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An Analysis on Success Factors and Importance of Six Sigma Innovation in Small and Medium Venture Companies

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중소·벤처기업의 6시그마 혁신 성공요인 및 중요도 분석

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Abstract This study examined the success factors of six sigma innovation in small- and medium-sized venture companies. The findings are summarized as follows. The importance of 20 items in a total of 4 factors showed that corporate vision was number one in the manager's support, followed by program composition, passionate support, high performance guarantee, and quality activity continuity.

This suggests that all members can operate the program by the structured system with a sense of united goal under the company-offered vision as a community when the goal, idea or vision of six sigma activities are shared to members of the entire organization. In addition, high success can be achieved when supported by company-wide enthusiasm and high compensation for sharers' innovative efforts of six sigma at the same time. Small- and medium-sized venture companies should develop brisk six sigma activities of advanced precision parts in such an environment that the technology competition is becoming increasingly fierce. The six sigma movement should be developed as a niche strategy for small organizations with united vision sharing by company-wide operational commitment and high self-esteem for the organizational characteristics of small- and medium-sized venture companies run by key minority organizations and members.

요 약 본 연구는 중소·벤처기업의 6시그마 혁신 성공요인을 도출하기 위해 실증 조사하였다. 분석결과 총 4가지 요인 20개 문항 중 도출된 중요도를 보면 경영자 지원 요인에서의 당해 기업의 비전이 제 1순위로 나타났으며, 그 다음으로 프로그램구성, 열정적 지원, 높은 성과 보장과 품질활동지속 순으로 나타났다.

이는 전 조직 구성원에 공유될 때 구성원 모두 하나의 공동체로 회사에서 제시하는 비전 아래 일치된 목표 의식을 가지고 구조화된 시스템에 의한 프로그램의 운영이 가능해진다. 또한, 전사적 회사차원에서의 열의를 갖고 지원과 동시 공유자들의 6시그마 혁신적 노력에 걸맞은 높은 보상이 뒤따를 때 높은 성공을 이룰 수 있음을 시사한 것으로 평가할 수 있다.

이 같이 중소·벤처기업의 기술 경쟁력이 갈수록 치열해지는 환경에서 첨단 정밀 부분의 6시그마 활동 또한 더욱 활발한 활동 전개를 해야 한다. 그리고 핵심 소수 조직과 구성원에 의해 운영되는 중소·벤처기업 조직 특성에 맞는 전사적 차원의 운영 몰입과 높은 자긍심에 의한 일치된 비전 공유로 소규모 조직에 적합한 틈새전략으로써 6시그마 운동 전개가 되어야 할 것이다.

Keywords : Education and Training, Innovation Factors of Six Sigma, Manager's Support, Performance Compensation, Quality Control

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1. Introduction

Small and medium venture companies refer to the range of standards set by the Basic Law of Small and Medium Enterprises(SMEs) with less than 1,000 employees and sales of less than 150 billion won. The total quality management(TQM) activities based on the quality control(QC) of domestic innovative SMEs and venture companies have helped to improve the quality of many SMEs and venture companies into six sigma management innovation activities due to the innovative techniques with the times[1]. These SMEs and venture companies have become a driving force in sustainable management and over the past 20 years since the introduction of six sigma in Korea, it has become an opportunity to spread to all SMEs and venture companies such as manufacturing and service industries. six sigma activities have started with quality innovation to develop into process and management innovation[2]. In recent years, however, the polarization has begun to emerge among domestic SMEs and venture companies that have introduced six sigma, and from venture companies that have long pursued six sigma quality activities. In other words, there are venture companies that have evolved into a new quality methodology in line with their innovation capabilities reflecting the change of the times, while there are venture companies that lose or give up the direction of six sigma[3]. This is because six sigma is attributable to short-term and direct performance. To implement sustainable and successful six sigma, SMEs and venture companies should figure out and apply the key success factors of innovation activities in consideration of innovation factors from a long-term perspective. Because SMEs and venture companies can establish innovation strategies that respond to the changing environment by accumulating innovation factors inside the enterprise. This innovation capability can maintain sustainable quality management activities as a series of corporate characteristics by promoting and supporting corporate innovation strategies[1].

six sigma requires a lot of change for an innovative drive. It is important how to bring about this change and make it acceptable to organizational members[3], but it is not easy to apply six sigma properly in the organization of SMEs and venture companies. In recent research, this is also the reason why the failure factors of the introduction of organizational innovation or management innovation are placed on the characteristics of organizational human resource change management rather than the characteristics of the operating system[4]. For the successful execution of six sigma, fair compensation through the application and evaluation of key success factors must be supported to guarantee high performance.

The innovation factors of six sigma, which requires such efforts, must be applied by priority, but most of the existing studies are normative or case studies, which analyzed successful cases targeting system projects of large companies, and lack empirical studies on the relationship between success factors of six sigma and performance in SMEs and venture companies[2,3,5].

In other words, the existing studies show that studies on large companies such as process innovation[1], organizational commitment[1], knowledge creation[3], and innovation capability[2] as well as studies on direct relationship between success factors of six sigma and management performance are the mainstream. There are very few empirical studies on organizations for the structure of SMEs and venture companies concerning innovative success variables that promote these innovation success factors.

The significance of this study is to look into the key success factors and importance of six sigma innovation activities targeting managers of six sigma innovation in SMEs and venture companies.

2. Analysis Frame and Survey Design

2.1 Setting of AHP Analysis Model

This study is intended to analyze how SMEs and venture companies recognize the relative importance of success factors in six sigma innovation activities. To achieve this, the structural drawing of six sigma activities was made as shown in Table 1. It was made by a literature review and a survey targeting manufacturing companies engaged in six sigma activities[6].

The AHP(Analytic Hierarchy Process) in this study is used to know the priority of alternatives. In the AHP, the importance of the evaluation items can be figured out by the hierarchical structure through a pairwise comparison between each item, and the qualitative evaluation criteria as well as the quantitative evaluation criteria can be easily processed as experts' experience and intuition are reflected in the result of evaluation[7].

As shown in Table 1, the success priority model considered in six sigma activities is composed of two hierarchies. The parent elements, success factors six sigma innovation are composed of 4 items such as manager's support, education and training, performance compensation and quality management. As sub-elements, 5 items are assigned to each of parent factors to be composed of a total of 20 items[8].

Table 1. Sub-contents by Type

Success Factors of six sigma innovation			
Manager's Support	Education and Training	Performance Compensation	Quality Control
① Corporate Vision Suggestion ② Strategic Direction Suggestion ③ Passionate Support ④ System Support ⑤ R&D Capability Support	① Program Composition ② Educational Obligation Completion System ③ Regular Evaluation ④ Organizational Linkage ⑤ Learning Capability	① Fair Compensation ② Valuable Qualification Reflection ③ High Performance Guarantee ④ Compensation System ⑤ Innovation Performance Evaluation	① Continuous Quality Control Activities ② Quality Improvement Design Reflection ③ Continuous Management ④ Process Improvement ⑤ Equal Resource Allocation

2.2 Survey Design

2.2.1 Survey Period

In this study, a survey was carried out to managers in SMEs and venture companies, which are currently promoting the six sigma movement, of companies producing machine precision parts in Changwon Industrial Complex, South Gyeongsang Province. After the preliminary review, this researcher collected questionnaires from the site with the help of the local business council secretary through February 21 to February 28, 2018.

2.2.2 Survey Method

In the AHP, if the consistency ratio(CR) value of pairwise comparison is higher than 0.1, it means that the consistency is insufficient and it needs to be reviewed[6].

The AHP technique is used to analyze the effect of each decision factor on success. And a survey was carried out to managers of six sigma promotion activities.

2.2.3 Survey Target

The empirical survey targets are quality managers in SMEs and venture companies - which have performed six sigma quality management activities in the metal, manufacturing, steel, automobile, and engineering fields by IT-based advanced scientific innovation technology - with less than 1,000 employees and sales of less than 150 billion won.

Table 2. Survey Target and Method

Classification	Content
Survey Target	Dire Manager who takes a direct part in six sigma innovation activities (Experienced Persons)
Survey Period	2018. 2. 21. ~ 2018. 2. 28
Survey Method	Personal Visit or Phone, e-mail
Survey Questionnaire	A Total of 100 Copies
Survey Content	Innovation Success Factors of Six Sigma

2.3 Composition of Pairwise Comparison Matrix

The contribution to the parent elements is given as the importance of the 9-point scale through the pairwise comparison, and if the direct sub-hierarchies is composed of n elements, all of them need n(n-1)/2 comparisons[9]. Data evaluated by AHP are based on estimates of the relative importance between elements derived through pairwise comparisons between elements in the hierarchy. A reliable scale is needed to make quantitative judgments. At this time, 9-point scale through pairwise comparison is often used[7].

2.3.1 First Open Questionnaire

Based on the basic data obtained from the previous research and literature analysis, the questionnaire items were developed to extract the success factors of six sigma innovation, and an open questionnaire was composed through expert review[10].

2.3.2 Second Importance Recognition Questionnaire

The structured questionnaire items were composed in consideration of the importance of recognition through the process of categorization and experts' conference on the success factors of six sigma innovation detected through the first open survey.

2.3.3 Third AHP Questionnaire

The third AHP questionnaire based on the second recognition importance questionnaire was made as shown in Fig 1, and the priority analysis of success factors was conducted as follows.

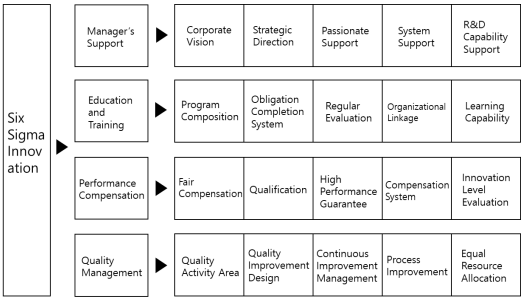

Fig. 1. AHP Survey Item Composition

2.4 Data Collection and Analysis Method

2.4.1 Data Collection

The survey for data collection of this study was conducted from February 21 to February 28, 2018, and the first open questionnaire, the second recognition importance questionnaire and the third priority questionnaire were immediately collected at the site through direct visit.

2.4.2 Data Processing

Data collected in this study are processed using Microsoft Excel 2013 and Expert Choice 2000. The consistency ratio(CR) of questionnaire response was set at 0.1 or less, and the priority of the six sigma innovation success factors was drawn by pairwise comparisons between the relative importance values of each hierarchy.

2.4.3 AHP Analysis Method and Procedure

The procedure for applying AHP can be roughly classified into the process of layering decision-making problems and the process of calculating the relative importance of decision-making factors through hierarchical analysis. It has the following four steps for this.

The first step is to layer decision-making factors. The most comprehensive decision-making target is given to the top layer, and more detailed decision-making factors are broken down toward the lower layer. At this time, decision-making factors between layers and factors of same layers must maintain a dependent relationship and an independent relationship, respectively. This step is the most important in applying AHP as a process of establishing a hierarchical tree and creating the overall decision-making structure.

The second step is to make a pairwise comparison of 2 decision-making factors. The data for judgment are collected through the pairwise comparison, and the decision maker preferences are quantified on the 9-point scale proposed by Saaty(1980).

The third step is to use the eigenvalue method to estimate the relative weight of decision-making factors. Here, the weight refers to a priority vector, which is the relative importance or preference of the factors. Saaty points out the eigenvalue method is optimal for the weight estimation when the consistency of judgment data is not perfect, and there are also many calculation softwares using the eigenvalue method for practical application.

At this time, the weight is the relative importance or preference of factors. If the relative importance of n factors within a layer is called wi(i=1, ・・・, n), a_{ij} in pairwise comparison matrices can be estimated as wi/wj(i, j=1, ・・・, n). All factors of matrices are represented by the following equation.

$$\sum_{j}^{n} aij \cdot wi = n \cdot wi(i,j=1, \cdot \cdot \cdot, n)$$

This step also determines the consistency ratio by identifying how consistently an evaluator has evaluated the item. Consistency is a measure of the logical contradiction of evaluator's judgment. The consistency ratio(CR), which divides consistency index(CI) into random index(RI), is used to test consistency.

This can be represented as CR=(CI/RI)x100%.

The RI in the formula for the consistency ratio is also called a random number index, that is to say an average random index, a random index, and a random consistency index. It means consecutive random numbers, which do not have an order or rule of specific arrangement. The reciprocal matrix is created by the random setting of numerical values from 1 to 9. The value calculated the average consistency index of this matrix indicates the permissible limit of consistency. The table 3 shows the random index when n changes from 1 to 10. And the consistency ratio should be performed for all stages of layer. If the consistency ratio is less than 10% according to the empirical rule, it is stated that evaluator's judgment on evaluation items is consistent.[10]

Table 3. Random Index

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

n=Standard of n, The size of the matrix[11]

The consistency hypothesis and test statistic are as follows.

Null hypothesis(Ho): Decision makers' evaluation is done randomly.

Test statistic(CR): Consistency Ratio = CI/RI

Here, if the CR value is less than 0.1, it is rejected. Consequently, the fact that CR has a value below 0.1 means that respondents performed the pairwise comparison while maintaining complete consistency. On the other hand, if the CR value is more than 0.1, it means that it lacks consistency, which it needs reviews.

The fourth step is a process of bringing together the relative weight of evaluation standards calculated in each layer to determine the relative weight or priority of alternatives in the lowest layer. It is to determine the composite weight of alternatives in the lowest layer to look into how they have the influence or importance in achieving the most general goal of decision-making problems in the lowest layer. This is to bring together the weights in each layer determined in the previous step, which the composite importance of alternatives in the kth lower layer forwith respect to the top layer can be determined through the following equation.

$$c[1,k] = \prod_{j=2}^{k} B_i$$

Here, C[1, k]: The composite weight of kth layer factors for the 1st layer

Bi: The ni-1・ni matrix containing the rows that make up the estimated w vector

ni: The number of factors in the Ith layer

At this time, in the composite importance of the entire layer, the weight matrix of the directly higher layer for the lowest layer is multiplied by the weight

matrix determined in the upper layer. The method to determine this process repeatedly through the upper layer is accepted without controversy.

The weight determined through the above-mentioned steps judges the relative importance of each evaluation item and decides the priority of decision-making alternatives. The AHP may differ in its interpretation of evaluation standards due to the fact that the relative importance of evaluation standard doesn't take into account the measurement unit of each standard and the ambiguity included in the evaluation scale.[11]

3. Research Result

3.1 Characteristics of Sample

3.1.1 Individual Characteristics

The general characteristics of those surveyed showed that for industry, 66 persons(66%) in charge of car precision and parts was the highest, followed by 33 persons(33%) in charge of manufacturing and 1 person(1%) in charge of petrochemistry/iron. For age group, 55 persons(55.0%) in their 40s were the highest, followed by 38 persons(38.0%) in their 50s. For gender, 96 persons(96%) and 4 persons(4%) were male and female, respectively. For career, 96 persons(96%) were over 10 years, and 4 persons(4%) were between 5 and 10 years, which most of them had over 10 years of career.

Table 4. General Characteristics of Those Surveyed

Classification	Contents	Frequency	%
Industry	Petrochemistry, Iron	1	(1.0)
	Manufacturing	33	(33)
	Car Precision, Parts	66	(66)
Age Group	30s	6	(6.0)
	40s	55	(55.0)
	50s	38	(38.0)
	Over 60s	1	(1.0)
Highest Level of Schooling	Graduate School(Master)	9	(9.0)
	College Graduation	91	(91.0)
Gender	Male	96	(96.0)
	Female	4	(4.0)
Career	5~10 Years	4	(4.0)
	Over 10 Years	96	(96.0)
	Total	100	(100.0)

3.1.2 Critical Factors of Rough Classification

The relative importance(priority) of experts' six sigma improvement showed that in the results of rough classification importance, manager's support(.285), performance compensation(.255), quality management (.238) and education and training(.222) were ranked first, second, third and fourth, respectively. Education and training was relatively low in the importance ranking. The consistency ratio(CR) of questionnaire response was 0.001, which the concordance was verified.

Table 5. Critical Factors by Main Area

Parent Factor Name	Totality	Ranking
1. Manager's Support	.285	1
2. Education and Training	.222	4
3. Performance Compensation	.255	2
4. Quality Management	.238	3
CR	0.001	

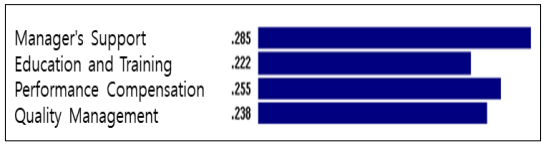

Fig. 2. Critical Factors by Main Area

3.1.3 Importance of Detailed Activities

The critical factors of manager's support by main area were drawn on the 5-point scale. They showed that corporate vision(.260), passionate support(.214), strategic direction(.207), system support(.183) and R&D capability support(.135) were ranked first, second, third, fourth and fifth, respectively, which corporate vision was the most important, followed by passionate support. R&D capability support was relatively low in the importance ranking. The

consistency ratio(CR) of questionnaire response was less than 0.06, which the concordance was verified.

Table 6. Critical Factors of Manager's Support by Main Area

Parent Factor Name	Totality	Ranking
Corporate Vision	.260	1
Strategic Direction	.207	3
Passionate Support	.214	2
System Support	.183	4
R&D Capability Support	.135	5
CR	0.06	

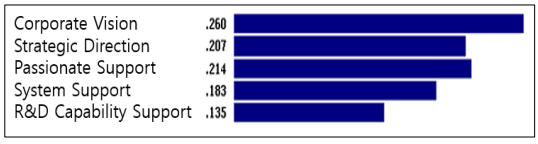

Fig. 3. Critical Factors of Manager's Support by Main Area

Table 7. Critical Factors of Education and Training by Main Area

Parent Factor Name	Totality	Ranking
Program Composition	.286	1
Obligation Completion System	.221	2
Regular Evaluation	.188	3
Organizational Linkage	.172	4
Learning Capability	.133	5
CR	0.01	

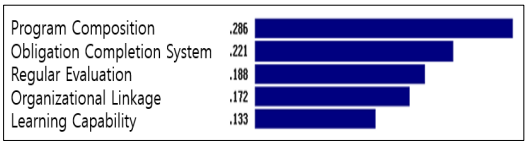

Fig. 4. Critical Factors of Education and Training by Main Area

The critical factors of performance compensation by main area showed that high performance guarantee(.235), innovation level evaluation(.217), fair compensation(.215), compensation system(.193) and qualification(.140) were ranked first, second, third, fourth and fifth, respectively, which high performance guarantee was the most important, followed by innovation level evaluation. Qualification was relatively low in the importance ranking. The consistency ratio(CR) of questionnaire response was 0.01, which the concordance was verified.

Table 8. Critical Factors of Performance Compensation by Main Area

Parent Factor Name	Totality	Ranking
Fair Compensation	.215	3
Qualification	.140	5
High Performance Guarantee	.235	1
Compensation System	.193	4
Innovation Level Evaluation	.217	2
CR	0.01	

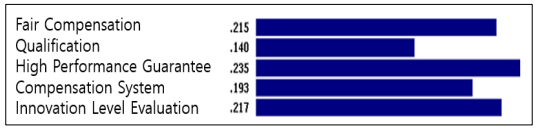

Fig. 5. Critical Factors of Performance Compensation by Main Area

The critical factors of quality management by main area showed that quality activity area(.254), process improvement(.246), quality improvement design(.203), continuous improvement management(.167) and equal resource allocation(.129) were ranked first, second, third, fourth and fifth, respectively, which quality activity area was the most important, followed by process improvement. Equal resource allocation was relatively low in the importance ranking. The consistency ratio(CR) of questionnaire response was 0.07, which the concordance was verified.

Table 9. Critical Factors of Quality Management by Main Area

Parent Factor Name	Totality	Ranking
Quality Activity Area	.254	1
Quality Improvement Design	.203	3
Continuous Improvement Management	.167	4
Process Improvement	.246	2
Equal Resource Allocation	.129	5
CR	0.07	

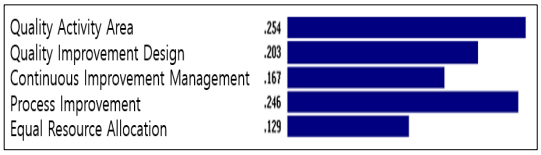

Fig. 6. Critical Factors of Quality Management by Main Area

3.1.4 Total Influence Analysis

After analyzing the importance of each aspect, the influence value is a meaning of composite weights. The composite weight is a product of importance values of each factor side, which it can judge the priority by each item of competency factors required for the whole group. The ranking of influence showed that corporate vision(0.074) was the highest, followed by program composition(0.063), passionate support(0.061), high performance guarantee(0.06) and quality activity area(0.06). While learning capability(0.03), equal resource allocation(0.031) and organizational linkage(0.038) were low in the ranking of influence.

Table 10. Influence Value Ranking

Classification	Parent Factor Name	Importance	Influence Value	Ranking
Manager's Support (.285)	Corporate Vision	.260	0.074	1
	Strategic Direction	.207	0.059	6
	Passionate Support	.214	0.061	3
	System Support	.183	0.052	10
	R&D Capability Support	.135	0.038	16
Education and Training (.222)	Program Composition	.286	0.063	2
	Obligation Completion System	.221	0.049	11
	Regular Evaluation	.188	0.042	14
	Organizational Linkage	.172	0.038	17
	Learning Capability	.133	0.03	20
Performance Compensation(.255)	Fair Compensation	.215	0.055	8
	Qualification	.140	0.036	18
	High Performance Guarantee	.235	0.06	4
	Compensation System	.193	0.049	12
	Innovation Level Evaluation	.217	0.055	9
Quality Management(.238)	Quality Activity Area	.254	0.06	5
	Quality Improvement Design	.203	0.048	13
	Continuous mprovement Management	.167	0.04	15
	Process Improvement	.246	0.059	7
	Equal Resource Allocation	.129	0.031	19

4. Conclusion

As for the above-mentioned findings, the importance of 20 items in a total of 4 factors showed that corporate vision was ranked first in a manager's support factor, followed by program composition, passionate support, high performance guarantee and quality activity area.

This implies that all organizational members can achieve a high success when the company's goal, principle or vision of six sigma activities are concretely suggested and shared to them, and when the operation of programs with a sense of goal in accord under its vision as a community, the support of programs with company-wide enthusiasm, and high compensation for innovative efforts of six sigma to men of merit are followed by the structured system. This result supports previous studies advocating that the company can maximize the achievement of its goal when the subdivided activities for department's task are suggested and managed through the company-wide passionate support and the materialized program in the process of quality activities under its enthusiastic one matched goal and unified vision said by Lee[2], and it shows that this study demonstrates the importance and significance of the practical application to the field.

In other words, many existing companies have been performing six sigma activities, but they have achieved a high success rate under the well-organized structure of most conglomerates. As tested in this study, it is recommended to apply six sigma to small and medium venture companies. Especially, they should encourage

all members to actively share their vision and participate in six sigma innovation activities beyond the lack of organization of low members in a limited few persons of SMEs and the corporate internal climate that the corporate vision drawn from above is shared only by executives and directors. This implies that the company-wide passionate support can lead to high performance and quality, and improve the above-mentioned problems from an industrial perspective, differing from previous studies.

Consequently, these small venture companies should develop the six sigma movement as a niche strategy for small organizations with vision sharing by company-wide operational commitment and high pride for organizational characteristics of small and medium companies beyond the organizational structure of large companies depending on program composition and high performance compensation in accordance with large company organizations to improve early efficiency of advanced precision parts in an increasingly competitive technology environment.

Finally, this study has limitations on the generalization of the results in that a survey was carried out to technical development managers of venture companies in specific manufacturing fields, and follow-up studies through nationwide sampling are required in the future.

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