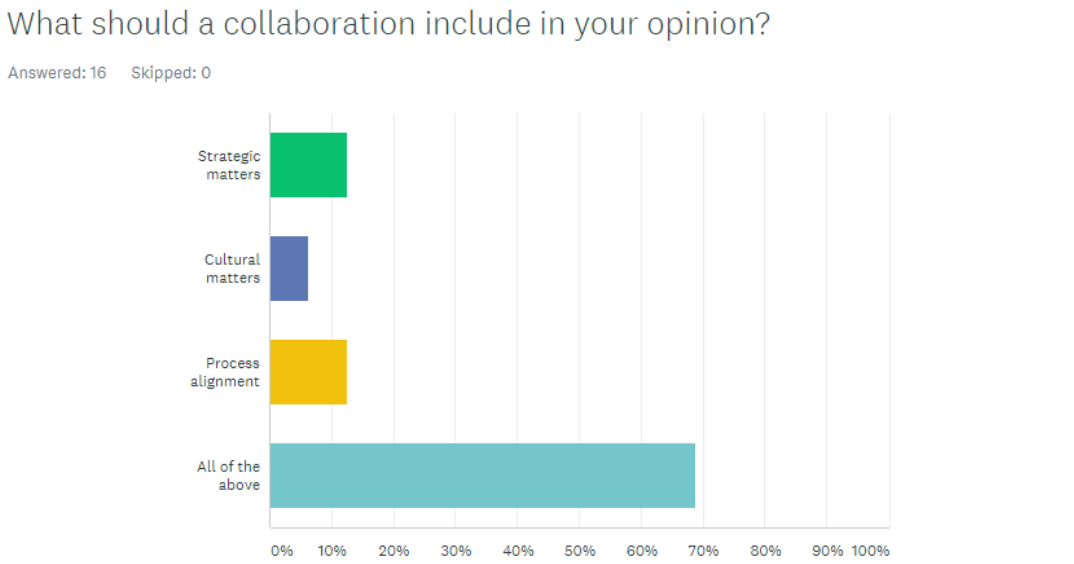
Figure 13. *Impact of digitization on collaboration*

6.1.2.3. *Pillars of digitized supplier collaboration*

The third question was constructed to examine what the building blocks of digitized supplier collaboration are. The question contains four options. The respondents were asked to choose between the four alternatives; Strategic matters only, cultural matters only, process alignment only, and all of the above.

The aim of the last option was to check whether suppliers' value one over another or all.

This is evident from the diagram below that digitized collaboration should not favour one pillar over another, but rather create an ecosystem through combining all pillars of digitization together as suggested by the survey result, where 68.75% of respondents agree that all pillars are important to form a sustainable digitized collaboration.



ANSWER CHOICES	RESPONSES	
Strategic matters (1)	12.50%	2
Cultural matters (2)	6.25%	1
Process alignment (3)	12.50%	2
All of the above (4)	68.75%	11
TOTAL		16

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
1.00	4.00	4.00	3.38	1.05

Figure 14. *Pillars of digitization*

6.1.2.4. *Need of standardization to realize a digitization*

The first question was constructed to examine the supplier's awareness of digitization, which comprises of three options. The respondents were asked to choose between the three alternatives; yes = there is a need for it, maybe = Not aware of it, and no = there is no need. The frequency distribution of the three alternatives in the figure below shows that there is a need standardization/guidelines when initiating digitization.

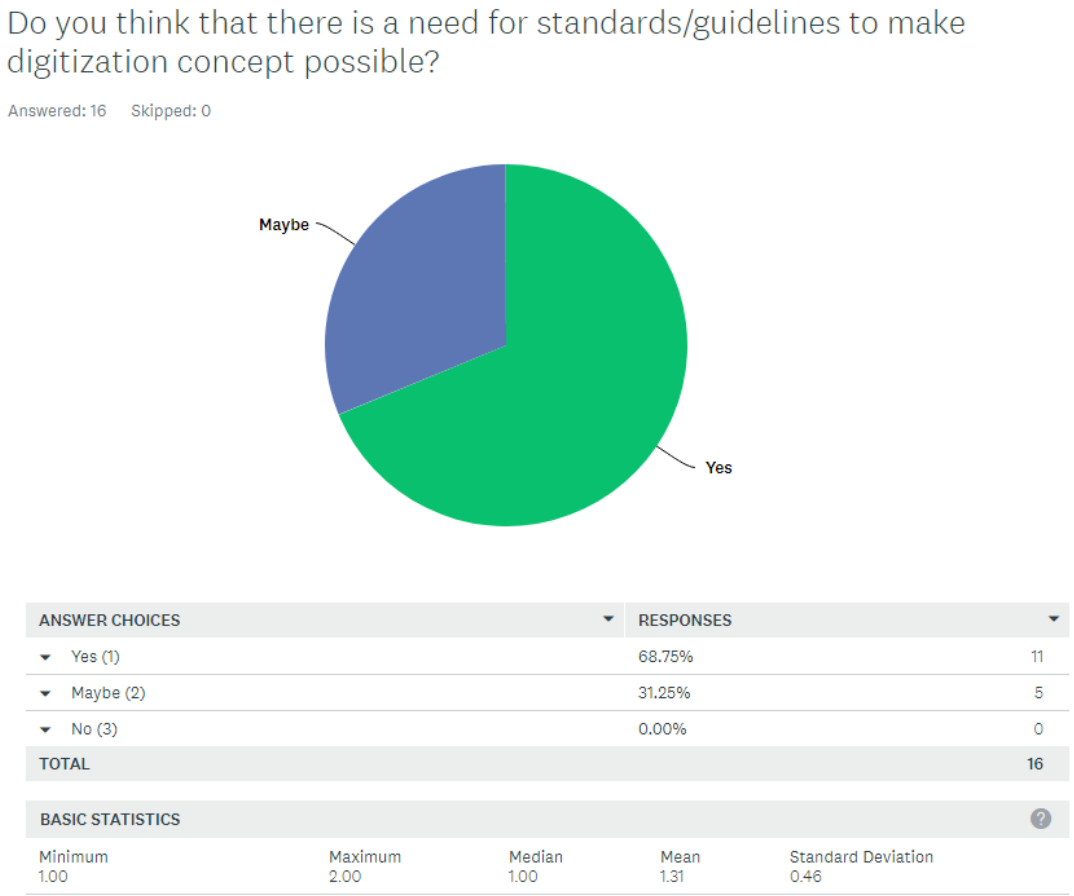


Figure 15. *Need for standardization in accomplishing digitization*

6.1.2.5. *Importance of mutually agreed KPIs for digitizing collaboration*

The fifth question was constructed to examine the role of mutually agreed KPIs in a digitized collaboration that includes three options. The respondents were asked to choose between the three alternatives; yes = successful digitized collaboration requires mutually agree KPIs, maybe = they are required on a moderate level, and no = there is no need for mutually agreed KPIs in successful digitized collaboration. The frequency distribution of the three alternatives in the figure below shows that 68.75% of respondents agree that there has to be mutually agreed KPIs in order to rip the fruit of the success from a digitized supplier collaboration.

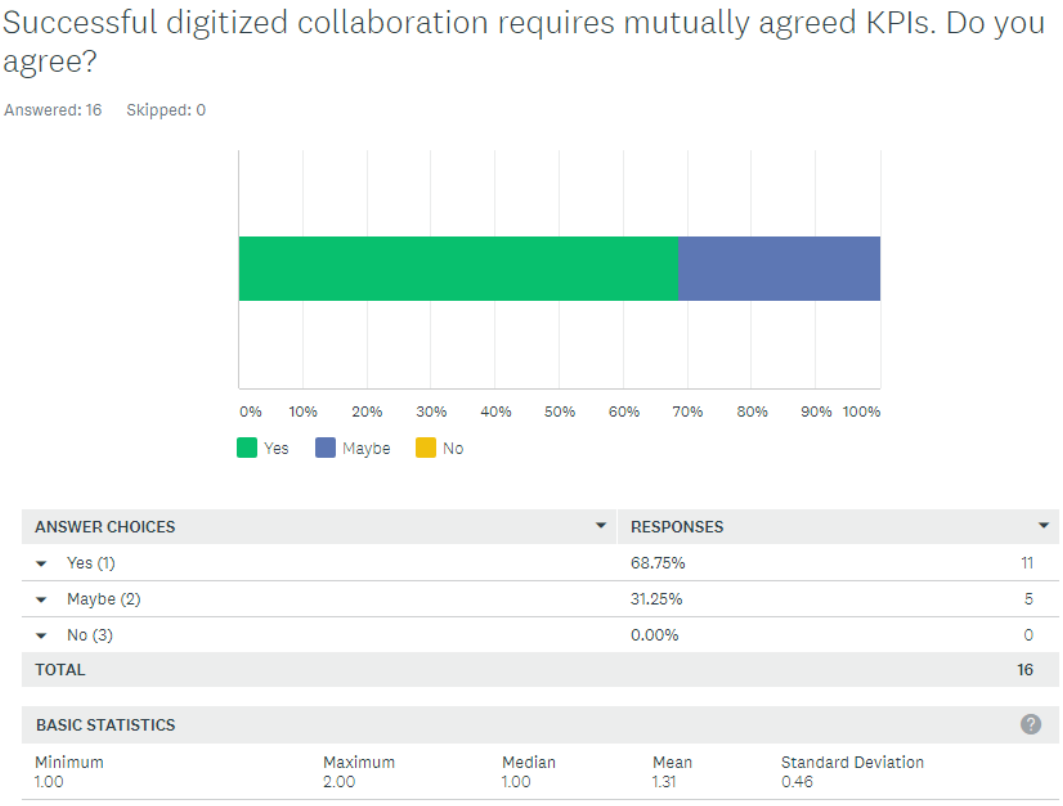


Figure 16. *Importance of mutually agreed KPIs*

6.1.2.6. *Commitment as a requirement to sustain digitized collaboration*

The last question was constructed to examine whether suppliers are committed to digitized collaboration or not. This comprises of three options. The respondents were asked to choose between the three options; very = highly committed, fairly = moderately committed, and not really = no commitment in digitized collaboration. The first option represents that the suppliers are extremely committed because they see it as a requirement to sustain the collaboration as well as success. The second option represents the degree of commitment that is directly proportional to a commitment from the other suppliers. They see it as an important factor for sustaining a collaboration, however, they don't tie themselves for big and/or long-term commitment. The third option is self-evident that mostly occur in a short-term business relationship.

The frequency distribution of the three alternatives in the figure below shows that participants have favoured first two options, which means that either they are tremendously committed and expect the same or they act in a similar manner as the amount of commitment customer shows.

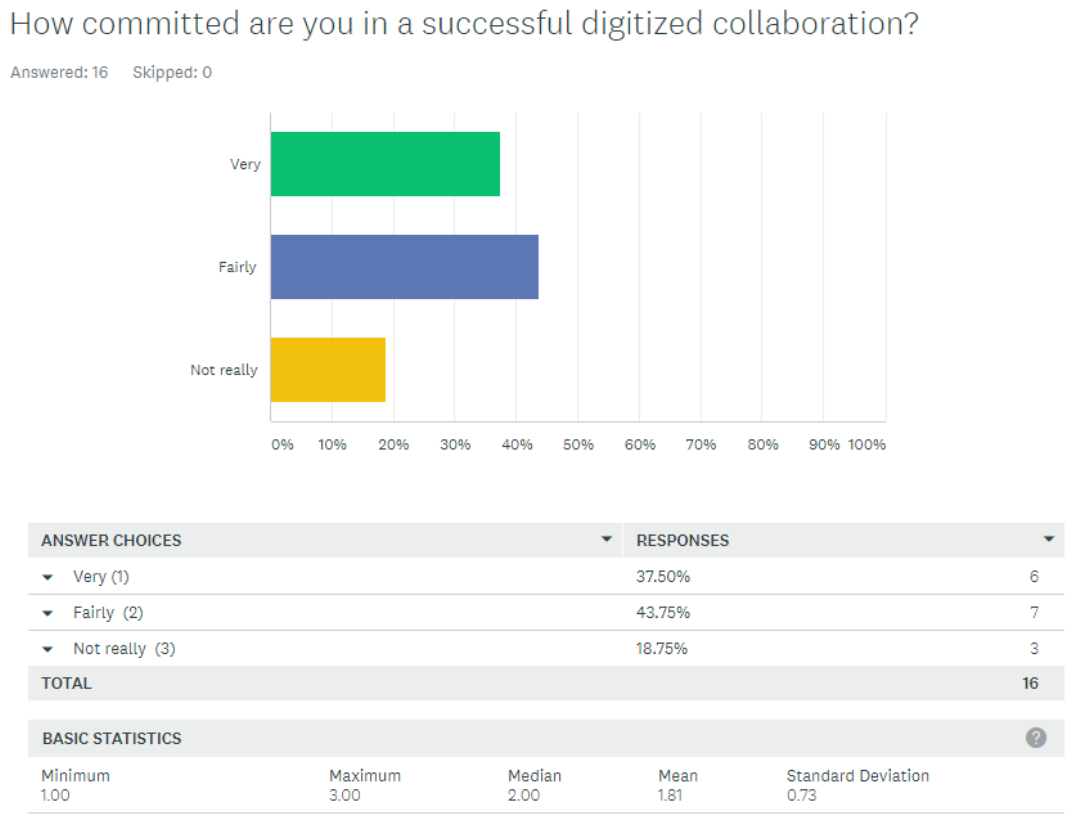


Figure 17. *Role of commitment in sustaining digitization*

6.2. Three-point estimation

The author has developed a three-point estimation model. The purpose of the tool is to increase the reliability of a company's delivery time estimation. This tool is designed in a way that it takes input from a company's project assuming a company is using the project gate model to accomplish a project. The model divides supplier collaboration into three scenarios: projected time for key system procurement, time estimation for material procurement, and time estimation for module procurement. The activities for each scenario are outlined as shown in the table below:

***Table 3**. Projected time for key system procurement*

Task	**Pessimistic (P)**	**Optimistic (O)**	**Most Likely (M)**
A			
B			
C			
D			
E			

***Table 4**. Time estimation for material procurement*

Task	**Pessimistic (P)**	**Optimistic (O)**	**Most Likely (M)**
A			
B			
C			
D			
E			

***Table 5.** Time estimation for module procurement*

Task	**Pessimistic (P)**	**Optimistic (O)**	**Most Likely (M)**
A			
B			
C			
D			
E			

The model further incorporated the pre-determined values and outlined KPIs for digitized supplier collaboration of a company into the model to forecast expected delays as shown in the following tables below.

***Table 6**. Preparation for expected delays calculation*

Estimation	**Task**	**Pessimistic (P)**	**Optimistic (O)**	**Most Likely (M)**
Expected duration of implementing new innovation before design release to manufacturing				
1. Reference process for estimation: A to Z, a company decides				
2. Remarks: a company decides based on its context				
	Total			
Expected duration of implementing new innovation after design release to manufacturing				
1. Reference process for estimation: A to Z, a company decides				
2. Remarks: a company decides based on its context				
	Total			
Expected duration of sourcing new suppliers				
1. Reference process for estimation: A to Z, a company decides				
2. Remarks: a company decides based on its context				

	Total			
Expected time impact of Disputes / Issues among WOIMA supply chain				
1. Reference process for estimation: A to Z, a company decides				
2. Remarks: a company decides based on its context				
	Total			

Table 7. *Calculating expected delays*

	Amount	
FLEXIBILITY		**Estimation**
A		0
B		0
	Total	0
INNOVATION	**Amount**	**Estimation**
A		0
B		0
	Total	0
Expected Delays	0	

In the table above, letters A, B…. Z represents an activity/task that a company performs to accomplish a goal. The tool has been prepared by the author which a company can acquire upon inquiry. The last row in the table provides the outcome for the expected delays.

6.3. Monte Carlo Simulation

This model is created with the aim to find out the necessary resources (time & money) and the workforce needed to successfully digitalize a supplier collaboration process for a company. As Patrick in his article suggested that companies still don't *have the necessary resources and workforce to implement digitalization efficiently and effectively* (Patrick, 2018). Hence, this model will help a company to anticipate its resources and workforce before beginning the journey of digitization.

The author has created a framework for the digitization of supplier collaboration. The framework is divided into 4 phases; Design, Map, Initiate & Iterate. Each step is comprised of certain tasks/activities. This, however, depends on where a company stands. For example, one company can have 4 different activity in the design phase, while another might complete this phase with just 3 activities. Each activity requires time, money, and people to complete it. This depends on a company how they allocate time, money, and people for such project considering its current circumstances and where it wants to go and how fast. The simulation has been illustrated by the author with the help of hypothetical data as shown in the following tables below. The unit of time and cost is month and € respectively.

Table 8. *Design phase.*

	Design								
Task/ Activity	Time (T)			Cost (C)			No. of employees (N)		
	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)

A	4	3	2	12000	10000	8000	5	4	3
B	4	3	2	12000	10000	8000	5	4	3
C	4	3	2	12000	10000	8000	5	4	3
D	4	3	2	12000	10000	8000	5	4	3
	16	12	8	48000	40000	32000	20	16	12

Table 9. *Map phase.*

	Map								
Task/ Activity	Time (T)			Cost (C)			No. of employees (N)		
	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)
A	2	1.5	1	8000	6000	4500	4	3	2
B	2	1.5	1	8000	6000	4500	4	3	2
C	2	1.5	1	8000	6000	4500	4	3	2
D	2	1.5	1	8000	6000	4500	4	3	2
	8	6	4	32000	24000	18000	16	12	8

Table 10*. Initiate phase.*

		Initiate							
Task/ Activity	Time (T)			Cost (C)			No. of employees (N)		
	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)
A	5.5	4	3	15000	12000	10000	3	2	1
B	5.5	4	3	15000	12000	10000	3	2	1

C	5.5	4	3	15000	12000	10000	3	2	1
D	5.5	4	3	15000	12000	10000	3	2	1
	22	16	12	60000	48000	40000	12	8	4

Table 11*. Iterate phase.*

		Initiate							
Task/ Activity	Time (T)			Cost (C)			No. of employees (N)		
	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)
A	4.5	3	2	11000	9000	7500	3	2	1
B	4.5	3	2	11000	9000	7500	3	2	1
C	4.5	3	2	11000	9000	7500	3	2	1
D	4.5	3	2	11000	9000	7500	3	2	1
	18	12	8	44000	36000	30000	12	8	4

6.3.1. Result

Table 12. *The time needed to successfully complete the digitization of supplier collaboration.*

The result after 5000 simulations: Time					
	Design	Map	Initiate	Iterate	Total
Mean	11.98925919	6.015545557	16.34610471	12.36595337	46.59124848
SD	1.326332398	0.668875382	1.704543087	1.67157009	5.307266237
Min	6.73685679	3.742339759	10.33621775	6.086466518	28.85888933
Max	17.53261057	8.583666892	22.27220011	19.20216241	67.44931636

The table above suggests that if a company has 4 tasks in each phase that takes time as specified in the previous tables, then expected time for design, map, initiate, and iterate phase is 11.98, 6.01, 16.34, and 12.36 months respectively. Similarly, the total expected time to complete such digitized collaboration project is 46.59 months.

Table 13. *Money needed to successfully complete the digitization of supplier collaboration.*

The result after 5000 simulations: COST					
	Design	Map	Initiate	Iterate	Total
Mean	39959.7894	24367.49387	48659.11786	36374.7547	149629.6702
SD	2666.829711	2312.607432	3311.096036	2341.656382	10535.47772
Min	30996.69737	15811.0923	38045.91698	29021.44755	110400.8229
Max	49735.22265	34064.78244	60209.11149	43817.45047	193475.6474

The table above suggests that if a company has 4 tasks in each phase that requires money as specified in the previous tables, then expected cost for design, map, initiate, and iterate phase is 39959.78, 24367.49, 48659.11, 6374.75 euros respectively. Similarly, the total expected cost to complete such digitized collaboration project is 149629.67€.

Table 14*. The workforce needed to successfully complete the digitization of supplier collaboration.*

The result after 5000 simulations: NO. OF EMPLOYEE					
	Design	Map	Initiate	Iterate	Total
Mean	16.01824059	12.04510152	8.022304844	7.991871304	43.93454825
SD	1.331393859	1.322724049	1.355444036	1.317062401	5.318531909
Min	10.72167768	7.133204852	3.059539995	2.615751641	23.5137983
Max	20.64137942	16.59237672	12.95172817	12.81890667	65.39419971

The table above suggests that if a company has 4 tasks in each phase that workforce as specified in the previous tables, then expected no. of the workforce needed for design, map, initiate, and iterate phase is 16, 12, 8, and 7 respectively. Similarly, the total no. of the expected employee to complete such digitized collaboration project is 43.

7. CONCLUSION

The aim of the thesis was to investigate whether aligning the collaboration between the company X and its existing and future suppliers through digitization in the supply chain will facilitate optimal operations throughout the supply chain and hence increase the effectiveness of the supply chain. In order to gain insights into the digitization of supplier collaboration, the author was assigned with a set of research questions from the company X (see section 1.3). A case study was chosen as a research method, in addition, a survey as a strategy for collecting data.

What is evident from literature and the company's practice on the digitization of supplier collaboration is that it is a process of converting the manual traditional form of operations into digital form with the help of technology. A traditional form of supplier collaboration increases the complexity of the supply chain when more suppliers are added to the network that makes it difficult to manage (see sub-chapter 2.3). However, digitization of supplier collaboration reduces the manual work and time spend on it dramatically through automation, bring downs all the silos involved with it to foster transparency and visibility throughout the supply chain as every part of the supply chain and all its members are connected with each other. The survey also supports this as 75% of respondents agreed that digitizing supplier collaboration will increase the effectiveness of supplier collaboration and thus will have a positive impact on the supply chain. I have developed a roadmap (see chapter 3, figure 7) that a company can deploy to facilitate the process of achieving this goal.

It can be further illustrated that a process that is developed needs a set of determining factors that ensure the success of implementing it. Chapter 4 depicts the possible critical success factors that a company should look out for when implementing a digital tool for digitization. I propose the most beneficial critical success factors for company X based on the discussion and investigation from and on the company that I have done.

Table 15. *The proposed deciding factor for company X*

Strategic success factor	Operational success factor	Cultural success factor
Set strategic goal and objective(s) are met	Reduced pre-sourcing time	Communication and understanding are high
Improved Project management and maintenance	Less time devoted to Negotiation	Increased in trust level
High strategic collaborative planning and execution	Optimized Order placement	Increase in mutuality
Increased SCM performance	Improved transaction process and optimized transaction cost	Increased information sharing
Continuous improvement of digital tool/technology	Reduced administrative time in monitoring and controlling the process	Motivation

Similarly, the previous studies have also outlined that a successful implementation of a digital platform/technology also needs a measurement system that is developed mutually to ensure its effectiveness (SCC, 2012; Berttram & Schrauf, 2016; Rogers, 2016; Puhtila, 2018). This is further supported by a survey conducted among suppliers where almost 69% of respondents agreed that lists of KPIs need to satisfy all parties involved. Therefore, this work has outlined a set of KPIs (see chapter 5, table 2) that can be used to measure the

performance of digitized supplier collaboration while focusing on developing company X's chosen capabilities. Similarly, two simulation models; three-point estimation and Monte Carlo simulation were developed to forecast delivery time for procurement and to measure required resources (time & money) and workforce needed to complete a successful digitized supplier collaboration project respectively.

Digitization is a new evolving paradigm that has been growing rapidly recently. Previous research shows that only 10% of the world's companies are fully engaged in the digitization process (Berttram & Schrauf, 2016). The survey conducted among suppliers confirmed this as only 25% of respondents were fully aware of the concept of digitization, whereas 50% moderately, and rest poorly aware of the paradigm. Thus, it can be concluded that educating suppliers on the concept of digitization of supplier collaboration is an undeniable necessity and future investment for any organization initiating their journey on this archetype. Therefore, a framework was constructed to realize the implementation of the digitization in supplier collaboration in the supply chain. This answers the very last question that the author was assigned to.

7.1. Limitations and suggestions for future research

There are some limitations involved in the empirical part of this thesis; the number of suppliers was limited, survey questionnaires were only a few due to time and circumstances, and thus simple quantitative method was used to analyse the results.

The importance of strategic and cultural elements has been recognized in previous studies. Therefore, a large-scale quantitative study in the future on how these elements are interconnected, and how they impact the performance of a company when collaborating in the digitalized supply chain is worth exploring. Similarly, regardless of the importance of the digitization, the involvement of companies in it is relatively small. Hence, research that focuses on preparing a framework that will allow them to assess their current state and benchmark, and take initiative in harnessing digitization advantages to achieve company's growth and success is needed to build a connected ecosystem. Another area that demands further research is security on the digital ecosystem.

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APPENDICES

APPENDIX 1. Survey questionnaire

Digital Supplier Collaboration

Questionnaire

Key questions to be answered by suppliers

1. How familiar are you with the concept of digitization?

- ◯ Very
- ◯ Moderate
- ◯ Low

2. Do you think that digitizing collaboration process makes it more effective?

- ◯ Yes
- ◯ Maybe
- ◯ No

3. What should a collaboration include in your opinion?

- ◯ Strategic matters
- ◯ Cultural matters
- ◯ Process alignment
- ◯ All of the above

4. Do you think that there is a need for standards/guidelines to make digitization concept possible?

- ○ Yes
- ○ Maybe
- ○ No

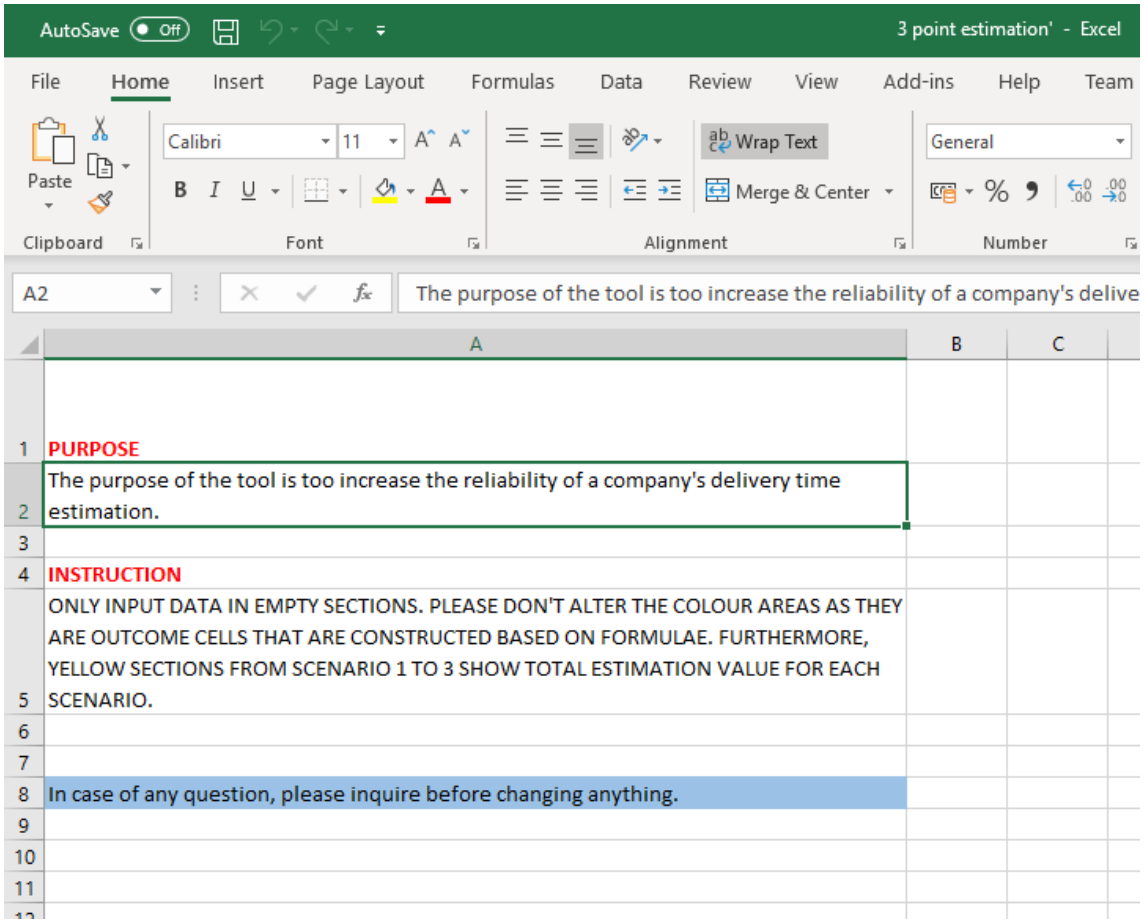
5. Successful digitized collaboration requires mutually agreed KPIs. Do you agree?

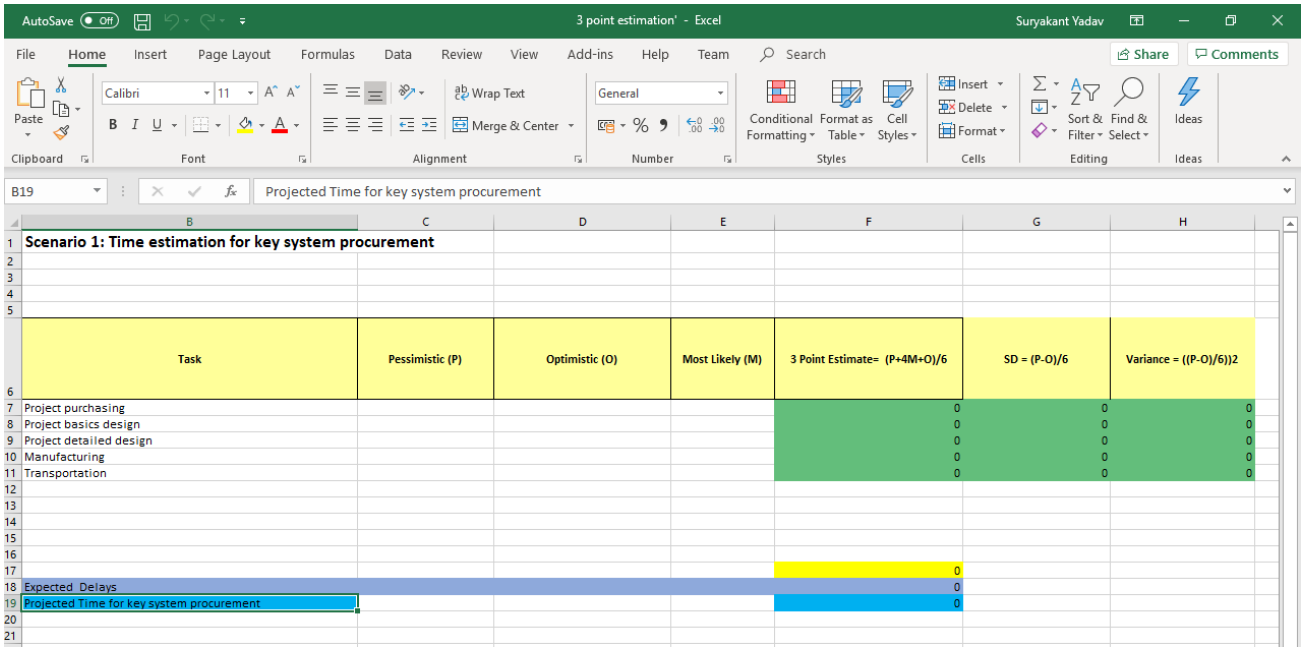
- ○ Yes
- ○ Maybe
- ○ No

6. How committed are you in a successful digitized collaboration?

- ○ Very
- ○ Fairly
- ○ Not really

APPENDIX 2. Three-Point-Estimation





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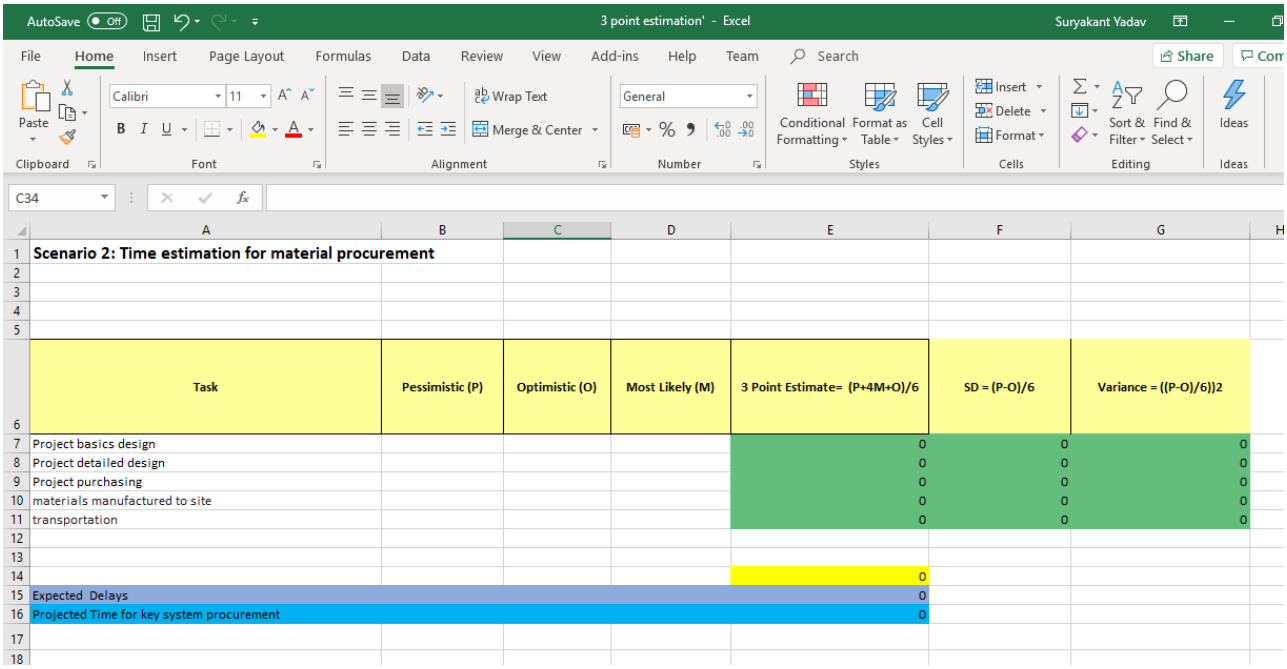
B19 | Projected Time for key system procurement

Scenario 1: Time estimation for key system procurement

Task	Pessimistic (P)	Optimistic (O)	Most Likely (M)	3 Point Estimate= (P+4M+O)/6	SD = (P-O)/6	Variance = ((P-O)/6))2
Project purchasing				0	0	0
Project basics design				0	0	0
Project detailed design				0	0	0
Manufacturing				0	0	0
Transportation				0	0	0
				0		
Expected Delays				0		
Projected Time for key system procurement				0		



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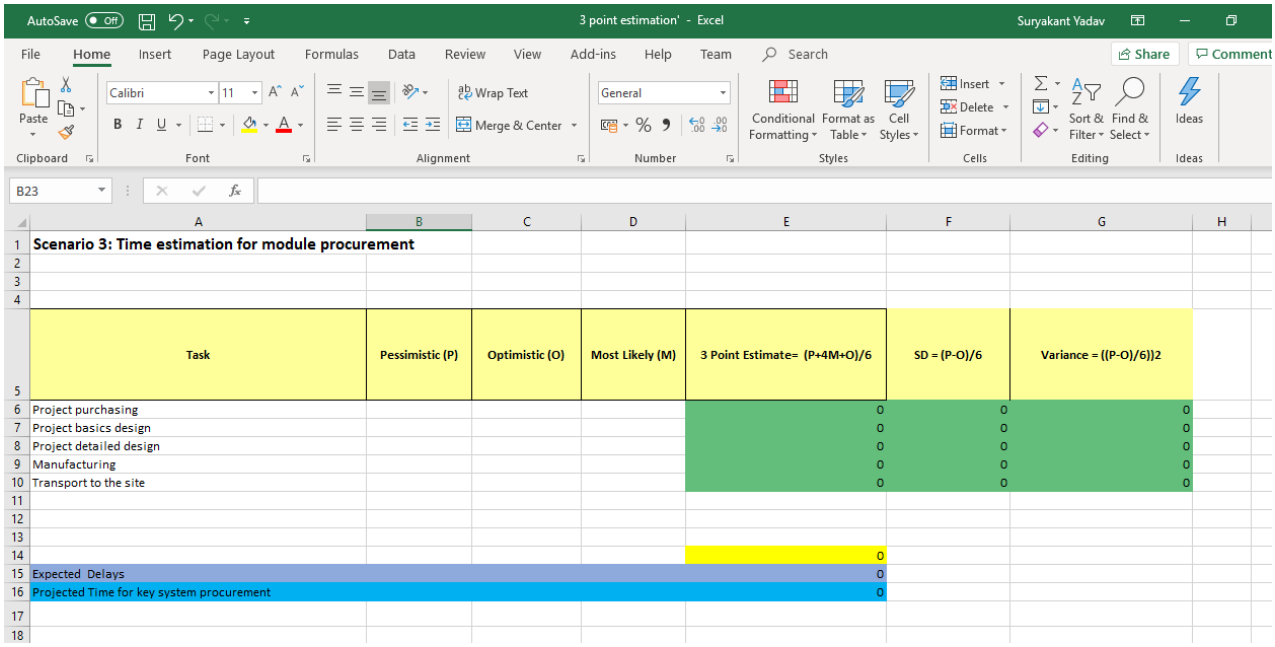
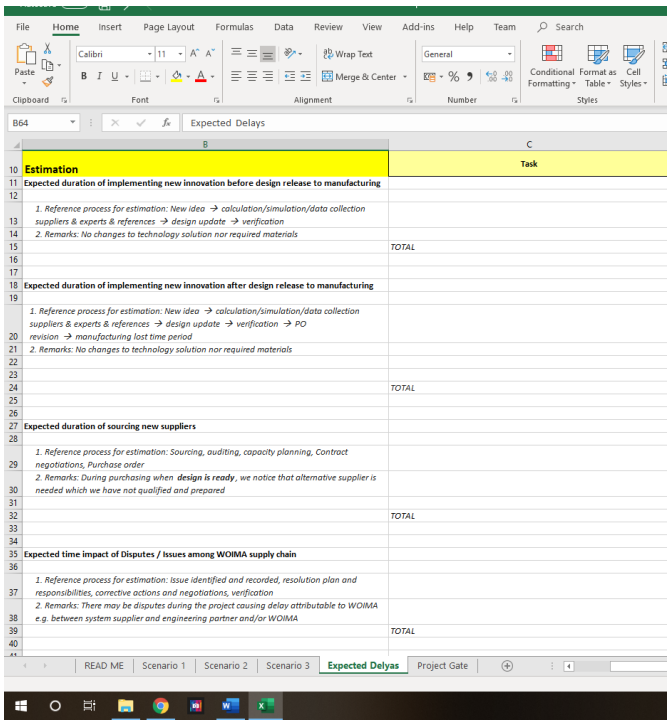
C34

Scenario 2: Time estimation for material procurement

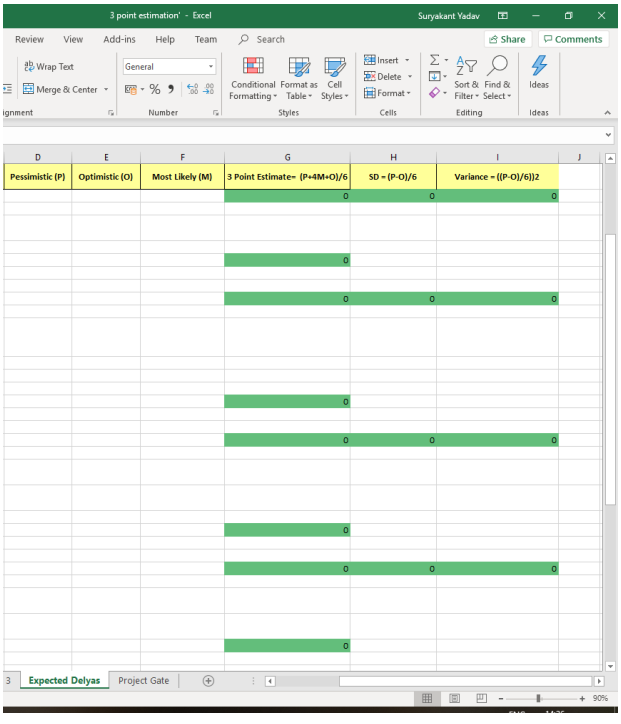
Task	Pessimistic (P)	Optimistic (O)	Most Likely (M)	3 Point Estimate= (P+4M+O)/6	SD = (P-O)/6	Variance = ((P-O)/6))2
Project basics design				0	0	0
Project detailed design				0	0	0
Project purchasing				0	0	0
materials manufactured to site				0	0	0
transportation				0	0	0
				0		
Expected Delays				0		
Projected Time for key system procurement				0		



	A	B	C	D	E	F	G	H
1	**Scenario 3: Time estimation for module procurement**							
2								
3								
4								
5	**Task**	**Pessimistic (P)**	**Optimistic (O)**	**Most Likely (M)**	**3 Point Estimate= (P+4M+O)/6**	**SD = (P-O)/6**	**Variance = ((P-O)/6))2**	
6	Project purchasing				0	0	0	
7	Project basics design				0	0	0	
8	Project detailed design				0	0	0	
9	Manufacturing				0	0	0	
10	Transport to the site				0	0	0	
11								
12								
13								
14					0			
15	Expected Delays				0			
16	Projected Time for key system procurement				0			
17								
18								

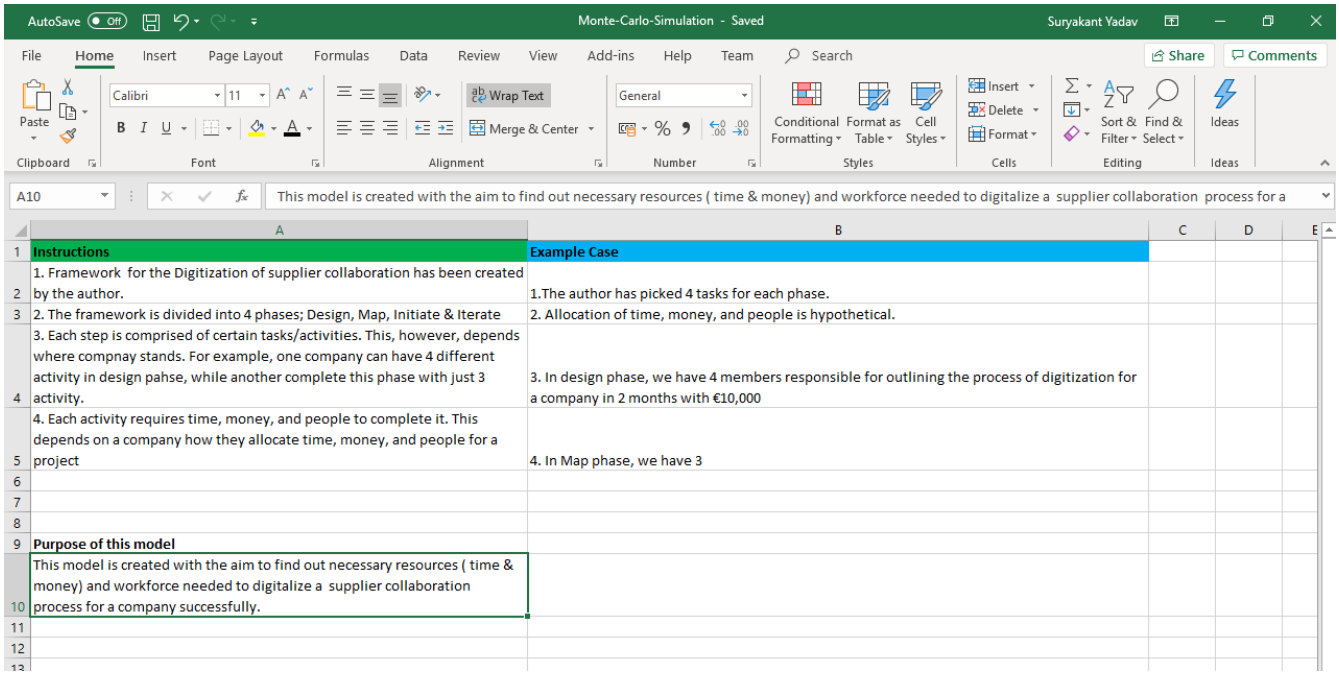


	B	C
10	**Estimation**	**Task**
11	**Expected duration of implementing new innovation before design release to manufacturing**	
12		
13	*1. Reference process for estimation: New idea → calculation/simulation/data collection*	
14	*2. Remarks: No changes to technology solution nor required materials*	
15		TOTAL
16		
17		
18	**Expected duration of implementing new innovation after design release to manufacturing**	
19		
20	*1. Reference process for estimation: New idea → calculation/simulation/data collection suppliers & experts & references → design update → verification → PO revision → manufacturing lost time period*	
21	*2. Remarks: No changes to technology solution nor required materials*	
22		
23		
24		TOTAL
25		
26		
27	**Expected duration of sourcing new suppliers**	
28		
29	*1. Reference process for estimation: Sourcing, auditing, capacity planning, Contract negotiations, Purchase order*	
30	*2. Remarks: During purchasing when **design is ready**, we notice that alternative supplier is needed which we have not qualified and prepared*	
31		
32		TOTAL
33		
34		
35	**Expected time impact of Disputes / Issues among WOIMA supply chain**	
36		
37	*1. Reference process for estimation: Issue identified and recorded, resolution plan and responsibilities, corrective actions and negotiations, verification*	
38	*2. Remarks: There may be disputes during the project causing delay attributable to WOIMA e.g. between system supplier and engineering partner and/or WOIMA*	
39		TOTAL
40		



D	E	F	G	H	I
Pessimistic (P)	**Optimistic (O)**	**Most Likely (M)**	**3 Point Estimate= (P+4M+O)/6**	**SD = (P-O)/6**	**Variance = ((P-O)/6))2**
			0	0	0
			0		
			0	0	0
			0		
			0	0	0
			0		
			0	0	0
			0		
			0	0	0
			0		

APPENDIX 3. Monte Carlo Simulation.



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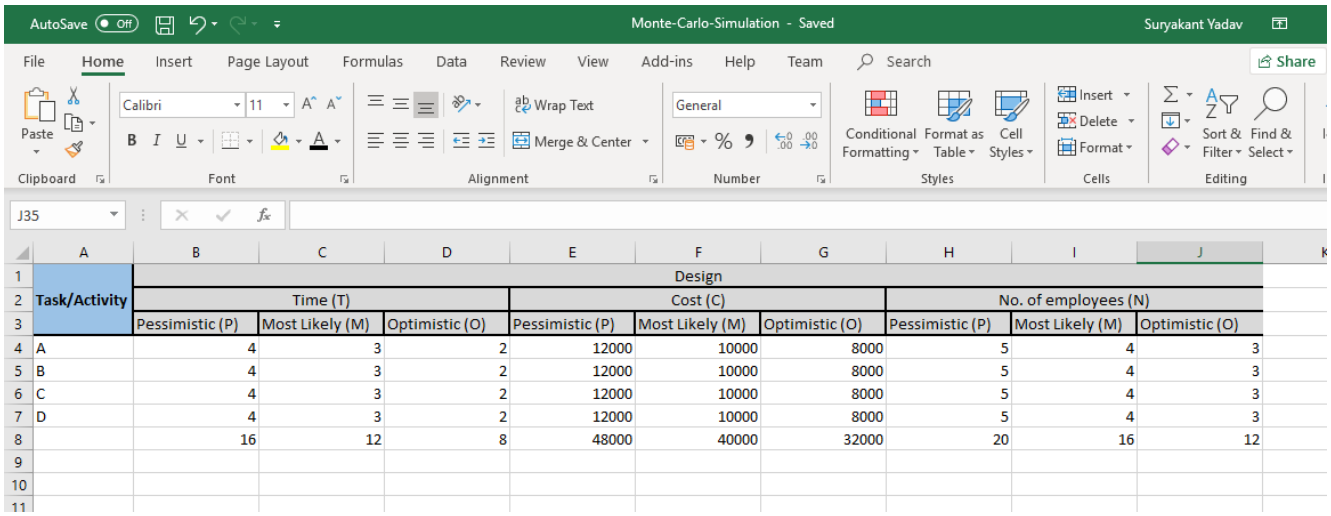
A10 — This model is created with the aim to find out necessary resources (time & money) and workforce needed to digitalize a supplier collaboration process for a

	A	B	C	D
1	**Instructions**	**Example Case**		
2	1. Framework for the Digitization of supplier collaboration has been created by the author.	1.The author has picked 4 tasks for each phase.		
3	2. The framework is divided into 4 phases; Design, Map, Initiate & Iterate	2. Allocation of time, money, and people is hypothetical.		
4	3. Each step is comprised of certain tasks/activities. This, however, depends where compnay stands. For example, one company can have 4 different activity in design pahse, while another complete this phase with just 3 activity.	3. In design phase, we have 4 members responsible for outlining the process of digitization for a company in 2 months with €10,000		
5	4. Each activity requires time, money, and people to complete it. This depends on a company how they allocate time, money, and people for a project	4. In Map phase, we have 3		
6				
7				
8				
9	**Purpose of this model**			
10	This model is created with the aim to find out necessary resources (time & money) and workforce needed to digitalize a supplier collaboration process for a company successfully.			
11				
12				



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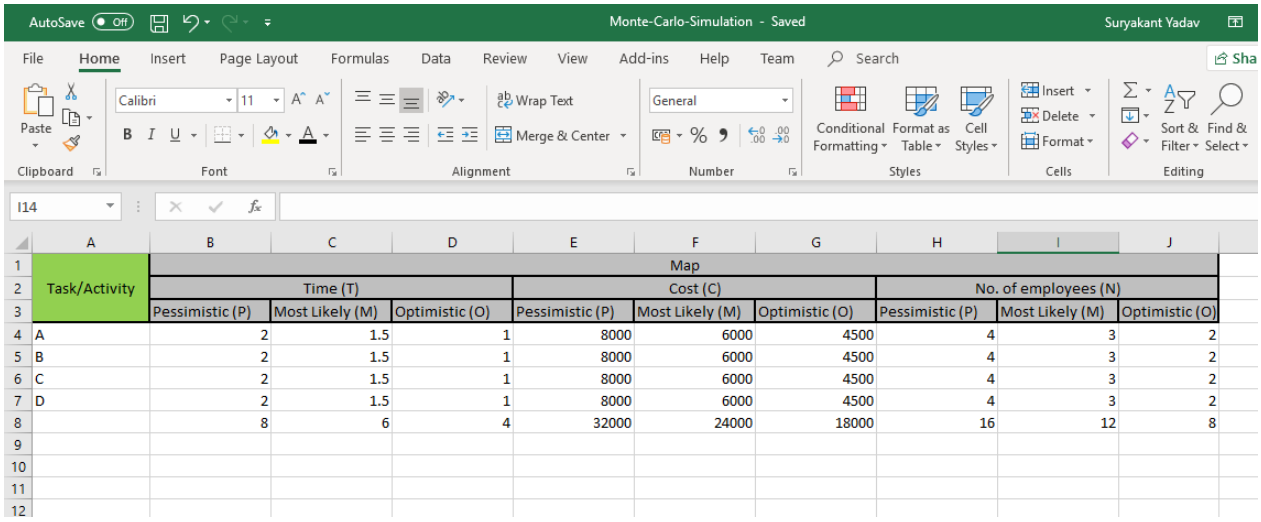
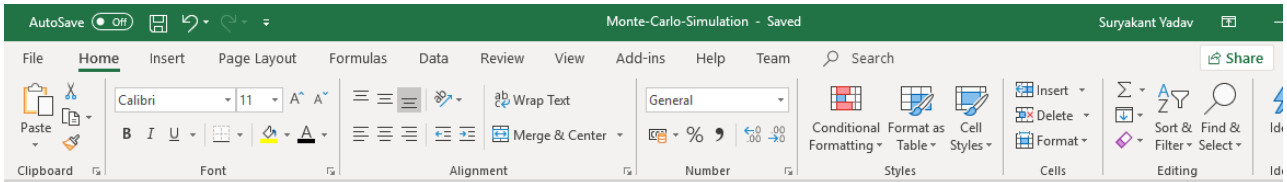
J35

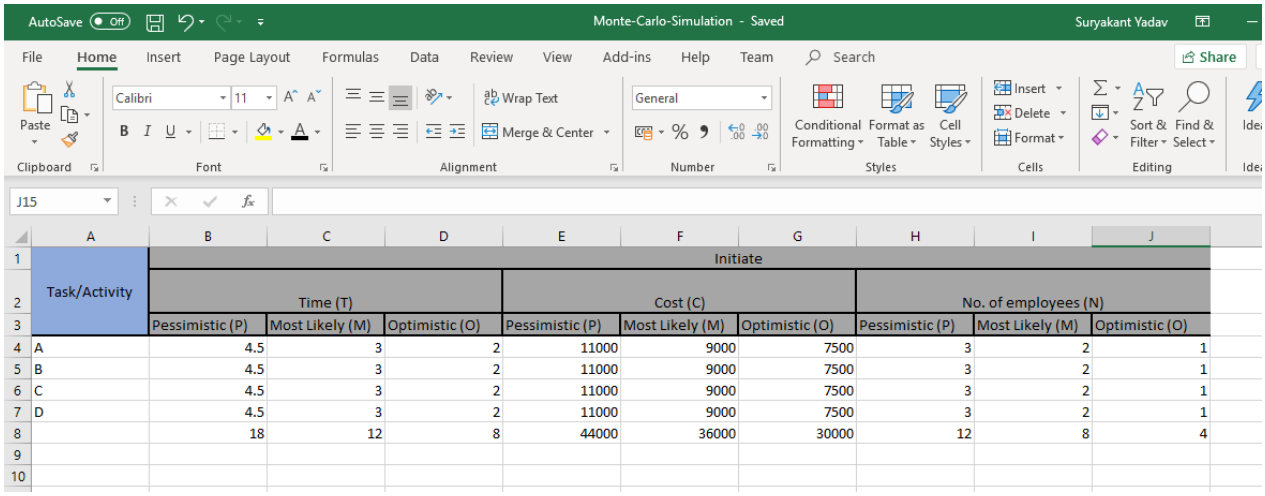
	A	B	C	D	E	F	G	H	I	J
1		Design								
2	**Task/Activity**	Time (T)			Cost (C)			No. of employees (N)		
3		Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)
4	A	4	3	2	12000	10000	8000	5	4	3
5	B	4	3	2	12000	10000	8000	5	4	3
6	C	4	3	2	12000	10000	8000	5	4	3
7	D	4	3	2	12000	10000	8000	5	4	3
8		16	12	8	48000	40000	32000	20	16	12
9										
10										
11										



	A	B	C	D	E	F	G	H	I	J
1		Map								
2	Task/Activity	Time (T)			Cost (C)			No. of employees (N)		
3		Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)
4	A	2	1.5	1	8000	6000	4500	4	3	2
5	B	2	1.5	1	8000	6000	4500	4	3	2
6	C	2	1.5	1	8000	6000	4500	4	3	2
7	D	2	1.5	1	8000	6000	4500	4	3	2
8		8	6	4	32000	24000	18000	16	12	8
9										
10										
11										
12										



	A	B	C	D	E	F	G	H	I	J
1		Initiate								
2	Task/Activity	Time (T)			Cost (C)			No. of employees (N)		
3		Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)
4	A	5.5	4	3	15000	12000	10000	3	2	1
5	B	5.5	4	3	15000	12000	10000	3	2	1
6	C	5.5	4	3	15000	12000	10000	3	2	1
7	D	5.5	4	3	15000	12000	10000	3	2	1
8		22	16	12	60000	48000	40000	12	8	4
9										
10										



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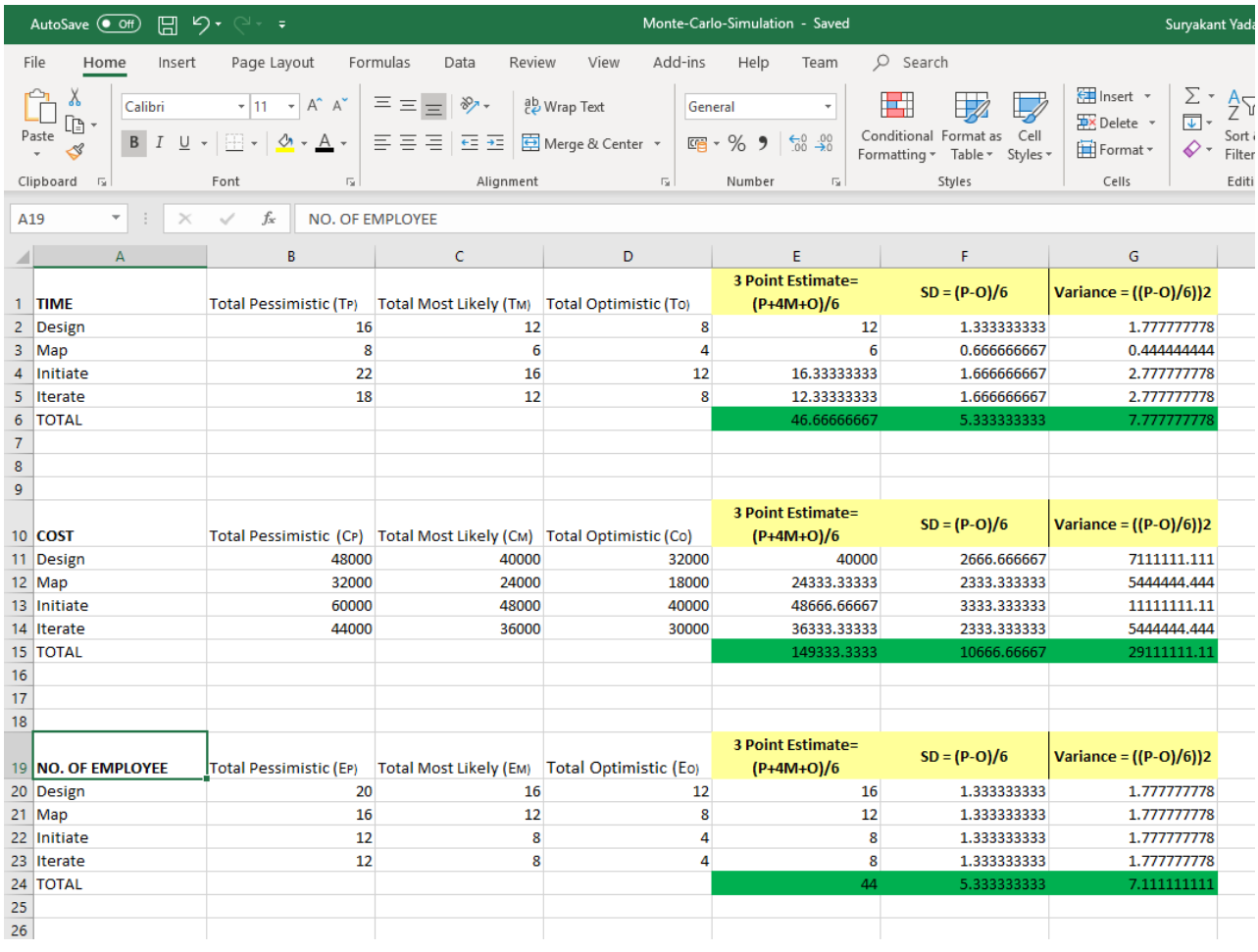
Paste | Calibri 11 | Wrap Text | General | Conditional Formatting | Format as Table | Cell Styles | Insert | Delete | Format | Sort & Filter | Find & Select

Clipboard | Font | Alignment | Number | Styles | Cells | Editing

J15

	A	B	C	D	E	F	G	H	I	J
1		Initiate								
2	Task/Activity	Time (T)			Cost (C)			No. of employees (N)		
3		Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Most Likely (M)	Optimistic (O)
4	A	4.5	3	2	11000	9000	7500	3	2	1
5	B	4.5	3	2	11000	9000	7500	3	2	1
6	C	4.5	3	2	11000	9000	7500	3	2	1
7	D	4.5	3	2	11000	9000	7500	3	2	1
8		18	12	8	44000	36000	30000	12	8	4
9										
10										



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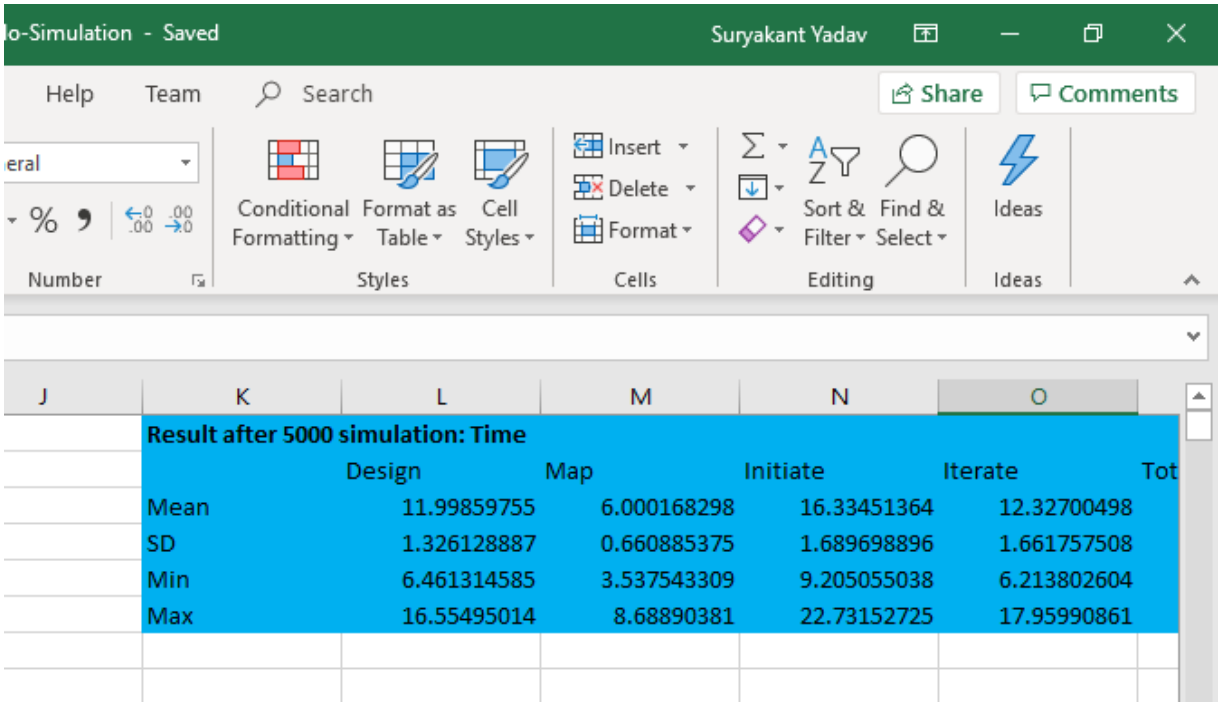
A19 NO. OF EMPLOYEE

	A	B	C	D	E	F	G
1	**TIME**	Total Pessimistic (T_P)	Total Most Likely (T_M)	Total Optimistic (T_O)	**3 Point Estimate= (P+4M+O)/6**	**SD = (P-O)/6**	**Variance = ((P-O)/6))2**
2	Design	16	12	8	12	1.333333333	1.777777778
3	Map	8	6	4	6	0.666666667	0.444444444
4	Initiate	22	16	12	16.33333333	1.666666667	2.777777778
5	Iterate	18	12	8	12.33333333	1.666666667	2.777777778
6	TOTAL				46.66666667	5.333333333	7.777777778
7							
8							
9							
10	**COST**	Total Pessimistic (C_P)	Total Most Likely (C_M)	Total Optimistic (C_O)	**3 Point Estimate= (P+4M+O)/6**	**SD = (P-O)/6**	**Variance = ((P-O)/6))2**
11	Design	48000	40000	32000	40000	2666.666667	7111111.111
12	Map	32000	24000	18000	24333.33333	2333.333333	5444444.444
13	Initiate	60000	48000	40000	48666.66667	3333.333333	11111111.11
14	Iterate	44000	36000	30000	36333.33333	2333.333333	5444444.444
15	TOTAL				149333.3333	10666.66667	29111111.11
16							
17							
18							
19	**NO. OF EMPLOYEE**	Total Pessimistic (E_P)	Total Most Likely (E_M)	Total Optimistic (E_O)	**3 Point Estimate= (P+4M+O)/6**	**SD = (P-O)/6**	**Variance = ((P-O)/6))2**
20	Design	20	16	12	16	1.333333333	1.777777778
21	Map	16	12	8	12	1.333333333	1.777777778
22	Initiate	12	8	4	8	1.333333333	1.777777778
23	Iterate	12	8	4	8	1.333333333	1.777777778
24	TOTAL				44	5.333333333	7.111111111
25							
26							



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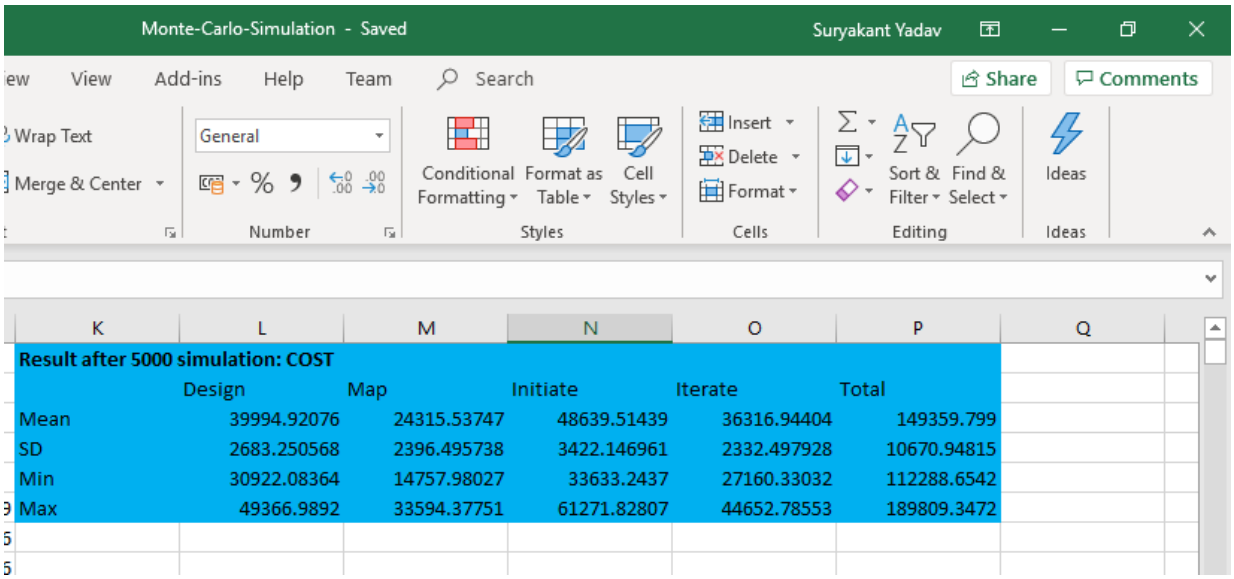
eral Conditional Formatting Format as Table Cell Styles Insert Delete Format Sort & Filter Find & Select Ideas

Number Styles Cells Editing Ideas

	J	K	L	M	N	O
		Result after 5000 simulation: Time				
			Design	Map	Initiate	Iterate	Tot
		Mean	11.99859755	6.000168298	16.33451364	12.32700498	
		SD	1.326128887	0.660885375	1.689698896	1.661757508	
		Min	6.461314585	3.537543309	9.205055038	6.213802604	
		Max	16.55495014	8.68890381	22.73152725	17.95990861	



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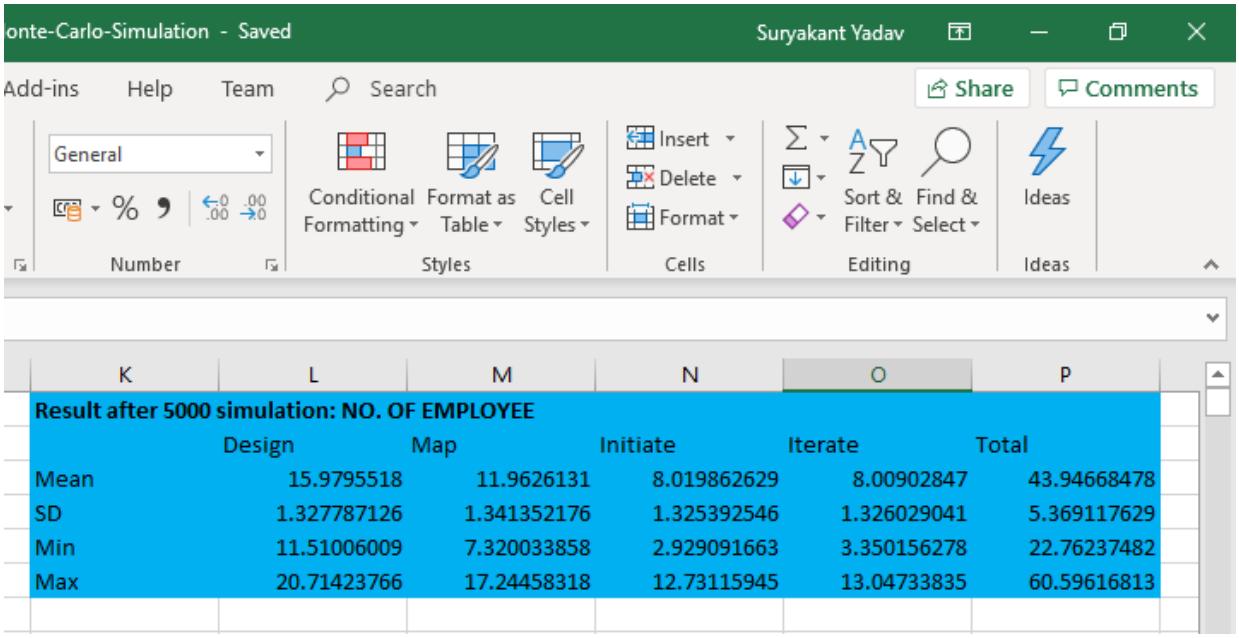
Wrap Text General Conditional Formatting Format as Table Cell Styles Insert Delete Format Sort & Filter Find & Select Ideas

Merge & Center Number Styles Cells Editing Ideas

	K	L	M	N	O	P	Q
	Result after 5000 simulation: COST						
		Design	Map	Initiate	Iterate	Total	
	Mean	39994.92076	24315.53747	48639.51439	36316.94404	149359.799	
	SD	2683.250568	2396.495738	3422.146961	2332.497928	10670.94815	
	Min	30922.08364	14757.98027	33633.2437	27160.33032	112288.6542	
9	Max	49366.9892	33594.37751	61271.82807	44652.78553	189809.3472	
5							
5							



	K	L	M	N	O	P
Result after 5000 simulation: NO. OF EMPLOYEE						
		Design	Map	Initiate	Iterate	Total
Mean		15.9795518	11.9626131	8.019862629	8.00902847	43.94668478
SD		1.327787126	1.341352176	1.325392546	1.326029041	5.369117629
Min		11.51006009	7.320033858	2.929091663	3.350156278	22.76237482
Max		20.71423766	17.24458318	12.73115945	13.04733835	60.59616813