Supply Chain Insider

Volume 07, Issue 01, 2022. 94-144
Article Received: 17-04-2022
Accepted: 28-08-2022
Available Online: 30-08--2022
ISSN: 2617-7420 (Print), 2617-7420 (Online)
www.supplychaininsider.org

A BAYESIAN BELIEF NETWORK STUDY ON BUSINESS PERFORMANCE FROM THE PERSPECTIVE OF DIFFERENT LEAN TOOLS

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Abstract

This study creates and employs a Bayesian Belief Network to demonstrate the monetary and non-effects of various permutations of lean approaches on the value of the companies (BBN) The Bayesian Belief Network is used to analyze the effects of nine small factors on three successful measures. The BBN is built on lean principles that encourage organizational responsiveness, effectiveness, quality, productivity, and time of operations, all of which would improve the supplier's sustainable, non-financial, and financial results. This study offers a fresh perspective on how Bayesian networks might be applied to business performance measurements that take into account both the tangible and intangible outcomes under shifting business situations.

Keywords: BAYESIAN NETWORK, BUSINESS PERFORMANCE, LEAN TOOLS

Chapter 01

INTRODUCTION

1.1 INTRODUCTION

A management strategy known as lean manufacturing focuses on eliminating waste while also ensuring efficiency. From architecture, and manufacturing to delivery, this technique can be extended to all facets of a business. Lean Production aims to reduce costs by making the organization more effective and sensitive to consumer demands. Efficiency is one of its specialties, with a focus on producing goods and services as quickly and cheaply as possible. A kind of production process without waste is a lean solution. Waste has seven sorts. These include waste from overproduction, ready-time waste, stock- and transportation-related waste, processing-related waste, motion-related waste, and waste from defective products. Lean is described as a holistic collection of techniques that together empower waste to be minimized and eliminated, making the business more versatile and sensitive to customers. Lean is regarded as a collection of methods for generating value for the client with little to no waste in the process. In fashion sectors that are assembly-oriented or have a high degree of routine human operations, Lean is most often used. There are usually sectors in which production is significantly impacted by the quality and attention to detail of persons who operate manually with instruments or operational equipment. Improved processes can remove large amounts of duplication or inefficiency for these types of businesses. In the clothing industry, by reducing process waste, motivating employees with better collaboration, increasing greater efficiency in the implementation process, and converting the company into a learning organization, the Lean Manufacturing model will eliminate operating costs in manufacturing. In Bangladesh's economy, the ready-made apparel (RMG) industry plays a pivotal role. Now Bangladesh is the second largest exporter country in the world after China.

The Bayesian Belief Network (BBN) offers a condensed form of a joint probability distribution and shows the causal probabilistic relationship between a group of random variables and their conditional dependencies. Additionally, it can be applied to a wide range of activities, including prediction, anomaly detection, diagnostics, automated insight, reasoning, time series prediction, and uncertain decision-making. Numerous fields use Bayesian networks. An illustration would be the diagnosis of diseases, enhanced web searches, spam filtering, gene regulatory networks, etc. Additionally, this list is expandable. These networks' main goal is to attempt to explain the structure of causal relationships. This study can help Bangladeshi businesses implement a novel idea: assessing business performance using based on the Bayesian network from the standpoint of lean tools.

1.2 THE OUTCOMES OF THE STUDY

The purpose of this research is as follows:

- To identify different lean tools that affect the business performance of an RMG organization
- To formulate the Bayesian Network model that predicts the performance of a Business Organization by incorporating different lean tools & techniques

1.3 THE METHODOLOGY OF THE RESEARCH

The methodology to achieve the objectives of this research would be as follows:

- ❑ Different variables related to lean tools were identified.
- ❑ The variables excluding the least important ones were selected as nodes in the Bayesian Network for our model.
- ❑ The states and links of the variables will be defined and the initial BBN will be formed.
- ❑ The initial networks will be modified using expert feedback.
- ❑ The interrelationship between different variables will be defined through the generation of a Conditional Probability Table.
- ❑ The BBN model was finalized with all the nodes, states, and links.
- ❑ Data for different states of the independent variables will be collected
- ❑ The Performance of the organization will be calculated using the BBN model.

- The model was validated using strategic planning.

1.4 ORGANIZATION OF THE STUDY

There are six chapters in the study, each containing a list of sources.

Chapter 1 is labeled as “Introduction” which describes the widespread production and process of Lean management. The Applications of the Bayesian Belief Network are also discussed. The objective of the research is outlined with some directions of research methodologies.

Chapter 2 provides Literature Reviews of Lean that include different usage of lean tools in previous research. The study related to BBN has also been described. In this chapter, the detailed review of the literature gives an idea of the background and gaps in this research area.

The Theoretical Background of Lean Management includes SMV, KAIZEN, PARETO ANALYSIS, PDCA, VSM, TAKT TIME, etc. discussed in Chapter 3 entitled "Theoretical Background". BBN is also focused on in this chapter.

Chapter 4 presents a detailed description of the Model Development. Dependency Map between lean tools, the performance criteria, and performance decisions are also illustrated in this section.

Chapter 5 shows how the model formulated in chapter 4 is implemented and introduced the solution techniques that can be applied to solve this model.

Chapter 6 lists the contributions of this research, and summarizes the conclusions which are followed by a list of references.

Chapter 02

LITERATURE REVIEW

2.1 STUDY RELATED TO LEAN MANAGEMENT

Kumar Dey & Taposh (2018) worked at Interstoff Apparels Limited, Gazipur, Bangladesh. They point out sewing flaws in a certain "knit T-shirt." Pareto analysis, Data from direct observation was collected. Using Pareto analysis, some major defects were observed. A rating was given for lean implementation using 5S. A suggestion for using PDCA was finalized. Some results from the suggestion and an outcome were made.(Rahman, Dey, Kapuria, & Tahiduzzaman, 2018) Rubayet & M L Rahman (2012) introduced a lean manufacturing system to the RMG sectors in Bangladesh. From the collecting data, they identified six types of waste overproduction, non-value-adding processing, waiting, defect excess motion, and unnecessary transportation. After that, using Pareto analysis they find out that man is most responsible for the most waste and mistakes among man, machines, materials, and other things. In addition, they find out that for shading problems 31% of the sewing defects happened. Then they have shown two cause and effect diagrams for "waste of time" and 'rejection of garments". At last, they gave some guidelines based on 5s.(Karim & Rahman, 2012) Ariful & Saima (2015) implemented Kaizen for workers' safety, workers satisfaction, and pride in work, which motivate them to work. The tools they used were TPM, 5S, Cause & effect diagram, and SMV. They used this cycle time to calculate SMV with a 10% allowance. The efficiency based on implementing KAIZEN was calculated. They also calculate their efficiency as Defects per Hundred (DHU). After implementing kaizen DHU reduced from 108 to 84.(Akter & Yasmin, 2017) Raid Al-Aomar (2012) concentrated on expanding the application of lean by introducing lean manufacturing in the sewing sector. The effects on the development of these approaches are evaluated and an enhanced future VSM state is produced. Results reveal a 96% reduction in manufacturing wastes and a 43% reduction in lead time.(Obeidat & Pei, 2012) Habob and Khalid (2018) analyze the temporal study of the textile industry in Sudan with an emphasis on all stages of garment production, from packaging to design (JIN, 5S, Quality assurance, Checklists). After implementing lean methods, they identified low-value tasks like pointless transportation and established the typical workday in two businesses. Comparison of the time difference between three workers' flow, piecing by sewing, finishing, pressing and packaging were measured.(Habob, Elgalib, Aa, & Elfaki, 2018) In 2013, Masudul & Rifat Khan focuses on identifying and reducing waste and improving productivity. They defined waste using value source mapping. The wastes found by VSM were rated using Pareto analysis. They discover that the value added time for Case-A is only 31 minutes, while the value-added time for Case-B is only 3.44 minutes and 18314.5 minutes for non-value added and unavoidable non-value added time. KANBAN was also utilized to reduce excess raw material inventory and waiting. They observed, after proposing a new approach, that the cumulative value added and inevitable non-value added period for Case-A and Case-B were just 821.34 min and 954.09 min, respectively.(Talukder, Afzal, Rahim, & Khan, 2013) In 2017, Afsana Haque & Saif researched continuous improvement. Using lean equipment, they reduced manufacturing cycle time by 8 percent, reduced the waiting time by an average of 35 percent, reduced the number of operators needed to manufacture equivalent amounts of clothing by 14 percent, reduced rework level by 80 percent, reduced transport time by about 20 percent, reduced production lead time to a substantial level, continued inventory work at a maximum of 100 pieces.(Haque, Jubair, Khan, & Saif, 2017)Mazedul & Monirul Islam (2013), Lean firms excel in providing customers with the best products at the lowest prices with both the shortest lead times. The Lean strategy can be summed up in five elements, according to James P. Womack and Daniel Jones' book "Lean Thinking." Delivering the highest-quality, lowest-cost products with the shortest lead time is a hallmark of lean businesses (Islam, Khan, & Islam, 2013). Lean production concepts have been adopted for twenty years, according to Deepika & Sivakumar (2019), and they have significantly impacted numerous manufacturing businesses. The idea of lean thinking was successfully adopted in medium-sized firms following its introduction in major companies belonging to the automotive industry. Considering comparative evidence and research on the economic effects of small firms, we can observe that they are numerous and contribute significantly to the total value created in the non-financial market economy. Investigate the implementation of the industry of lean construction practices and create a fair and relevant structure that provides six-letter scores for the simplest lean construction practices.(Sterlin, 2019) Pradeep & Arvinth, (2017) explains the decrease in lead-time for steering knuckles. Observing the new steering knuckle production system, the actual lead-time for processing one part simultaneously in CNC machines was measured and found to be 20 minutes in contrast to the 535 components each shift demanded by the customer, they currently produce 500 components per shift. A VSM is created to evaluate the value-added and non-value-added operations carried out on the current production floor. After that, a potential value stream map is created to create a lean process flow and boost efficiency through process improvements. (Kumar, Arvinth, Kannan, & Hussian, 2017) Mohamed Jouhri & Aziz Soulhi, (2019) stated the method of making denim is also incredibly inefficient. To increase consumer loyalty, leaders in this sector are seeking to shift that by using modern processes that significantly eliminate water and use fewer resources and chemicals. To minimize waste and to be eco-friendly, this lean thinking must be "green In this article, based on some studies carried out in one of the largest laundries in Morocco NEW WASH, they focused on policy and tools used in lean green management, on why and how they can mix lean and green in the denim production process. They were able to infer by Measuring Simulation and by other statistical findings that sustainability/quality/supply chain/cost efficiency can be enhanced in this critical industry by using lean and green tools.(Jouhri & Soulhi, 2019) Ma Ga (Mark), Paul & Sachin B. Modi (2010), checking internal and external validity is an important activity for scientific validation. Construction transparency, for this reason, is to calculate what needs to be measured. In this article, with the help of the required literature base, we have carefully described each construct in terms of critical characteristics. Performance has been a core goal of the industry since the conception of the assembly line and the subsequent growth of the Toyota Production System (TPS). A list of packages of lean activities includes JIT, complete quality management, total preventive maintenance, human resource management, pull, low configuration, managed procedures, efficient maintenance, and workers involved.(Yang, Hong, & Modi, 2011) Surabhi & Vinod (2017) has selected the pump manufacturing industry to integrate lean into their manufacturing process. The issues that occurred in the sector that influenced the production of the business were attributed to a rise in lead-time an unclassified inventory and an unorganized storage environment The Value Stream Mapping (VSM) technique, the selective inventory management approach for inventory classification, and the 5S to redesign the storage space were suggested as the most efficient approaches by the Lean area. These techniques were therefore used in the pump production facility to identify non-value-adding processes and reduce cycle times. (Vinod V.

Rampur & Surabhi Hathwar P.V., 2017) Hemadri, Samuel Raj & Ashok (2015), included the prompt delivery of goods to customers and the reduction of operational lead-time in such a battery manufacturing facility. This included mapping the company's processes and finding areas for change. The current State Map is intended to identify the status of the organization. To define sources of pollution, which are then discarded, the existing condition is analyzed. The potential state map is ready to display the places of change. Decreasing output lead-time and inventory ratios are the successes of valve stream visualization. The principles for modeling future state VSM are followed by this report. These guidelines consist of five factors that, without any expenditure, can easily be modified. They find that a result seen in future state maps will increase the amount of service and decrease WIP by at least 29.41 percent and 33.92 percent.(Hemadri Chadalavada, Samuel Raj D, Ashok Kumar R, & Sankar K, 2015) Mohan & Siva (2015), Research on the reduction of front and rear bumper power and the main concerns. Due to some issues such as cracks, paint chips off and minor losses, their project analysis relies on the decrease of bumpers. Different issues with bumpers are the reduction of bumpers due to the control of the paint chip in different areas of the bumpers. During material processing, the reduction in bumpers due to scratches in different areas of the bumpers must be managed. During the material handling and installation process, the reduction of bumpers due to slight damage incurred by component bending and shape changes must be managed. Overlapping of the paint on different parts of the bumpers to be monitored.(Prasad, Mydeen, Kumar, & Thayumanavar, 2015) Zakaria & Mohamed (2017) identified tilt production as the most convenient way to eliminate needless waste from manufacturing and deliver what customers require. He adopted lean manufacturing to reduce automated assembly line waste.(Zakaria, Mohd, Nik, Fadzil, & Ab, 2017) Ahmed and Ahmad researched the lamp manufacturing process in 2011 and used the Pareto analysis and cause impact diagram to minimize defects. Their goal was to target zero errors with zero damage and zero waste.(Application & Analysis, 2012) In their article, Joshi and Jugulkar summarized that the approach causing the impact diagram is easy to understand the causes of output defects. It meets any feasible key therapies at first and then eliminates the defects as much as possible.(Joshi & Jugulkar, 2014)Meyers and Stewert found that it is important to plan the development environments using 5S. Subsequently, the most suitable tools are used to work out the key problems for you to build a lifestyle of non-stop change. The goal of the 5S approach is to retain working places in excellent condition through their garage, organization, and cleanliness. 5S utility in an employer usually offers the following blessing offices to emerge as more effective, clean, coordinated, evolving job situations and workforce values; employee versatility, protection, and motivation; embodying everyday sports with the assistance of staff; discounting disaster-related casualties and breaks; minimizing fees, unproductive time, region and events.(Meyers & Stewart, 2015) With the help of the trigger impact diagram, Juriani (2015) proposed multiple causes and remedial steps in his publication. To eliminate casting defects in foundries, his thesis was particularly useful. To analyze the stoppage losses in a textile factory in Bangladesh, Pareto analysis and cause impact diagram (CED) was applied. The cause impact diagram for idling and minor stoppage, and breakdown losses were analyzed and drawn and a Pareto analysis was also carried out where the main stoppage losses were found to be idling and minor stoppages, breakdown, lack of yield, decreased speed, etc. They also provided the factory with several ideas to mitigate this failure. Pareto analysis, which allows one to find the faults and effects, which should be the key causes, is an effective lean method, close to the trigger effect diagram.(Juriani, 2015) In a garment factory in India, SAMUEL (2014) used TPM as a primary lean instrument to tackle these problems. For the case study, where 5 separate sewing machines were chosen for TPM implementation, they picked the T-Shirt output layout. Before and after the TPM implantation, the output quality levels of the sewing machines were studied. They discovered that the lead time improvement brought on by the adoption of TPM on sewing machines as well as the interaction impact with the kaizen tool is also evident, with performance improvements ranging from 15% to 30% in terms of product lead time change.(Senthilkumar & Thavaraj, 2014) Alimran & Saiful (2018) by applying numerous statistical methods to research the quality assurance method of a chosen garment factory. For data processing purposes, they used the ANOVA test and an experimental sample test. Via a regression study on average DHU percent, they find that the industry's quality assurance framework is in a stronger place and it is thoroughly recommended for further growth to incorporate the TQM theory.(Hossain, Islam, Islam, & Islam, 2018) Among the probing money and lean foundations for all the businesses surveyed, there is a fine dating. In the Gaza Strip, Lean Creation has been used. This has shortened the steps in the process. With the aid of 57 percent, the full mission was cut. The research was conducted in different nations and found that lean manufacturing has a significant impact on value efficiency.(Talla, Abu-naser, Amuna, & Shobaki, 2017) The Canadian root cause analysis system summarizes that this root cause analysis is the most critical factor for understanding production defects. They attempted to fix the case by reviewing and describing the issue and knowledge void.(Doggett, 2014) In their post, Fawaz & Rajgopal (2007) pointed out that VSM is a technique based on paper and pencil. The precision level is therefore small, and the number of variants that can be treated is poor. A large number of enterprises are "high type of variety-low volume" businesses. This required a variety of value sources, and a single VSM cannot adequately describe them. They proposed an alternative and ground-breaking framework for the standardized application of VSM to commodities involving non-linear value streams based on a preliminary analysis to define the longer critical development path utilizing the Temporary Bill of Content. After designing the primary path, potential improvements were considered, and all sharing with secondary paths was viewed as additional development. The study thus continued iteratively before the maximum was attained or the frequency of the WIP decreased below the decreased level.(Abdulmalek & Rajgopal, 2007) Nitin & Durgesh (2017) aims to recognize crucial challenges in the adoption in the United Arab Emirates of the Lean Manufacturing Framework (LMS). They address the different results predicted from the efficient implementation of LMS.(Upadhye & Sharma, 2017)

2.2 STUDY RELATED TO LEAN TOOLS AFFECTING BUSINESS PERFORMANCE

The variables identified in this literature review are listed in Table 2.1 for the convenience of the readers.

Table 2.1: Tools selection chart from paper reviews:

Tools form the paper review	Mostly used in Bangladesh	Used in mass production	Selected tools
5S	Value Stream Mapping	Takt Time	Value Stream Mapping
Standard Minute Value	Bottleneck Analysis		
Continuous Flow	Takt Time	Continuous flow	
Pareto Chart	Standardized Work	Fishbone process	Fishbone process

Heijunka (Level Scheduling)	Continuous Flow		
Kaizen	PDCA (Plan, Do Check, Act)	Standard Minute Value	
Kanban (Pull System)			Takt Time
Takt Time	Overall Equipment Effectiveness (OEE)	Standardized work	Continuous Flow
Value Stream Mapping		Kaizen	
Fishbone process	Standard Minute Value		PDCA (Plan, Do Check, Act)
		5S	

2.3 PROPOSED METHODOLOGY

The Bayesian Network has been used to evaluate the organizational variables that affect risk. In dynamic questions, Bayesian Belief Networks are preferred over other intelligence approaches. Nearly all sectors such as shipping, international investment, logistics, human-machine engagement, technology roadmap, and electricity have generally acknowledged the various applications of Bayesian Confidence Networks for the development of decision support scenarios. In systematic reviews in the field of data mining, Bayesian networks have also been employed in scenario analysis and decision making, according to Büyüközkan and Kayakutlu's study paper. Since it is an artificial intelligence tool, Bayesian network scenarios are employed in this domain to model how social capital or agents operate in behavioral analysis. In addition to the mathematical and graphical representation of conditional dependencies, the use of Bayesian methods has several advantages, including the capacity to dynamically update the model with new information. Bayesian networks are directed acyclic graphs where the nodes are variables of random interest and the edges are informative or causally dependent variables. (Networks, 2015) Garvey et al. (2015) created a BN model that simulates graph theory to evaluate the spread of supply network risk. When a significant amount of historical data is available for creating the linkages between the parameters, it would be appropriate. Additionally, the model works well for a limited set of nodes with binary states, requiring less computing work. In 2020, Paul, Kabir, Ali, and Zhang.

2.4 RESEARCH GAP

After studying previous research papers, it has been identified that there is yet to explore more regarding BBN that predicts the performance of a Business Organization incorporating different lean tools & techniques. The first shortcoming identified in previous works of literature was the lack of presence of all categories of variables in the model. Rarely, too, was the integration of the combined effects of these variables noted. BBN, however, has trouble dealing with a large number of nodes. Therefore, designing the model would entail dimensionality reductions. However, very few studies have addressed recommendations for such modeling. This study attempted to resolve all these problems and proposed likely solutions for them. Finally, business performance has been correlated with various variables in the sense of implementing lean tools.

Chapter 03

Theoretical Background

3.1 Lean Tool

A method known as lean manufacturing focuses on reducing waste in production processes while also increasing productivity. The foundation of lean development is a range of fundamental principles, including Kaizen, or continuous improvement, Kanban, overall quality control, the PDCA cycle, cycle length, Heijunka, etc.

3.1.1 Standard Minute Value: Standard Time, often known as the "Standard Minute Value" or "SMV," is the amount of time required for a skilled person to complete a task at "Standard Performance." Additional Relaxation, System Delay, and Planned Contingencies allowances are provided by the SMV. The SMV is the fundamental time computation, and its precision and accuracy are crucial because they serve as the foundation for key business operations like output targets, line balance, production planning, incentive programs, and the measurement of operator output and factory productivity.

3.1.2 Kaizen: "Continuous improvement" or "change for the better" are the meanings of the Japanese word "kaizen." All employees participate in processes that continuously grow operations according to a Japanese corporate ideology. Kaizen experiences a boost in production since it is a gradual and deliberate process. The kaizen principle has been included in a wide range of theories. It entails improving work conditions by fostering a sense of community, strengthening daily operations, sustaining employee satisfaction, and making jobs more fulfilling, less taxing, and safer.

3.1.3 Value Stream Mapping: A lean processing technique known as value stream mapping (VSM) is used to evaluate, organize, and manage the information and material flow necessary to provide a product to a client. To represent multiple labor sources and information flows, it uses a set of common symbols. Objects are mapped to either add value or not add value from the user's perspective in order to remove items that do not add value. When repetitive steps are possible and multiple handoffs are accessible, value stream mapping can be utilized to optimize any process. Because they typically involve the transfer of a tangible item between stations, handoffs are simpler to picture in production.

3.1.4 Fish Bone Process: A fish bone process is a methodical approach for identifying and responding to the "root causes" of issues or incidents. The core tenet of the fishbone process is that good management requires more than just "putting out fires," but also finding a means to prevent them. Organizations can use the fishbone approach to avoid the temptation to describe just one aspect to find the fastest solution (but normally incomplete). It also helps to cease dealing with the symptoms that cause crises or incidents rather than the true, underlying problems. There is an implication that a technique is utilized in the study even though the term "fishbone process" is used in a general sense.

3.1.5 Continuous Flow: Continuous flow is a lean strategy that helps one to transfer a single object across any step of our process rather than sorting job objects into batches. It means constantly working, moving, or producing the output of each item, from raw material to finished product. This process is called the method because it helps one to consistently send items to the market. This gives us the chance to bring service to our consumers more often.

3.1.6 Pareto Analysis: A decision-making process called Pareto analysis is based on the 80/20 rule, which states that 80% of a project's benefits should be attained by completing 20% of the work or that 20% of the company's sources should be responsible for 80% of the dilemma. This method of decision-making accurately identifies the few input variables that have the greatest influence on the outcome, whether it be positive or negative. The Pareto analysis is valid in diverse areas, from economics to quality control.

3.1.7 PDCA Cycle: The plan-do-check-act loop is a four-step model for progress to be completed. Much like a circle has no limit, for continual enhancement, the PDCA loop should be replicated repeatedly.

3.1.8 Takt Time: Takt time is the length of time it takes a producer to produce each unit to meet the demand from customers. Takt time is a crucial tool for ensuring that materials move as efficiently as possible through each station in a lean production line.

3.1.9 Process flow improvement: Improving current procedures to achieve new priorities and targets on the factory floor. Improvement of processes reveals the effects, such as moving to improve efficiency and reducing costs.

3.2 Bayesian Belief Network

Using a Directed Acyclic Graph(DAG) to express conditional dependencies between random variables, a Bayesian Belief Network or Bayesian Network or Belief Network is referred to as a Probabilistic Graphical Model (PGM) Probabilistic models can describe variables' relationships and be used to measure probabilities.

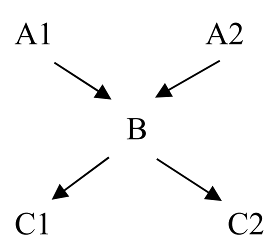

Fig 3.1: Example of Probabilistic Graphical Model

It is a Probabilistic Graphical Model. Here “A1” and “A2” are the parent node of “B” & “B” is the parent node of “C1” and “C2”. The probabilities are calculated in the belief networks by the following formula

$$\mathbf{P}(X_1, X_{2\ldots,}\ X_n) = \prod \mathbf{P}\ (X_i \mid pa\ (X_i)\ \text{[here i=1….n]… (i)}$$

In the case of joint probability, the joint probability for occurrences A and B is determined by multiplying the likelihood of event A by the probability of event B.

This can be stated formally as follows:

P (A and B) = P (A given B) * P (B)… (ii)

Conditional models may require enormous amounts of data to account for all possible outcomes, and it may be impossible to accurately calculate probabilities in practice. Though it is a drastic simplification, simplifying assumptions can be effective, as in the case of Naive Bayes, where they include the conditional independence of all random variables. An alternative is to create a model that maintains conditional independence and known conditional dependence between random variables in all other circumstances. The recognized conditional reliance in a graph model with steered edges is specifically captured by Bayesian networks, a graphical probabilistic model. All missed relations are described by the conditional independencies in the model. As a result, Bayesian Networks provide a practical way to visualize a domain's probabilistic model, examine all interactions between random variables, and describe causal probabilities for scenarios supported by the available data.

Chapter 04

MODEL DEVELOPMENT

4.1 PROBLEM STATEMENT AND METHODOLOGY

Business Performance is affected by the operation of the Lean tool. Therefore, BBN has been used in this study to measure business performance. With the help of the Bayesian Belief Network (BBN), it has been shown that there is a causal probabilistic relationship between several random variables, as well as their conditional dependencies, and it is given a concise description of a joint probability distribution. Multiple sections of this section will lay out how Bayesian Belief Networks can be used to judge how well lean variables function. Bayesian networks are suitable for taking on an incident that has happened and estimating the possibility that the causal factor was any of many potential known triggers.

4.2 IDENTIFICATION OF LEAN TOOLS AFFECTING BUSINESS PERFORMANCE

Nine lean variables were chosen from the standpoint of some garments produced in Bangladesh after a thorough review of the literature on numerous lean manufacturing tools. Value Stream Mapping is being controlled by both takt time and Standard Minute Value (SMV) since VSM quantifies the time and value taken at each stage of the process. Hence it is the child node whereas Takt Time and SMV are the parent nodes. Similarly, KAIZEN and Continuous flow highly affect the process flow improvement therefore, Kaizen and continuous flow are the parent nodes of Process flow improvement. Pareto chart and Fishbone process respectively identifies quality result and the root cause of a problem which help PDCA to manage. Thus PDCA is the child node of the Pareto chart, Fishbone process, and Kaizen.

These nine lean techniques were selected from different research papers and expert opinions, as explained below:

- Node 1 (Standard Minute Value): Used frequently in the fashion sector. It is the time taken to complete a specified task by a skilled worker employed at "Standard Performance".(Talukder et al., 2013)
- Node 2 (Takt time): It corresponds to the amount of time per unit for a producer to produce enough products to satisfy consumer demand. Frequently used in readymade garments of Bangladesh for increasing productivity. (Mahendran, 2016)

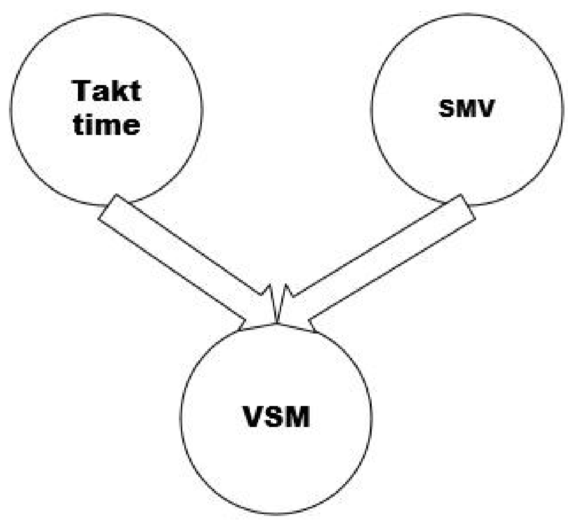

Fig 4.1: Sub-model 01

- Node 6 (Value stream mapping): Value stream mapping is a very helpful tool used to identify waste in the whole value stream. The actual time, waiting time, and cycle time from SMV affect VSM. Takt time results in demand/ inventory which shows the difference between the current state map and the future state map. Hence it is the child node of Takt Time and Single Minute Value (SMV) (Talukder et al., 2013)

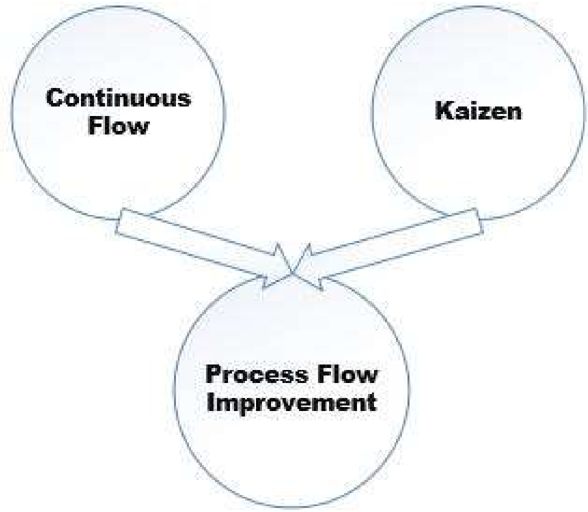

Fig 4.2: Sub-model 02

- Node 3 (Continuous flow): Uses for producing a large number of products. In Bangladesh, readymade garments use this tool to increase their batch production performance.(Syduzzaman, Rahman, Islam, Habib, & Ahmed, 2014)
- Node 4 (Kaizen): It is a Japanese phrase used to cut down on waste and stages that don't add value to speed up the flow of activities. We adopted this lean tool after consulting experts.

- Node 7 (Process flow improvement): To maximize performance, adhere to best practice guidelines, or simply improve quality and the user experience for clients and end users, process flow improvement is the business practice of identifying, assessing, and enhancing current business processes. (Singh, Singh, Chokshi, Chavan, & Dabhi, 2015) KAIZEN is a continuous improvement process that aims for productivity, effectiveness, safety, and waste reduction that upgrades process flow improvement and Continuous flow involves moving one work unit at a time. Therefore, Kaizen and Continuous flow are the parent nodes of Process flow improvement.

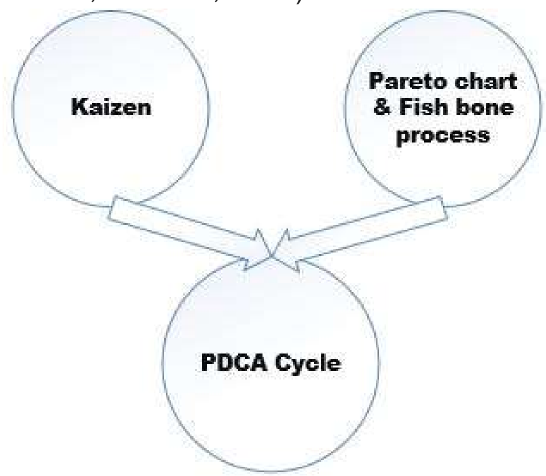

Fig 4.3: Sub-model 03

- Node 5 (Pareto chart): This lean tool displays quality outcomes by ranking faults from most severe to least severe. It is currently widely used in the business that makes clothes. (Talukder et al., 2013)
- Node 5 (Fishbone process): Also referred to as an "Ishikawa diagram," which identifies the fundamental reasons for an issue or malfunction. (Talukder et al., 2013)
- Node 8 (PDCA cycle): An iterative four-step management methodology used for the monitoring and quality development of operations and goods of the industry. (Akter & Yasmin, 2017) Pareto chart analyzes major and minor problems of the process. The Fishbone process identifies the root cause of a problem. PDCA depends on both of the tools. Hence, it is the child node in the study.

4.3 DEPENDENCY MAP CONSTRUCTION

Performance factors of the model are calculated as productivity, responsiveness, effectiveness, quality, and timely review of the literature of success indicators for the lean variables. The three important measures of sustainability, non-financial success, and financial performance that evaluation studies often look at were chosen as our Bayes Map's decision nodes. A supply chain management from the sector is asked to assess the connections between the five performance criteria, three performance decisions, and the nine lean criteria. They are required to complete two charts that link the performance decisions, performance criteria, and tools. The relation-based arrow between every node has been drawn.

They used two types of signs:

- If the relation between the nodes is strong then they used the “right” sign ✓
- In addition, if they find weak relation between the nodes they used the "cross" sign ✗

4.3.1 Dependency map 01

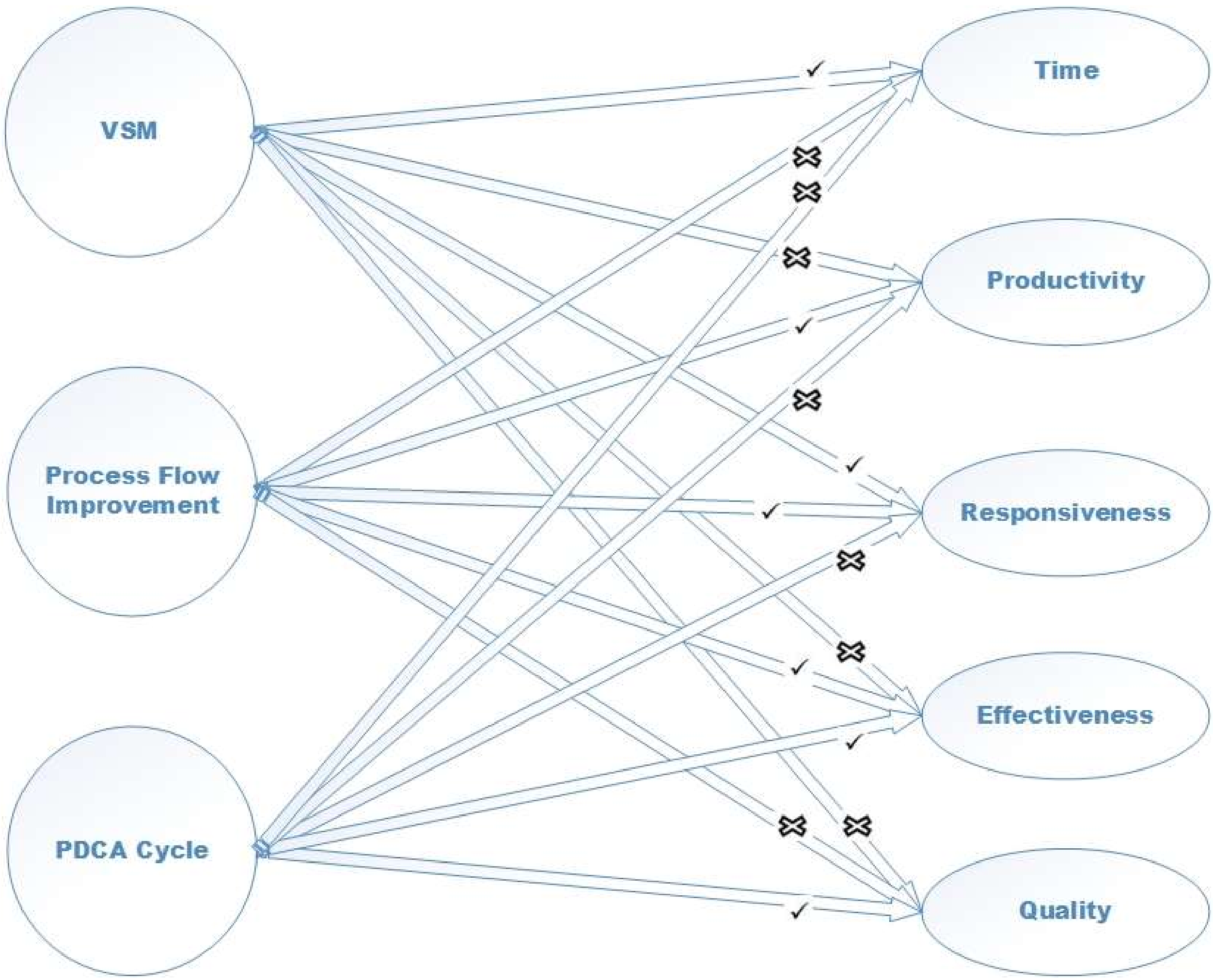

Fig 4.4: Dependency map between the lean tools and performance

From the first dependency map between the selected lean tools and performance criteria, we find that time is dependent on VSM. Besides, there are certain factors like productivity and process flow improvement, which are dependent on each other. In addition, responsiveness is individually dependent on VSM and process flow improvement. Moreover, effectiveness is dependent on process flow improvement and the PDCA cycle, and quality is dependent on the PDCA cycle.

4.3.2 Dependency map 02

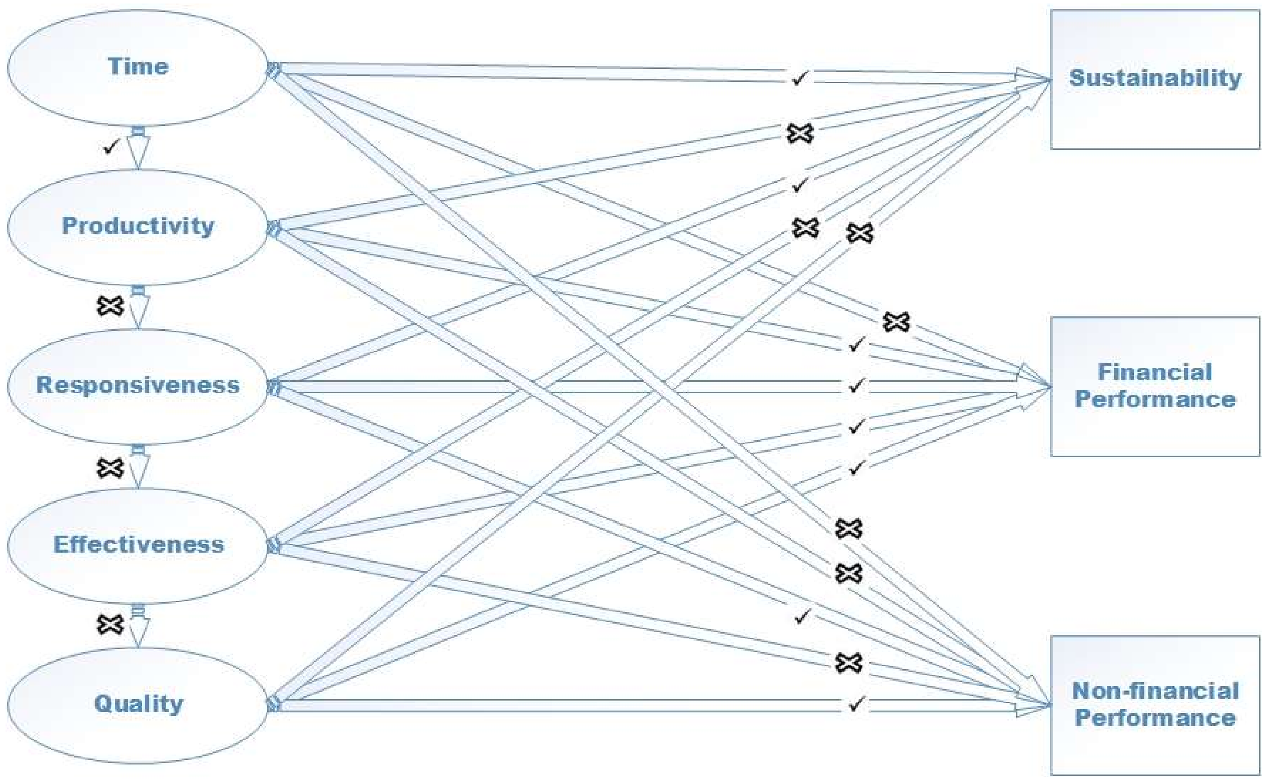

Fig 4.5: Dependency map between the performance criteria and performance decisions

From the second dependency map between the performance criteria and performance decisions, it has been identified that sustainability is dependent on time and responsiveness. Besides that, financial performance is dependent on productivity, responsiveness, effectiveness, and quality. In addition, non-financial performance is also dependent on responsiveness and quality. Moreover, time and productivity are related to each other.

4.4 CONSTRUCTION OF BAYESIAN MAP

The dependency maps are generalized to create a Bayesian Map based on relationships. In order to eliminate or combine the demands, the supply chain administrator from the sector who reacted to the relationships looked at the combined data and made the following adjustments. Here Fish bone process and the Pareto chart have been taken as a combined factor.

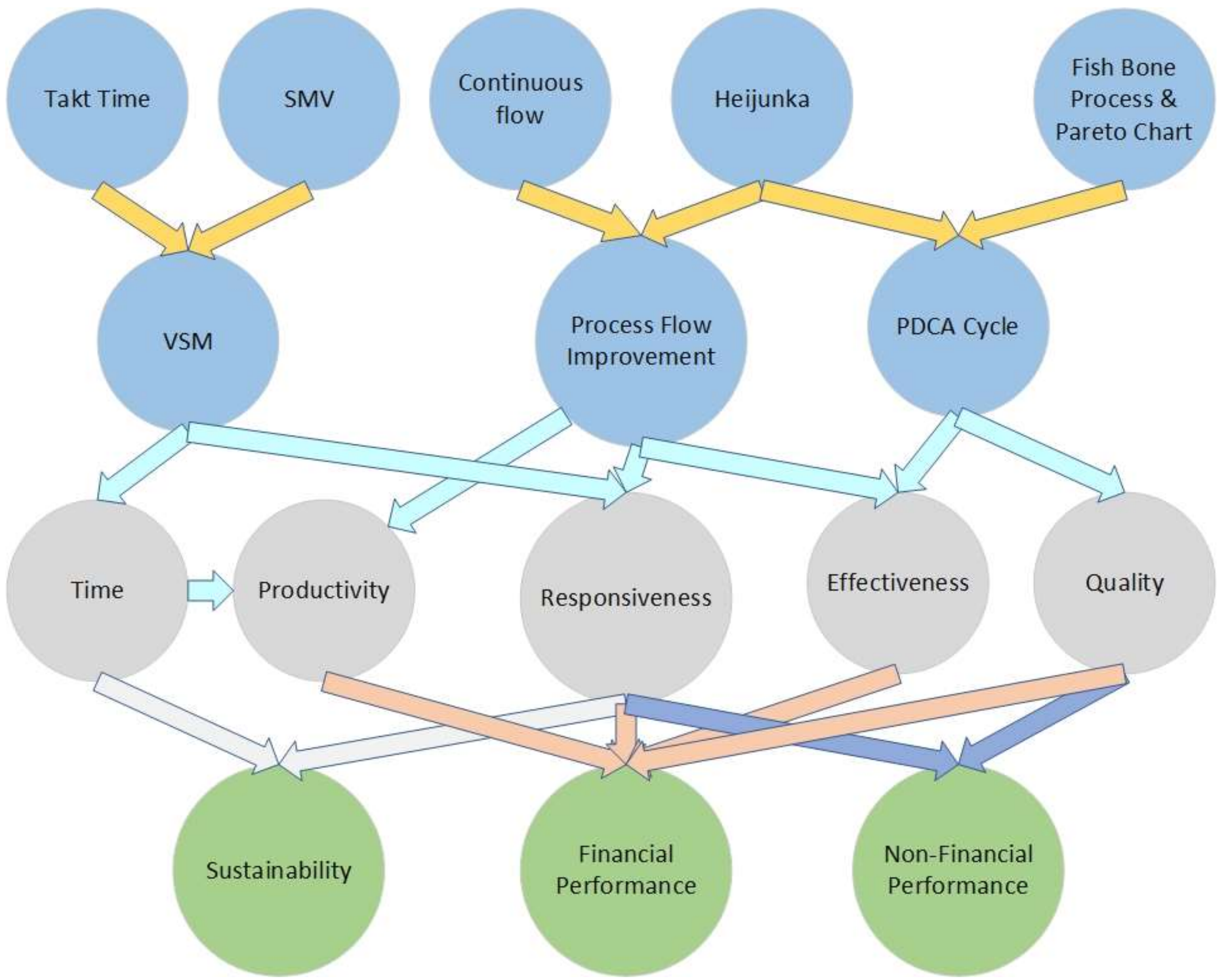

Fig 4.6: Proposed Bayesian Model

Chapter 05

MODEL IMPLEMENTATION

5.1 GENERATING VALUES OF THE PARENT NODES USING THE AHP METHOD

Due to data availability issues and concerns for confidentiality, the prior probabilities of the parent nodes are constructed using the AHP approach. A systematic approach for arranging and evaluating complex judgments, based on mathematics and psychology, is the analytic hierarchy process (AHP). It is an accurate methodology for evaluating the weight of decision factors. The interactions of individual professionals are used by pair-wise analyses to measure the relative magnitudes of variables. For finding the probabilities using the AHP method, a discussion has been organized with three decision makers (DMs). With the help of them, the probabilities of the independent nodes or parent nodes find out.

Table 5.1: Comparison matrix for Takt time:

Takt time	Low	High	column/sum	column/sum	Criteria weights
Low	1.00	2	0.66667	0.66667	0.67
High	1/2	1.00	0.33333	0.33333	0.33
Sum	1.50	3.00			

Table 5.2: Comparison matrix for SMV:

SMV	Low	High	column/sum	column/sum	Criteria weights

Low	1.00	0.80	0.44444	0.44444	0.44
High	1.25	1.00	0.55556	0.55556	0.56
Sum	2.25	1.80			

Table 5.3: Comparison matrix for Continuous improvement:

Continuous improvement	Low	High	column/sum	column/sum	Criteria weights
Low	1.00	0.43	0.30000	0.30000	0.30
High	2.33	1.00	0.70000	0.70000	0.70
Sum	3.33	1.43			

Table 5.4: Comparison matrix for Kaizen:

Parent node	Low	High	column/sum	column/sum	Criteria weights
Low	1.00	0.57	0.36364	0.36364	0.36
High	1.75	1.00	0.63636	0.63636	0.64
Sum	2.75	1.57			

Table 5.5: Comparison matrix for Fishbone process and Pareto chart:

Fishbone process & Pareto chart	Low	High	column/sum	column/sum	Criteria weights
Low	1.00	0.71	0.41667	0.41667	0.42
High	1.40	1.00	0.58333	0.58333	0.58
Sum	2.40	1.71			

5.2 GENERATION OF CONDITIONAL PROBABILITIES CONSIDERING EXPERT'S CREDIBILITY

After determining the values of parent nodes, the probabilities of the child nodes were calculated. For this, the tools were divided between two parameters. For high-performance rating, "high" is used as a parameter and for low-performance rating, "low" is used as a parameter. It also finds out the credibility factor of the three decision-makers according to their experience level $E_k \in [0, 10]$ and confidence level $C_k \in [0, 10]$. This method is collected from (paper reference). The equation that has been followed for finding the credibility factor (W_k) is:

$$W_k = \frac{C_k E_k}{Max_{k=1}^{k} (C_k E_k)}$$

Table 5.6: Credibility factor (W_k) of 3-decision maker:

DMs	E_k	C_k	$E_k * C_k$	W_k
1	8	9	72	1
2	9	7	63	0.875
3	7	7	49	0.681

Table 5.7: Weighted Conditional Probability of VSM using credibility factor:

VSM (DM 1)					
		low	high	W_k*low	W_k*high
node 1/node 2	low/low	0.87	0.13	0.87	0.13
	low/high	0.78	0.22	0.78	0.22
	high/low	0.34	0.66	0.34	0.66
	high/high	0.87	0.13	0.87	0.13
VSM (DM 2)					
		low	high	W_k*low	W_k*high
node 1/node 2	low/low	0.29	0.71	0.25	0.22
	low/high	0.22	0.78	0.19	0.17
	high/low	0.84	0.16	0.73	0.64
	high/high	0.11	0.89	0.10	0.09
VSM (DM 3)					
		low	high	W_k*low	W_k*high
node 1/node 2	low/low	0.11	0.89	0.08	0.60
	low/high	0.63	0.37	0.43	0.26
	high/low	0.59	0.41	0.40	0.28
	high/high	0.76	0.24	0.52	0.16
VSM (Final)					

		low	high
node 1/node 2	low/low	0.56	0.44
	low/high	0.68	0.32
	high/low	0.49	0.51
	high/high	0.80	0.20

Table 5.8: Weighted Conditional Probability of Process flow improvement using credibility factor:

Process flow improvement (DM 1)					
		low	high	W_k*low	W_k*high
node 3/node 4	low/low	0.18	0.82	0.18	0.82
	low/high	0.97	0.03	0.97	0.03
	high/low	0.60	0.40	0.60	0.40
	high/high	0.16	0.84	0.16	0.84
Process flow improvement (DM 2)					
		low	high	W_k*low	W_k*high
node 3/node 4	low/low	0.88	0.12	0.77	0.68
	low/high	0.45	0.55	0.39	0.34
	high/low	0.44	0.56	0.39	0.34
	high/high	0.74	0.26	0.65	0.57
Process flow improvement (DM 3)					
		low	high	W_k*low	W_k*high
node 3/node 4	low/low	0.08	0.92	0.06	0.62
	low/high	0.17	0.83	0.12	0.57
	high/low	0.24	0.76	0.16	0.52
	high/high	0.79	0.21	0.54	0.14
Process flow improvement (Final)					
		low	high		

node 3/node 4	low/low	0.32	0.68
	low/high	0.61	0.39
	high/low	0.48	0.52
	high/high	0.46	0.54

Table 5.9: Weighted Conditional Probability of PDCA Cycle using credibility factor:

PDCA Cycle (DM 1)					
		low	high	W_k*low	W_k*high
node 4/node 5	low/low	0.29	0.71	0.29	0.71
	low/high	0.38	0.62	0.38	0.62
	high/low	0.11	0.89	0.11	0.89
	high/high	0.17	0.83	0.17	0.83
PDCA Cycle (DM 2)					
		low	high	W_k*low	W_k*high
node 4/node 5	low/low	0.25	0.75	0.22	0.19
	low/high	0.84	0.16	0.74	0.65
	high/low	0.07	0.93	0.06	0.05
	high/high	0.87	0.13	0.76	0.66
PDCA Cycle (DM 3)					
		low	high	W_k*low	W_k*high
node 4/node 5	low/low	0.02	0.98	0.01	0.67
	low/high	0.92	0.08	0.62	0.06
	high/low	0.53	0.47	0.36	0.32
	high/high	0.86	0.14	0.59	0.09
PDCA Cycle (Final)					
		low	high		
node 4/node 5	low/low	0.25	0.75		
	low/high	0.57	0.43		

	high/low	0.30	0.70
	high/high	0.49	0.51

Table 5.10: Weighted Conditional Probability of Production lead-time using credibility factor:

Production Lead time (DM 1)					
		Low	High	Wk*low	Wk*high
Node 6	low	0.70	0.30	0.70	0.30
	high	0.48	0.52	0.48	0.52
Production Lead time (DM 2)					
		Low	High	Wk*low	Wk*high
Node 6	low	0.36	0.64	0.32	0.56
	high	0.50	0.50	0.43	0.44
Production Lead time (DM 3)					
		Low	High	Wk*low	Wk*high
Node 6	low	0.58	0.42	0.39	0.29
	high	0.70	0.30	0.48	0.21

Production Lead time (Final)			
		Low	High
Node 6	low	0.55	0.45
	high	0.45	0.55

Table 5.11: Weighted Conditional Probability of Quality using credibility factor:

Quality (DM 1)					
		Low	High	Wk*low	Wk*high
Node 8	low	0.89	0.11	0.89	0.11
	high	0.66	0.34	0.66	0.34
Quality (DM 2)					
		Low	High	Wk*low	Wk*high
Node 8	low	0.79	0.21	0.69	0.19
	high	0.56	0.44	0.49	0.39
Quality (DM 3)					
		Low	High	Wk*low	Wk*high
Node 8	low	0.49	0.51	0.33	0.35
	high	0.41	0.59	0.28	0.40

Quality (Final)			
		Low	High
Node 8	low	0.75	0.25
	high	0.25	0.75

Table 5.12: Weighted Conditional Probability of Productivity using credibility factor:

Productivity (DM 1)					
		low	high	W_k*low	W_k*high
node 7/node 9	low/low	0.41	0.59	0.41	0.59
	low/high	0.97	0.03	0.97	0.03
	high/low	0.21	0.79	0.21	0.79
	high/high	0.04	0.96	0.04	0.96
Productivity (DM 2)					
		low	high	W_k*low	W_k*high
node 7/node 9	low/low	0.72	0.28	0.63	0.55
	low/high	0.91	0.09	0.79	0.69
	high/low	0.55	0.45	0.48	0.42
	high/high	0.26	0.74	0.23	0.20
Productivity (DM 3)					
		low	high	W_k*low	W_k*high
node 7/node 9	low/low	0.87	0.13	0.60	0.09
	low/high	0.78	0.22	0.53	0.15
	high/low	0.65	0.35	0.44	0.24
	high/high	0.85	0.15	0.58	0.10
Productivity (Final)					
		low	high		
node 7/node 9	low/low	0.57	0.43		

	low/high	0.72	0.28
	high/low	0.44	0.56
	high/high	0.40	0.60

Table 5.13: Weighted Conditional Probability of Responsiveness using credibility factor:

Responsiveness (DM 1)					
		low	high	W_k*low	W_k*high
node 6/node 7	low/low	0.44	0.56	0.44	0.56
	low/high	0.66	0.34	0.66	0.34
	high/low	0.10	0.90	0.10	0.90
	high/high	0.61	0.39	0.61	0.39
Responsiveness (DM 2)					
		low	high	W_k*low	W_k*high
node 6/node 7	low/low	0.92	0.08	0.81	0.71
	low/high	0.54	0.46	0.47	0.41
	high/low	0.90	0.10	0.79	0.69
	high/high	0.47	0.53	0.41	0.36
Responsiveness (DM 3)					
		low	high	W_k*low	W_k*high
node 6/node 7	low/low	0.79	0.21	0.54	0.14
	low/high	0.99	0.01	0.68	0.00
	high/low	0.47	0.53	0.32	0.36
	high/high	0.25	0.75	0.17	0.51
Responsiveness (Final)					
		low	high		
node 6/node 7	low/low	0.56	0.44		
	low/high	0.70	0.30		

	high/low	0.38	0.62
	high/high	0.48	0.52

Table 5.14: Weighted Conditional Probability of Effectiveness using credibility factor:

Effectiveness (DM 1)					
		low	high	W_k*low	W_k*high
node 7/node 8	low/low	0.53	0.47	0.53	0.47
	low/high	0.49	0.51	0.49	0.51
	high/low	0.32	0.68	0.32	0.68
	high/high	0.84	0.16	0.84	0.16
Effectiveness (DM 2)					
		low	high	W_k*low	W_k*high
node 7/node 8	low/low	0.20	0.80	0.18	0.15
	low/high	0.67	0.33	0.59	0.51
	high/low	0.10	0.90	0.09	0.08
	high/high	0.57	0.43	0.50	0.44
Effectiveness (DM 3)					
		low	high	W_k*low	W_k*high
node 7/node 8	low/low	0.61	0.39	0.41	0.27
	low/high	0.97	0.03	0.66	0.02
	high/low	0.00	1.00	0.00	0.68
	high/high	0.73	0.27	0.50	0.18
Effectiveness (Final)					
		low	high		
node 7/node 8	low/low	0.56	0.44		
	low/high	0.62	0.38		

	high/low	0.22	0.78		
	high/high	0.70	0.30		

Table 5.15: Weighted Conditional Probability of Sustainability using credibility factor:

Sustainability (DM 1)					
		low	high	W_k*low	W_k*high
node 9/node 11	low/low	0.63	0.37	0.63	0.37
	low/high	0.45	0.55	0.45	0.55
	high/low	0.67	0.33	0.67	0.33
	high/high	0.95	0.05	0.95	0.05
Sustainability (DM 2)					
		low	high	W_k*low	W_k*high
node 9/node 11	low/low	0.89	0.11	0.78	0.68
	low/high	0.53	0.47	0.47	0.41
	high/low	0.92	0.08	0.80	0.70
	high/high	0.32	0.68	0.28	0.25
Sustainability (DM 3)					
		low	high	W_k*low	W_k*high
node 9/node 11	low/low	0.43	0.57	0.29	0.39
	low/high	0.50	0.50	0.34	0.34
	high/low	0.14	0.86	0.09	0.59
	high/high	0.56	0.44	0.38	0.30
Sustainability (Final)					
		low	high		
node 9/node 11	low/low	0.54	0.46		
	low/high	0.49	0.51		

	high/low	0.49	0.51		
	high/high	0.73	0.27		

Table 5.16: Weighted Conditional Probability of Non-financial Performance using credibility factor:

Non-financial Performance (DM 1)					
		low	high	W_k*low	W_k*high
node 11/node 13	low/low	0.30	0.70	0.30	0.70
	low/high	0.87	0.13	0.87	0.13
	high/low	0.15	0.85	0.15	0.85
	high/high	0.89	0.11	0.89	0.11
Non-financial Performance (DM 2)					
		low	high	W_k*low	W_k*high
node 11/node 13	low/low	0.73	0.27	0.64	0.56
	low/high	0.74	0.26	0.65	0.57
	high/low	0.87	0.13	0.76	0.66
	high/high	0.88	0.12	0.77	0.67
Non-financial Performance (DM 3)					
		low	high	W_k*low	W_k*high
node 11/node 13	low/low	0.70	0.30	0.48	0.20
	low/high	0.73	0.27	0.50	0.19
	high/low	0.94	0.06	0.64	0.04
	high/high	0.55	0.45	0.37	0.31
Non-financial Performance (Final)					
		low	high		
node 11/node 13	low/low	0.49	0.51		
	low/high	0.69	0.31		

	high/low	0.50	0.50
	high/high	0.65	0.35

Table 5.17: Weighted Conditional Probability of Financial Performance using credibility factor:

Node 10/11/12/13	low	low	low	Wk*low	Wk*low	Wk*low	high	high	high	Wk*high	Wk*high	Wk*high
low/low/low/low	0.97	0.79	0.65	0.97	0.69	0.44	0.03	0.21	0.35	0.03	0.18	0.24
low/low/low/high	0.50	0.95	0.88	0.50	0.83	0.60	0.50	0.05	0.12	0.50	0.04	0.08
low/low/high/low	0.46	0.60	0.75	0.46	0.53	0.51	0.54	0.40	0.25	0.54	0.35	0.17
low/low/high/high	0.62	0.70	0.14	0.62	0.61	0.10	0.38	0.30	0.86	0.38	0.27	0.58
low/high/low/low	0.85	0.09	0.94	0.85	0.07	0.64	0.15	0.91	0.06	0.15	0.80	0.04
low/high/low/high	0.29	0.03	0.48	0.29	0.03	0.32	0.71	0.97	0.52	0.71	0.85	0.36
low/high/high/low	0.36	0.97	0.71	0.36	0.85	0.48	0.64	0.03	0.29	0.64	0.02	0.20
low/high/high/high	0.48	0.12	0.63	0.48	0.10	0.43	0.52	0.88	0.37	0.52	0.77	0.25
high/low/low/low	0.44	0.83	0.79	0.44	0.72	0.54	0.56	0.17	0.21	0.56	0.15	0.14
high/low/low/high	0.42	0.59	0.29	0.42	0.52	0.20	0.58	0.41	0.71	0.58	0.36	0.48
high/low/high/low	0.82	0.48	0.88	0.82	0.42	0.60	0.18	0.52	0.12	0.18	0.45	0.08
high/low/high/high	0.31	0.63	0.69	0.31	0.55	0.47	0.69	0.37	0.31	0.69	0.32	0.21
high/high/low/low	0.36	0.07	0.33	0.36	0.06	0.22	0.64	0.93	0.67	0.64	0.81	0.46
high/high/low/high	0.31	0.79	0.22	0.31	0.69	0.15	0.69	0.21	0.78	0.69	0.18	0.53

high/high/high/low	0.55	0.59	0.40	0.55	0.52	0.27	0.45	0.41	0.60	0.45	0.36	0.41
high/high/high/high	0.06	0.95	0.98	0.06	0.83	0.66	0.94	0.05	0.02	0.94	0.05	0.02

Table 5.18: Final values of financial performance

Financial Performance(Final)		
Node 10/11/12/13	Low	High
low/low/low/low	0.82	0.18
low/low/low/high	0.75	0.25
low/low/high/low	0.58	0.42
low/low/high/high	0.52	0.48
low/high/low/low	0.61	0.39
low/high/low/high	0.25	0.75
low/high/high/low	0.66	0.34
low/high/high/high	0.40	0.60
high/low/low/low	0.66	0.34
high/low/low/high	0.44	0.56
high/low/high/low	0.72	0.28
high/low/high/high	0.52	0.48

high/high/low/low	0.25	0.75
high/high/low/high	0.45	0.55
high/high/high/low	0.53	0.47
high/high/high/high	0.61	0.39

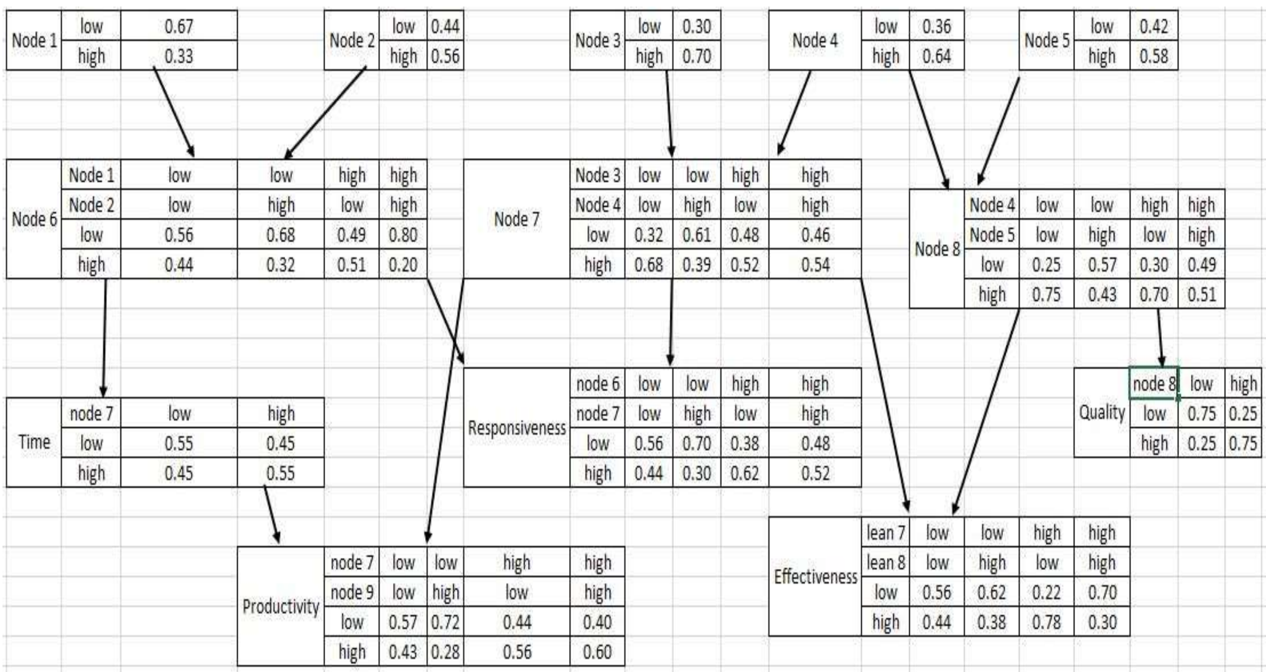

Fig 5.1: Final Conditional Probability Table for tools and performance criteria

	Time	low	low	high	high
	responsiveness	low	high	low	high
Sustainability	low	0.54	0.49	0.49	0.73
	high	0.46	0.51	0.51	0.27

	Productivity	low	low	low	low	low	low	low	low	high	high	high	high	high	high	high	high
	Responsiveness	low	low	low	low	high	high	high	high	low	low	low	low	high	high	high	high
	Effectiveness	low	low	high	high	low	low	high	high	low	low	high	high	low	low	high	high
	Quality	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high
Financial Performance	low	0.82	0.75	0.58	0.52	0.61	0.25	0.66	0.40	0.66	0.44	0.72	0.52	0.25	0.45	0.53	0.61
	high	0.18	0.25	0.42	0.48	0.39	0.75	0.34	0.60	0.34	0.56	0.28	0.48	0.75	0.55	0.47	0.39

	Responsiveness	low	low	high	high
	Quality	low	high	low	high
Non-financial Performance	low	0.49	0.69	0.50	0.65
	high	0.51	0.31	0.50	0.35

Fig 5.2: Final conditional probability table for performance decision

5.3 SCENARIO ANALYSIS

To generate more realistic success criteria, the scenario study aims to determine how much of an impact the Lean Element has on the factors of time, effectiveness, productivity, responsiveness, and quality. Netica software is utilized to determine the outcome of several situations for this analysis. The inferences are never thought to contain errors, and normalized odds are always used (Ɛ= Ø). The normalized likelihood value for this instance is 0.675, which indicates that it would provide persuasive evidence of great success if there was a high demand for lean tools. Calculating the (prior) marginal likelihood, P (Xi), of a network's vector Xi is a specific kind of problem in probabilistic inference. In this case, Equation 3 does not use facts to inform the inference process, i.e. = Ø is presumed. Below are three situations that are described in detail: the worst case, the best scenario, and the normal scenario.

Scenario 01: The Worst Case is built to use only the minor signs of the best lean tools. Takt time, SMV, continuous flow, Kaizen, Fishbone system, and Pareto map are added as low effective on other nodes in this scenario. It is observed in Figure 5.3 that nodes 6, 7 & 8 are dependent on the root factors, though they still have a 44 to 75 percent possibility of application. However, with up to 44 to 75 percent possibility of high node 6, 7 & 8 values, high time with a probability of 49.4 percent, high productivity with a probability of 45.6 percent, high response performance with a probability of 43.6 percent, high efficiency with a probability of 41.2 percent and high quality with a probability of 62.5 percent. Price reductions still have a 45.6 percent chance of being highly profitable, but there is also a 44.3 percent chance that they will have high non-financial performance or a 39.4 percent chance that they will have high sustainability performance. This scenario illustrates that the use of lean tools has a huge effect on sustainability and financial and non-financial performance.

Scenario 02: The Best Case is designed to apply all the lean instruments with 100% high efficiency. Without a doubt, the Fishbone process and Pareto chart are used, Continuous Flow is executed with 100% efficiency, the plant's SMV and Takt time are flawless, and Kaizen is used at its best. This is an idealized arrangement that rarely comes to pass. There is a good rate of changes in the end performances with the complete deployment of the lean tools. According to the data, there is a 43.7 percent likelihood of having high financial performance, a 41.5 percent chance of having good non-financial performance, and a 44.8 percent chance of having high sustainability performance. The difference between the worst case and best case, which is only 1-2 percent, is not striking when compared to the first scenario.

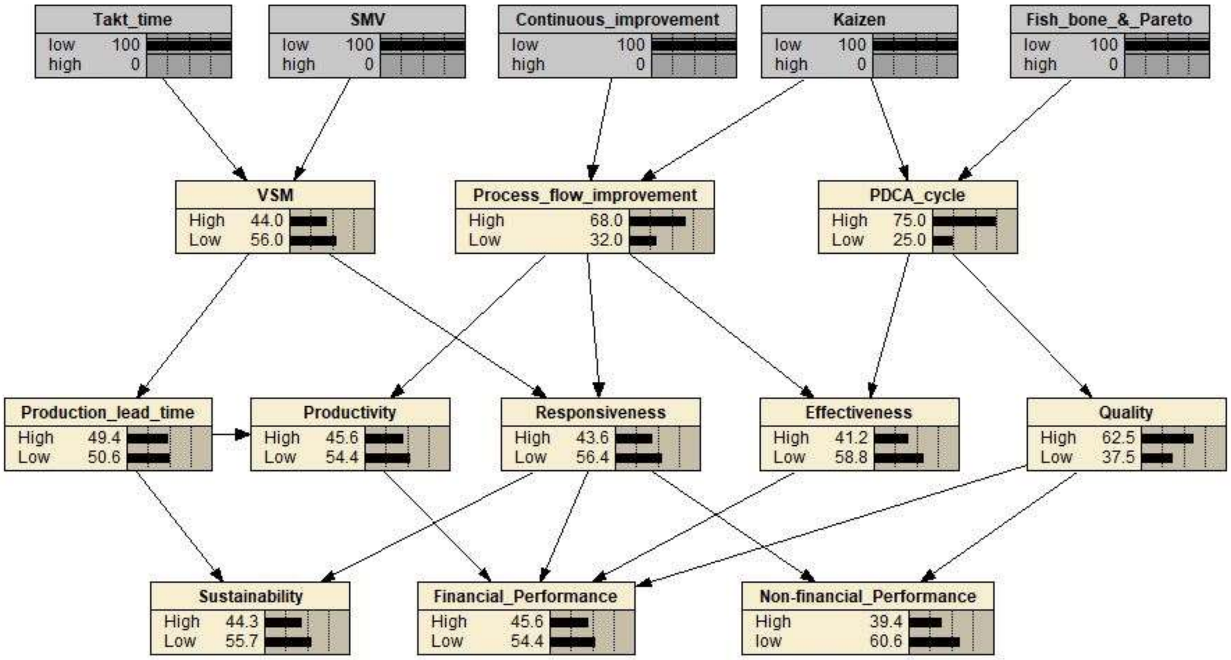

Fig 5.3: Worst Case Analysis

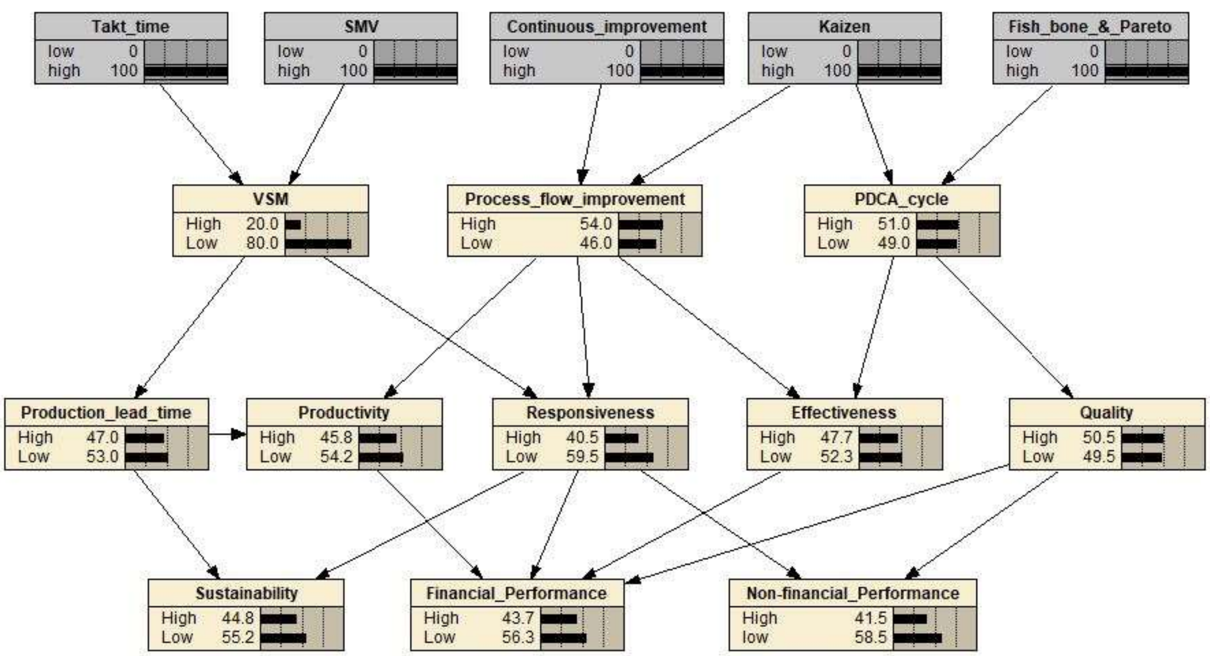

Fig 5.4: Best Case Analysis

Scenario 03: In this scenario, every independent node that is used are remain 50% highly effective. It almost suits the real scenario cases. Limited amounts of individual outcomes are permitted for the second and third stage Lean Tools, e.g. Although SMV, Takt time, Continuous flow, Kaizen or Fishbone process, or Pareto chart may not occur, Value Stream Map could be used 44 percent effectively. It is specifically noted that none of the lean tools with 100 percent performance was applied and used. They are thought to be utilized on average, others don't exist at all, and some have average results when employed. Only 25.7 percent are projected to achieve strong non-financial performance in this scenario because components of effectiveness and quality are held low with a possibility of no more than 21 to 24 percent. It is also a matter of fact that the probability of a high productivity rate is not much lower than compared to scenario 02.

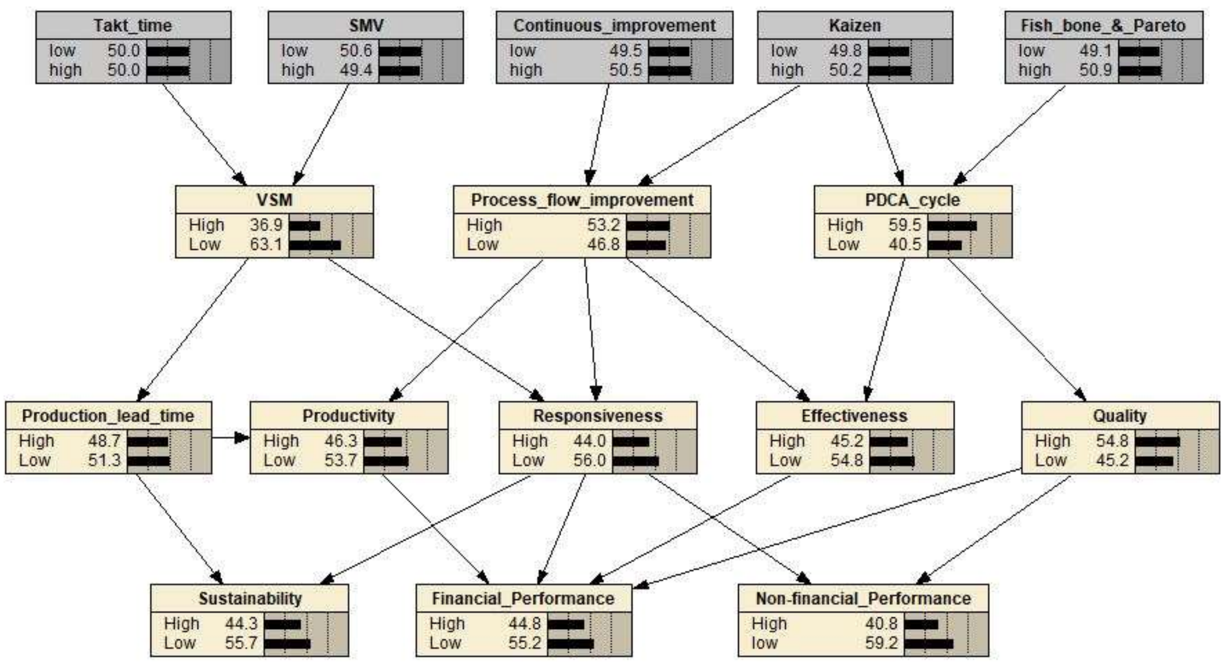

Fig 5.5: Average case scenario

Compared to other performance decisions, we can see that the performance probability of financial performance has not changed that much. Still in average mode, it has a best effective performance than other scenarios. This is the case where it is appropriate to examine monetary concepts in depth. Compared to scenario 02, sustainability sees a 0.5 percent decline but seems to have the best probability of seeing average results. This accomplishment indicates that sustainability is strongly dependent on the components of time and responsiveness. Overall compared with scenario 01 we can understand that lean tools are effectively important for this performance decisions. Especially on non-financial performance, these have a deep effect to increase the percentage rate.

Chapter 06

CONCLUSION

Consistency is the most critical challenge for customer satisfaction. Not only in the manufacturing sector of clothes, but also in every manufacturing industry. High quality enhances consumer satisfaction by raising the significance of the product. It establishes the brand or organization's identity and establishes a close relationship with the exporter, resulting in large levels of sales and increased earnings. The shortcomings in the textile industry are one form of substantial loss or minimization of advantage. Any manufacturer's primary objective should be to produce and deliver high-quality goods on schedule. However, material failures typically result in rejection, rework, time-consuming, unnecessary effort, and dissatisfied customers.

The goal of this analysis is to show the financial and non-financial ramifications of incorporating various variations of lean company efficiency strategies. In the analysis of the influence of variables under shifting circumstances, the Bayesian belief network (BBN) is used. To evaluate the effect on three success metrics, there are eight lean variables studied. The Bayesian Belief Network is based on lean elements that stimulate organizational responsiveness, effectiveness, quality, productivity, and time, which would have a positive effect on supplier's financial, non-financial, and sustainable results. For vendors in the market, a case analysis is performed and situations with various variations of lean variables are analyzed. This approach offers a unique perspective that takes into consideration both the tangible and intangible outcomes under shifting business situations by using the Bayesian network to market performance measurements.

Using lean methods, this paper has studied the very productive fabric defects. Kaizen, Pareto map & Fishbone process, Continuous flow, Enhancement of process flow, Takt time, VSM, SMV, and PDCA loop are the lean instruments. The PDCA loop decreases faults, improves efficiency, and makes more benefits. The Pareto graph suggests that other broken stitches, slip stitches, exposed seams, etc. are the main accumulated defects. We can quickly find the most serious defects from this table, and then we can use the lean tool to find the root reasons for that defect. We use lean tools to mitigate defects after taking corrective steps for the triggers found. Finally, the PDCA cycle aims to prepare for ongoing quality enhancement by eliminating errors, performing the plan-based process, and next testing and recording the process by the proper procedures.

This research extends and utilizes a Bayesian Belief Network (BBN) model to show how different lean management techniques affect business efficiency. It determines how the lean variables and the output elements interact. Three new scenarios have been introduced. The worst-case scenario is the first one, in which no meaningful lean tool is deployed. The likelihood of high non-financial performance or high sustainability performance is only determined to be 39.4% or 44.3%, respectively. Additionally, it has been noted that sustainability is most negatively impacted. In the second situation, maximal lean tools are applied and a 1-2 percent difference is detected relative to the first scenario. The most practical one can be used as the third example. As it varies by using only one of the integrated lean tools from the original example. When the last example is used, non-financial performance is more affected because only 40.8 percent are expected to attain high non-financial performance, whereas effectiveness and quality are held low with a likelihood of not more than 44%.

The proposed BBN-based performance assessment model may give information at the segment or unit level and organizational level. It can be expanded to include nodes of utility and judgment, thereby offering a decision method dependent on anticipated utility for ranking workers. The effectiveness of BBN, however, depends on the feedback of the interactions of specialists in the BBN systems and CPTs in the BBN. The standard of the evaluation of the BBN relies directly on the knowledge supplied by experts. The coordination of numerous specialists from different fields of expertise will entail a robust network structure.

By proving those lean elements significantly increase non-financial aspects in productivity and efficiency, this research advances intelligent methods to corporate management. It is shown that there is little to no effect of implementing any Lean Element on the financial factors. Only for the case study of the garment supply chain are these results drawn. The generalization of solutions can be replicated with supply chains in other sectors.

REFERENCES

F. A. Abdulmalek and J. Rajgopal (2007). Using simulation to evaluate the advantages of lean manufacturing and value stream mapping: A process sector case study, 107, 223-236.https://doi.org/10.1016/j.ijpe.2006.09.009

S. Akter, R. Yasmin (2017). implementation of kaizen for ongoing productivity improvement in the implementation of kaizen for ongoing product development in Bangladesh's textile sector (May 2015).Application, A. N., & Analysis, O. F. P. (2012). Ilrrnm~llmlllllfi "'03\."

Doggett, M. (2014). A Statistical Comparison of Three Root Cause Analysis Tools, (August).

J. K. Ghosh (2008). By Uffe B. Kjaerulff and Anders L. Madsen, "Bayesian Networks and Influence Diagrams: A Guide to Construction and Analysis." Review of International Statistics. https://doi.org/10.1111/j.1751-5823.2008.00062 26.x

Elgalib, M. A. E. A., K. Aa, and E. A. F. Elfaki, along with Habob, M. A. (2018). The use of the Lean manufacturing system in Sudan's apparel industry, 6(7), 26–31.

A. Haque, T. Jubair, K. Khan, & S. M. Saif (2017). Open Access Bangladeshi garment manufacturers' prospects for implementing lean manufacturing, (9), 86–96.

Hemadri Chadalavada, Sankar K., Samuel Raj D., and Ashok Kumar R. (2015). Lean Manufacturing Used to Reduce Production Lead Time in a Battery Manufacturing Unit. V4(04), 842–847, International Journal of Engineering Research and. https://doi.org/10.17577/ijertv4is040986

A. Hossain, S. Islam, M. S. Islam, & S. Islam (2018). Quality Assurance System of the Bangladeshi Textile Industry: A Case Study, 5(2), 21–28 https://doi.org/10.9790/019X-05022128

M. M. Islam, A. M. Khan, and M. M. Islam (2013). Application of Lean Manufacturing to Increase Productivity in Bangladesh's Textile Sector. Journal of Scientific & Engineering Research: International, 4 (2). taken from www.ijser.org

Joshi, A., and L. M. Jugulkar (2014). INVESTIGATION, ANALYSIS, AND DEFECT REDUCTION USING QUALITY CONTROL TOOLS OF METAL CASTING DEFECTS.

M. Jouhri and A. Soulhi (2019). How Lean and Green Management Enhance Performances in Denim Manufacturing, 8(04), 566–571.

A. Juriani (2015). Foundry Casting Defects Analysis and Corrective Measures using Industrial Case Studies, 12(6), 43–53. https://doi.org/10.9790/1684-12614354

Rahman, C. M. L., and Karim, R. (2012). Performance Analysis Using Lean Manufacturing Tools: A Case Study International Conference on Industrial Engineering and Operations Management Proceedings 2012, 1725-1734.

Hussian, A. S., Arvinth, R., Kannan, & Kumar, K. P. (2017). Steering Knuckle Production, 5(07), 1–5. Evaluation and Implementation of Lean Manufacturing

S. Mahendran (2016). Lean Manufacturing Technique Implementation using Matlab Simulation Software in the Automotive Industry: A Case Study, 4(24), 1–7.

Stewart, J. R., and Meyers, F. E. (2015). Lean Manufacturing Motion and Time Study, 2002.

Systems, B. B. (2015). Using Bayesian Belief Networks, assess the impact of lean manufacturing on business performance. https://doi.org/10.1016/j.eswa.2015.04.016

& Pei, Z. J. Obeidat, M. S. (2012). Lean Manufacturing in the Sewing Industry: Implementation Lean Manufacturing in the Sewing Industry: Implementation (May).

Zhang, G., Ali, S. M., Paul, S., and Kabir (2020). Analyzing the risk of supply-chain disruption due to transportation: a case study from the Bangladeshi pharmaceutical sector. 37(April), 100485, Research in Transportation Business and Management. https://doi.org/10.1016/j.rtbm.2020.100485

Mydeen, S. S. R., Prasad, M. M., Kumar, S. S., and Thayumanavar, A. L. (2015). Front and rear bumper rejection control utilizing lean manufacturing, 3(26), 1-4.

Rahman, M., Tahiduzzaman, M., Dey, K., & Kapuria (2018). Using 5S and PDCA, the Bangladeshi apparel industry can reduce sewing errors. 5(1), 17–24, American Journal of Industrial Engineering. https://doi.org/10.12691/ajie-5-1-3

Senthilkumar, B., and H. S. Thavaraj (2014). A TPM Implementation Evaluation in the Indian Clothing Industry- Review of Literature Based on a Lean Philosophy, 4(6), 11–18.

M. D. Singh, S. Singh, A. Chokshi, H. Chavan, and D. Dabhi (2015). Improvement of Process Flow Using 5S, Kaizen, and Visualization. 4(3), 1103–1112 International Journal of Innovative Research in Science, Engineering, and Technology. https://doi.org/10.15680/IJIRSET.2015.0403063

D. D. Sterlin (2019). A Study on the Indicators of the Lean Management System and Its Effect on Waste Reduction, 1–7.

Surabhi Hathwar, Vinod V. Rampur, and P. V. (2017). Lean Concepts and Principles are being implemented in the manufacturing of pumps. V6(06), 762–766 in International Journal of Engineering Research and. https://doi.org/10.17577/ijertv6is060270

Islam, M. M., Syduzzaman, M., Rahman, M. M., Habib, M. A., and Ahmed, S. (2014). Implementing the TQM approach in the clothing industry. Scientific Journal of Europe.

Talla, S. A. El, Shobaki, M. J. Al, Abu-naser, S. S., & Amuna, Y. A. (2017). The Lean Management of Technical Colleges Operating in the Gaza Strip and the Creative Environment (December).

M. H. Talukder, M. A. Afzal, M. A. Rahim, & M. R. Khan (2013). Lean tools for waste reduction and productivity improvement. 4(11), 1844–1855, International Journal of Scientific and Engineering Research. Retrieved from "5CWaste-Reduction-and-Productivity-Improvement-through-Lean-Tools.pdf" at http://www.ijser.org

N. Upadhye, D. Sharma (2017). An Empirical Study of Selected Issues in the Implementation of Lean Manufacturing in the UAE, 5 (2).

Yang, M. G., Modi, S. B., and Hong, P. (2011). An empirical investigation of manufacturing companies reveals the effects of lean manufacturing and environmental management on financial performance. 129(2), 251-261, International Journal of Production Economics. https://doi.org/10.1016/j.ijpe.2010.10.017

Nik, Z., Fadzil, M., Mohd, N., & Ab, F. Zakaria, N. H. (2017). Implementing lean manufacturing helped the 01048 electronic assembly line reduce waste.

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