International Journal of Quality & Reliability Management

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QUALITY PAPER

Modeling Deming's quality principles to improve performance using interpretive structural modeling and MICMAC analysis

Received 31 July 2018
Revised 25 November 2018
Accepted 4 December 2018

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Abstract

Purpose – The purpose of this paper is to study the 14 principles of Edwards Deming and create significant relationships between them. No research has been reported on the implementation of Total Quality Management (TQM) using Deming's 14 principles. To fill this gap, Interpretive Structural Modeling (ISM) and MICMAC analysis have been developed to understand mutual interactions among variables and find both the dependence and driving power of these variables.

Design/methodology/approach – The research paper discusses a blend of practical applications and introduces a theoretical framework. An ISM-based methodology is used to study and examine interactions between identified variables, while MICMAC analysis is used to identify the dependence and driving power.

Findings – This research utilizes Deming's 14 quality principles, with experts from academia and industry consulted to identify contextual relationships among variables. The result shows that the stated principles "take action to accomplish the transformation," "institute training," "encourage education to employees" and "institute leadership" are strategic requirements, while "drive out fear," "break down barrier between staff areas" and "eliminate numerical quotas" are tactical requirements. "Adopt the new philosophy," "create constancy in improvement of product and service" and "cease dependence on mass inspections" are operational requirements for TQM applications.

Originality/value – An ISM-based quality framework, dependence power and driving power of variables using MICMAC analysis have been recommended to the service and manufacturing industry as a new focus area in the implementation of TQM.

Keywords Total Quality Management (TQM), Interpretive Structural Modelling (ISM), MICMAC analysis, Edwards Deming

Paper type Research paper

1. Introduction

In the twenty-first century, companies are struggling for improvements in their supply chains. The key success factor is not only to improve a company's supply chain but how fast it can implement changes compared to its competitors. As a result, competition is not between companies, but between supply chains. Hence, a good leader will drive their team forward to manage changes in all aspects of business, and improve the efficiency of the organization. As per Delavigne and Robertson (1994), in this world there are three types of changes: evolutionary change, revolutionary change and change in the process of evolution. These types of changes have been studied by Shewhart and later by Deming.

The author sincerely thanks Dr Sachin Modgil, Dr Rohit Singh and Dr Surendra Kansara for continuous support in understanding of ISM and anonymous referees whose constructive comments led to a substantial improvement of the paper.

International Journal of Quality & Reliability Management

0265-671X
DOI 10.1108/IJQRM-07-2018-0204

Several management scholars continue to write, speak and be aware of the principle of quality across across all the organizations. Prominent among them are Juran (1989) and Crosby (1990, 1992), and each of them has developed important ideas which have been accepted by the industry. However, it is Deming's "quality" formulation that has become the rule in guiding the actions of many managers. Deming's involvement in the quality movement in Japan is well recognized in both the eastern and the western worlds. The success story of Japan is partly credited to its adoption, modification and extension of the scope of Deming's theory of 14 points of management, producing their own unique concepts of production and Total Quality Management (TQM). Deming also claimed that up to 85 percent of the causes of any mistakes, variation, inefficiency problems and waste in any of business were the result of an organization's systems (Deming, 1988).

This paper is focused on modeling the enablers of the 14 principles of Deming using contemporary techniques widely utilized for multi-criteria decision making, such as Interpretive Structural Modeling (ISM). The remainder of the paper is organized as follows. Section 2 reports on the theoretical background of Deming's management theories. Section 3 explains ISM methodology and model development with relationships between variables. Section 4 explains driving power and dependence power of variables using MICMAC analysis, followed by Section 5 which explains the results of this research work followed by a detailed discussion in Section 6. Finally, Section 7 extrapolates some of the contributions and shortcomings of the research presented.

2. Theoretical background

The influence that the late W. Edwards Deming and his management methods (Deming, 1982b, 1986; Walton, 1986) had on TQM practices in industry has been significant. Therefore, it is not surprising to learn that even after his passing, Deming and his contribution to industry is still highly visible which include (Rungtusanatham *et al.*, 2003):

- the Deming Prize, Japan's national quality award which encouraged the formation of the Malcolm Baldrige National Quality Award in the USA;
- the Deming Electronic Network, an electronic mail network formed by the spontaneous convergence of various groups, nationally (e.g. Wisconsin, Georgia, California, etc.) and internationally (e.g. the UK, Russia, France, etc.), and devoted to the study of Deming's teachings;
- the Deming Cooperative, an Internet World Wide Web site to publicize information related to Deming and his teachings;
- the W. Edwards Deming Institute^{TM}, a nonprofit organization devoted to encouraging Deming's quality management philosophy; and
- the Deming Scholars MBA Program at Fordham University, a graduate degree program aimed at educating and training the next generation of managers in Deming's quality management philosophy.

Deming's contributed not only to the quick regeneration of the Japanese economy after the Second World War (Yoshida, 1989), but also to the turnaround and continued success of well-known US organizations (e.g. Ford Motor Company) following the adoption of the Deming management method. The Deming management method – a phrase created by Walton (1986) to cover the breadth of Deming's TQM approach – is most well known as a prescriptive set of 14 points. However, while the 14 principles first appeared in printed form in the early 1980s (Deming, 1982a), they had been proposed as early as the 1940s (Yoshida, 1989) and subsequently industrialized and crystallized over a period of four decades. During this time, Deming's consulting with firms in Japan and the USA led him to derive generalizations that ultimately became the 14 points. The "seven deadly diseases" and the "obstacles" presented earlier (Duncan and Van Matre, 1990; Walton, 1986; Yoshida, 1989) noted:

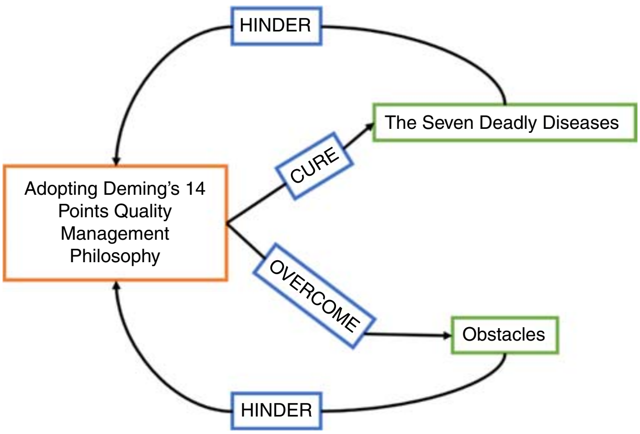
> There were not, Dr Deming says, always 14. When he first put them in writing 20 years ago, there were ten or fewer. In his work with Japanese companies, problems were absent that he would encounter only later in [the US]. It was not necessary to counsel the Japanese to "drive out fear," […] By the same token, his admonition […] to "remove barriers to pride of workmanship" was not necessary in Japan.

2.1 *Deming management method*

In parallel to Deming's 14 point management method are the so-called "seven deadly diseases" that hinder organizational performance and present numerous barriers to developing quality management (Deming, 1982b, 1986). These diseases include pursuit of short-term profits, a lack of purpose and too many changes in management personnel. The 14 points in Deming's management method are imperatives or "commands," and meant to serve as tenets of both intra-organizational and inter-organizational behavior (Anderson *et al.*, 1994). When adopted by firms, these 14 principles can offer a "cure" for the seven deadly diseases and support organizations in overcoming the obstacles to manufacture and deliver high-quality products and services (see Figure 1).

The core elements of Deming's theory include what is known as a Profound Knowledge system, which is made up of four inter-related parts. These are: an understanding of a certain system (in other words, a given organization is a system that must be understood by those within it); an understanding of what variation means in an organization, in terms of the variability in services and their responses; a theory of knowledge on behalf of organizational management which must understand and publicly state the philosophy underpinning its actions; and a collective psychology where management observes and has an understanding of the behavior of its employees.

Deming also advises that management teams adopt continuous improvement in the style of "plan, do, act and then study," or PDAS (Redmond *et al.*, 2008). He articulated the idea that organizational change must begin with the individual, and that this comes from an understanding and implementation of the profound knowledge system. To be successful, TQM has many long-term imperatives. One of these is that leaders in an organization must have a passion for TQM. Without it, top management's belief and energy for TQM could be diverted to other priorities. While Deming insisted that there was no "instant pudding,"



Source: Deming (1986)

Figure 1. Deming's 14 points, seven deadly diseases and obstacles

several management consultants when establishing themselves with clients recommended short-term gains instead of long-term changes (Petersen, 1999). As a result of the desire for short-term gains, process enhancements and reductions in cycle times become very popular, and in some cases become the ultimate objective for organizations.

Deming's 14 quality principles are shown in Table I.

Below each of Deming's 14 quality principles are stated in detail:

(1) Create constancy of purpose for improvement of product and service

Deming recommendeds radical new definition of a company's role. Instead of making money, business should survive and provide jobs through innovation, research and development, constant improvement and maintenance. Long-term business survival is certainly one of the most cited aims of senior managers. Creating a short-term reaction to long-term planning is a primary goal of a business, and this includes approaching a new project with improved performance and a lower budget compared to previous ones.

Practically speaking, this approach should start with planning and allocate maximum resources for training and education, based on what the business has learned from its past experience, and complete risk analysis, cost-benefit analysis and contingency plans. By implementing these strategies a business can constantly improve its services. It also suggests managers should focus on a long-term vision and be flexible:

(2) Adopt the new philosophy

Customers' demands are changing very fast and competition is also growing quicker than ever, so managers need to adopt a new philosophy according to market conditions and the technology revolution. Management should commit to a "quality philosophy" rather than merely expect the work force to do so. Management should also orientate a more forward direction – not at competitors, but at customers – which will be a game changer for the business. Companies need to put always customers first rather than react to competitive pressure and innovate their product as per the needs of the market.

Managers should resist challenges by learning new responsibilities and assuming leadership for change position. Over a period of time managers will realize that economies of scale can be achieved by increasingly creating supporting services:

(3) Cease dependence on mass inspections

Defective products are either reworked or thrown out, but both practices are unnecessarily expensive. In effect a company is paying workers to make defects and then correct them. So quality will come less from inspection, and more from process improvement. Inspection is expensive, ineffective and too late in the process. Management should focus on continuous

Sr. No.	Principle	Sr. No.	Principle
A01	Create constancy of purpose for improvement of product and service	A08	Drive out fear
A02	Adopt the new philosophy	A09	Break down barrier between staff areas
A03	Cease dependence on mass inspections	A10	Eliminate Slogans, exhortations, and targets for the work force
A04	End the practice of awarding business on the basis of price tags alone	A11	Eliminate numerical quotas
A05	Improve constantly and forever the system of production and service	A12	Remove barriers that rob people of pride of workmanship
A06	Institute training	A13	Encourage education and self- improvement for everyone
A07	Adopt and institute leadership	A14	Take action to accomplish the transformation

Table I.
Deming's 14 quality principles

improvement in the production process because the world is moving so fast and technology is becoming disruptive. Companies are moving toward automation so the chances of defects being manufactured in the process are going to reduce:

(4) End the practice of awarding business on the basis of price tags alone

Sometimes purchasing departments look for the lowest priced vendor which can lead to the selection of lower quality suppliers. Instead managers should look for the best quality at a price they can afford and aim to achieve that with a single vendor.

There are fewer chances for a business to survive that delivers a poorly developed product or service to customers even if it is the cheapest on the market. Poor quality at a "good" price results in remaking a service or product, imposing greater costs to the organization. Billions of dollars are wasted yearly because of an emphasis on price at the expense of quality. Business will expand only through long-term relationships with suppliers across a supply chain. Working with the same vendors over time will make business operations more effective, meaning lower prices and higher returns:

(5) Improve constantly and forever the system of production and service

> Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs. (Deming, 1986, p. 23)

Commitment to quality must come from the top management, and continuous improvement in production processes should be followed by each and every member of organization. Quality starts with the intent of management; improvement is not a single effort but a continuous journey that businesses should follow to reduce waste and improve quality. It is the role and responsibility of management to keep an eagle eye on continuous improvement in design, product, process, training, supervising, maintenance, etc. Deming was quick to point out that organizations that focus on continuous improvement will be truly reactive to customers' needs, and maintain higher standards:

(6) Institute training

Institute training should be provided to each and every level of an organization. There was one survey of European industry (Dale and Cooper, 1993) which found five aspects of TQM where most employees require training, these aspects are: integration of quality and business planning, top management commitment in TQM, quality cost and cost effectiveness of TQM, employee involvement in TQM, and TQM and marketing. Top management of the company needs to provide sufficient resources to its management teams to train employees so that they can serve the customer with a better quality product. The involvement of employees in the training program leads to a better quality process in the organization without any defects:

(7) Adopt and institute leadership

Batley (1994) identified elements of leadership which influence quality, including: performance, perceived situation, vision and mission, leader behaviors, use of tradition and personal quality:

> The job of management is not supervision, but leadership. The aim of management should be to improve the performance of man and machine […]. (Deming, 1986, p. 54 and 248)

Several times Deming criticized leaders who do not take care of their employees. Leadership is one of the major components of the organization. It is the element through which organizations achieve long-term and short-term goals in a competitive environment (Rowley and Sherman, 2003). Leaders should provide all the necessary resources to employees who enhance their skills and comfort them in the workplace. There are a significant number of authors who believe that without leadership one cannot improve quality in an organization (Dahlgaard *et al.*, 1995; Lakshman, 2006; Spanbauer, 1995). There are several viewpoints on leadership in this context, one of which is Tofte (1995, p. 474) who said "leadership is a relationship between the people and all of them have equal opportunity to learn best leadership practices":

(8) Drive out fear

> The supposition is prevalent the world over that there would be no problems in production or in service if only our production workers would do their jobs in the way that they were taught. Pleasant dreams. The workers are handicapped by the system, and the system belongs to management. (Deming, 1986, p. 134)

This principle infers that fear is a fragment of the organization and may affect everyone. Such fear may affect employees' productivity and efficiency. So when this situation occurs, whether directly or indirectly, quality will suffer. Fear within the organization affects productivity and restricts knowledge sharing. Ryan and Oestreich (1991) identified some of the potential consequences when individuals speak out about fears, and these are:

- loss of employment;
- lack of career or financial advancement;
- loss of credibility; and
- interpersonal rejection.

Deming (1986) believed that fear must be driven out so that every employee can work effectively for the organization:

(9) Break down barriers between staff areas

> People in research, design, sales, and production must work as a team, to foresee problems of production and in use that may be encountered with the product or the service (Deming, 1986, p. 24).

According to Deming (1986) collaboration and team working is imperious in existing organizations. There are many barriers to collaborative working identified in the literature, which include poor negotiation skills, professional role demarcation and a lack of knowledge of each other's responsibility (D'Amour *et al.*, 2004; Hall and Weaver, 2001; Weinstein, 1998). Annual performance reviews for individual employees are one of the important barriers identified by Deming (1986). Deming's principle on teamwork is not just about problem solving and decision making, but also about more practical aspects which break down professional barriers in an organization (Weinstein, 1998; Oandasan and Reeves, 2005). According to Deming (1986), a different approach is required to set up a team in an organization which may result in a change of process and structure:

(10) Eliminate slogans, exhortations and targets for the work force

It is not always people who make mistakes, sometime processes force mistakes to be made. Many times firms have been known to eliminate slogans, exhortations and targets for the work force, but they never help employees for the good job. According to Deming there is no replacement for training employees to do a good job – just by giving a slogan and a target to work force they will not achieve the desired result. The key point is if managers are using slogans, it must be sincere and not just hype. So, slogans like "zero defects, eliminate waste" will not help workers to produce better quality or do a better job. Such exhortations only create adversarial relationships:

(11) Eliminate numerical quota

Numerical quotas will not help employees to do better job. Sometimes numerical quotas cost as much as the loss in terms of waste of time and productivity. In many of the factories, employees work at the optimum rate only in the last hour or two of the day. Workers have then completed their quotas for the day, and so a quota system will not improve the productivity of the organization or develop continuous improvement. Removing quota systems encourages the employee to apply new ideas in the workplace. Numerical quotas will become a guarantee for inefficiency and high cost, and can also produce a negative effect which generates frustration. Deming is not telling us to manage without numbers a company should have aims and strategies but not in isolation:

(12) Remove barriers that rob people of pride of workmanship

People are eager to do a good job and can often feel distressed when they cannot. Internal competition has created many barriers to cooperation; barriers always exist between the employees and their organization. These barriers exist because of poor communication, ignorance of an organization's mission and vision, as well as personal jealousies. So managers should adopt long-term perspectives to remove barriers, and every employee should work in teams toward common goals of the organization. Pride of workmanship does exist in the organization and not because of a lack of training, lack of supervision or resources:

(13) Encourage education and self- improvement for everyone

Organizations should invest in education of their employees, and give them proper on-the-job training while introducing worship of knowledge. The management of the company recognizes the importance of training and development. This is the only recipe for the promise of lifelong employment and organizational success. Organizations should keep their employees consistently motivated and encourage them to improve their education and training development. Employees should have an eagerness to learn new practices in the organization. The return on investment from employee education will always be higher compared to other returns. Employees in turn should appreciate the good work of other colleagues and help each other in the process. Automatically employees will grow and simultaneously the organization will also develop:

(14) Take action to accomplish the transformation

It will require a special top management team to carry out quality missions and implement strategy. Workers cannot do it on their own, nor can middle-level managers. Top management must take responsibility to transform a company by implementing the best quality practices in the organization, and they should create a corporate structure in order to implement their philosophy. Put everybody in the company to work on accomplishing the transformation. Transformation of the organization is everyone's responsibility (Deming, 1986, pp. 23-24). Organizations must integrate manufactures, suppliers and customers together to transform the process, culture and structure.

3. ISM and model development

ISM is an interactive learning process where a set of directly related variables are structured as a comprehensive, systemic hierarchical model known as structural model (Warfield, 1974; Sage, 1977). It was proposed by Warfield (1976) in order to analyze complex socioeconomic systems, and since then ISM has been used in various fields to convert complex relationships into a structural model. This technique helps to impose order and direction onto a complex relationship among the variables of a system, as discussed by Agarwal *et al.* (2007), Jharkharia and Shankar (2004) and Ramesh *et al.* (2010). The dependency on statistical data to get results makes structural equation modeling (SEM) ambiguous (Wisner, 2003), but ISM allows researchers to develop a deeper understanding of the relationships among key issues. Saxena and Vrat (1992) examined energy conservation in the Indian cement industry by applying the

ISM methodology, and it has since been used by several other researchers in different fields (Mandal and Deshmukh, 1994; Jharkharia and Shankar, 2004, 2005; Ravi and Shankar, 2005) to develop a better understanding of the systems under consideration.

Mandal and Deshmukh (1994) used the ISM methodology to analyze some key vendor selection criteria and have shown the inter-relationships of those criteria and their levels. Singh and Sushil (2013) identify and analyze the enablers of TQM and its outcome variables in the Indian airline industry using ISM modeling techniques. Ravi and Shankar (2017) studied interactions among variables of reverse logistics in the automobile industry also using ISM methodology.

The various applications of ISM are shown in Table II – ISM methodology is interpretive because brainstorming expert opinion from academics and industry determines how the variables are related. To test the theory put forward, a detailed explanation of Deming's 14 principles was circulated to the two sets of experts. After ten days, a session was organized to establish mutual relationships among the variables. A contextual relationship of the type "construct to" was chosen (does one variable construct to another variable?). Experts were asked to answer this in terms of "yes" or "no." If the answer was "yes" it was to be further interpreted (in terms of answering a "how" question) in a single line. After seven days, the list of variables and inter-relationship diagram were circulated for any further modification. So, on the basis of the relationships that were obtained, an overall structure about the complex set of variables can be generated. The steps involved in the ISM methodology are as follows.

Step 1: identification of set of variables affecting a system or which are relevant to the study. This can be done with the help rigor literature review, opening of expert from academic and industry or brainstorming session with experts.

Step 2: define the contextual relationship between variables which indicates whether or not one variable leads to another.

Step 3: construction of Structural self-interaction matrix (SSIM) for the variables. SSIM indicates a pairwise relationship between the attributes of the system under consideration.

Step 4: developing a reachability matrix from the SSIM and the matrix is checked for transitivity. Step 4 is concerned with the construction of the reachability matrix. Transitivity is the basic assumption made in ISM that leads to the final reachability matrix; it states that if an attribute A is related to B and B is related to C, then A is necessarily related to C.

Sr. No.	Area of Application	Contributor
1	Cement industry	Saxena and Vrat (1992)
2	Vendor selection	Mandal and Deshmukh (1994)
3	Waste management	Sharma and Gupta (1995)
4	Reverse logistics	Ravi and Shankar (2005)
5	Six Sigma	Soti *et al.* (2010)
6	Supply chain collaboration	Ramesh *et al.* (2010)
7	Third-party reverse logistics providers	Govindan *et al.* (2012)
8	Information security management	Chander *et al.* (2013)
9	Analyzing factors inhibiting implementation of Total Productive Maintenance (TPM)	Poduval and Pramod (2015)
10	Analysis of green supply chain barriers	Dube and Gawande (2016)
11	Modeling of critical risk factors in software engineering project	Samantra *et al.* (2016)
12	Modeling the enablers of green supply chain management	Malviya and Kant (2017)
13	Integrating quality management in manufacturing and service counterparts	Goyal, G. *et al.* (2017)
14	Risk analysis and mitigation for perishable food supply chain	Prakash *et al.* (2017)
15	Investigation into the hierarchical nature of TQM variables	Veltmeyer and Mohamed (2017)
16	Identifying critical success factors for sustainable growth of Indian banking sector	Shamshad, M *et al.* (2018)

Table II. Application areas of ISM

Step 5: the reachability matrix obtained in the fourth step is partitioned into different levels.

Step 6: based on the relationships given in step 5 in the reachability matrix, a directed graph is drawn and the transitive links are removed.

Step 7: the resultant digraph is converted into an ISM, by replacing variable nodes with statements.

Step 8: the ISM model developed in the seventh step is reviewed to check for conceptual inconsistency and necessary modifications are made.

Mandal and Deshmukh (1994) and Soti *et al.* (2010) presented the steps in the form of a flow chart. Figure 2 represents the various stages of ISM in the form of a flow chart.

3.1 Self-Structural Interaction Matrix (SSIM)

Table III indicates pairwise relationships between the variables of Deming's 14 principles for TQM. In this research, two experts – one each from academia and industry – were utilized to

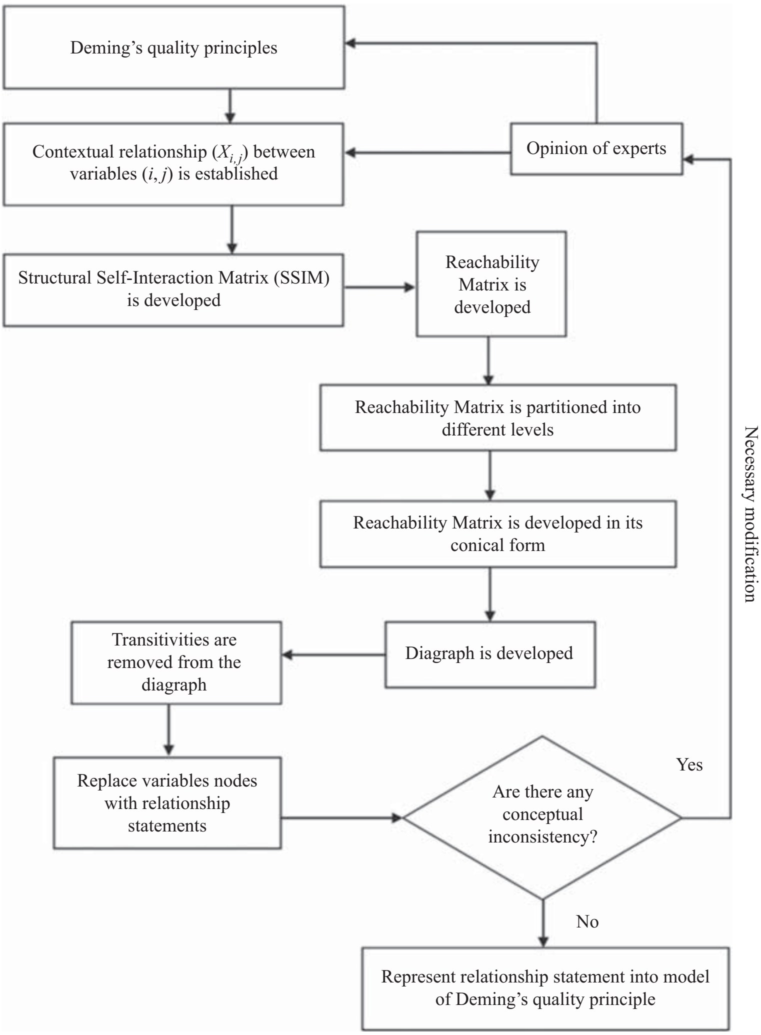


Figure 2. Flow diagram for preparing ISM

Table III.
Self-Structural Interaction Matrix (SSIM) of Deming's 14 quality principle

	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
A1	O	O	X	O	O	A	A	A	O	A	O	V	O
A2		O	X	X	O	X	A	X	O	O	X	A	V
A3			O	A	O	A	O	O	O	A	O	A	A
A4				V	O	A	O	O	A	X	O	X	O
A5					V	O	A	O	O	O	X	O	X
A6						X	O	O	O	O	V	A	O
A7							O	X	A	O	O	V	A
A8								A	O	V	A	A	V
A9									O	A	O	V	A
A10										X	O	V	A
A11											V	A	O
A12												O	O
A13													O

identify contextual relationships among the variables. The ISM modeling technique has been used with experts' opinions based on various techniques, such as brainstorming, in developing contextual relationships among the elements (Charan *et al.*, 2008). As suggested in the ISM methodology (Warfield, 1974; Mandal and Deshmukh, 1994; Thakkar *et al.*, 2005, 2007, 2008; Talib *et al.*, 2011a, b; Gupta *et al.*, 2013; Sahney, 2015), the following four symbols have been used to denote the direction of the relationship between the elements i and j:

(1) V is used for the relationship from construct i to construct j but not in both directions.

(2) A is used for the relationship from construct j to construct i but not in both directions.

(3) X is used for both direction relations from i to j and j to i.

(4) O is used for no relation between two constructs which means the relation between the elements does not appear to be valid.

A similar logic holds for the Deming's quality principle:

- Variable A9 helps to alleviate variable A13. It implies that if the barrier between staff areas is removed then it would help self-improvement for everyone. Hence, "V" in Table III denotes the relationship between variables A9 and A13.
- Variable A2 can be alleviated by variable A8, in other words "drive out fear" would help to alleviate variable 2 and adopt the new philosophy. Thus "A" denotes the relationship between variables A2 and A8 in SSIM.
- Variable A6 ("institute training") and variable A7 ("adopt institute leadership") would help complete each other. Thus "X" denotes the relationship between these two variables.
- No relationship exists between variable A3 – i.e. "cease dependence on mass inspection" and variable A9 – i.e. "break down barriers between staff areas." Thus, "O" denotes the relationship between variable A3 and A9 in Table III.

3.2 Reachability matrix construct from SSIM and check for transitivity

The SSIM is transformed into a binary matrix called an "initial reachability matrix" and by substituting V, A, X, O by 1 and 0 as per the following rules, a binary matrix can be achieved, and it is presented in Table IV:

- if the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0;

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
A1	1	0	0	1	0	0	0	0	0	0	0	0	1	0
A2	0	1	0	1	1	0	1	0	1	0	0	1	0	1
A3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A4	1	1	0	1	1	0	0	0	0	0	1	0	1	0
A5	0	1	1	0	1	1	0	0	0	0	0	1	0	1
A6	0	1	0	0	0	1	1	0	0	0	0	1	0	0
A7	1	0	1	1	0	1	1	0	1	0	0	0	1	0
A8	1	1	0	0	1	0	0	1	0	0	1	0	0	1
A9	1	0	0	0	0	0	1	1	1	0	0	0	1	0
A10	0	0	0	1	0	0	1	0	0	1	1	0	1	0
A11	1	0	1	1	0	0	0	0	1	1	1	1	0	0
A12	0	1	0	0	1	0	0	1	0	0	0	1	0	0
A13	0	1	1	1	0	1	0	1	0	0	1	0	1	0
A14	0	0	1	0	1	0	1	0	1	1	0	0	0	1

Table IV.
Reachability matrix

- if the (i, j) entry in the SSIM is *A*, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1;
- if the (i, j) entry in the SSIM is *X*, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1; and
- if the (i, j) entry in the SSIM is 0, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Following these rules, the initial reachability matrix for the variables is complete. The initial reachability matrix for the main attributes has been derived from the SSIM by substituting the concerned binary values.

The dependence power is equal to the total number of elements (including itself) which help to achieve it. The driving power of the elements is equal to the total number of elements (including itself) which help to achieve it. The rank of each variable in the final reachability matrix along with the driving and dependence power is also shown in Table V.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	Driving power	Rank
A1	1	1*	1*	1	1*	1*	0	1*	0	0	1*	0	1	0	9	4
A2	1	1	1*	1	1	1*	1	1*	1	1*	1*	1	1*	1	14	1
A3	1*	1*	1	1	1*	0	0	0	0	0	1*	0	1*	0	7	5
A4	1	1	1*	1	1	1*	1*	1*	1*	1*	1	1*	1	1*	14	1
A5	1*	1	1	1*	1	1	1*	1*	1*	1*	0	1	0	1	12	3
A6	1*	1	1*	1*	1*	1*	1	1*	1*	0	0	1	1*	1*	12	3
A7	1	1*	1	1	1*	1	1	1*	1	0	1*	1*	1	0	12	3
A8	1	1	1*	1*	1	1*	1*	1	1*	1*	1	1*	1*	1	14	1
A9	1	1*	1*	1*	1*	1*	1	1	1	0	1*	0	1	1*	12	3
A10	1*	1*	1*	1	1*	1*	1	1*	1*	1	1	1*	1	0	13	2
A11	1	1*	1	1	1*	0	1*	1*	1	1	1*	1	1*	0	12	3
A12	1*	1	1*	1*	1	1*	1*	1	1*	0	1*	1	0	1*	12	3
A13	1*	1	1	1	1*	1	1*	1	1*	1*	1	1*	1	1*	14	1
A14	1*	1*	1	1*	1	1*	1	1*	1	1	1*	1*	1*	1	14	1
Dependence Power	14	14	14	14	14	12	12	13	12	8	12	11	12	9	171	
Rank	1	1	1	1	1	3	3	2	3	6	3	4	3	5		

Note: 1*, transitivity relationship

Table V.
Final reachability matrix

The initial reachability matrix is subjected to transitivity check. That is, the interpretations of relationships developed in the initial reachability matrix are checked to determine if all relations are correctly assessed. Transitivity of the contextual relation is a basic assumption in ISM (Singh and Sushil, 2013), and it is very critical to remove the same. In initial reachability matrix, A3-A10 is 1 and A10-A2 is 1; hence, A3-A2 must be 1. However, initial reachability matrix shows that A3-A2 is 0. All such gaps present in the initial reachability matrix have been examined and modified to obtain the final reachability matrix, shown in Table V.

3.3 Level partition

The last stage in the process being investigated involves the extraction of hierarchical ordering from the reachability matrix by level partitioning, and then finding out the reachability and antecedent set for each construct (Warfield, 1977). The purpose of this stage is to enable the construction of the digraph from the reachability matrix. The reachability set for a particular element consists of the element itself and other elements which can help to achieve it. The antecedent set for a particular attribute consists of itself and the other attributes which may help to alleviate it. The intersection set for each attribute is the intersection of corresponding reachability and antecedent sets. Then, if intersection set and reachability set are the same, that attribute is considered to be level I and given top position in the ISM hierarchy (Kannan and Haq, 2007). This means the attribute would not help to alleviate any other attribute above its own level. As soon as the first iteration is completed, it is classified as level I and discarded. The same process is repeated on the remaining attributes to determine level II attributes.

These iterations are continued until all the levels of each attribute have been determined, which are shown in Tables VI–XI. The identified levels help to construct the digraph and in turn the final model of ISM. After removing the transitivity, the digraph is finally converted into ISM as shown in Figure 3.

4. MICMAC analysis

MICMAC refers to the Matrice d’Impacts Croisés Multiplication Appliquée á un Classement (Hussain, 2011). MICMAC analysis works on the principle of the multiplication properties of matrices (Diabat and Govindan, 2011; Kannan *et al.*, 2009), and one of the key objectives of this analysis is to examine and categorize variables of interest in terms of driving power and dependence power (Mandal and Deshmukh, 1994), wherein all the variables are classified into four specified clusters (Hussain, 2011) with the following characteristics (full details in Table XII):

- Cluster 1 contains “autonomous factors” which have neither high dependence nor high driving power.
- Cluster 2 contains “dependent factors” which have high dependence and low driving power.
- Cluster 3 contains “linkage factors” (relay variables) which have high dependence and high driving power.
- Cluster 4 contains “independent factors” (influence variables) which have low dependence and high driving power. The driving power and dependence of each of these variables are shown in Table V.

Dependence power and driving power diagram is required to be developed, this diagrammatic representation is also called MICMAC analysis, which benefits from the examination and labeling from Deming’s quality principles in terms of driving power and dependence (Mandal and Deshmukh, 1994; Singh and Sushil, 2013).

Variable names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A1	A1 A2 A3 A4 A5 A6 A8 A11 A13	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A3 A4 A5 A6 A8 A11 A13	I
A2	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	I
A3	A1 A2 A3 A4 A5 A11 A13	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A3 A4 A5 A11 A13	I
A4	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	I
A5	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A12 A14	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A12 A14	I
A6	A1 A2 A3 A4 A5 A6 A7 A8 A9 A12 A13 A14	A1 A2 A4 A5 A6 A7 A8 A9 A10 A12 A13 A14	A1 A2 A4 A5 A6 A7 A8 A9 A12 A13 A14	
A7	A1 A2 A3 A4 A5 A6 A7 A8 A9 A11 A12 A13	A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A2 A4 A5 A6 A7 A8 A9 A11 A12 A13	
A8	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	
A9	A1 A2 A3 A4 A5 A6 A7 A8 A9 A11 A13 A14	A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A2 A4 A5 A6 A7 A8 A9 A11 A13 A14	
A10	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13	A2 A4 A5 A8 A10 A11 A13 A14	A2 A4 A5 A8 A10 A11 A13	
A11	A1 A2 A3 A4 A5 A7 A8 A9 A10 A11 A12 A13	A1 A2 A3 A4 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A3 A4 A7 A8 A9 A10 A11 A12 A13	
A12	A1 A2 A3 A4 A5 A6 A7 A8 A9 A11 A12 A14	A2 A4 A5 A6 A7 A8 A10 A11 A12 A13 A14	A2 A4 A5 A6 A7 A8 A11 A12 A14	
A13	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A1 A2 A3 A4 A6 A7 A8 A9 A10 A11 A13 A14	A1 A2 A3 A4 A6 A7 A8 A9 A10 A11 A13 A14	
A14	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14	A2 A4 A5 A6 A8 A9 A12 A13 A14	A2 A4 A5 A6 A8 A9 A12 A13 A14	

Table VI.
Iteration 1

Variable names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A6	A6 A7 A8 A9 A12 A13	A6 A7 A9 A10 A13 A14	A6 A7 A9 A13	
A7	A6 A7 A8 A9 A11 A12 A13	A6 A7 A8 A9 A10 A11 A13 A14	A6 A7 A8 A9 A11 A13	
A8	A7 A8 A9 A10 A11 A12 A14	A6 A7 A8 A9 A10 A11 A12 A13 A14	A7 A8 A9 A10 A11 A12 A14	II
A9	A6 A7 A8 A9 A11 A13 A14	A6 A7 A8 A9 A10 A11 A13 A14	A6 A7 A8 A9 A11 A13 A14	II
A10	A6 A7 A8 A9 A10 A11 A12 A13	A8 A10 A11 A13 A14	A8 A10 A11 A13	
A11	A7 A8 A9 A10 A11 A12 A13	A7 A8 A9 A10 A11 A12 A13 A14	A7 A8 A9 A10 A11 A12 A13	II
A12	A8 A11 A12 A14	A6 A7 A8 A10 A11 A12 A13	A8 A11 A12	
A13	A6 A7 A8 A9 A10 A11 A12 A13 A14	A6 A7 A9 A10 A11 A13 A14	A6 A7 A9 A10 A11 A13 A14	
A14	A6 A7 A8 A9 A10 A11 A13 A14	A8 A9 A12 A13 A14	A8 A9 A13 A14	

Table VII.
Iteration 2

In Table V, entries of "1" are added along columns and rows showing the driving power and dependence power, respectively. Subsequently, driving power and dependence power's diagrammatic representation is shown in Figure 4. Dependence power is plotted on the X axis and the driving power (influence) is plotted on the Y axis.

The first quadrant consists of "autonomous variables." These variables have both weak driving power and weak dependence, and are relatively disconnected from the system. In this cluster we do not have any such variables which specify that no variable can be considered as disconnected from the entire system, and therefore the management has to pay attention to all the identified variables.

Table VIII. Iteration 3

Variable names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A6	A6 A7 A12 A13	A6 A7 A10 A13 A14	A6 A7 A13	
A7	A6 A7 A12 A13	A6 A7 A10 A13 A14	A6 A7 A13	
A10	A6 A7 A10 A13	A10 A14	A10	
A12	A12	A6 A7 A12 A13	A12	III
A13	A6 A7 A12 A13	A6 A7 A10 A13 A14	A6 A7 A13	
A14	A6 A7 A10 A13 A14	A14	A14	

Table IX. Iteration 4

Variable names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A6	A6 A7 A13	A6 A7 A10 A13 A14	A6 A7 A13	IV
A7	A6 A7 A13	A6 A7 A10 A13 A14	A6 A7 A13	IV
A10	A6 A7 A10 A13	A10 A14	A10	
A13	A6 A7 A13	A6 A7 A10 A13 A14	A6 A7 A13	IV
A14	A6 A7 A10 A13 A14	A14	A14	

Table X. Iteration 5

Variable names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A10	A10	A10 A14	A10	V
A14	A10 A14	A14	A14	

Table XI. Iteration 6

Variable names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A14	A14	A14	A14	VI

Table XII. Clusters and its characteristics

Cluster no.	Cluster	Characteristics	Driving Power	Dependence	Variables
1	Autonomous variables	These variables are relatively disconnected from the system and may not be strong	Weak	Weak	
2	Dependent variables	These variables are mostly dependent on others and are weak	Weak	Strong	A01, A03
3	Linkage variables	These variables are extremely unstable so any action on them would affect other variables and also have feedback on them	Strong	Strong	A02, A04, A05, A06, A07, A08, A09, A11
4	Independent variables	Variable with very strong driving power called key variables so they influence other enabling variables	Strong	Weak	A10, A14

The second quadrant consists of "dependent variables" with weak driving power but strong dependence. These variables generally depend on other variables and therefore any action taken on other variables would affect these. In this research study, A01 and A03 variables were found to be in the category of dependent variables.

The third quadrant has "linkage variables" (relay variables) that have strong driving power and strong dependence. One of the significant characteristics of linkage variables are that they are extremely unstable. Thus, any action on them would affect other variables and also include feedback on them, so managers must take special care in handling these variables. In the research presented here, variables A02, A04, A05, A06, A07, A08, A09, A11, A12 and A13 were found to be in linkage variables category. At the same time these variables are very fluid and dependent. Relay variables are further identified as stake variables and target variables. Stake variables are variables within cluster III, more precisely located around the diagonal. Target variables are also in cluster III, under the diagonal rather than along the north-south frontier. These variables are rather more dependent than influent (Veltmeyer and Mohamed, 2017).

The fourth quadrant consists of "independent variables" (influence variables) having strong driving power but weak dependence power. As independent variables possess high driving power, policymakers should give more attention to these types of variables as they can influence other enabling variables. It has been found that variables with very strong driving power known as key variables fall into the category of independent or linkage variables. In this investigation, variables like A10 and A14 were found to be in the category of independent variables.

Some of the variables appeared on the midpoint of the matrix and could be part of any cluster. Variable A12 was lying on center line of matrix and therefore they can be part of cluster III or cluster IV.

5. Results

The ISM model reveals that if firms "eliminate slogans, exhortations and targets for the work force" (A10) and "take action to accomplish the transformation" (A14), variables are significant for the initiation of implementing quality principles in manufacturing and service organization. As it appears at the base of the ISM hierarchy, lack of top management commitment and coordination between departments are the most potent barriers, possessing high driving power and low dependence power (Muruganantham *et al.*, 2018). As such, effective top management will play a significant role in the successful implementation of TQM in organization (Dubey and Singh, 2015; Thakkar *et al.*, 2008; Dewangan *et al.*, 2015; Goyal *et al.*, 2017; Keshaorao Digalwar *et al.*, 2015; Singh and Sushil, 2013). Studies revealed that it is significant for the top management to take a leadership role and show strong commitment during the implementation of TQM to inspire employees toward improved quality standards (Rivers and Bae, 1999; Lee and Asllani, 1997). This can help the top management in deciding on the priority and focus on those variables which lead to the desired results in the form of outcome variables.

"Institute training" (A06), "adopt and institute leadership" (A07) and "encourage education and self- improvement for everyone" (A13) are needed in every phase of the successful implementation of TQM. Top management involvement will lead training and education to employees (Singh and Sushil, 2013). Similarly, the commitment of top management, as well as efficient and visionary leadership, will set create a basis for the implementation of TQM in an organization (Thiagarajan and Zairi, 1997). Training and education of employees is considered to be an extremely important investment for TQM success (Baidoun, 2003). Quality begins and ends with training (Thiagarajan and Zairi, 1997), and therefore training and education based on total quality must be planned and provided if TQM implementation is to be completed successfully (Thiagarajan and Zairi, 1997).

"Barriers that rob people of pride of workmanship" (A12) occur due to inadequate and/or insufficient training or education (Miller, 1991). Meanwhile Deming (1986) believes that people are mostly not at fault for shoddy workmanship, and that quality is primarily a function of top management (Krantz, 1989); so human commitment here is to "institute training" (A06), adopt and institute leadership (A07) and "encourage education" (A13). These variables lead to the "removal of barriers that rob people of pride of workmanship" (A12), as per Figure 3.

The MICMAC analysis shows that the "take action to accomplish the transformation" (A14) variable is an independent variable, as it possesses high driving power – organizations should therefore focus on it, as they have the ability to influence or affect other variables.

6. Discussion

The main objective of this research work was to rank the quality principle of Deming in order to analyze the interactions among variables which support the successful implementation of TQM in a service and manufacturing organization. To achieve these objectives, MICMAC analysis of the driving power and dependence power of variables were classified into four clusters, as shown in Figure 4, and ISM-based model was developed, as shown in Figure 3. This was completed in order to fully understand the interactions among different variables so that the management of an organization may focus on those variables which are more influential for TQM implementation. This practice can increase both an organization's productivity and performance, and will thus help in improving customer satisfaction, thereby increasing market share. The MICMAC analysis helps to classify and collate variables in terms of driving power and dependence power. It is seen from Figure 4 that there are no

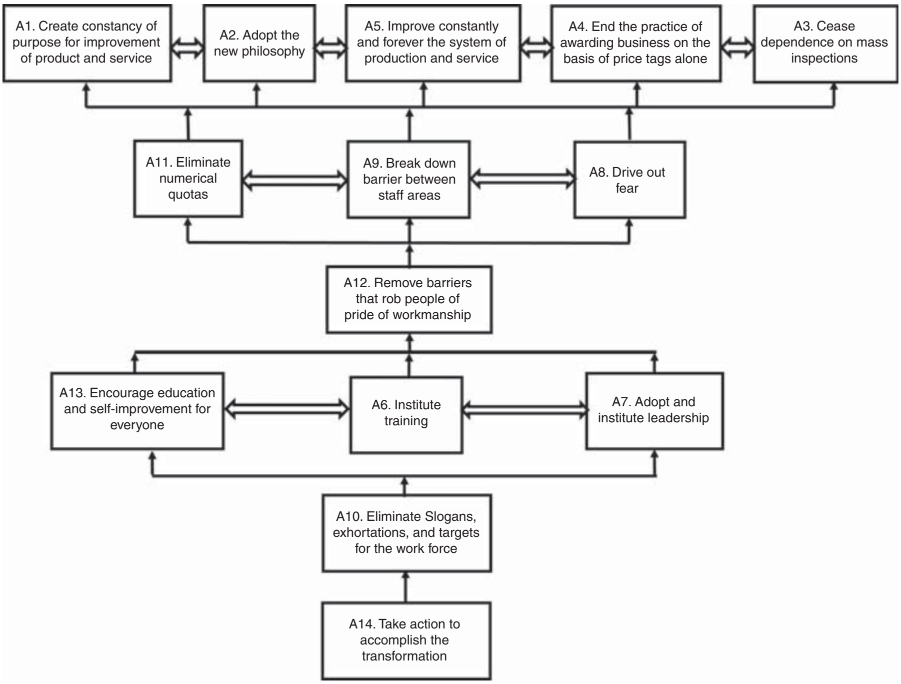


Figure 3.
ISM-based model for Deming's 14 quality principle

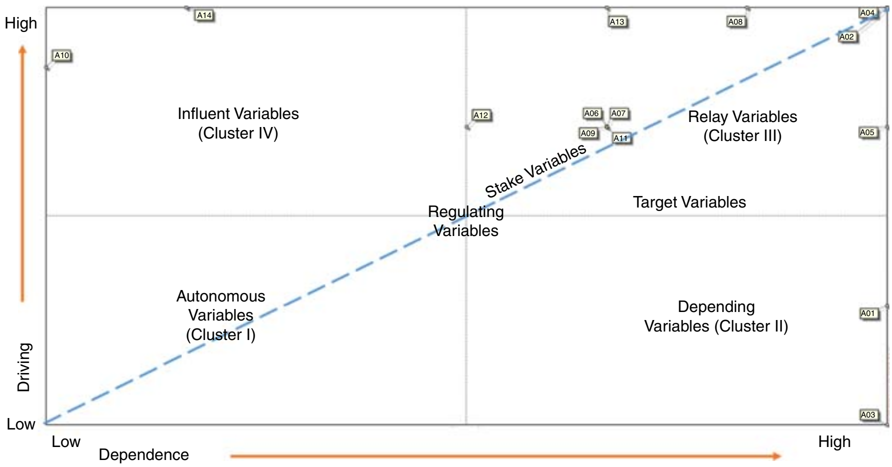


Figure 4.
Driving power and dependence diagram for Deming's quality principle

autonomous variables, which shows that all Deming quality variables play a significant role in the implementation of TQM program.

Variables such as "eliminate slogans, exhortations and targets for the work force" (A10) and "take action to accomplish the transformation" (A14) are clubbed together into the fourth cluster of the driver-dependence matrix diagram (MICMAC analysis). All these variables have strong driving power and weak dependent power and are called driver variables (influence variables). Since take action to accomplish the transformation (top management) variable lies at the bottom of ISM and has the strongest driving power (Figure 4), it is the most important variable for the successful implementation of TQM.

Variables such as "create constancy of purpose for improvement of product and service" (A01), "adopt the new philosophy" (A02), "cease dependence on mass inspections" (A03), "end the practice of awarding business on the basis of price tags alone" (A04) and "improve constantly and forever the system of production and service" (A05) come into the category of the outcome variables. These variables are seen at the top of the ISM, and these are dependent on mid-level and bottom-level variables.

Hence, in order to achieve the preferred result in the form of outcome variables, top management must focus on variables having high driving power, and frame TQM implementation strategies based upon these results and findings.

7. Conclusion

In this research investigation an ISM-based model has been developed for the successful implementation of TQM programs in service and manufacturing organization for improving customer satisfaction, efficiency and increasing market share. In this paper, Deming's 14 quality principles have been used to find interactions among variables to implement TQM. Although a large amount of literature is available on TQM enablers, no study has been undertaken to understand the interactions among Deming's 14 quality principles. The major contribution of this research work is the development of contextual relationships among variables through a systematic framework which can be used for any service and manufacturing organization. A major finding of this research work is that the "role of top management," "institute training," "encourage education to employees" and "institute leadership" are significant variables for successful implementation of TQM in service and manufacturing organizations. These variables have the strongest driving power and the weakest dependence power and lie at the bottom of the ISM model.

This study has some important managerial implications which are as follows:

- Linkage variables need to be carefully handled by the top management, as they possess strong driving power and strong dependence. A total of nine quality principles have appeared as the linkage variable in this study and thus need to be adopted by companies.
- Variables like A1, A2, A3, A4 and A5 are weak drivers but strongly dependent on other quality variables. Thus, these variables depict some of the desired objectives of TQM.
- Findings include development of TQM competent organization, setting up time framework to deploy quality based on organizational developmental capabilities and capacities. The effective use of the model leads to breakthrough strategies in TQM deployment, which can help to improve the management of resources and ultimately provide substantial financial benefits.
- The variables identified in this ISM model are quite general, and therefore with minimal adjustments, they can be used in the context of any other supply chain for increasing its efficiency and performance.

This research also has some limitations. Two experts were used for developing contextual relationships among identified variables. Therefore, the expert's knowledge, their understanding of industry and its operations might have affected the final results of the ISM model. ISM methodology has the capability of developing an initial model, which has been done in this research. SEM, on the other hand, has the capability of statistically testing an already developed theoretical model. Future research would attempt to validate the proposed model through the use of SEM. Still, findings are crucial for top management, production managers and consultants for TQM implementation.

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