Six Sigma project selection via quality function deployment

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Abstract: Six Sigma is one of the most widely used methodologies in many organisations for improving the quality of process/product to enhance customer satisfaction and company revenue. A detailed literature review discloses that the project selection is an area of extreme importance for assuring the success of Six Sigma implementation, but that has been less researched in the past. This research paper aims to develop a project selection method by combining quality function deployment and Six Sigma to assist the organisations as well as Six Sigma consultants for selecting right project. A real-time case study from an Indian small- and medium-sized enterprise is explored in this paper to see the sights of the proposed methodology.

Keywords: project selection; Six Sigma; QFD; quality function deployment; SMEs; small- and medium-sized enterprises; customer satisfaction; quality.

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1 Introduction

Six Sigma is a key business improvement approach being practiced in many organisations (McAdam and Hazlett, 2010) to generate maximum business benefit and competitive advantage (Sony and Naik, 2011). This approach identifies and eliminates defect (Sadraoui et al., 2010), mistakes or failures in business processes (Aboelmaged, 2010) by focusing on those process performance characteristics that are of critical importance to customers (Kumar et al., 2009). Focussing on the customer needs, Six Sigma projects are formed, the requirements and current performance are measured, the criteria and key variables that affect the customer satisfaction are analysed and process is improved, by monitoring and checking the systems the process is controlled (Prasada Reddy and Venugopal Reddy, 2010). Selection of most viable project is the critical step in Six Sigma framework (Soti et al., 2011). Since the success of Six Sigma programme hinges on project selection (Büyüközkan and Öztürkcan, 2010), the identification of high-impact projects at the initial stage of Six Sigma implementation will result in significant breakthroughs in a rapid timeframe (Hossain et al., 2010).

The evidence from the published literatures on Six Sigma showed that project selection is less researched in the past. This paper is dedicated to carryout research in this area and to develop a methodology for assuring right project selection at the start of Six Sigma. Quality function deployment (QFD), a known prioritisation tool (Andronikidis et al., 2009; Anwar et al., 2010), is used to select most appropriate Six Sigma project alternative. The proposed methodology is developed upon the define–measure–analyse–improve–control (DMAIC) Six Sigma methodology and so abbreviated as quality function deployment–measure–analyse–improve–control (QFDMAIC). This paper chronicles the design, development and implementation of QFDMAIC framework through a real-time case study conducted in small- and medium-sized enterprise (SME) in India. This paper is organised as follows: in Section 2, the research background is discussed through an extensive literature collections. Sections 3 and 4 discuss about the features of Six Sigma and QFD, respectively. In Section 5, the developed model is detailed. In Section 6, a case study from an Indian SME is given to explore the effectiveness of the proposed approach. In Section 7, the result achieved by the QFDMAIC model is presented and finally Section 8 concludes the paper with some scope for future research exertion in QFDMAIC model.

2 Literature review

Many published literatures on Six Sigma have discussed about project selection either as a critical factor or as a success factor for implementation. Some authors have also discussed about the methodologies to select suitable project for Six Sigma implementation. Hence, in this paper, the literature survey is designed to focus on papers discussed about the challenges for Six Sigma; project prioritisation in Six Sigma and critical success factors for Six Sigma programme as major theme. To avoid never ending revision, papers published from the year 2000 to 2011 are collected. Each paper was carefully reviewed and then organised to produce a classification based on the theme on which it has been built. Although this research is not an exhaustive, it serves as a comprehensive base for an understanding of Six Sigma project selection. It is unavoidable to have a paper that is relevant to more than one theme, so listing a paper under more than one theme was allowed. For example, a paper may address critical success factors for Six Sigma implementation but provide information on project prioritisation technique. An elaboration of the cited themes is presented in Sections 2.1–2.3.

2.1 Six Sigma success factors

Table 1 provides a comprehensive list of authors who had contributed intensively towards the identification of key factors for success of Six Sigma implementation and found that they have commonly discussed about 13 factors being primarily contributing success to Six Sigma programme. Those factors are:

1. Organisational involvement and commitment
2. Selection of projects
3. Culture orientation
4. Correlating business goal with Six Sigma implementation
5. Coordination and team work
6. Mode of communication
7. Organisational structure and resource capacity
8. Motivation, training and development
9. Customer involved business culture
10. Measurement system and information media
11. Accountability and reward plans
12. Underlying tools and techniques within Six Sigma
13. Project monitoring and tracking skills

Table 1 Literatures discussing about Six Sigma success factors

No.	*Author(s)*	*Journal name*	*Year*
1	Sanders and Hild	*Quality Engineering*	2000
2	Antony and Banuelas	*Measuring Business Excellence*	2002
3	Coronado and Antony	*Expert Systems with Applications*	2002
4	Byrne	*Journal of Organisational Excellence*	2003
5	Antony	*Managerial Auditing Journal*	2004a
6	Antony and Fergusson	*Managerial Auditing Journal*	2004
7	McAdam and Evans	*Int. J. Six Sigma and Competitive Advantage*	2004a
8	Wessel and Burcher	*The TQM Magazine*	2004

Table 1 Literatures discussing about Six Sigma success factors (continued)

No.	*Author(s)*	*Journal name*	*Year*
9	Frings and Grant	*Quality and Reliability Engineering International*	2005
10	Hahn	*Quality and Reliability Engineering International*	2005
11	Knowles et al.	*Int. J. Logistics: Research and Applications*	2005
12	Szeto and Tsang	*Int. J. Six Sigma and Competitive Advantage*	2005
13	Antony	*Business Process Management Journal*	2006
14	Buch and Tolentino	*Journal of Organisational Change Management*	2006a
15	Buch and Tolentino	*Leadership and Organisation Development Journal*	2006b
16	Ho et al.	*Int. J. Six Sigma and Competitive Advantage*	2006
17	Kwak and Anbari	*Technovation*	2006
18	Laosirihongthong et al.	*Int. J. Innovation and Technology Management*	2006
19	Linderman et al.	*Journal of Operations Management*	2006
20	Nonthaleerak and Hendry	*Int. J. Six Sigma and Competitive Advantage*	2006
21	Revere et al.	*Int. J. Quality and Productivity Management*	2006
22	Antony et al.	*Leadership in Health Services*	2007
23	Chakrabarty and Tan	*Managing Service Quality*	2007
24	Cheng	*Int. J. Six Sigma and Competitive Advantage*	2007
25	Kumar	*Int. J. Six Sigma and Competitive Advantage*	2007
26	Shanmugam	*Total Quality Management and Business Excellence*	2007
27	Antony	*Int. J. Productivity and Performance Measurement*	2008
28	Antony et al.	*The Journal of Operations Research Society*	2008
29	Chung et al.	*Total Quality Management and Business Excellence*	2008
30	Feng and Manuel	*Int. J. Health Care Quality Assurance*	2008
31	Hilton et al.	*Total Quality Management and Business Excellence*	2008
32	Jenicke et al.	*The TQM Journal*	2008
33	Prabhushankar et al.	*Int. J. Six Sigma and Competitive Advantage*	2008
34	Roger et al.	*Journal of Operations Management*	2008
35	Schroeder et al.	*Journal of Operations Management*	2008
36	Shahabuddin	*Int. J. Quality and Productivity Management*	2008
37	Yang et al.	*Int. J. Six Sigma and Competitive Advantage*	2008
38	Timans et al.	*Int. J. Six Sigma and Competitive Advantage*	2009
39	Aboelmaged	*Int. J. Quality and Reliability Management*	2010
40	Brun	*Int. J. Production Economics*	2010
41	Sambhe and Dalu	*Int. J. Six Sigma and Competitive Advantage*	2011a
42	Sony and Naik	*Int. J. Business Excellence*	2011

Selection of projects is one among the factors which is heavily discussed by many authors (Antony and Banuelas, 2002; Antony et al., 2005; Brun, 2010; Chakrabarty and Tan, 2007; Coronado and Antony, 2002; Ho et al., 2006; Kumar, 2007; McAdam and Evans, 2004a; Nonthaleerak and Hendry, 2006; Yang et al., 2008). McAdam and Evans

(2004a) have claimed that the Six Sigma programme is weak in understanding customer needs and transforming these needs into projects. Antony (2004a) stated that most of the projects fall behind schedule or fail due to a questionable linkage of these projects to the organisation's strategic business goals. An organisation becomes frustrated with the Six Sigma initiatives if the projects do not deliver the expected bottom-line results. This causes management to shift their attention and resources on other initiatives (Hilton et al., 2008; Jenicke et al., 2008; Szeto and Tsang, 2005). In their attempt to fortify the difficulties to implement Six Sigma in an Indian service organisation, Sony and Naik (2011) have listed the stated factors as key important ingredients for the success of the methodology. Sambhe and Dalu (2011a) have exercised to develop existing Six Sigma programme to make it suit to an Indian auto component manufacturing industry by reviving the fit-falls in the approach to achieve competitive edge. Brun (2010) has boiled that Six Sigma is not a magic bullet that solves problems automatically by having some data entered into software and analysing the results. It requires people who are good thinkers with creativity and strong analytical skills. A project chosen for Six Sigma implementation can be the right project for the organisation to work on and still be a failure because the wrong people were assigned to the project (Shahabuddin, 2008). The personnel assigned the job of project identification and selection should include managers who have been trained as Six Sigma champions, as well as other key Six Sigma knowledge resources, such as master black belts (MBBs), (black belts) BBs, (green belts) GBs and yellow belts, who bring experience in determining the feasibility and management of projects under consideration (Antony et al., 2008; Feng and Manuel, 2008; Yang et al., 2008).

2.2 Six Sigma challenges

The commonly discussed challenges and limitations by the author listed in Table 2 are:

1. Subjective judgement for selection of projects for Six Sigma deployment.
2. Project management and tracking skill of Six Sigma practitioners.
3. The 1.5 sigma shift resulting in a 3.4 defect per million opportunities (DPMOs) does not make sense in service processes.
4. The impact of leadership styles on Six Sigma success needs more research.
5. No unified standards have been accepted regarding the contents of belt training.
6. The relationship between the cost of poor quality (COPQ) and the sigma quality level is based on experience not empirical research.
7. The relationship between COPQ and its financial impact in SMEs needs further research, since SMEs are hardly considering quality costs.
8. Availability of quality data is still a great challenge in Six Sigma projects.
9. In some cases, the solutions driven by Six Sigma are expensive and only a small part of the solution is implemented at the end.
10. The calculation of defect rates is based on the assumption of normality, while the calculation of defect rates for non-normal situations is not yet properly addressed.

11 Owing to dynamic market demands, critical-to-quality characteristics should be critically examined at all times and refined as necessary.

12 Training programmes usually do not address forecasting and time series methods.

Table 2 Literatures discussing about Six Sigma challenges

No.	*Author(s)*	*Name of the journal*	*Year*
1	Sanders and Hild	*Quality Engineering*	2000
2	Antony et al.	*IEEE Control Systems Magazine*	2001
3	Antony and Banuelas	*Measuring Business Excellence*	2002
4	Feld and Stone	*Performance Improvement*	2002
5	Hammer	*IEEE Engineering Management Review*	2002
6	Antony	*The TQM Magazine*	2004b
7	Goh and Xie	*The TQM Magazine*	2004
8	McAdam and Evans	*Int. J. Six Sigma and Competitive Advantage*	2004a
9	McAdam and Lafferty	*Int. J. Operations and Production Management*	2004
10	Senapati	*Int. J. Quality and Reliability Management*	2004
11	Van Den Heuvel et al.	*Quality and Reliability Engineering International*	2004
12	Gijo and Rao	*Measuring Business Excellence*	2005
13	Hahn	*Quality and Reliability Engineering International*	2005
14	McAdam et al.	*Int. J. Organisational Analysis*	2005
15	Antony	*Business Process Management Journal*	2006
16	Goh et al.	*Int. J. Six Sigma and Competitive Advantage*	2006
17	Ho et al.	*Int. J. Six Sigma and Competitive Advantage*	2006
18	Kwak and Anbari	*Technovation*	2006
19	Lee and Choi	*Total Quality Management and Business Excellence*	2006
20	McClusky	*Measuring Business Excellence*	2006
21	Nonthaleerak and Hendry	*Int. J. Six Sigma and Competitive Advantage*	2006
22	Revere et al.	*Int. J. Quality and Productivity Management*	2006
23	Antony et al.	*Leadership in Health Services*	2007
24	Cheng	*Int. J. Six Sigma and Competitive Advantage*	2007
25	Kumar	*Int. J. Six Sigma and Competitive Advantage*	2007
26	Yeung	*Int. J. Six Sigma and Competitive Advantage*	2007
27	Antony	*Int. J. Productivity and Performance Measurement*	2008
28	Antony et al.	*The Journal of Operations Research Society*	2008
29	Kumar et al.	*Int. J. Production Economics*	2008
30	Liu et al.	*IEEE Transactions on Magnetics*	2008
31	Roger et al.	*Journal of operations management*	2008
32	Shahabuddin	*Int. J. quality and productivity management*	2008
33	Natarajan and Morse	*Int. J. quality and productivity management*	2009
34	Timans et al.	*Int. J. Six Sigma and competitive advantage*	2009
35	Desai and Patel	*Int. J. Business Excellence*	2010
36	Deshmukh and Lakhe	*Int. J. Quality and Productivity Management*	2010
37	Lall and Gupta	*Int. J. Quality and Productivity Management*	2010
38	Soti et al.	*Int. J. Business Excellence*	2011

Although Six Sigma is a powerful strategy and has impact on industry and service sectors, Six Sigma still lacks a theoretical underpinning with other management theory (Antony, 2008). Hammer (2002) argued that Six Sigma has been the target of criticism and controversy in the quality community characterising it as 'total quality management (TQM) on steroid'. One of the main criticisms is that subjective judgement of project identification (Goh and Xie, 2004). Organisations must realise that Six Sigma is not the universal answer to all business issues, and it may not be the most important management strategy that an organisation feels a sense of urgency to understand and implement Six Sigma (McClusky, 2006).

To ensure the long-term sustainability of the Six Sigma method, organisations need to analyse and identify suitable project to properly utilise Six Sigma principles, concepts and tools (Antony et al., 2007). Training is another important challenge in implementing Six Sigma projects successfully and should be part of an integrated approach (Cheng, 2007). Training should also cover both qualitative and quantitative measures and metrics, leadership, and project management practices and skills (Kumar et al., 2008). Organisations without a complete understanding of real challenges of Six Sigma projects are likely to fail (Roger et al., 2008). Senior management's strong commitment, support and leadership are essential to dealing with any cultural issues or differences related to Six Sigma implementation. If the commitment and support of utilising various resources do not exist, organisation should probably not consider adopting Six Sigma (Shahabuddin, 2008).

2.3 Project selection in Six Sigma

Selection of Six Sigma projects has received substantial attention from authors listed in Table 3 and they strongly advocate that the right selection of Six Sigma projects is one of the most critical factors for the effective deployment of a Six Sigma programme. Antony and Banuelas (2002) have coined project selection as one of the important key ingredients for effective and successful implementation of Six Sigma programme. They have also stressed for developing proper criteria for selecting right project to avoid delayed result and a great deal of frustration. Antony (2004a,b) has indicated some project selection criteria when a service organisation wants to implement Six Sigma programmes. Those criteria include financing, customer satisfaction, cost, risks and alignment of strategic business goals and objectives. If project selection is systematically sloppy, the entire Six Sigma effort could fail. Banuelas et al. (2006) have pointed to project selection criteria employed in UK organisations based on the results of a survey study.

These criteria include customer satisfaction, financial benefits, top management commitment and the integration with the company's strategy. Also, he has identified some tools; cost benefit analysis, cause and effect matrix, brainstorming and Pareto analysis which are commonly employed in UK organisations to identify and prioritise projects.

Table 3 Literatures discussing about Six Sigma project selection

No.	*Author(s)*	*Name of the journal*	*Year*
1	Antony et al.	*IEEE Control Systems Magazine*	2001
2	Antony and Banuelas	*Measuring Business Excellence*	2002
3	Antony	*Managerial Auditing Journal*	2004a
4	Antony	*The TQM Magazine*	2004b
5	Antony et al.	*Int. J. Quality and Reliability Management*	2005
6	Antony	*Business Process Management Journal*	2006
7	Banuelas et al.	*The TQM Magazine*	2006
8	Kumi and Morrow	*Program: Electronic Library and Information Systems*	2006
9	Kwak and Anbari	*Technovation*	2006
10	Antony et al.	*Leadership in Health Services*	2007
11	Choo et al.	*Management Science*	2007
12	Jung and Lim	*Project Management Journal*	2007
13	Kumar et al.	*The TQM Magazine*	2007
14	Savolainen and Haikonen	*The TQM Magazine*	2007
15	Bonilla et al.	*Int. J. Six Sigma and Competitive Advantage*	2008
16	Chao and Chia	*Expert Systems with Applications*	2008
17	Hu et al.	*Int. J. Production Research*	2008
18	Kahraman and Büyüközkan	*Journal of Multiple-Valued Logic and Soft Computing*	2008
19	Kumar et al.	*Int. J. Production Economics*	2008
20	Prabhushankar et al.	*Int. J. Six Sigma and Competitive Advantage*	2008
21	Shahabuddin	*Int. J. Productivity and Quality Management*	2008
22	Su and Chou	*Expert Systems with Applications*	2008
23	Wright and Basu	*Int. J. Six Sigma and Competitive Advantage*	2008
24	Kumar et al.	*Business Process Management Journal*	2009
25	Yang and Hsieh	*Expert Systems with Applications*	2009
26	Brun	*Int. J. Production Economics*	2010
27	Büyüközkan and Öztürkcan	*Expert Systems with Applications*	2010
28	Aboelmaged	*Int. J. Quality and Reliability Management*	2010
29	Sambhe and Dalu	*Int. J. Productivity and Quality Management*	2011a
30	Sambhe and Dalu	*Int. J. Six Sigma and Competitive Advantage*	2011b
31	Sony and Naik	*Int. J. Business Excellence*	2011
32	Soti et al.	*Int. J. Business Excellence*	2011

Kumar et al. (2007) applied a designed experimental analysis (DEA) model to derive the efficient Six Sigma projects. They identified inputs and outputs of the Six Sigma projects, and then applying a basic DEA model, they derived the efficient frontier of Six Sigma projects. Also, they carried out a sensitivity analysis to study the impact of variation in projects' inputs and outputs on project performance and to identify the critical inputs and outputs. Moreover, Su and Chou (2008) employed three main steps for selecting Six Sigma projects. Those steps are understanding and analysing the voice of customers

(VOCs), drawing up the organisation's business strategic policies and deploying the possible Six Sigma projects based on the organisation's business policies and the VOCs. Chao and Chia (2008) developed an approach for the creation and evaluation of critical Six Sigma projects and ranking them based on identified criteria. They applied a fuzzy AHP methodology for ranking projects. Kumar et al. (2008) developed a mathematical programming methodology for selecting the best Six Sigma projects. They used a non-linear binary model based on Taghuchi function to select the best projects. Kahraman and Büyüközkan (2008) developed a weighted additive fuzzy goal programming methodology for selecting the best suitable portfolio of projects in Six Sigma. They used fuzzy AHP for deriving the importance weights of criteria such as maximise financial benefits, maximise process capability, maximise customer satisfaction, minimise cost, minimise project completion time and minimise risk. Yang and Hsieh (2009) proposed to adopt national quality award criteria as the Six Sigma project selection criteria and proposed a hierarchical criteria evaluation process. The strategic criteria are evaluated by the management team using a Delphi fuzzy multiple-criteria decision-making method. Then, the tactical sub-criteria which contain additional operational issues are evaluated by the Six Sigma champion. Büyüközkan and Öztürkcan (2010) have developed a novel approach based on a combined analytic network process (ANP) and decision-making trial and evaluation laboratory (DEMATEL) technique to help companies determine critical Six Sigma projects and identify the priority of these projects especially in logistics companies. First of all, the Six Sigma project evaluation dimension and components are determined. DEMATEL approach is then applied to construct interrelations among criteria. The weights of criteria are obtained through ANP. Aboelmaged (2010) proposed a comprehensive methodology for the evaluation and selection of the Six Sigma projects based on three main categories of criteria including business criteria, technological and process criteria, and financial criteria which contain eight sub-criteria. For deriving the overall utility of projects, they have designed an adaptive neuro-fuzzy inference system which is capable to consider interrelations among criteria. In this approach, optimal portfolio of projects which should be implemented is obtained by applying a fuzzy-weighted additive goal programming model. Although this review does not claim to be exhaustive, it does provide reasonable insights into the state-of-the-art in Six Sigma project selection research.

3 Six Sigma

3.1 Definition

Six Sigma is a disciplined process which helps companies to focus on developing and delivering nearly defect free products and services (Soti et al., 2011). It is an organised and systematic business performance improvement strategy that relies on statistical and scientific methods to reduce waste and the number of defects within the Six Sigma level (Antony, 2004a; Banuelas and Antony, 2003). Six Sigma level is the benchmarking factor for the ability of the process to fulfil the requirement (Yang and Hsieh, 2009). Table 4 illustrates how sigma levels would equate to defect rates and organisational performances, which are often measured in terms of DPMOs (Sambhe and Dalu, 2011b). DPMO is the number of defective opportunities that do not meet the specification limits out of one million opportunities.

Table 4 DPMO and sigma level

	Process mean fixed		*Process mean with 1.5 shift*	
Sigma level	*Non-defective rate*	*DPMO*	*Non-defective rate*	*DPMO*
1σ	86.26894	317,311	30.2328	697,672
2σ	95.44998	45,500	69.1230	308,770
3σ	99.73002	2,700	93.3790	66,811
4σ	99.99366	63.4	99.3790	6,210
5σ	99.9999943	0.57	99.97674	233
6σ	99.9999998	0.002	99.99966	3.4

3.2 Method

The application of Six Sigma has the ability to reduce the variation of the characteristics of the product or service from the target by using either a continuous improvement or a design/redesign approach (Aboelmaged, 2010). The first approach follows the phases: define, measure, analyse, improve and control. This approach is known as DMAIC methodology.

The second approach progresses through the phases: define, measure, analyses, design and verify. This is known as the define–measure–analyse–design–verify (DMADV) methodology (Banuelas and Antony, 2003). DMAIC is used for improving an existing process, whereas DMADV is employed for the design of products (Banuelas and Antony, 2003; Snee, 2004). The conventional DMAIC concept is explained in Table 5.

Table 5 Six Sigma DMAIC cycle

Define phase	Through this phase, Six Sigma project is drafted and the process to be improved is identified. After identifying the process by using suitable techniques, the process is documented. One such technique that is often used is the flow-charting technique. Finally, the customer's requirements are identified, analysed and prioritised.
Measure phase	During this phase, data are collected to evaluate the level performance of the process and provide information for the subsequent phases. The Six Sigma team decides the characteristics to be measured, the person doing the measurement, the measuring instruments, target performance and sampling frequency. Finally, the process capability is calculated.
Analyse phase	In this phase, Six Sigma team analyses the data collected to find the key variables which cause process variation and discovers the causes for defects. Alternative ways of improving the process are also evaluated during this phase. The various tools used in this phase are root-cause analysis, cause and effect diagram, Pareto charts, failure mode and effects analysis and design of experiments.
Improve phase	Here, the Six Sigma team modifies the process to stay within the maximum permissible range of the performance of the key variables. The process performance has to be monitored and measured. If it is satisfactory, it can be institutionalised. Solutions for process improvement are obtained through process simplification, parallel processing and bottleneck elimination.
Control phase	This phase has the purpose of sustain the improvements established through the previous phases. By using control charts, the critical variables related to the performance are controlled to keep an eye on the process performance after improvement.

3.3 Benefit and advantages of Six Sigma

The benefits of Six Sigma in business organisations are: defect reduction, cycle time reduction, manufacturing cost reduction, market share growth, productivity improvement, product/service development, customer retention and culture change (Lall and Gupta, 2010; Sambhe and Dalu, 2011a). These benefits can be achieved through the successful implementation of Six Sigma. The successful implementation depends upon the training given to individuals of the organisation in the fundamental concepts and tools involved in the application of Six Sigma (Deshmukh and Lakhe, 2010).

The levels of training given to individuals in organisations during the execution of Six Sigma projects are categorised into GB, BB and MBB (Brun, 2010). Six Sigma is a methodology also helps to (Prabhushankar et al., 2008):

- increase the performance of the company by the improvement of the quality of its processes
- prepare business collaborators with advantage of efficiency by eliminating the defects
- get tools to reduce the costs
- provide methods tested to measure precisely and increase the return on investment
- allow undervaluing the financial risks
- accent puts to the measure of the defects
- imply all the personnel in real activities with the strategic objectives
- develop the statistical analysis of the data
- improve comprehension, control and performance of the key processes.

3.4 Why Six Sigma?

All the processes, whatever is their degree of accuracy, are unable to produce the same product always exactly. There will be always a small variation between the products considered identical, and these are the variability's which lead to non-quality (Goh and Xie, 2004). Whatever be the studied machine and the characteristic observed, one always notes dispersion in the distribution of the characteristic (Kumar et al., 2008). These variations come from the whole of the process of production. The aim of Six Sigma is to improve quickly, continuously and significantly the processes by eliminating these variability's (Natarajan and Morse, 2009). This methodology is used to improve the processes, the products and the services, to reduce the costs of all kinds and to improve quality (Desai and Patel, 2010). The objective is simple: to satisfy the customer by having processes without defect with advanced tools of progress and to reduce variability (Timans et al., 2009). Moreover, Six Sigma is a change of positive and major culture with real financial results (Wright and Basu, 2008). To have a process Six Sigma means that the difference between the limit of low specification and the limit of high specification of the customer can contain six times the standard deviation (or Sigma) of the production curve of the process (Schroeder et al., 2008). Thus, the variations of a characteristic generally follow a bell-shaped curve: law of Gauss or normal law (central limit theorem).

If the average of the production is centred on the target, it is thus natural to find values lain between ±3 standard deviations, if values leave these limits, one has a strong probability that the process is not centred any more on the target, it is then necessary to identify the causes of variability to centre the process. All the processes have variability, which have causes very few, (20% causes = 80% of the effects). If one knows these causes, one should be able to control them, then the designs must give robust processes to the remaining variations that is true for the processes, the products, the transfers and the services (Kahraman and Büyüközkan, 2008).

3.5 Applications

The application of Six Sigma in a variety of industries is well-documented in literatures. It starts with a business strategy and ends with top–down implementation, with a significant impact on profit if successfully deployed (Antony et al., 2005; Yang and Hsieh, 2009). Examples in the manufacturing sector include Motorola and GE as the most famous. The application of Six Sigma is from the manufacturing field to encompass all business operations, such as services, transactions, administration, R&D, sales and marketing, and especially to those areas that directly affect the customer (Timans et al., 2009).

4 Quality function deployment

QFD was conceived in Japan in the late 1960s and Mr Akao first presented its concept and method (Chan and Wu, 2002). It is a concept and methodology under the umbrella of 'TQM' and it is one of the few techniques that could potentially have a quality improvement impact throughout a company's process (Akao and Mazur, 2003). Its objectives are to identify and prioritise customer requirements and to translate these requirements into appropriate company requirements (Celik et al., 2009).

4.1 Definition

QFD has been defined as 'a system for translating consumer requirements into appropriate company requirements at each stage from research and product development to engineering and manufacturing to marketing/sales and distribution' (Nagendra and Osborne, 2000). QFD takes the VOC and deploys it throughout the firm. Through QFD, the VOC aligns the company's resources to focus on maximising customer satisfaction. QFD facilitates the growth and prosperity of a firm by developing an array of products that are attractive to existing and new customers.

4.2 Benefits

Products designed with QFD may have lower production cost, shorter development time and higher quality than products developed without QFD (Akao and Mazur, 2003). These benefits are attracting an increasing number of product development practitioners to the QFD methodology (Celik et al., 2009). Although manufacturing industries were the first to adopt QFD, service and government organisations are also using it in their efforts to improve performance (Bottani and Rizzi, 2006; Nagendra and Osborne, 2000).

4.3 Method

QFD is taking the VOC from the beginning of product development and deploying it throughout the firm via a sequence of phases. Through QFD, the VOC aligns the company's resources to focus on maximising customer satisfaction and minimising waste (Mehrjerdi, 2010). Listening to the customer requires that management work to gain an understanding of its customers at three levels (Yamashina et al., 2002).

The first level is understanding the basic wants and needs of the customer. A cross-functional team using a variety of market research methods (e.g. individual interviews, focus groups, and mail and telephone surveys) generates a list of customer requirements. The information collected during this stage is referred to as the 'spoken' quality demands and performance expectations. The requirements are usually vague (e.g. the car has a 'good ride') or incomplete and must be further refined into measurable characteristics. There is also information, which is not directly given by the customer, but must be included in the analysis to obtain a more complete understanding of customer requirements. The 'unspoken' attributes are often overlooked by the customer or assumed to be incorporated into the product (e.g. plane arrives safely). The product must fulfil all of these basic requirements, along with attaining high levels of performance to achieve a competitive level of customer satisfaction.

Secondly, QFD drives the company to go beyond these data collection techniques and to identify fundamental customer needs and root product functions. In addition to the spoken and unspoken wants of the customer, QFD forces the design team to determine hidden customer requirements by studying how customers use a product, examining the product's applications and learning customer behaviours. For example, customers may express a desire to have the bank offer more convenient hours. One response would be to open the bank for longer hours. Another would be to offer access to its services via the internet, thus facilitating banking for extended hours.

Finally, to sustain long-term market share, QFD is a vehicle to provide unexpected features to the product which 'excite and delight' the customer in addition to learning the basic quality, performance attributes and root product functions. These features are not usually known by the customer because they are either unaware of technological advances (e.g. new laser applications) or have become accustomed to standard product uses or applications. While some new characteristics have evolved from technological breakthroughs, not all new features can come through research and development. 'New' features or product applications are found when time is spent understanding the customer and the usage of the product (Celik et al., 2009).

4.4 Models

There are two dominant models which are similar but different approaches to QFD (Gonzalez et al., 2004):

1. *Akao's Matrix of Matrices Model*: It is also known as the more popular approach adopted in Japan.
2. *The Four-Matrix Model*: It is also known as the more common approach adopted in the West.

The Four-Matrix Model covers basic steps, while the Matrix of Matrices Model simultaneously deals with quality, technology, reliability and cost considerations (Akao and Mazur, 2003).

4.5 Applications

The original applications of QFD were in the areas of shipbuilding and e-industries. Although applications of QFD were originally mostly in industries such as automobiles, electronics and software, it quickly spread to other industries such as government, banking, healthcare, education and research (Sher, 2006). Now, it covers almost all types of industries worldwide. QFD is also used in various fields for determining customer needs, developing priorities, formulating annual policies, manufacturing strategies, benchmarking and environmental decision-making (Gonzalez et al., 2004).

5 Proposed methodology

This research approach develops a QFD-Six Sigma interface model. Based on a snapshot review conducted on various published literatures on QFD, it is identified as a best technique to remove bottlenecks in the Six Sigma project selection and also to make Six Sigma more robust to changes in customer demands at all times. Application of QFD concept in Six Sigma application will enable organisations to recognise the value of listening to customers and using matrix structure of QFD to evaluate how the organisation should respond to the customer inputs while selecting Six Sigma projects. The proposed QFDMAIC methodology shown in Figure 1 is developed in steps as explained as follows:

Step 1 The deployment of a business plan

The model development begins with a vision of where the company wishes to be in some period such as five or ten years. The vision statements are treated as 'voice of organisation'. It is taken as input for QFDMAIC model and translated them into set of objectives as shown in Figure 2. The first step involves the development and examination of objectives through brainstorming session to translate the vision statement into more specific actionable issues. In this matrix format, the vision statements are inputs on the left side of the matrix. Objectives developed to the vision statements are shown across the top of the matrix. The centre of the matrix where the vision and objectives intersect is used to record the presence and strength of relationship between these inputs and actionable issues. Symbols are used to indicate the strength of relationships. The relationship between each vision statement with each one of the objectives is examined by the field experts and recorded.

Step 2 Objectives vs. strategies

The objectives which were the output in the previous step are taken as input in this step. Strategies which are answering the question of how the objectives will be accomplished are identified and placed across the top of the new matrix as shown in Figure 3. Here also the relationship symbols are used to easily check the relationship between strategies and objectives.

Figure 1 QFDMAIC methodology (see online version for colours)

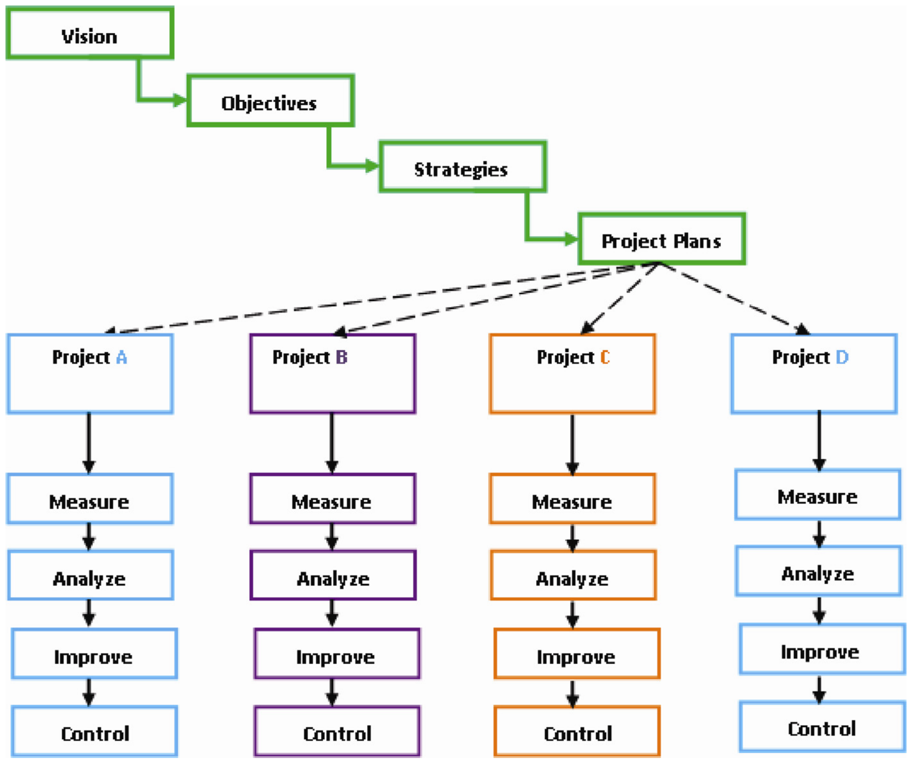
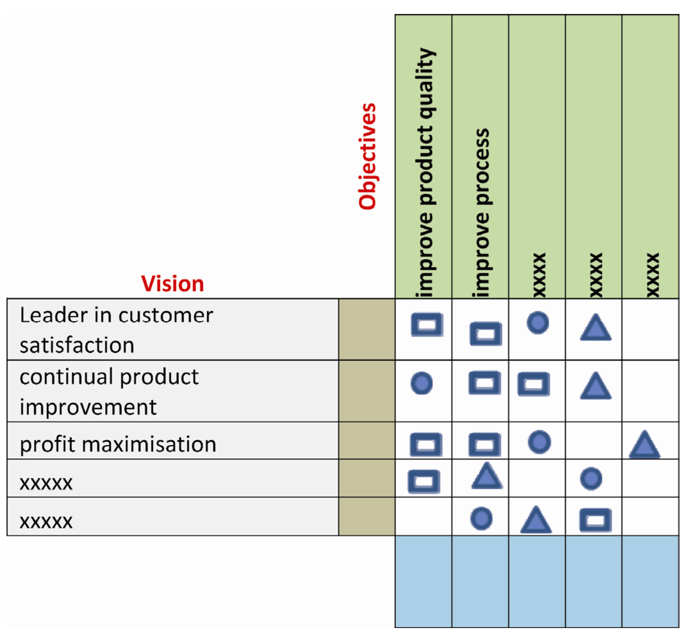


Figure 2 Vision vs. objectives matrix (see online version for colours)



Step 3 Strategies vs. project plans

The strategies from previous step are transferred to left side of the new matrix as shown in Figure 4. The project plans are placed across the top of the matrix to represent how the strategies will be accomplished. Identifying possible projects to fulfil the stated strategies is the important task in this model and requires a cross-functional team member to formulate project plans. Interrelationship is also questioned here by symbols.

Step 4 Scrutinise project plans

In this step, the project plans are scrutinised by the team members to determine most critical one in which to implement Six Sigma first. Also, the responsibility for executing the project in the company can also be determined. For example, in Figure 4, the first project plan 'improving process capability' is associated with manufacturing department. Hence, a team of manufacturing department personals may be formed to improve the process capability through Six Sigma approach.

Figure 3 Objectives vs. strategies matrix (see online version for colours)

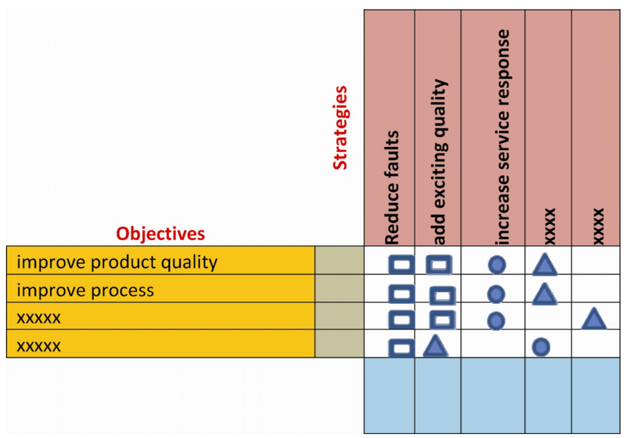
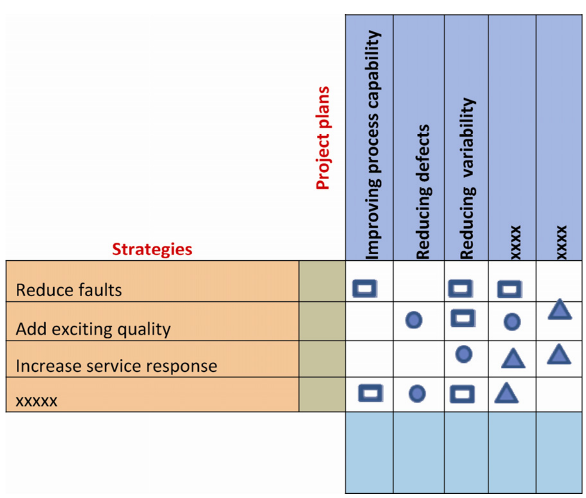


Figure 4 Strategies vs. project plans matrix (see online version for colours)



6 Case study

In this section, a case study conducted in an automobile service centre is presented. The organisation is an authorised service centre for a popular Indian brand passenger car. To maintain the confidentiality agreement made between the authors and the company, the name of the firm cannot be revealed in this paper. The case study company is hereafter referred as ‘company X’ in the discussion which follows. The company X focuses strongly on customer satisfaction as the main driver for its success by minimising the service-related complaints. The quality of service is maintained by customer feedback method conducted by their principle (car manufacturer) without to the knowledge of company X. After 48 hr of vehicle delivery from the service centre, the customers are contacted by the manufacturer’s call centre peoples to get the feedback regarding the service centre experience and their level of satisfaction. To ascertain the level of customer satisfaction level, a specially designed evaluation technique was used and based on the evaluation report, the service centre management was informed for any discrepancies. The car manufacturer has a dealer management practice in which they award ratings annually to their dealers across the country. Since the evaluation report is taken as reference for rating, the service centres are put in pressure not only to provide quality service, but also to get All India Rating. The subject company has developed their own feedback method in which they get the customer feedback after 24 hr of vehicle delivery. By doing so, they can manage service quality and to get good feedback at manufacturer’s follow-up. The growth in vehicle population in recent days makes the customer complaints also rose up in the vertical axis which put the company into hurdle.

6.1 Business vision of the company

As per the evaluation report released by the manufacturer for the year 2010, the company X is ranked as no. 3 in overall rating (all India) and ranked as no. 2 in overall rating (South). Since the ratings is used as one of the key marketing criteria’s by the company X, it is imperative to the organisation to improve the performance level to score no. 1 in ranking. For ranking the dealers, the manufacturer is using a parameter called customer satisfaction index, which is calculated through selected five service quality-related factors for which the values are obtained directly from the customers through feedback calls. To reach the company’s target of top position in ranking, it is become clear that the company has to satisfy their customers still more. This lays the vision statement for the company X as:

- assuring customer satisfaction at all time
- providing innovative service
- continual improvement of employees and staffs.

6.2 Vision statements and associated objectives

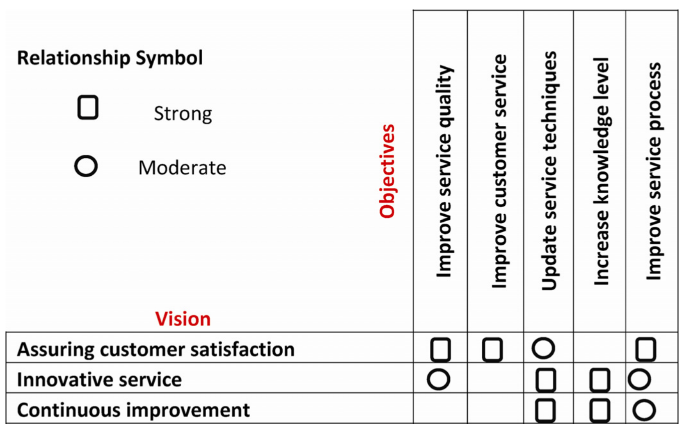
The followings are the typical ideas generated during brainstorming to develop objectives for the stated vision:

- Improve service quality.
- Identify critical service action in which customer dissatisfaction is more.

- Enlarge the scope of existing service techniques (update).
- Examine the knowledge level of staff and employees about customer complaints and solutions.
- Develop a training curriculum to match changing needs.
- Improve customer service.
- Improve service process.

Following this, the first matrix is constructed as shown in Figure 5. The vision statements are listed as input on the left side. The objectives are listed across the top of the matrix. The strength of relationship between vision and objective is categorised as strong, moderate and weak. While identifying the objectives by the brainstorming session, its relationship nature also estimated and entered in the middle section of the matrix using symbols.

Figure 5 Vision statements and associated objectives (see online version for colours)



6.3 *Developing strategies*

This step involves determining the needed strategies to fulfil the stated objectives. Figure 6 shows the next matrix in which the objectives are placed at the left and strategies related to these objectives are listed across the top of the matrix.

6.4 *Strategies and project plans*

Next level of deployment is shown in Figure 7. The strategies from prior matrix are entered in the left side of the matrix. Project plans, the next level of details arrived with the help of company employees are entered across the top of the matrix. The same sequence of action is followed on this matrix as on prior ones. Relationships are determined and placed in the matrix. After reaching the project plan matrix, the materialising of actions are done.

Figure 6 Developing strategies (see online version for colours)

Relationship Symbol

□ Strong

○ Moderate

△ Weak

Objectives / Strategies	I mprove problem diagnose ability	Improve work quality	Availability of spare parts	Promptness in delivery	Improve service layout	Determine training needs	Improve communication	Develop user-friendly service
Improve service quality	□	□	○	△	□			
Improve customer service	△	△	○	□	□	○	□	□
update service techniques	○	□				○	○	
Increase knowledge level			△	○		□	□	
Improve service process		○	□	□	□			

Figure 7 Developing project plans (see online version for colours)

Relationship Symbol

□ Strong

○ Moderate

△ Weak

Strategies / Project plans	Improve ability to fix problem first time	Improve problem interpretation	Improve technical ability	Inventory management	Improve work-time management	Ergonomic design of layout	Improve work competency	Enhance service initiation	Develop right communication channel	Improve in-service experience	Design of customer feedback system
Improve problem diagnosing ability	□	□	□	△			○				
Improve work quality	○	□	□		○	□	□				
Availability of spare parts	△			□	○				□		
Promptness in delivery	○	○	△	○	○			□			
Improve service layout				○	○	□					
Determine training needs	○	○	□	○			□			□	
Improve communications				○	○			△	□	□	□
Develop user-friendly service								□	○	□	□

6.5 Reviewing the project plans

At this point, a feasibility review of project plans is carried out to spot the right project to achieve the ultimate vision of the company. Since each project is unique and it has its own impact on company's vision, it is decided to rank the plans and then to choose the project which is ranked as high.

To do so, the relationship between the strategies and project plans is assigned with weights as 9 for strong relationship, 3 for moderate relationship and 1 for weak relationship. The aggregate relationship value of each project plan is computed by summing all the relationship values across all the strategies. For example, the project plan 'ergonomic design of layout' has strong relationships with strategies 'improve work quality' and 'improve service layout'. Hence, aggregate relationship strength is 9 + 9 = 18. In a similar way, all other values are calculated and tabulated in Table 6.

Table 6 Relationship strength of project plans

Project no	*Project plans*	*Aggregate relationship value*	*Rank*
1	Improve ability to fix problem first time	19	VI
2	Improve problem interpretation	24	III
3	Improve technical ability	28	I
4	Inventory management	22	IV
5	Improve work time management	15	VIII
6	Ergonomic design of layout	18	VII
7	Improve work competency	21	V
8	Enhance service initiation	19	VI
9	Develop right communication channel	21	V
10	Improve in-service experience	27	II
11	Design of customer feedback system	18	VII

7 Results of the study

The application of QFDMAIC approach in company X revealed that 'improving the technical ability of the employees and frontline staffs' found most critical project (see Table 6) to align business activities towards company vision. Improvements in technical ability will result in improvement of problem diagnosing ability, improvement of work quality and effective determination of training needs as justified in Figure 7, since these strategies bear strong relationship with selected project. It also has considerable impact on timely delivery of the vehicle even though it has weak relationship with this strategy. Consequently, Figure 6 as evidence, any improvement in problem diagnosing ability will strongly improve the quality of service and assist to plan for updating the required techniques to solve the service problems. Moreover, it will also affect the customer service positively by solving their complaints using the updated techniques and the ability to solve. Similarly, the improvement in work quality will influence the service quality and service technique updating which can be visualising from Figure 6. It will also influence the customer service process to some extent. Finally, from Figure 5, it is being inferred that improvement in service quality and customer service process will assure customer satisfaction that is what the company expects. Being an authorised service outlet in the city, the company X every day receives 30 more cars in an average for service complaints. Each customer expects from the company to serve them as they wish, but in practice, it is a highly challenging task for the company. In this light, the company aims at least to satisfy 80% of the customers fully with available man power and techniques. Hence, at present, the company is not in position to spare some persons to activate this model and they expect some training from experts in the methods. Also, the company felt that it would be convenient for them if the Six Sigma implementation is outsourced, because implementation of this model requires training in the methodology. However, deployment of the model summarised in this paper will certainly improve the quality of service provided by the company which in turn will satisfy the real needs and requirements of the customers.

8 Conclusion

This paper proposed a model QFDMAIC developed by using QFD and Six Sigma DMAIC approach for identifying and prioritising the projects for implementing Six Sigma. The design and development of QFDMAIC model is progressed through development of organisation's vision, determination of objectives, identification of right strategies and formulation of project plans. Upon the application of the proposed model in an Indian SME who is engaged in customer service, it is turned out that the technical ability improvement is identified as most important project to implement Six Sigma. Deployment this model enabled the company to identify the focal point of its organisation and also which processes, attention channels or other services have to be improved to satisfy its customer's expectations. Once customers get the idea that they are rightly addressed, they will take care of the company. The results of this paper work provide greater stimulus for implementing Six Sigma in customer service industry in future because Six Sigma is meant only for manufacturing since its inception.

One limitation of this study is the initial tempo of resistance offered by the participants. This is mainly due to lack of knowledge of the programme. Hence, the company has to device appropriate counselling to the active participants to make them to involve hearty. Product and service quality can only be successfully improved when the most important needs of customers are satisfied. As the service quality of the subject company is competitively bided by their principles, the company is in thrust of satisfying each of its customers. Hence, there is massive scope of using the QFDMAIC methodology to improve the quality of services. Along with that, the rapidly growing competition in customer service forcing the organisations to seek the answer of how to satisfy their customers and gain competitive advantage over competitors by applying this methodology.

This technique can be extensively used by strategic planning and marketing divisions of similar companies to identify and apply competitive business strategies and tactics. Further studies can be carried out to develop formal QFDMAIC methodology for various business sectors and build computerised QFDMAIC systems for providing continuous, iterative improvement in those sectors. Being a pioneer attempt for Six Sigma project selection using the concept QFD, this work may receive considerable attention among industrial consultant and Six Sigma practitioners. Since the selection of right project for successful and meaningful Six Sigma implementation through this model is based on the company's vision, it becomes important for companies to have an organised method to identify and examine their customers' want and needs in frequent time interval to revise company vision. For service-oriented companies such as finance, banking, telecommunication, automotives and healthcare companies, customer research is an important task to catch what they expect. Hence, these companies are required to invest fund for continuous customer follow-up. Without customer research, implementing Six Sigma is not worthwhile. In future, this model may be enriched with a technique for customer research to formulate the organisation's vision. Another important area for future development of the model is inclusion of other ingredients to QFD matrix. Evaluation of co-relationship between the project plans is much important ingredient because execution of one project may improve or affect the execution of another project. Hence, it is imperative to check the interrelationship of project plans before going for Six Sigma implementation.

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