The Critical Success Factors of Six Sigma in China Manufacturing Industry*

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Abstract

Six Sigma has been one of main quality improvement approaches since Motorola first invented Six Sigma in 1987. Many scholars and consult experts have discussed the critical success factors of implementing Six Sigma management, but most of them are based on related theories or qualitative analyses. In the paper, we first review critical success factor of Six Sigma status quo based on literature. Then we design the questionnaire and survey China manufacturing enterprises that have introduced Six Sigma management. And finally, we analyze the critical success factors of China manufacturing industry implementing Six Sigma management by using structural equation model and find that leadership and Six Sigma strategy, focus on market and customer, evaluation and motivation, selecting, managing and implementing Six Sigma projects are four critical success factors of China manufacturing enterprises implementing Six Sigma management. At the same time, the paper also presents the relationships between the critical success factors. The results are of important role in China manufacturing industry locating resources, eliminating waste and improving Six Sigma performance.

Key Words: Six Sigma Management, Critical Success Factor, Evaluation, Positive Analysis, Structural Equation Model

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1. Introduction

Since Motorola invented Six Sigma and received Malcolm Baldrige National Quality Award in 1988, Six Sigma as a quality improvement framework has been gaining increasing attention and acceptance in industry and academic (Haln *et al.*, 2000), and particularly from 1995, a number of prestigious global firms, such as General Electric (GE) and Allied Signal, have launched a Six Sigma program and made a great success. Behind the exponential nature of the spread of Six Sigma among global corporations, there has also been a strong deployment into vast number of large, medium and small sized enterprises. Six Sigma has quickly become a main method of quality management (Watson, 2003). Up to now, articles, instructor's manuals, audio and visual tapes and CD have a trend of exponential growth (Goh, 2002). The application scales of Six Sigma have extended from manufacturing to services, health, public administer and software development (Harris and Harris, 2002; Revere *et al.*, 2004; Hong and Goh, 2003). The idea of Six Sigma has been accepted gradually. Six Sigma management has became a metric, a methodology and a philosophy for quality improvement (Yue and Ma, 2006).

Six Sigma is unlikely to be a panacea for all quality ills (Goh, 2002), although it has many advantages in improving products and services, and its successful rate is higher than others methods, such as total quality management, zero defect, and so on. The statistical report, indexed from the famous consulting company Deloitte, shows that about 20% corporations reached the balance point that they expected. Those also explain that implementing Six Sigma is a hard and complex process. With the development of foreign consulting corporations entering China market and Six Sigma into education contents, Six Sigma will become one part of active management practice. Irrespective of Six Sigma will be developed, the key elements of success are invariable, such as emphasis on customer satisfaction, reducing variability in performance, a highly disciplined approach with data driven, appropriate technical tools to leverage the concepts, and the continuing uncompromising commitment from top management (Haln *et al.*, 2000).

Many scholars, consulting and Six Sigma experts have studied and analyzed what are the critical success factors of implementing Six Sigma management. These analyses are based on literature studies or practice experience. Little attention is paid to quantitative analysis and less to the cause and effect among factors. In the paper, we set up a model of critical success factors of implementing Six Sigma in China manufacturing industries, which is based on questionnaires from more than 200 enterprises. The exploratory factor analyses and structural equation model are used to verify and confirm the effective of the model. The results are important for manufacturing enterprises to optimize their resources, focus on key factors and improve the efficiency of implementing Six Sigma. The paper is arranged as follows: In section two, some literature on critical success factors of implementing Six Sigma are reviewed. In section three, questionnaire is designed, which is based on criteria for Six Sigma management (The Six Sigma Promotion Committee of China, 2007). In section four, the effective of investigation results are tested by using exploratory factor analysis, and then the results are analyzed and explained by using structural equation model. And at last conclusions are summarized and some research fields are pointed out.

2. Review of critical success factors of Six Sigma

What are the critical success factors? Yusof and Aspinwall point out in researching small and medium enterprises for total quality management that critical success factors are vital to organization success, without these factors, organization will be failure·(Yusof and Aspinwall, 1999). The Six Sigma expert R. D. Snee first introduces the critical success factors into Six Sigma management and points out Six Sigma relies on a combination of eight characteristics including bottom-line results created, senior management leadership is active, a disciplined approach (MAIC) is used, rapid project completion (3-6 months), clearly defines success, infrastructure (MBB, BB, GB) established, customers and processes are the focus and a sound statistical approach is used (Snee, 1990). Blakeslee Jr. considers that seven key principles are critical to ensuring companies reap an investment in Six Sigma business performance improvement, those are committed leadership, integration with top-level strategy, business process framework, customer and market intelligence network, projects produce real savings or revenues, full-time Six Sigma team leaders and incentives for all (Blakeslee, 1999). Goldstein, based on practice and consult experience, summarizes thirteen key success factors that are deployment plan, active participation of the senior executives, project reviews, technical support (Master Black Belts), full-time vs. part-time resources, training, communications, project selection, project tracking, incentive program, safe environment, supplier plan and customer "WOWS" (Goldstein, 2001). Banuelas and Antony, having summarized literatures and Six Sigma practice in British, point out critical success factors for the successful implementation of Six Sigma included management commitment and involvement, understanding Six Sigma methodology, tools and techniques, linking Six Sigma top business strategy, linking Six Sigma with customers, project selection, reviews and tracking, organizational infrastructure, culture change, project management skill, linking Six Sigma to suppliers, training, and linking Six Sigma with human resources (Banuelas and Antony, 2002). Starbird argued Six Sigma process is part of a management system to achieve business excellence in organizations and presented keys to Six Sigma success as: start process management (identify core processes, customer needs and measures), drive performance through reporting (leaders must maintain and report opportunity lists, status of active project/resources, and results from finished projects) and integrate championing of active projects (select and charter projects and require update during existing staff meetings) (Starbird, 2002). Chen studied relationship between business and Six Sigma, and pointed out the top factor in success of Six Sigma is DAMIC integration (Chen, 2006). Lee used survey results from practitioners to investigate success factors, and found that the following ordering of success factors from most to least important: top management commitment, statistical/analytical tool usage, managerial capabilities of trained participants (i.e. black belts), managerial process, personality of black belt, Six Sigma training programs, adoption of previous quality programs and others (Lee, 2002). Byrne and Norris analyzed the relationship Baldrige criteria and Six Sigma, then pointed out the combination of committed leadership, customer and market focus, strategy integration, full-time Six Sigma team leaders, incentives and accountability, quantifiable measures and results, and business process framework are strategic Six Sigma success factors (Byrne and Norris, 2003). Kwak and Anbari, based on various literature reviews and discussions with Six Sigma leaders in organizations that implement the Six Sigma management, identified four key elements of successful Six Sigma applications. Those elements are management involvement and organizational commitment, project selection, management and control skills, encouraging and accepting cultural change, and continuous education and training (Kwak and Anbari, 2006). Gupta, based on his management practice and consult experience, presented that a Six Sigma level of performance cannot be achieved without innovation (Gupta, 2005). Hariharan summarized 33 common roadblocks in a Six Sigma journey and presented CEO's guide to Six Sigma success (Hariharan, 2006). Brady and Allen reviewed success factors of Six Sigma and identified 13 distinct success factors listed by: top management commitment, team training, data system, structural approach, forming the right team, bottom line focus, team involvement, project selection, customer focused, right project leadership, goal based approach, change management and adaptable system (Brady and Allen, 2006). They also found close to 50% of the articles that mentioned at least one success factor included 'top management commitment' and a sizable fraction emphasized training programs involving adult participants from multiple disciplines.

Based on results from references, we find consensus in top management commitment and support, organization infrastructure, project management skills, structured methodology and statistical tools. Some of the success factors seem to be incompatible such as focus on bottom line and focus on customer. In order to understand what are success factors of Six Sigma management in China manufacturing industry, we design the questionnaire based on analyses, certification and improvement.

3. The critical success factors analysis and questionnaire

Any organization in the process of business improvement can follow a model to obtain advantages, such as Deming Prize, Malcolm Baldrige National Quality Award and European Quality Award. Those models provide a way to assessment, self-assessment and diagnosis to improve business performance. At present, there have not been recognized criteria to evaluate Six Sigma management. Some organizations, such as Korea Standard Society, China Six Sigma Promotion Committee, have made an effort in these respects.

Based on the Korea and performance excellence criteria, we have developed a framework to evaluate Six Sigma. These variables include Six Sigma leadership and strategy, organization infrastructure, focus on market and customer, select, manage and implement of Six Sigma project, evaluation and motivation, and business results. Since these variables are not measured directly, we need to provide some measurable indicators to reflect these six variables.

3.1 Six Sigma leadership and strategy

Six Sigma is a top-down approach that is led by enthusiastically and unwavering by top management. It is necessary for them to provide resources and to promote culture change. They are responsible for ensuring the successfully implementation of Six Sigma in their own areas of influence. At the same time, Six Sigma strategy should align with organization strategy. The following nine indicators can be used to reflect the characteristics of Six Sigma leadership and strategy.

- Top management has clearly set up organization direction, vision and core values.
- Top management has constructed an environment of empower, learn and innovation.
- The request and behavior of top leader lead the organization to understand and carry out Six Sigma philosophy.
- Top management support and actively participate in Six Sigma improvement activities (training, selecting project, stage review and results evaluation).
- Organization has established Six Sigma promoting strategy based on customer requirements.
- Six Sigma promoting strategy align with organization strategy.
- Six Sigma strategy and policy are communicated well from up to down.
- According to organization strategy and policy, function departments have established Six Sigma implementation goals and plans in details.
- Organization has provided suitable human, material and financial resources to achieve Six Sigma strategy goals.

3.2 Organization infrastructure

In this aspect, the primary task is to build team, then determine the roles and responsibilities of team number, and form a Six Sigma promoting organization system. Organization infrastructure and resources are necessary conditions for developing Six Sigma activities, which include the investment in quality education, data collection, management and analysis system, cultivating organizational culture, and so on. The indicators are listed as follows:

- Member of Six Sigma promoting organization is suitable for promotion and communication.
- There is a sound system and charter for Six Sigma promotion organization.
- Six Sigma promotion organization hold the meeting, review, summarize and make out promotion program on a regularly.
- There are clear and practical policies and plan for the members of Six Sigma promotion organization.
- Training programs based on project requirements and the level of participants from multiple disciplines.
- Quality education has a large proportion in the education investment.
- Systematically evaluate and feedback training results in the process of training improvement.
- Team member can solve problem well by applying appropriate methods and tools.
- There is a maturity system to collect, process and analyze data.
- Data and information is full, exact and reliable.
- There is an effective management system of poor quality cost, which is used in Six Sigma activities.
- There is an information platform which can be shared by empower.

3.3 Focus on market and customer

Market and customer are foundation for organization survival. It is a key objective for organization to understand what are customers requirements, to evaluate customer satisfaction and collect customer information. The following five indicators reflect the variable.

- Clearly define interior or exterior customer, and establish an integrated customer information system.
- Evaluate and predict customer requirements on a regularly.
- There is a perfect flow for dealing with customer complain and feedback.
- Measure customer (both interior and exterior) satisfaction and feedback the results into improvement.
- Top management check and evaluate work system, identify obstacles in customer satisfaction and implement suitable plan.

3.4 Select, manage and implement Six Sigma project

Six Sigma is implemented by projects. These include the setting of quality objectives for the business and monitoring progress toward these objectives, selection of Six Sigma projects, and mentoring and training project teams. Implementation is the responsibility of the project team members. The following ten indicators can reflect the variable:

- There is a systematical Six Sigma project selection procedure.
- Based on organization strategy, and customer complain or suggestions identify opportunities for improvement.
- CTQs (critical to quality) of functional departments are deployed effectively.
- Master Black Belts (MBBs) and Black Belts (BBs) have capabilities of Six Sigma activities.
- There are programs for team building.
- The structure of team member is suitable and efficiency.
- All functional departments participate in Six Sigma improvement activities.
- Team member can use methods and tools to solve practice problems effectively.
- There are suitable tracking procedures for monitoring and supervising project progress.
- Suppliers actively participate in Six Sigma improvement projects, and the organization provides support and review supplier's improvement activities.

3.5 Evaluation and motivation

A rational project evaluation system can arouse the enthusiasm of team member, and promote employee's career development. The variable is reflected by eight indicators.

- Set up a clear, objective and rational evaluation system of Six Sigma project.
- According to finance approach to evaluate project and results is recognized by finance department.
- There are formal channels to transmit project results and act as others project references within organization.
- Project results can communicate, share and learn between organization inside and strategy partners.
- There are performance assessment systems for team members
- There is an award system of project to support Six Sigma improvement activities.
- The award system is linked with project results, which can motivate the employees.
- There are many kinds of methods to promote employee career development.

3.6 Business results

The outcomes of Six Sigma management are usually required to be expressed in financial terms. Though financial results are very important, it is also should include human resource development, organization culture transition, both internal employee and external customer satisfaction, and so on. The following eight indicators reflect the variable:

- Improved customers satisfaction
- Enhanced the level of productivities and quality
- Improved marketplace performance and financial results
- Improved the quality of suppliers
- Reduced all kinds of cost
- Enhanced employee's positive attitude
- Promoted organization culture transition successfully
- The whole organization has understood Six Sigma philosophy and participated in improvement activities.

The questionnaire has been consulted by some MBB, BB of enterprises, such as AVIC I (China Aviation Industry Corporation I), TISCO(Taiyuan Iron and Steel Corporation), and some Six Sigma experts from the Six Sigma Promotion Committee of China. Finally, the questionnaire is established after trial survey and correction.

4. Questionnaire survey and results analyses

4.1 Questionnaire survey

Up to now, there are more than 600 enterprises have implemented Six Sigma in China. The selected samples are from two parts. One from enterprises have implemented Six Sigma quite well, the other from advanced training classes of Black Blets. Both are via the Six Sigma Promotion Committee of China. Investigators include senior managers, champions, MBBs, BBs and GBs, in which both BBs and GBs are 70%. The involved industries include mechanism, chemical, electron, aeronautics and astronautics, iron and steel, automobile, shipping, and so on. We distributed 352 questionnaires, of the 285 returned, 274 were valid (response rate 81.0%, usable rate 77.8%). We used a five-point Likert scale (1 = strongly disagree; 5 = strongly agree) to gather data for the questionnaire survey.

4.2 Descriptive analyses of samples

Table 1 presents descriptive analyses for the 274 valid samples. In Table 1, x_1, x_2, $\cdots$, x_9 present 9 indicators of the variable "Six Sigma leadership and strategy", respectively; x_{10}, x_{11}, $\cdots$, x_{21} present 12 indicators of the variable "organization infrastructure", respectively; and x_{22}, x_{23}, $\cdots$, x_{26} present 5 indicators of the variable "focus on market and customer", respectively; in the same way, y_1, y_2, $\cdots$, y_{10} present 10 indicators of the variable "select, manage and implement Six Sigma project", respectively; y_{11}, y_{12}, $\cdots$, y_{18} present 8 indicators of the variable "evaluation and motivation", respectively; and y_{19}, y_{20}, $\cdots$, y_{26} present 8 indicators of the variable "business results", respectively. In the type of X variables, the mean of x_1 is largest (4.09), which show top management has clearly set up organization direction, vision and core values, and the mean of x_{20} is smallest (3.23), which also show there is not an effective poor quality cost management system used in Six Sigma activities. In the type of Y variables, the mean of y_{18} is largest (3.80), which explain in the organizations there are many kinds of methods to promote employee career development, and the mean of y_{10} is smallest (2.91), which also explain Suppliers don't actively participate in Six Sigma improvement projects, and the organizations do not provide support and review supplier's improvement activities.

Table 1. Descriptive analyses of sample data

indicator	Mean	Standard deviation	indicator	Mean	Standard deviation	indicator	Mean	Standard deviation	indicator	Mean	Standard deviation
x_1	4.09	0.83	x_{14}	3.17	0.88	y_1	3.60	1.00	y_{14}	3.51	1.08
x_2	3.83	0.91	x_{15}	3.47	0.96	y_2	3.76	0.85	y_{15}	3.48	1.03
x_3	3.77	0.94	x_{16}	3.42	0.87	y_3	3.52	0.81	y_{16}	3.40	1.03
x_4	3.69	0.98	x_{17}	3.36	0.92	y_4	3.76	0.87	y_{17}	3.66	0.83
x_5	3.66	0.93	x_{18}	3.45	0.90	y_5	3.55	0.87	y_{18}	3.80	0.78
x_6	3.87	0.88	x_{19}	3.49	0.84	y_6	3.47	0.89	y_{19}	3.67	0.81
x_7	3.47	0.83	x_{20}	3.23	0.91	y_7	3.37	0.94	y_{20}	3.24	0.84
x_8	3.36	0.95	x_{21}	3.64	0.91	y_8	3.49	0.83	y_{21}	3.59	0.91
x_9	3.45	0.91	x_{22}	3.58	0.91	y_9	3.60	0.93	y_{22}	3.26	0.85
x_{10}	3.51	0.99	x_{23}	3.54	0.84	y_{10}	2.91	0.95	y_{23}	3.24	0.98
x_{11}	3.51	1.03	x_{24}	3.96	0.85	y_{11}	3.60	0.94	y_{24}	3.40	0.94
x_{12}	3.78	1.04	x_{25}	3.75	0.91	y_{12}	3.59	1.04	y_{25}	3.51	1.08
x_{13}	3.64	0.90	x_{26}	3.54	0.83	y_{13}	3.58	0.97	y_{26}	3.48	1.03

4.3 Exploratory factor analyses

Before carrying out exploratory factor analyses, we divided the whole data (274 samples) into equal two sections. The first section was used for exploratory factor analyses. The second section was used for constructing structural equation model and analyzed relationship between six variables. The principal component analysis method is used for exploratory factor analyses.

4.3.1 Six Sigma leadership and strategy

By analyzing the correlative matrix formed from nine indicators, we find that measure of sampling adequacy (MSA) of each indicator is greater than 0.87, and the MSA of population is 0.906. Using Burtlett sphericity hypothesis test, we obtain χ^2_{36} = 822.77, and p <

0.01, which means that the nine indicators are significant correlation at level $\alpha = 0.01$. Therefore, it satisfied the conditions of factor analysis. Moreover, one factor model explains 63.77% of total variance. The result of factor analysis is listed in the second column of Table 2.

4.3.2 Organization infrastructure

By analyzing the correlative matrix composed of twelve indicators, the results show that the MSA of each indicator is greater than 0.90, and the MSA of population is 0.924. Using Burtlett sphercity hypothesis test, we obtain $\chi^2_{66} = 1113.30$, and $p < 0.01$, which means that the twelve indicators are significant correlation at level $\alpha = 0.01$. So, it satisfied the conditions of factor analysis. In addition to, one factor model explains 59.12% of total variance. The result also is listed in the fourth column of Table 2.

4.3.3 Focus on market and customer

By analyzing the correlative matrix composed of five indicators, the results show that the MSA of each indicator is greater than 0.84, and the MSA of population is 0.862. Using Burtlett sphercity hypothesis test, we obtain $\chi^2_{10} = 447.24$, and $p < 0.01$, which means that the five indicators are significant correlation at level $\alpha = 0.01$. So, it satisfied the conditions of factor analysis. One factor model explains 73.75% of total variance. The factor analysis result is listed in the sixth column of Table 2.

Table 2. Exploratory factor analysis results of "Six Sigma leadership and strategy", "organization infrastructure" and "focus on market and customer"

Six Sigma leadership and strategy	factors	organization infrastructure	factors	focus on market and customer	factors
x_1	.780	x_{10}	.818	x_{22}	.888
x_2	.830	x_{11}	.776	x_{23}	.863
x_3	.833	x_{12}	.786	x_{24}	.804
x_4	.802	x_{13}	.782	x_{25}	.882
x_5	.783	x_{14}	.771	x_{26}	.854
x_6	.752	x_{15}	.684		
x_7	.853	x_{16}	.815		
x_8	.802	x_{17}	.832		
x_9	.744	x_{18}	.801		
		x_{19}	.782		
		x_{20}	.673		
		x_{21}	.685		

4.3.4 Select, manage and implement Six Sigma project

By analyzing the correlative matrix formed from ten indicators, we find that MSA of each indicator is greater than 0.89, and the MSA of population is 0.924. Using Burtlett sphericity hypothesis test, we obtain χ^2_{45} = 916.98, and p < 0.01, which means that the ten indicators are significant correlation at level α = 0.01. It satisfied the conditions of factor analysis. One factor model explains 63.08% of total variance. The result of factor analysis is listed in the second column of Table 3.

4.3.5 Evaluation and motivation

By analyzing the correlative matrix composed of eight indicators, the results show that the MSA of each indicator is greater than 0.86, and the MSA of population is 0.887. Using Burtlett sphercity hypothesis test, we obtain χ^2_{28} = 768.73, and p < 0.01, which means that the eight indicators are significant correlation at level α = 0.01. So, it satisfied the conditions of factor analysis. In addition to, one factor model explains 62.55% of total variance. The result also is listed in the fourth column of Table 3.

4.3.6 Business results

By analyzing the correlative matrix composed of eight indicators, the results show that the MSA of each indicator is greater than 0.85, and the MSA of population is 0.889. Using Burtlett sphercity hypothesis test, we obtain χ^2_{28} = 635.59, and p < 0.01, which means that the eight indicators are significant correlation at level α = 0.01. It satisfied the conditions of factor analysis. One factor model explains 73.75% of total variance. The factor analysis result is listed in the sixth column of Table 3.

Table 3. Exploratory factor analysis results of "select, manage and implement Six Sigma project", "evaluation and motivation" and "business results"

select, manage and implement Six Sigma project	factors	evaluation and motivation	factors	business results	factors
y_1	.819	y_{11}	.824	y_{19}	.866
y_2	.761	y_{12}	.737	y_{20}	.837
y_3	.722	y_{13}	.782	y_{21}	.829
y_4	.810	y_{14}	.722	y_{22}	.714
y_5	.815	y_{15}	.862	y_{23}	.753
y_6	.815	y_{16}	.868	y_{24}	.630
y_7	.848	y_{17}	.846	y_{25}	.747
y_8	.786	y_{18}	.660	y_{26}	.795
y_9	.849				
y_{10}	.703				

The results of exploratory factor analysis show that each indicator satisfies basic requirements. Therefore, we can construct structural equation model and verify research hypotheses.

4.4 Structural equation model and research hypotheses

Structural equation model is composed of measurement model and structural model two parts. Measurement model describes the relationship between the indicators and latent variables. It can be expressed as:

$$X = \Phi_x \xi + \delta \qquad Y = \Phi_y \eta + \varepsilon \tag{1}$$

Where X and Y are vectors consisting of exogenous indicators and endogenous indicators, respectively, δ and ϵ are X's and Y's error vector, respectively, ξ and η are exogenous latent variables and endogenous latent variables, respectively. Φ_x is the relation matrix between exogenous indicators and exogenous variables. Φ_y is the relation matrix between endogenous indicators and endogenous variables. And $E(\varepsilon) = 0$, ε has non-correlation with ξ, $E(\delta) = 0$, ε has no-relation with η.

Structural model describes the relationship between latent variables. It can be expressed as:

$$\eta = B\eta + \Gamma\xi + \zeta \tag{2}$$

where B is a coefficient matrix expressing the relation between endogenous latent variables. Γ is also a coefficient matrix describing exogenous variables' effect on endogenous variables', and ζ is error vector, it also reflects endogenous variables that could not explained in structural model, and $E(\zeta) = 0$. In the model, the exogenous variables are independent, while endogenous variables are dependent.

In our research, we consider "Six Sigma leadership and strategy", "organization infrastructure" and "focus on market and customer" as exogenous latent variables, and expressed as ξ_1, ξ_2, ξ_3, respectively. So do "select, manage and implement Six Sigma project", "evaluation and motivation" and "business results" as endogenous latent variables, and expressed as η_1, η_2, η_3, respectively. At the same time, we make eight hypotheses as follows:

H_1: "Six Sigma leadership and strategy" has significant effect on "select, manage and implement Six Sigma project";

H_2: "Six Sigma leadership and strategy" has significant effect on "evaluation and motivation";

H_3: "Six Sigma leadership and strategy" has significant effect on "business results";

H_4: "organization infrastructure" has significant effect on "select, manage and implement

Six Sigma project";

H_5: "focus on market and customer" has significant effect on "evaluation and motivation";

H_6: "focus on market and customer" has significant effect on "business results";

H_7: "evaluation and motivation" has significant effect on "select, manage and implement Six Sigma project";

H_8: "select, manage and implement Six Sigma project" has significant effect on "business results."

Based on theory analyses and hypotheses, we construct a path diagram (Figure 1). In Figure 1, six ellipses present six latent variables, where ξ_1, ξ_2 and ξ_3 are exogenous variables, respectively, and η_1, η_2 and η_3 are endogenous variables, respectively. Rectangles present the reflective indicators of those latent variables.

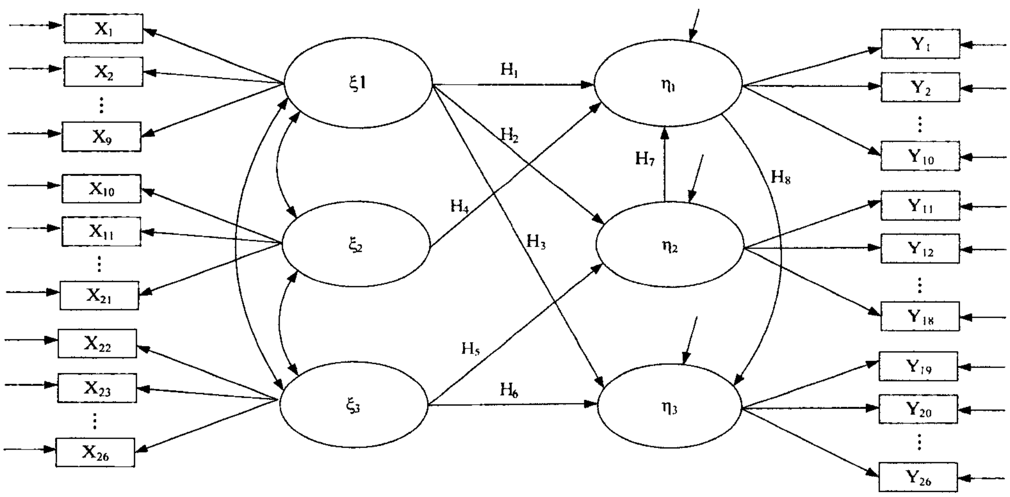

Figure 1. Theory model of structure equation for critical factors analyses

4.5 Analyses of model and verification of hypotheses

Now, we use the second section data to analyze the model. Based on the correlation coefficient matrix, we apply LISREl 8.70 to estimate, assess and modify the model four times. We comprehensively adopt criteria such as root mean square of approximation (RMSE), non-normed fit indicator (NNFI), comparative fit indicator (CFI), parsimony normed fit indicator (PNFI) and parsimony goodness of fit indicator (PGFI), and finally, we obtain the path diagram (Figure 2) and T-test values diagram (Figure 3) of standardized coefficients. The results of model fit measures and standards are shown in Table 4. In both Figure 2 and Figure 3, KSI 1, KSI 2 and KSI 3 are exogenous variables ξ_1, ξ_2 and ξ_3, respectively, and ETA 1, ETA 2 and ETA 3 are endogenous variables η_1, η_2 and η_3, respectively. From

Figure 3, we can find that T-tests are significant at level α = 0.01. So, the hypotheses H_2, H_5, H_6 and H_7 are verified.

Table 4. The results of model fit measures and standards

Fit measure	χ^2	df	Absolute fit measure	Incremental fit measure		Parsimonious fit measure	
			RMSEA	NNFI	CFI	PNFI	PGFI
Standard			< 0.10	> 0.90	> 0.90	> 0.50	> 0.50
Our model	2666.84	1267	0.086	0.966	0.968	0.899	0.536

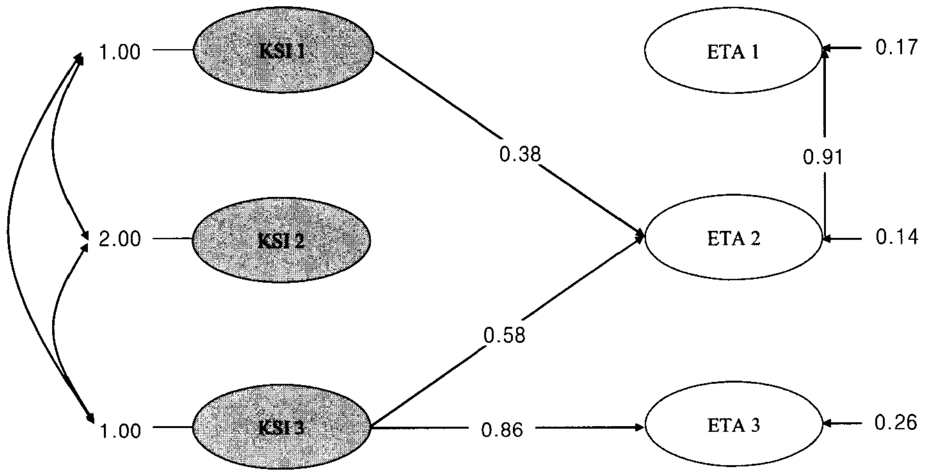

Figure 2. The path diagram of standardized coefficients

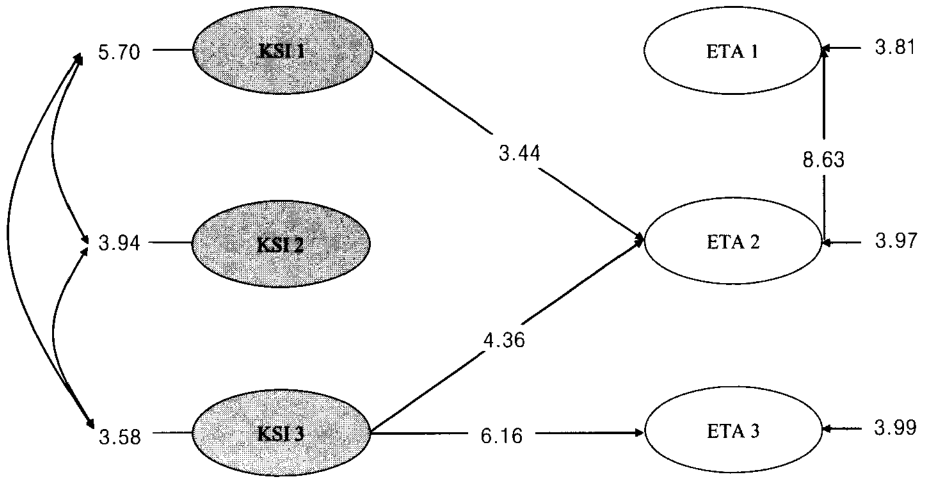

Figure 3. T-test values diagram of standardized coefficient

4.6 Analyses of validity and reliability

When implementing analyses of validity, we first should check three aspects. ① if there are irrational parameters in the model, such as negative variance, standardized coefficient approximating 1. ② if fit measures meet standards. ③ if standardized parameters are significant. Our model satisfies the three basic requirements. In addition to, the expected value of cross-validation indicator (ECVI) equals to 20.22, which is smaller than independent model value (ECVI = 331.34) and saturation model value (ECVI = 20.26), therefore, the cross-validation of the model meets requirements.

In the structural equation model, reliability (R^2) of individual observed indicator, 44 out of 52 are greater than 0.5, the other 8 indicators are also greater than 0.3, which mean indicators system is acceptable. Composite reliability (CR) of the latent variables is greater than 0.8, which mean the reliability of latent variables is excellent. Average variance extracted (AVE) of latent variables is greater than 0.5 except for ξ_1' which also equal to 0.48. Based on these results, we can conclude the reliability of model is acceptable. Reliability of individual observed indicator, CR and AVE of latent variables are listed in Table 5.

Table 5. R^2 of individual observed indicators, CR and AVE of latent variables

variables	R^2	CR	AVE	variables	R^2	CR	AVE	variables	R^2	CR	AVE
ξ_1		0.89	0.48	x_{18}	0.37			y_9	0.56		
x_1	0.66			x_{19}	0.56			y_{10}	0.59		
x_2	0.56			x_{20}	0.55			η_2		0.92	0.58
x_3	0.46			x_{21}	0.61			y_{11}	0.62		
x_4	0.58			ξ_3		0.84	0.51	y_{12}	0.64		
x_5	0.62			x_{22}	0.34			y_{13}	0.59		
x_6	0.62			x_{23}	0.59			y_{14}	0.59		
x_7	0.69			x_{24}	0.41			y_{15}	0.45		
x_8	0.58			x_{25}	0.61			y_{16}	0.56		
x_9	0.62			x_{26}	0.62			y_{17}	0.62		
ξ_2		0.89	0.62	η_1		0.93	0.59	y_{18}	0.53		
x_{10}	0.38			y_1	0.52			η_3		0.91	0.56
x_{11}	0.61			y_2	0.61			y_{19}	0.52		
x_{12}	0.48			y_3	0.66			y_{20}	0.36		
x_{13}	0.59			y_4	0.58			y_{21}	0.40		
x_{14}	0.49			y_5	0.55			y_{22}	0.74		
x_{15}	0.69			y_6	0.51			y_{23}	0.66		
x_{16}	0.61			y_7	0.71			y_{24}	0.53		
x_{17}	0.61			y_8	0.62			y_{25}	0.66		
								y_{26}	0.66		

4.7 Research results

Based on our hypotheses and structural equation model, we should refuse hypotheses H_1, H_3, H_4 and H_8, while accept H_2, H_5, H_6 and H_7. According to T-test values in Figure 3, we can conclude that 4 paths are significant unequal to 0 at level $\alpha = 0.01$. Therefore, we summarize research results as follows:

(1) "Six Sigma leadership and strategy" has significant effect on "evaluation and motivation", and via the "evaluation and motivation", "Six Sigma leadership and strategy" has indirect effect on "select, manage and implement Six Sigma project." Though "Six Sigma leadership and strategy" has no directly effect on "select, manage and implement Six Sigma project", its indirect effect is very important.

(2) "Evaluation and motivation" plays a decisive role on "select, manage and implement Six Sigma project."

(3) "Focus on market and customer" has very important effect on "evaluation and motivation." At the same time, both "Six Sigma leadership and strategy" and "focus on market and customer" has indirect effect on "select, manage and implement Six Sigma project" via "evaluation and motivation."

(4) "Focus on market and customer" plays a decisive role on "business results". In the model, "focus on market and customer" is only a factor that has significant effect on "business results."

(5) "Organization infrastructure" has no significant effect on the other factors.

(6) "Select, manage and implement Six Sigma project" has no significant effect on "business results."

5. Conclusion and further research

The critical success factors of implementing Six Sigma management in China manufacturing industry can be concluded as Six Sigma leadership, set up and implement appropriate Six Sigma strategy, focus on market and customer, adopt effective evaluation and motivation measures, select, manage and implement Six Sigma projects.

Our research verifies that "focus on market and customer" plays a decisive role on "business results." In addition to, "focus on market and customer" has significant effect on "evaluation and motivation", which also explains that "evaluation and motivation" is based on "business results."

In the model, "evaluation and motivation" play a medium role. The two basic factors of influencing "select, manage and implement Six Sigma projects" and "business results" are "Six Sigma leadership and strategy" and "focus on market and customer." It is explains that organizations seclect, manage and implement Six Sigma projects dependent on top management decision making, Six Sigma strategy, market and customers.

"Organization infrastructure" has no significant effect on the other factors, which explains that it is not critical success factor for Six Sigma management. This result coincides with Chen's research results (Chen, 2006). It also tells us: it is unnecessary for organizations to emphasize the importance of a organization committee in the process of implementing Six Sigma management. Top leader should focus on Six Sigma strategy and make it alignment with organization strategy. On the one hand, senior leaders should focus on Six Sigma strategy deployment; on the other hand, they should provide necessary resources to carry out organization strategies.

The survey objects in our research are manufacturing enterprises that are implementing Six Sigma management. Most enterprises have introduced Six Sigma management only for two or three years. It is possible to have some problems. In theory, "select, manage and implement Six Sigma projects" should have direct effect on "business results", however, research results show that the relationship between them is not significant. The reason may be that organizations do not bring the results of Six Sigma projects into financial performance assessment in the current China account system. It is also a problem need to be further researched.

In China manufacturing enterprises that are carrying out Six Sigma management are not too much and located unbalance, it is difficult to obtain large samples. Though the sample meet requirement in our research, it is not enough for more detail analyses. We need more samples to verify results further.

Six Sigma management is just at introduce stages in China, there are many problems need to be solved. The factors that influence Six Sigma management are very complex. We will subdivided investigation object, such as electron industry, iron and steel industry, and obtain more details results.

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