A Bayesian Approach to Improve Service Sector Performance - A Lean Perspective

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Abstract

Service sector in the US contributes a high proportion of GDP, four out of five people work in services. It is important to enable service firms to make the most out of the domestic and the international opportunities. Services focus on the project based Six Sigma application and selecting the critical quality factors and business strategies to improve key performances and retain competitive advantages in the globe. However, the service sectors and its surroundings becoming more and more complex, it is simply not possible to solve all the problems and improve key performances given the limited resources. The purpose of this study is to develop a model that provides a systematic evaluation to identify the key quality factors and potential business strategies to enhance the effectiveness of service performance. Deriving from the Bayesian Network methodology, the proposed model combines a graphical approach to represent relational attributes and variables of interests. The probabilistic inference is made to estimate the likelihoods of the variable aiming the process improvement. The developed model can be used to assess the prioritizing efforts towards the critical business success and key performances associated with Six Sigma initiatives.

Keywords (12 font)
Bayesian Network, Service Sector, Probabilistic Inference, Lean Six Sigma

1. Introduction

The service industries account for a significant economic growth at any country's economy and support a future wave of trade and globalization. Technological innovation, satellite, software, energy, telecommunication, transportation, and infrastructure are increasingly making services exportable at a low price with expanded applications, at a faster rate. Most service processes such as supply chain procurement, shipping, invoicing, billing, payroll, inventory, customer order entry, baggage handling need to serve customer demands at the right time, in the right place, at the right condition and means. However, due to the technological advances, the service industries face relentless challenges to remain competitive in the global market. Organizations face constants to find effective and innovative strategies to update the service for business success. Artificial intelligence approaches such as Bayesian inference networks or, Bayesian networks have recently used in system assessment, aid to find the critical factors, significantly improve service sector performance. Bayesian inference networks assess the performance, given the current performance information in the assessment model.

The perception of combining Lean strategy and Six Sigma principles became popular, which originated from small manufacturing industries to improve productivity and compete. The concept has been quickly adopted by many large companies and service sectors. Early examples of manufacturing companies implementing a combined effort of Lean and Six Sigma include aircraft-engine-controls firm, BAE Systems Controls in 1997 (Sheridan, 2000), Lockheed Martin Aeronautical Systems, Northrop Grumman in 1999.

Traditionally business logistics is not integrated with Lean Six Sigma strategies. Combining the logistics supports with the Lean Six Sigma strategy would provide a base to implement decision support framework that ensures quality assurance, cycle time compression, cost reduction, coordination, and on-time delivery commitment. The inclusion of successful logistic supports in comprehensive Lean Six Sigma strategies will increase the dimension of an integrated service system, inevitable to support constantly evolving challenges and performance improvement. The integrated Lean Six Sigma and logistics have a wider scope to improve the internal operations, procurement, delivery management, and focus on integrating the service function into the overall process improvement.

If the applications are based on either with SS along in a service system or the business strategies separately, the system will receive limited benefits. However, an integrated approached appropriate business strategies and total quality management under Bayesian network provide assurance to drive the critical factors to improve the operation quality in a service system. The application of Bayesian inference to find the critical variables is simple when it involved only a few variables. However, when the system becomes more complex and a great number of variables are involved, Bayesian and decision-theoretic schemes are suitable for that analysis. When the inference becomes difficult with many related variables, the BN techniques are designed to solve such complex problems in a more efficient manner (Li et. al, 2013).

The objective here is to develop a Bayesian network model to find the critical quality factors conjoin with business strategies during the Lean Six Sigma analysis. The analysis and viewpoints are for the possible improvement of a company's business value. The model will provide the following:

- Identify where problems lie and the potential impact on operations.
- Identify the influence of each node over the supply chain performance
- The viewpoints provide the companies help to realize business value.

The purpose of this paper is to provide a Bayesian Network model to aid in quantifying and prioritizing the service section improvement efforts. The rest of this paper is organized as follows. The next section discusses the six-sigma factors include the growing role of services in the economy and the benefits of Bayesian networks model. Section 3 presents the Bayesian networks model to identify critical quality factors and business strategies in the service section. Sections 4 presents the implied results of the Bayesian model. The last section provides concluding remarks.

2. Lean Six Sigma Factors and Bayesian Networks

The model investigates the critical factors to improve the service quality of a system using the Bayesian network. Two of the most common service quality improvement frameworks used in this paper are the Six Sigma methodology and the appropriate business strategies. Under the Bayesian network, the Six Sigma (6σ) technique along with the critical quality indicators and appropriate business strategies are inferred with the probability to identify the root causes within the system. Six Sigma strategy helps to achieve a balance operation by reducing disruptions in the system, making the system flexible and improving the process by eliminating waste, excessive inventory and cycle time variation to make a company's operation a success. Although Six Sigma process has been developed in the manufacturing industry, however, it is increasingly applied to a variety of different systems to improve the efficiency while maintaining the service quality. The efficacy of Six Sigma application has been proven in the service industries.

2.1 Lean Six Sigma and Quality Factors

Six Sigma, quality factors, and business strategies are used in the paper as a combined approach. Determination of Critical Success Factors is the key to implement Six Sigma. The Six Sigma approach allows users to improve product quality by determining the relationship between output and errors in process inputs. Six Sigma indicates low product variability resulting in a long-term defect level below 3.4 defects per million opportunities (DPMO). The six-sigma approach is based upon the DMAIC (Define, Measure, Analysis, Improve, and Control) total quality principles. The six-sigma concept originally developed by Motorola Corporations, which then implemented and established in the private, public, government and industrial sectors. The benefits of implementing a total quality approach along with the Lean strategy are the reduction of system variation, product return, and backlogging. The continuous improvement in the quality of products and processes is a constant concern at organizations, as a response to growing competition and the demands of the market (Requeijo and Cordeiro, 2013). Six Sigma can be used in the service sector for reducing processing time, processing errors, customer complaints, payment errors, invoicing errors, errors in inventory, inaccurate report of income, inaccurate report of cash flow, delay in service delivery, billing errors, waiting time (Ahmad, 2013). Integrated Quality System (IQS) is an essential part of a service industry. Business strategies drive the business operations while Six Sigma contributes to quality improvement, together contribute to improving the overall customer service. Table 1 presents the quality management practices in organizations based upon Six Sigma methodology to improve their business performance.

Table 1 Literature studies with six sigma applications*

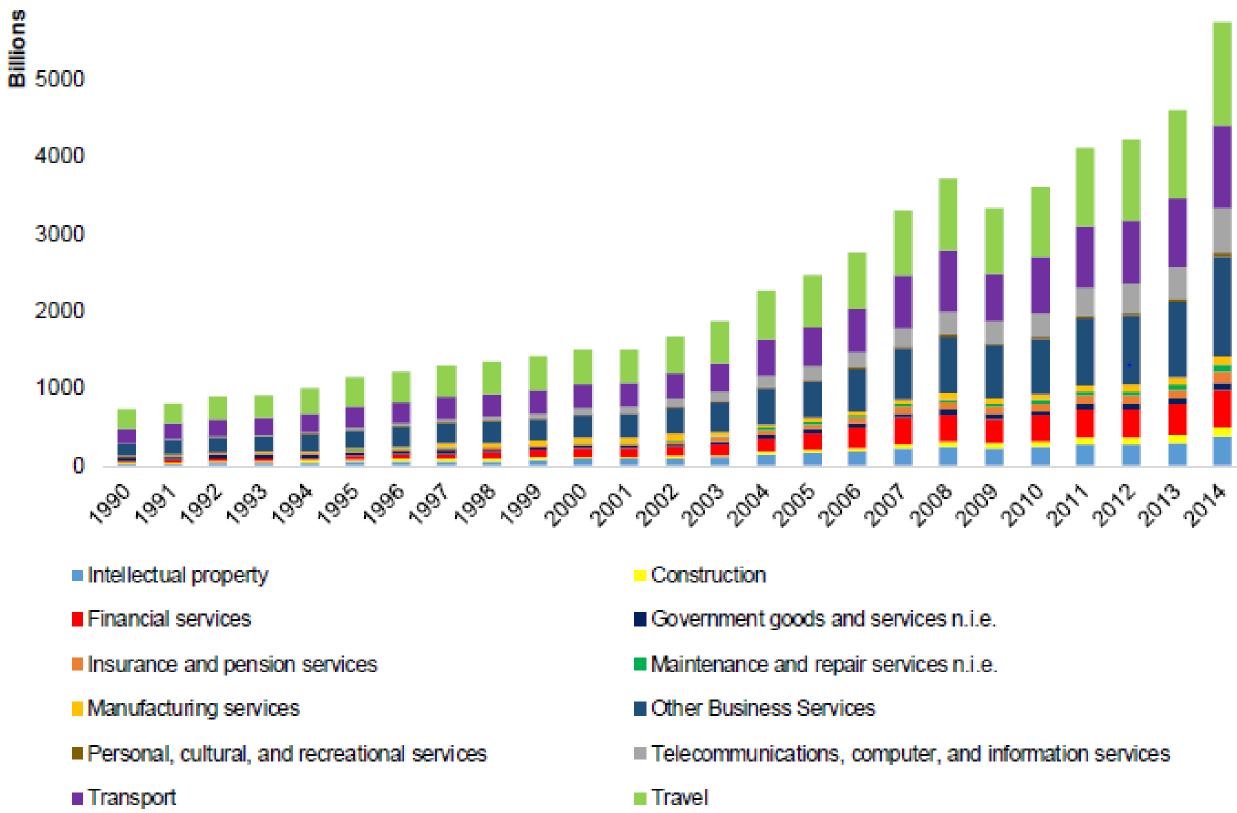
Authors	Six Sigma Applications
Kumar and Sosnoski (2009)	Used Six Sigma process to improve shop floor production quality and cost.
Calia et al. (2009)	Implementation of Six Sigma improved significantly the performance of the pollution preventive program.
Nabhani and Shokri (2009)	Reducing the delivery lead time in a food distribution through the implementation of Six Sigma methodology
Gijo et al. (2011)	Application of Six Sigma methodology reduced defects of grinding process from 16.6% to 1.19%.
Kaushik et al. (2012)	Six Sigma methodology has been applied to a small unit manufacturing bicycles chains with dwindling productivity levels.
Ahmad (2013)	Service Sector Performance Management through Six Sigma
Sharma and Sharma (2013)	Application of Six Sigma methodology to improve OEE level, reduction in rework, reduction in maintenance versus operation cost and reduction in defect rate
Mishra and Sharma (2017)	Measuring business performance in a supply chain network using Six Sigma methodology.

*Partially adapted from (Mishra and Sharma, 2017)

2.2. Service Industry

In most developed countries, service sectors and service related exports are the growing economies. The service economy in these countries involves in international trading, e-commerce, transportation, financial services, education, healthcare, and logistics. Technological innovations provide a wide array of services executed in one location and consumed in many other places, persuaded to move offshore to low-cost locations. The internet and other systems of network technologies like mobile phones, big data, and artificial intelligence are providing technical changes to production techniques and business processes. The software has become the main component of all hardware systems (Loungani et. al., 2017). The share of services export in total goods and services export has doubled from around 9 percent in 1970 to over 20 percent by 2014. Service sectors have been a game-changer, offering an opportunity to revive and sustain globalization. There are two potential reasons for the resilience of trades in the service sector: First, demand for a range of traded services is less cyclical, and second, services trade and production are less dependent on external finance (Borchert and Mattoo, 2009).

Services trade has been more resilient than trade in goods to shocks and financial crisis. Recent evidence from the United States shows that services trade has weathered the financial crisis much better than goods trade. For example, as of February 2009, the value of US goods imports had declined year-on-year by 33 percent and the value of goods exports by 21 percent; services imports and exports each had declined by less than 7 percent. Particularly important to note is that the range of modern services has continued to grow since the crisis. Perhaps more important is the fact that services export from developing countries has been more resilient than from advanced economies. Modern business services have been substantially more resilient than traditional services (Ariu, 2014). The growing of services will remain an imperative for diversification and competitiveness of nations across the development spectrum (Reinsdorf and Slaughter, 2009; Gervais and Jensen, 2014; Leo and Philippe, 2014). Figure 1 illustrates the services exports of the World, (in billions of U.S. dollars).



Source: Loungani (et al., 2017)

Figure 1. Service exports of the world by sector (in billions of U.S. dollars).

Six Sigma is an integrated tool, critical to identify strategic factors to sustain innovation and growth in the service system. The important factors include service quality, reliability, price, and delivery speed, essential to achieve success in service industries. The Six Sigma application has a proven track record of improved operational efficiency and reduction of costs. Examples of Six Sigma approach implementation in service industries is presented in Appendix A.

2.3 Bayesian Network Approach

Bayesian networks have been used in several service areas in the recent years such as healthcare service and research, resource allocation, decision making, manufacturing and general service industries applying the high dimensional data to develop learning algorithms to identify critical factors while learning the correct network structure. A Bayesian network can be described in terms of qualitative components, consists of the acyclic directed graph (DAG), quantitative components, consists of joint probability distribution that factorizes into a set of conditional probability distributions governed by the structure of the DAG (Kjaerulff and Madsen, 2010).

In a formal definition (Friedman et al., 1997), a Bayesian network is an annotated directed acyclic graph that encodes a joint probability distribution over a set of random variables **Ω**. A Bayesian network for **Ω** is a pair $B = <G, \theta>$ where G represents a directed acyclic graph and θ represents the set of parameters that quantifies the network. In the graph, the vertices correspond to the random variables $X_1, X_2, \cdots X_n$ and the edges represent the relationships between the variables. The parameters specify as $\theta_{x_{i|\Pi_{x_i}}} = P_B(x_i|\Pi_{x_i})$ for each value x_i of X_i and Πx_i of Π_{Xi}, where Π_{Xi} denotes the set of parents of X_i in G. A Bayesian network B defines a joint probability among $X_1, X_2, \cdots X_n$ as:

$$P_B(X_1, X_2, \cdots X_n) = \prod_{i=1}^{n} P_B(x_i|\Pi_{x_i}) = \prod_{i=1}^{n} \theta_{x_{i|\Pi_{x_i}}}$$

The Bayesian network method incorporates the uncertainties about the unknown parameter. The probability distribution is used to quantify this uncertainty and predict the parameters. The Bayesian network (BN) is a relational diagram, and a probabilistic graphical representation to study the uncertainties of decision variables. For a complex system, the BN helps to draw a conclusion about the likelihood of occurrence of certain events. A Bayesian network should consist of the following (Jenson, 2001):

- A set of variables and a set of directed edges between variables;
- Each variable has a finite set of mutually exclusive states;A set of variables and a set of directed edges between variables;
- Each variable has a finite set of mutually exclusive states;
- The variables together with the directed form a directed acyclic graph (DAG). A directed graph is acyclic if there is no directed path $(A_1 \rightarrow \cdots \rightarrow A_n \ s.t. A_1 = A_n)$
- To each variable A with parents $B_1, \cdots B_n$ conditional variables contain $P(A|B_1, \cdots B_n)$.

There are a few advantages of applying Bayesian networks techniques in system diagnosis.

- Bayesian networks contain a conditional probability distribution for every combination of variable values and provide an estimation of diagnosis instantly.
- In the domain of service process improvement, it is often difficult to collect data. The Bayesian s analysis does not require specific diagnostic observations. The algorithm can produce inference with minimum or no sample sizes.
- Bayesian networks use prior information from various sources, such as the technique can incorporate knowledge of subject matter experts and past data.
- These models naturally focus on the relationship between actions, knowledge, and uncertainty. The model includes decision-making consequences on variables associated with the process outcomes.

3. Service Factor Analysis with Bayesian Networks

The Bayesian network model uses two target variables, three objectives variables, and two indicator variables. Identifying the critical quality factors and the business strategies are considered the top challenges. The study considers Six Sigma, quality factors, and appropriate business strategies are the foundation for innovation and increasing the company's efficiency and growth. The Six Sigma, quality factors, and appropriate business strategies are three fact-based quality factors, considered as the objective variables, the main components to measure the system performance. The variables in the service operation performances and customer retention are considered the indicator variables. The indicator variables are (i) customer retention, and (ii) key performance indicators. Due to the uncertainty of a variable, researchers focus probabilistic inference for model parameters. Two indicator variables, (i) customer retention (R) and (ii) key performance indicators (K) produces two nodes, both are conditional upon three objective variables, business strategies (B), Six Sigma (6σ) and quality indicators (Q), which produce three nodes. Further, the two target variables, (i) customer satisfaction (C), and (ii) total quality management (TQM) develop this network model. These variables target the binary reasoning, each with the state 'no or yes'. The 'no' indicates 'strategies will not work'. The Six Sigma, quality factors and business strategies in the objective variables are manifested by the value observed in the two indicator variables by the customer retention and key performance indicators. The relationship between the variables is shown in Figure 2.

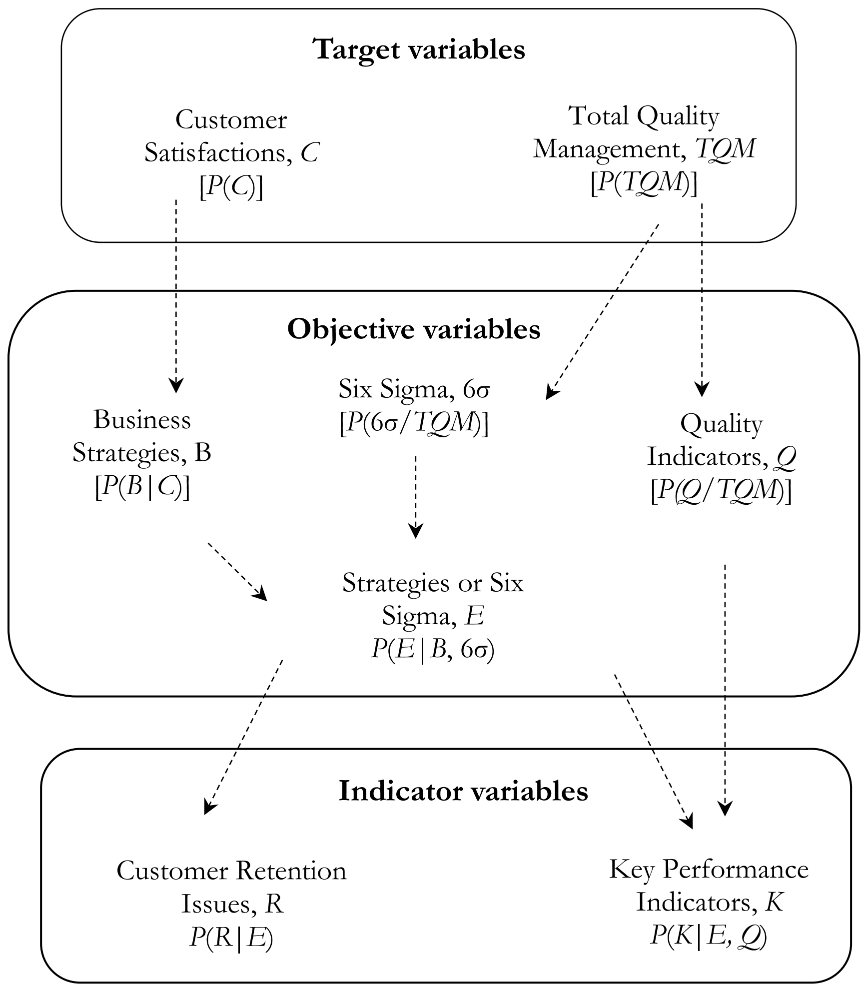


Figure 2. Bayesian network and relationship among the variables

Target variables:
P(*C*): probability of indicators subjected to customer satisfactions.
P(*G*): probability that competition in quality program will impact the service performance.

Objective variables:
P(*B*): probability that business strategies will help to cope with various customer needs
P(6*σ*): probability that implementing Six Sigma will lead to be an improved service sustainability
P(*Q*): probability that quality indicators will help to service quality and customer satisfaction

Indicator variables:
P(*R*): probability that a combination of business strategies and quality indicators are critical to improve customer retention and satisfaction
P(*K*): probability that either strategies and quality program jointly or Six Sigma program improve the key performance indicators.

The general perception of integrated Six Sigma and business strategies in a service system is to function as a single entity. Table 2 illustrates the importance of the prior information considered in the decision support system in the service performance analysis.

Table 2: Flat and Information prior variables

		Flat prior					**Informative prior**				
Target variables	Customer Satisfaction	*P*(C)= (1.0, 0.0)					*P*(C)= (0.85, 0.15)				
	Total Quality Management	*P*(TQM)= (1.0, 0.0)					*P*(TQM)= (0.60, 0.40)				
Objective variables	Business Strategies	*P*(B|C)	C = No		C = Yes		*P*(B|C)	C = No		C = Yes	
		B = No	1		0		B = No	0.9		0.3	
		B = Yes	0		1		B = Yes	0.1		0.7	
	Six Sigma	*P*(6σ|TQM)	TQM = No		TQM = Yes		*P*(6σ|TQM)	TQM = No		TQM = Yes	
		6σ = No	1		0		6σ = No	0.85		0.2	
		6σ = Yes	0		1		6σ = Yes	0.15		0.8	
	Quality Indicators	*P*(Q|*TQM*)	Q = No		Q = Yes		*P*(Q|TQM)	Q = No		Q = Yes	
		Q = No	1		0		Q = No	0.6		0.4	
		Q = Yes	0		1		Q = Yes	0.4		0.6	
Indicator variables	Customer Retention	*P*(R|6*σ*)	R = No		R = Yes		*P*(R|T)	R = No		R = Yes	
		R = No	1		0		R = No	0.95		0.02	
		R = Yes	0		1		R = Yes	0.05		0.98	
	Performance Indicator	*P*(K|Q, 6σ)	K = No		K = Yes		*P*(K|Q, 6σ)	K = No		K = Yes	
			Q = No	Q = Yes	Q = No	Q= Yes		6σ = No	6σ = Yes	6σ = No	6σ = Yes
		K = No	1	0	0	0	K = No	0.9	0.2	0.25	0.1
		K = Yes	0	1	1	1	K = Yes	0.1	0.8	0.75	0.9

4. Results

The Bayesian network model contributes to finding the critical quality factors in an integrated service system to gain business advantages in the global market. The model uses the probabilistic inferences of the observable variables and estimates the likelihood of each of these variables to improve the service operations. The methodology provides a decision-making base among the factors incorporated in business logistics and Six Sigma approaches. The illustrative example provides the knowledge and reasoning for the impacted factors as it is observed in the indicator variables. Understanding the impact of a factor is crucial to implement strategies that would bring continuous improvement in the service and keep the operating cost at a minimum. The Bayesian network model identifies the value and non-value activities and respond to the improvement by eliminating the non-value activities from the process. The process ultimately minimizes the defects, process variation, which leads to increase service quality, reputation, and business success. The integrated approach empowers customer values, retention and key performance indicators, which leads to lower investment, service cost, and improve service quality. If these strategies are not used properly, there is a chance that service efficiency will be affected significantly.

Customer satisfaction and total quality management are the prime activities concerns most service sectors. The coordinated effort of implementing quality factors such as critical quality indicators, Six Sigma conjoin with appropriate business strategies support effective higher customer retention and key performance improvement. A service industry will achieve such benefits when it identifies the possible scope of activities to improve the business strategies and critical quality indicators based on the performance and commitment to customer satisfaction and total quality management. The strategic effect of business strategies, critical quality indicators and Lean Six Sigma on target variables is shown in Table 2.

Table 2. Strategic effects on target variables

	Flat Prior		Informative Prior	
Node	Mean	Standard deviation	Mean	Standard deviation
Lean Six Sigma	1.0	0	1.458	0.4982
Strategies	2.0	0	1.777	0.416
Quality	1.0	0	1.567	0.4955

Implementing quality factors and appropriate business strategies, service firms able to finetune the area where there are lacking and take possible steps to improve or invest for improvement. Initially, the model was run with no prior information (i.e., flat priors were considered for the variables). Later, with some information about the customer retention and performance observation, the model shows how to change the focus on selecting quality factors and identify the area of the investment and concentration. If the success and improvement of a service system only depend on business strategies, it may often require an excessive focus on operation, labor, and service. With the increasing utilization of quality factors under total quality management, it may achieve the performance gains and balanced system operation. With some prior information, the effectiveness of six-sigma application increases to 46% and the need for identifying quality factor increases to 57% while the investment focus on business strategies reduce from 100% to 73% for service improvement. The Bayesian network techniques find the appropriate balance of investment focus to improve the system performance.

5. Conclusion

This study investigates the service sector functionality to identify the critical service quality factors, resource allocation, and strategic alliances through the application of Lean Six Sigma concepts. The service sector contributes significantly to a country's GDP and job creation. The improvement of a service system cannot succeed without considering various uncertainties in the system. Auditing the current service system and prioritizing the improvement effort is performed in the form of a Bayesian network model. The model presented in this paper helps to improve the performance of an integrated service sector by evaluating alternative quality factors and customer alliance strategies. The Bayesian network is a learning method that uses prior distribution as functions. If the prior distribution is based on evidence, it is called informative prior; it is classified as non-informative or flat prior. In this network model, seven variables represent the nodes. There are three variables represents competitive strategies. Informative and non-informative (Flat) prior is specified for each variable. The analytical technique based on Bayesian network process with the illustrative example provides the knowledge and reasoning to turn attention towards the impact of the Six Sigma applications in service industries.

Once the Bayesian network model is constructed, the parameters of the model are updated dynamically with changes. The model provides the key inputs, which gradually improves as the new information is integrated into the model. The result of this study provides the empirical evidence that effective integration of quality factors enhances service performance, effective to establish a long-term relationship with the partners' companies. The assessment would bring significant financial return by reducing rework and errors while improving the quality of services. The result shows the likelihood and impact of implementing any of these quality factors consequently improve the entire service industry performance. The implementation of these quality factors may begin with initial resistance from unit staffs and supervisor due to rapid change of practices. The study shows how to reduce the traditional view of sole dependence on customer alliance but implement six sigma applications to identify appropriate quality factors and strategies to improve the service system. Bayesian network is a suitable domain that a company can utilize the critical quality factors and appropriate business strategies to increase applications.

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Appendix A: Service Sector Applications with Six Sigma[2]

Service Function	Service Sector for Six Sigma Application
Airline industry	Baggage handling, number of mistakes in reservation, waiting time at the check-in counter, etc.
Shipping and transportation	Wrong shipment of items, wrong shipment address, late shipment, wrong customer order, etc.
Public utilities	Late delivery of service, number of billing errors, waiting time to restore the service after a fault has been reported, call center of the utility company, etc.
Accounting and finance	Payment errors, invoicing errors, errors in inventory, inaccurate report of income, inaccurate report of cash flow, etc.
Healthcare	Proportion of medical errors, time to admit in an emergency room, number of successful surgical operations per week, number of wrong diagnoses, waiting time to serve at the reception in a hospital etc.
Banking	Fund transfer processing time, number of processing errors, number of customer complaints received per month, number of ATM breakdowns, duration of ATM breakdowns, etc.
Healthcare	Reduce number of x-ray examinations and errors system wide. Reduce waste in product and time in x-ray examinations administration. Improve patient satisfaction with x-ray examinations experience.
Tourism	Develop a systemic plan to reduce time waste and tour event variation. Improve quality assurance in hospitality. Improve tourism satisfaction and use human to deliver services.
Hospitality	Reduce the high turnover rate of employees in the hospitality organization. Improve staffing needs
Manufacturing	Product operations manual, Service training

[2]Partially adopted from Aazadnia et al, 2008

Appendix B: Win BUGS Code

(Flat Prior)

```
Model       { customer ~ dcat(p.customer[1:2])
              tqm ~ dcat(p.tqm[retention,1:2])
              six.sigma ~ dcat(p.six.sigma[tqm,1:2])
              quality ~ dcat(p.quality[tqm,1:2])
              either <- max(strategy, six.sigma)
              retention ~ dcat(p.retention[either,1:2])
              performance ~ dcat(p.performance [either, quality,1:2])      }

Data        list(retention = 2, performance = 2, p.tqm = c(0.60,0.40),
            p.strategy = structure(.Data = c(1.0,0.0,0.0, 1.0), .Dim = c(2,2)),
            p.quality = structure(.Data = c(1.0,0.0,0.0,1.0), .Dim = c(2,2)),
             p.six.sigma = structure(.Data = c(1.0,0.0,0.0,1.0), .Dim = c(2,2)),
            p.retention = structure(.Data = c(1.0,0.0,0.0,1.0), .Dim = c(2,2)),
             p.performance = structure(.Data = c(1.0,0.0, 0.0,1.0, 0.0, 1.0, 0.0,1.0), .Dim = c(2,2,2)))

Initials    list(retention = 1, strategy = 1, six.sigma = 1, performance = 1, quality = 1).
```

(Informative Prior)

```
Model       { customer ~ dcat(p.customer[1:2])
              tqm ~ dcat(p.tqm[retention,1:2])
              six.sigma ~ dcat(p.six.sigma[tqm,1:2])
              quality ~ dcat(p.quality[tqm,1:2])
              either <- max(strategy, six.sigma)
              retention ~ dcat(p.retention[either,1:2])
              performance ~ dcat(p.performance [either, quality,1:2])      }
Data
            list(retention = 2, performance = 2, p.tqm = c(0.60,0.40),
            p.strategy = structure(.Data = c(0.90,0.10,0.30,0.70), .Dim = c(2,2)),
            p.quality = structure(.Data = c(0.70,0.30,0.40,0.60), .Dim = c(2,2)),
            p.six.sigma = structure(.Data = c(0.85,0.15,0.20,0.80), .Dim = c(2,2)),
            p.retention = structure(.Data = c(0.90,0.10,0.05,0.95), .Dim = c(2,2)),
            p.performance = structure(.Data = c(0.9,0.1,  0.2, 0.8, 0.25,0.75, 0.1,0.9), .Dim = c(2,2,2)))

Initials    list(retention = 1, strategy = 1, six.sigma = 1, performance = 1, quality = 1).
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Biography

Mohammad Anwar Rahman is an Associate Professor of Manufacturing and Construction Management Program at the Central Connecticut State University. His research and teaching focus on supply chain strategy & logistics, decision making under uncertainty and six sigma quality process. His articles appeared in academic journals including European Journal of Operations Research, Journal of the Operational Research Society and published book chapters. He presented papers at national and international conferences and regularly serves as a journal reviewer. Rahman served as PI and Co-PI in research projects sponsored by The American Association of University Professors (AAUP), US Department of Transportation (USDOT) and Mississippi Department of Education (MDE). He participated in Pan-American Advanced Studies Institutes Program Award (PASI-NSF), NASA Academy of Aerospace Quality Workshop award. He serves as a board member of Industrial Engineering and Operations Management (IEOM), and member of other professional forums.