Critical Success Factors for Statistical Process Control in the Enterprises Operating in Hanoi, Vietnam

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Abstract:
Implementing Statistical Process Control (SPC) in enterprises in countries all over the world has been proven, brought quality improvement and cost reduction thereby increased business performance and competitiveness. The research conducted a deep interview expert working in universities and enterprises and a quantitative survey on enterprises implementing SPC in order to identify Critical Success Factor for SPC. 7 CSFs were found. Their impacts on hard and soft quality of products (consequences of SPC) were assessed. Policy implications were proposed for the success of SPC in Vietnamese enterprises.

Keywords: Statistical process control, critical success factor, hard quality, soft quality

1. Introduction
In the context of global competition, nation’s competitiveness depends on their productivity and product quality. Quality innovation is implementing Statistical Process Control (SPC). Japan is one of countries first implemented SPC. Researches all over the world show that SPC has mainly been implemented in productive enterprises. Benefits of SPC in enterprises are increased quality and reduced costs thereby improved business performance and competitiveness. The Vietnamese government and enterprises are concerned about SPC implementation to improve their product quality. This paper aims at identifying Critical Success Factors (CSFs) and proposing suggestions for SPC deployment in Vietnamese enterprises.

2. Method
This research performed an overview of studies on Statistical Process Control (SPC) implementation. In order to point out the list of CSFs of SPC in mechanical and manufacturing enterprises operating in Hanoi, a quantitative research was conducted. The deep interview was made to design questionnaire which followed by the survey on enterprises for identifying CSFs of SPC implementation and SPC impacts on (hard and soft) quality. Data collected was processed by SPSS 22 for windows.

3. Results of the Research

3.1. Theoretical Background
SPC is the use of a set of statistical techniques/tools to control the production process, analyze and track the causes of variations in quality characteristics or parameters by which to control and improve it. The concept of SPC was first time introduced by Walter A. Shewhart in 1920. So far, various concepts of SPC have been introduced depending on views, times, countries, and industries.

SPC is a set of statistical techniques used to control the production process (Ben & Antony, 2000; Caulcutt, 1996; Young & Winistorfer, 1999) eliminating errors and defects (Sower, 1990; Oakland JS, 2003), and used to classify, minimize process variations and manage it systematically (Ben & Antony, 2000; Rosenkrantz, 2002; Juran, 1988). In order to better understand SPC we need to clarify the terms of process, control, variations and statistics.

Process is a set of activities by which machines and equipments are combined to transform inputs (such as materials, methods, information) to into desired output (product, information, or service) (Oakland, 2003). Process variations are fluctuations of activities and factors in the production process that make results (products, services) of the production process unequal and unstable. Shewhart argues that there are two causes of fluctuations in the production process: (i) Common causes; (ii) Special causes. Common causes, reflecting the nature of the process, include old and worn-out machinery and equipment in the course of operation, environments change over time and differences in the professional capability and the operation of employees in previous versus after production processes. Managers can minimize common causes occurring in the process on a regular basis, but cannot eliminate them completely. Those causes can be detected through control charts and the process is considered statistically controlled. Special causes come from abnormal impacts.
such as improper use of raw materials and improperly installed or damaged machinery and equipments; Instructions or designs are incomplete or inaccurate; ungrasped customers’ needs. Special causes of variations appear out of control and infrequently leading to big variations because they shift process parameters. The goal of SPC is to discover causes of variations by which to adjust process and eliminating its variations.

SPC is an important measure focusing on efforts to reduce variations resulted from internal and external causes to improve product quality and reduce production costs.

The process needs to be controlled in order to maintain its stability. Therefore, control is the process of evaluating results, comparing performance with a goal or standard, and taking corrective actions if needed. Critical Success Factor (CSF) is the necessary condition in an organization or a particular project to achieve its mission and goals.

Daniel (1961) emphasized 3 to 6 CSFs which mainly focused in management and can be applied in all fields or any organization. Anthony et al. (1972) emphasized the need for adjusting CSF for both strategic objectives and management objectives of organizations. According to them planning and control systems are responsible for reporting found CSFs to managers.

Pinto and Slevin (1987) considered CSFs to be factors, if resolved, that would significantly improve the chances of project implementation. However, according to Esteves (2004), both did not mention the comprehensive concept proposed by Rockart (1979), in order to find an ideal combination of environment conditions and business characteristics of a specific company.

3.2. Statistical tools in SPC

Many quality consultants and SPC users have suggested that there are 07 basic tools (traditional) collected and introduced by Ishikawa in 1985, Mizuno (1988) introduced 07 new ones, a few argue that there are 12 to 15 different tools (Caulcutt, 1996).

The statistical tools used by many enterprises are the following (7QC Tools) including: (i) Check Sheet; (ii) Cause and Effect Diagram; (iii) Control Chart; (iv) Scatter Diagram; (v) Process Flow Chart; (vi) Pareto Chart; (vii) Histogram (Ishikawa, 1985; Oakland JS, Statistical Process Control, 2003; Diên, 1994).

3.3. Research Directions for SPC Success

Researches on this topic have been performed in three directions: Building a process of implementing SPC; CSFs for SPC in enterprises; Results of successful SPC implementation in enterprises.

Implementing SPC is a process which main activities relate to Management, Statistical, Teamwork, Engineering (MEST): Culture change and knowledge sharing; Statistical knowledge; Management skills; and engineering (Ben & Antony, 2000; Antony & Taner, 2003).

CSFs of SPC

Researches on finding CSFs have been done in two directions; Firstly, (qualitative) research based on personal experience and the success of typical businesses to show the success factors of SPC implementation; Secondly, (quantitative) experimental research through practical research projects implemented in businesses.

3.3.1. Qualitative Researches

Qualitative researches suggested a step-by-step procedure for SPC implementation in production and services enterprises (Does et al., 1997; Robinson et al., 2000; Antony & Taner, 2003) and pointed out CSFs for SPC deployment (Xie and Goh, 1999; Antony, 2000; Robinson et al., 2000)

3.3.2. Quantitative Researches

A lot of quantitative researches had been performed on enterprises in various industries in different countries (Gordon e al., 1994, and Harris & Yit, 1994, in the US; Rungtusanatham e al. (1997, in Sweden; Rungasamy e al., 2002, and Grigg, 2004, in the UK; Phyanthamillumaran and Fernando, 2008, in Malaysia; Evans & Mahanti, 2012, in India; Rantamaki et al., 2013, in Finland; Soriano e al., 2017, in Brazil).

Results of researches mentioned above revealed that most of the procedures had been built step by step - from perception, deployment, training, formation of SPC teams, measurement to data collection systems and control chartbuilding. However, the specific explanations for the implementation of SPC in enterprises have not been paid enough attention.

Most of researches pointed out CSFs for SPC implementation in enterprises are: (i) Top management Commitment; (ii) Team work; (iii) SPC training and education; (iv) Control charts; (v) Identification of priority process; (vi) Identification of important characteristics of quality; (vii) Analysis of the measurement system; (viii) Knowledge exchange and sharing; (ix) Experimental research; (x) Use SPC software; (xi) SPC instructor; (xii) Data storage; (xiii) Quality Department; (xiv) SPC deployment.

Successful application of SPC in enterprises is reflected in the following aspects: (i) Product quality and economic factors; (ii) Employees’ attitude and behavior; (iii) Organization structure; (iv) Capability of the process; (v) Other factors.

According to Wilkinson (1992) results of successful SPC implementation can be clarified into two categories. Firstly, hard quality including a series of factors related to production engineering management, control process of quality functions deployment, reflecting direction of production management in enterprises. Secondly, soft quality pays more attention on establishing producer’s perception, raising customer satisfaction and improving management competence and experience.

3.4. Research model
Inheriting results of previous researches done on manufacturing and mechanic enterprises and our results obtained by the experts interview we select the following CSFs for SPC implementation: (i) Top management commitment; (ii) Team work; (iii) SPC training and education; (iv) Process focus; (v) Role of quality department; (vi) Deployment SPC and (vii) Documentation and update of knowledge. The seventh factor will lead to expenses incurred by enterprises and it is difficult to fulfill. However, data must be considered as one of inputs of the SPC operation. Data needs to be maintained in the repository and team members should have access to them to apply SPC (Figure 1).

![Research Model](image)

_Figure 1: Research Model_

Results and interpretations: 09 experts (of which 05 are top managers in enterprises - managers from operation, technical, and quality department, and executive managers; 04 lecturers working in this field (at Hanoi Industrial University, Hanoi Technology University, the National Economics University) were interviewed in order to design questionnaire for enterprise survey. Questionnaire includes variables using Likert scale of 5 (1 = Completely disagree, 5 = Completely agree). 600 copies of questionnaire were sent to mechanical and manufacturing enterprises in industrial zones and clusters in Hanoi. 384 responses (64 percent) were received, 272 (70.9 percent) left after screening. Observations are sufficient for analyzing and testing: n = 195, (Hair e.al., 1998) - minimum amount for EFA and exceeds minimum for multiple regression.

3.5. Hypothesis

**CSFs of SPC (hard quality)**
- H1.1 Top management commitment positively influences hard quality
- H1.2 Team work positively influences hard quality
- H1.3 SPC training and education positively influences hard quality
- H1.4 Role of quality department positively influences hard quality
- H1.5 Process focus positively influences hard quality
- H1.6 Deployment SPC positively influences hard quality
- H1.7 Documentation and update of knowledge of processes positively influences hard quality

**CSFs of SPC (soft quality)**
- H2.1 Top management commitment positively influences soft quality
- H2.2 Team work positively influences soft quality
- H2.3 SPC training and education positively influences soft quality
- H2.4 Role of quality department positively influences soft quality
- H2.5 Process focus positively influences soft quality
- H2.6 Deployment SPC positively influences soft quality
- H2.7 Documentation and update of knowledge of processes positively influences soft quality

3.6. Independent Variable Scale and Coding

Items of independent variables and their code are shown in Table 1.
Top management commitment - TMC

Top managers commit making efforts to improve quality TMC1
Top managers commit providing sufficient human resources for SPC implementation TMC2
Top managers commit providing sufficient financial resources for SPC implementation SPC TMC3

Teamwork - TW

Groups often discuss about quality improvements TW1
Members of the quality group come from different departments TW2
Someone supervises problem solving problems of quality group TW3
Quality improvement groups are clearly directed with efficiency and quality goals TW4

SPC training and education - TR

Training on SPC for employees before implementation TR1
Quality-related training for managers and supervisors TR2
Knowledge of SPC must be practiced after learning TR3
Data from actual production is applied immediately in the SPC TR4

Process Focus - PF

Regularly organize training classes, apply SPC TR5
Select a process to implement SPC with priority PF1
The manager supports selecting prioritized processes PF2
Flow chart, cause and results help determining the prioritized process PF3

Roles of quality department - QD

There are experts in the quality department to help implementing SPC QD1
Quality department provides on-site technical support QD2
A staff in the quality department supervising SPC implementation QD3
The quality department organizes discussion on actual data obtained QD4
The quality department detects problems that need to be solved on the database QD5
Quality department encourages those who are afraid of changes in SPC implementing QD6
Quality department organizes discussions between SPC implementers QD7

Deployment SPC - DP

SPC is implemented in different parts in the enterprise DP1
SPC is implemented according to a complete plan DP2
SPC is being implemented by quality improvement teams DP3
The majority of SPC implementers have related work DP4

Documentation and update of knowledge of processes - DUP

Collecting data on the process has to be performed on a regular basis DUP1
Data collected must be complete, accurate and reliable DUP2
Data should be stored for future use DUP3
Data must be in good storage, and corrected if needed DUP4

| Table 1: Independent Variable Scale and Coding |

| Dependent Variable Scale and Coding |

Items of dependent variables and their code are shown in Table 2.

Quality Performance hard aspects - QPHA

Decreased excess raw materials and remade products QPHA1
Decreased fluctuations in production process QPHA2
Decreased Production time QPHA3
Improved product distribution

Quality Performance soft aspects - QPSA

Increased customer satisfaction QPSA1
The company has more experiences of improvement and quality assurance QPSA2
Improved company image QPSA3
More strict production process management QPSA4

Table 2: Independent Variable Scale and Coding

3.7. Descriptive Statistics of the Sample

By type of ownership, 230 respondents are in the private sector, accounted for 84.6 percent, 33 are joint stock, accounted for 33.1 percent, 9 are state-owned, accounted for 3.3 percent.

By scale, most of respondents are SMEs - 178 small enterprises or 65.4 percent, 90 medium one or 33 percent, while only 4 large enterprises or 1.5 percent.
By age, 11 enterprises (4 percent) are less than 5 year-old, 44 enterprises (16.2 percent) are 6 – 10 year-old, 102 enterprises (37.5 percent) are 11 – 15 year-old and 115 enterprises (42.3 percent) are more than 15 year-old (Table 3).

| Type of ownership | Frequency | Percentage | Cumulative Percentage |
|-------------------|-----------|------------|-----------------------|
| State             | 9         | 3.3        | 3.3                   |
| Joint stock       | 33        | 12.1       | 15.4                  |
| Private           | 230       | 84.6       | 100                   |
| Total             | 272       | 100        |                       |

| Scale             | Frequency | Percentage | Cumulative Percentage |
|-------------------|-----------|------------|-----------------------|
| Large             | 4         | 1.5        | 1.5                   |
| Medium            | 90        | 33.1       | 34.6                  |
| Small             | 178       | 65.4       | 100                   |
| Total             | 272       | 100        |                       |

| Age               | Frequency | Percentage | Cumulative Percentage |
|-------------------|-----------|------------|-----------------------|
| <=5 years         | 11        | 4.0        | 4.0                   |
| 6-10 years        | 44        | 16.2       | 20.2                  |
| 11-15 years       | 102       | 37.5       | 57.7                  |
| >15 năm           | 115       | 42.3       | 100                   |
| Total             | 272       | 100        |                       |

Table 3: Descriptive Statistics of the Sample

3.7.2. Descriptive Statistics of the Level of Using Quality Instruments

Most of surveyed enterprises use 07 basic quality instruments, the average level is 2,813 – 3,335, in some processes. New quality instruments are used less, only in cases of problematic production processes, the average level is 2,077 – 2,235 (Table 4).

|                           | N   | Minimum | Maximum | Mean  |
|---------------------------|-----|---------|---------|-------|
| Flow charts               | 272 | 1.0     | 5.0     | 3.060 |
| Check sheet               | 272 | 1.0     | 5.0     | 3.335 |
| Cause effect diagram      | 272 | 1.0     | 5.0     | 3.092 |
| Pareto charts             | 272 | 1.0     | 5.0     | 2.982 |
| Histogram                 | 272 | 1.0     | 5.0     | 2.941 |
| Scatter diagram           | 272 | 1.0     | 5.0     | 2.813 |
| Control Charts            | 272 | 1.0     | 5.0     | 3.070 |
| Affinity Diagram          | 272 | 1.0     | 5.0     | 2.140 |
| Matrix Diagram            | 272 | 1.0     | 5.0     | 2.077 |
| Relation Diagram          | 272 | 1.0     | 5.0     | 2.235 |
| Matrix Data Analysis      | 272 | 1.0     | 5.0     | 2.158 |
| PDPC - Process Decision Program Chart | 272 | 1.0 | 5.0 | 2.235 |
| Arrow Diagram             | 272 | 1.0     | 5.0     | 2.228 |
| Check sheet               | 272 | 1.0     | 5.0     | 2.206 |
| Listwise                  | 272 |         |         |       |

Table 4: Descriptive Statistics of the Level of Using Quality Instruments

3.8. Evaluation of Scales

3.8.1. Descriptive Statistics of Independent Variables, Testing Distribution

Independent variables' scale is relatively divergent. Minimum and maximum is in the interval of 1 to 5. The average value of observations belongs to the interval of (3.53 – 3.81) showing similar assessment of importance of independent variable. Test of Skewness and Kurtosis showed their absolute value is in allowed limits (for Skewness, it is less than 3 and for Kurtosis it is less than 5). This means scale of independent variables is normal distribution.
Valid N (listwise) 272

| Statistic | Minimum | Maximum | Mean | Std. Deviation | Skewness | Kurtosis |
|-----------|---------|---------|------|----------------|----------|----------|
|           |         |         |      | Statistic      | Statistic |          |
| Statistic |         |         |      | Statistic      | Statistic |          |
| 1         | TCM1    | 272     | 2    | 5              | 3.74      | .750      | -.112    | .148    | -.339    | .294    |
| 2         | TCM2    | 272     | 1    | 5              | 3.72      | .737      | -.277    | .148    | -.223    | .294    |
| 3         | TCM3    | 272     | 1    | 5              | 3.80      | .752      | -.337    | .148    | -.229    | .294    |
| 4         | TW1     | 272     | 1    | 5              | 3.72      | .705      | -.118    | .148    | -.183    | .294    |
| 5         | TW2     | 272     | 1    | 5              | 3.77      | .704      | -.151    | .148    | .214     | .294    |
| 6         | TW3     | 272     | 1    | 5              | 3.81      | .772      | -.634    | .148    | .600     | .294    |
| 7         | TW4     | 272     | 1    | 5              | 3.80      | .782      | -.094    | .148    | -.314    | .294    |
| 8         | TR1     | 272     | 1    | 5              | 3.64      | .683      | -.180    | .148    | -.333    | .294    |
| 9         | TR2     | 272     | 1    | 5              | 3.72      | .769      | -.022    | .148    | -.238    | .294    |
| 10        | TR3     | 272     | 1    | 5              | 3.63      | .743      | -.150    | .148    | .061     | .294    |
| 11        | TR4     | 272     | 1    | 5              | 3.67      | .735      | -.122    | .148    | .070     | .294    |
| 12        | TR5     | 272     | 1    | 5              | 3.68      | .732      | -.102    | .148    | .059     | .294    |
| 13        | QD1     | 272     | 1    | 5              | 3.55      | .818      | -.501    | .148    | .416     | .294    |
| 14        | QD2     | 272     | 1    | 5              | 3.61      | .829      | -.504    | .148    | .462     | .294    |
| 15        | QD3     | 272     | 1    | 5              | 3.54      | .823      | -.422    | .148    | .160     | .294    |
| 16        | QD4     | 272     | 1    | 5              | 3.57      | .856      | -.444    | .148    | .359     | .294    |
| 17        | QD5     | 272     | 1    | 5              | 3.65      | .796      | -.184    | .148    | -.145    | .294    |
| 18        | QD6     | 272     | 1    | 5              | 3.61      | .788      | -.154    | .148    | -.134    | .294    |
| 19        | PF1     | 272     | 1    | 5              | 3.66      | .781      | -.302    | .148    | .261     | .294    |
| 20        | PF2     | 272     | 1    | 5              | 3.74      | .764      | -.379    | .148    | .222     | .294    |
| 21        | PF3     | 272     | 1    | 5              | 3.68      | .782      | -.344    | .148    | .060     | .294    |
| 22        | DP1     | 272     | 1    | 5              | 3.67      | .665      | -.048    | .148    | .281     | .294    |
| 23        | DP2     | 272     | 1    | 5              | 3.68      | .705      | -.037    | .148    | .106     | .294    |
| 24        | DP3     | 272     | 1    | 5              | 3.75      | .716      | -.319    | .148    | .398     | .294    |
| 25        | DP4     | 272     | 1    | 5              | 3.61      | .720      | -.286    | .148    | .239     | .294    |
| 26        | DUP1    | 272     | 1    | 5              | 3.53      | .748      | -.220    | .148    | .594     | .294    |
| 27        | DUP2    | 272     | 1    | 5              | 3.58      | .725      | -.330    | .148    | .197     | .294    |
| 28        | DUP3    | 272     | 1    | 5              | 3.67      | .709      | -.239    | .148    | .295     | .294    |
| 29        | DUP4    | 272     | 1    | 5              | 3.76      | .797      | -.330    | .148    | -.011    | .294    |
| 30        | QPHA1   | 272     | 1    | 5              | 3.72      | .700      | -.269    | .148    | .400     | .294    |
| 31        | QPHA2   | 272     | 1    | 5              | 3.78      | .704      | -.372    | .148    | .570     | .294    |
| 32        | QPHA3   | 272     | 1    | 5              | 3.76      | .684      | -.219    | .148    | .427     | .294    |
| 33        | QPHA4   | 272     | 1    | 5              | 3.78      | .696      | -.326    | .148    | .536     | .294    |
| 34        | QPSA1   | 272     | 1    | 5              | 3.81      | .728      | -.333    | .148    | .367     | .294    |
| 35        | QPSA2   | 272     | 1    | 5              | 3.77      | .655      | -.353    | .148    | .810     | .294    |
| 36        | QPSA3   | 272     | 1    | 5              | 3.78      | .700      | -.252    | .148    | .395     | .294    |
| 37        | QPSA4   | 272     | 1    | 5              | 3.77      | .744      | -.364    | .148    | .319     | .294    |

Table 5: Descriptive Statistics of Scale Of Variables

All Cronbach Alpha coefficients are larger than .7 (Table 5) meaning that items in a scale of all 07 independent and 02 dependent variables are closely correlated.

| Top management commitment | Cronbach’s Alpha coefficient | Number of Items | Significant of Cronbach Alpha Coefficient |
|---------------------------|-----------------------------|----------------|----------------------------------------|
|                            | .845                        | 4             | Significant                             |
| Team work                  | .751                        | 4             | Significant                             |
| SPC training and education | .849                        | 4             | Significant                             |
| Role of quality department | .834                        | 6             | Significant                             |
| Deployment SPC             | .783                        | 3             | Significant                             |
| Documentation and update of knowledge of processes | .867 | 6 | Significant |
| Process focus              | .736                        | 4             | Significant                             |
| Hard quality               | .857                        | 6             | Significant                             |
| Soft quality               | .867                        | 6             | Significant                             |

Table 6. Value of Cronbach Alpha coefficient
3.8.2. Testing Correlations

All correlation coefficients between total score of each respondent and score of each item are significant at 99 percent (Table 7) therefore regression of dependent (hard quality or soft quality) on independent (Top management commitment, Team work, SPC training and education, Role of quality department, Deployment SPC, Documentation and update of knowledge of processes, and Process focus) can be run by each of the two models.

|                | F_Commitment | F_Teams | F_Training | F_Qualitydepart | F_Process | F_Deployment | F_Documentation | HardQuality | SoftQuality |
|----------------|--------------|---------|------------|-----------------|----------|--------------|----------------|-------------|-------------|
| F_Commitment   | Pearson Correlation | 1       |            |                 |          |              |                |             |             |
|                | Sig. (2-tailed) | N 272   |            |                 |          |              |                |             |             |
| F_Teams        | Pearson Correlation | .226** | 1          |                 |          |              |                |             |             |
|                | Sig. (2-tailed) | N .000  |            |                 |          |              |                |             |             |
| F_Training     | Pearson Correlation | .357** | .215**     | 1               |          |              |                |             |             |
|                | Sig. (2-tailed) | N .000  | .000       |                 |          |              |                |             |             |
| F_Qualitydepart| Pearson Correlation | .293** | .178**     | .184**          | 1        |              |                |             |             |
|                | Sig. (2-tailed) | N .000  | .003       | .002            |          |              |                |             |             |
| F_Process       | Pearson Correlation | .447** | .232**     | .304**          | .365**   | 1            |                |             |             |
|                | Sig. (2-tailed) | N .000  | .000       | .000            | .000     | .000         |                |             |             |
| F_Deployment   | Pearson Correlation | .403** | .327**     | .310**          | .286**   | .369**       | 1              |             |             |
|                | Sig. (2-tailed) | N .000  | .000       | .000            | .000     | .000         | .000           |             |             |
| F_Documentation| Pearson Correlation | .349** | .210**     | .230**          | .161**   | .295**       | .221**         | 1           |             |
|                | Sig. (2-tailed) | N .000  | .000       | .000            | .000     | .000         | .000           |             |             |
| HardQuality     | Pearson Correlation | .421** | .303**     | .340**          | .296**   | .266**       | .379**         | .353**      | 1           |
|                | Sig. (2-tailed) | N .000  | .000       | .000            | .000     | .000         | .000           |             |             |
| SoftQuality     | Pearson Correlation | .434** | .341**     | .351**          | .308**   | .383**       | .412**         | .344**      | .720**      |
|                | Sig. (2-tailed) | N .000  | .000       | .000            | .000     | .000         | .000           | .000        | .000        |

Table 7: Correlations

3.8.3. Testing Hypothesis

Results of regression of first mode. Run regression Hard Quality on CSFs of SPC. Adjusted R Square = 0.304, F = 17.887, sig = .000b (Table 8)

| Model | R   | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|------|----------|-------------------|---------------------------|
| 1     | .567a| .322     | .304              | .48610                    |

Table 8: Model Summary

a. Predictors: (Constant), F_Documentation, F_Qualitydepart, F_Teams, F_Training, F_Deployment, F_Process, F_Commitment

| Model | Sum of Squares | Df | Mean Square | F    | Sig     |
|-------|----------------|----|-------------|------|---------|
| 1     | Regression     | 29.586 | 7 | 4.227 | 17.887 | .000b   |
|       | Residual       | 62.381 | 264 | 0.236 |         |         |
|       | Total          | 91.967 | 271 |      |         |         |

Table 9: ANOVAa

a. Dependent Variable: Hard Quality
b. Predictors: (Constant), F_Documentation, F_Quality depart, F_Teams, F_Training, F_Deployment, F_Process, F_Commitment
### Table 10: Coefficientsa

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. | Collinearity Statistics |
|-------|-----------------------------|---------------------------|---|------|-------------------------|
| 1     |                             |                           |   |      |                          |
| (Constant) | .434 | .314 | 1.382 | .168 |                          |
| F_Commitment | .185 | .057 | .202 | 3.254 | .001 | .665 | 1.505 |
| F_Teams | .131 | .057 | .126 | 2.307 | .022 | .855 | 1.169 |
| F_Training | .138 | .054 | .144 | 2.556 | .011 | .813 | 1.230 |
| F_Qualitydepart | .136 | .054 | .141 | 2.537 | .012 | .832 | 1.202 |
| F_Process | -.064 | .058 | -.068 | -1.106 | .270 | .688 | 1.454 |
| F_Deployment | .177 | .066 | .158 | 2.658 | .008 | .727 | 1.376 |
| F_Documentation | .201 | .060 | .185 | 3.332 | .001 | .835 | 1.197 |

a. Dependent Variable: HardQuality

All Beta coefficients have expected sign. F = 17,887, sig = 0.000 or there is a relation between CSFs of SPC and Hard Quality at 95 percent confidence. All VIF are less than 2 or there is no multicollinearity. The relation between dependent and independent variables is following:

\[ QPHA = 0.434 + 0.185TMC + 0.131TW + 0.138TR + 0.136QD + 0.177DP + 0.210DUP + \varepsilon \]

Results of testing by the first model show that \( H_{1.1}, H_{1.3}, H_{1.4}, H_{1.6}, H_{1.7} \) are accepted at 95 percent confidence.

Regression Analysis by the second model. Run regression Soft Quality on CSFs of SPC. All Beta coefficients have expected sign. All VIF are less than 2 or there is no multicollinearity. Adjusted R Square = 0.337. F = 20.703, sig .000b (figure 12) or there is a relation between Soft Quality and factors influencing successful SPC at 95 percent confidence.

### Table 11: Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---|----------|-------------------|---------------------------|
| 1     | .595a | .354 | .337 | .48692 |

a. Predictors: (Constant), F_Documentation, F_Qualitydepart, F_Teams, F_Training, F_Deployment, F_Process, F_Commitment

### Table 12: ANOVAa

| Model | Sum of Squares | Df | Mean Square | F | Sig. |
|-------|----------------|----|-------------|---|------|
| 1     | 34.360         | 7  | 4.909       | 20.703 | .000b |
| Residual | 62.592  | 264 | .237        |       |      |
| Total  | 96.952         | 271|             |       |      |

a. Dependent Variable: Soft Quality

b. Predictors: (Constant), F_Documentation, F_Qualitydepart, F_Teams, F_Training, F_Deployment, F_Process, F_Commitment

### Table 13: Coefficientsa

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. | Collinearity Statistics |
|-------|-----------------------------|---------------------------|---|------|-------------------------|
| 1     |                             |                           |   |      |                          |
| (Constant) | .134 | .315 | 4.26 | .671 |                          |
| F_Commitment | .155 | .057 | .165 | 2.727 | .007 | .665 | 1.505 |
| F_Teams | .162 | .057 | .152 | 2.834 | .005 | .855 | 1.169 |
| F_Training | .126 | .054 | .128 | 2.335 | .020 | .813 | 1.230 |
| F_Qualitydepart | .107 | .054 | .109 | 2.005 | .046 | .832 | 1.202 |
| F_Process | .091 | .058 | .093 | 1.555 | .121 | .688 | 1.454 |
| F_Deployment | .187 | .067 | .163 | 2.811 | .005 | .727 | 1.376 |
| F_Documentation | .160 | .060 | .144 | 2.654 | .008 | .835 | 1.197 |

a. Dependent Variable: SoftQuality
Results of testing by the second model show that $H_{2.1}$, $H_{2.2}$, $H_{2.3}$, $H_{2.4}$, $H_{2.6}$, $H_{2.7}$, are accepted at 95 percent confidence. The relation between dependent and independent variables is following

$$QPSA = 0.134 + 0.155TMC + 0.162TW + 0.126TR + 0.107QD + 0.187DP + 0.160DUP + \varepsilon$$

3.8.4. Comparison Impact of Group in Each Control Variable

3.8.4.1. By First Model

The results of testing Homogeneity of Variances by the first model are shown in the Table 16. Basing on that we can conclude that variances are different in groups given controlled variables scale and type of ownership, therefore they cannot be used for analysis of variance, and variances are not different in groups given controlled variable enterprise’s age therefore they can be used for analysis of variance (Table 16).

| Levene Statistic | df1 | df2 | Sig. | Decision |
|------------------|-----|-----|------|----------|
| Scale            | 6.152 | 269 | .002 | Accepted |
| Enterprise’s age | .696  | 268 | .555 | Rejected |
| Type of ownership| 3.209 | 269 | .042 | Accepted |

Table 14: Test of Homogeneity of Variances

| Sum of Squares | df | Mean Square | F | Sig. |
|----------------|----|-------------|----|------|
| Between Groups | 1.224 | 3 | .408 | 1.205 | .308 |
| Within Groups  | 90.743 | 268 | .339 |
| Total          | 91.967 | 271 |

Table 15: ANOVA

The result of ANOVA shows that there is no relation between enterprise’s age and Hard Quality.

3.8.4.2. By Second Model

The results of testing Homogeneity of Variances by the first model are shown in the Table 18. Basing on that we can conclude that variances are different in groups given controlled variables enterprise’s age and type of ownership, therefore they can be used for analysis of variance, and variances are different in groups given controlled variable enterprise’s scale therefore they can be used for analysis of variance (Table 16).

| Levene Statistic | df1 | df2 | Sig. | Decision |
|------------------|-----|-----|------|----------|
| Enterprise’s scale | 8.948 | 269 | .000 | Accepted |
| Enterprise’s age | .105  | 268 | .957 | Rejected |
| Type of ownership | 2.867 | 269 | .059 | Rejected |

Table 16: Test of Homogeneity of Variances

| Sum of Squares | df | Mean Square | F | Sig. |
|----------------|----|-------------|----|------|
| Between Groups | 775  | 3 | .258 | .720 | .541 |
| Within Groups  | 96.177 | 268 | .359 |
| Total          | 96.952 | 271 |

Table 17: ANOVA Enterprise’s Age and Soft Quality

F test (sig. = .541) shows that there is no relation between enterprise’s age and Soft Quality.

| Sum of Squares | Df  | Mean Square | F | Sig. |
|----------------|-----|-------------|----|------|
| Between Groups | 18.602 | 2 | 9.301 | 31.933 | .000 |
| Within Groups  | 78.350 | 269 | .291 |
| Total          | 96.952 | 271 |

Table 18: ANOVA Type of Ownership and Soft Quality

F test (sig. = .000) shows that there is a relation between type of ownership and Soft Quality.

| N   | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | Minimum | Maximum |
|-----|------|----------------|------------|---------------------------------|---------|---------|
|     |      |                |            | Lower Bound                      | Upper Bound |
| 1   | 9    | 3.0833         | .88388     | 2.9463                          | 3.2032  | 3.9670  |
| 2   | 33   | 3.1970         | .65776     | 1.1450                          | 3.0520  | 3.3420  |
| 3   | 230  | 3.8946         | .50437     | 0.0326                          | 3.8290  | 3.9601  |
| Total | 272  | 3.7831         | .59813     | 0.0338                          | 3.7117  | 3.8545  |

Table 19: Descriptive Statistics of Average of Soft Quality by Ownership Groups
Description of average value of Soft Quality in Table 19 shows differences between groups by type of ownership. The average value of group 1 is 3.0833; group 2 is 3.1970, group 3 is 3.8946.

4. Discussion and Conclusion

SPC is widely adopted by quality practitioners to assist, monitor, manage, analyze and improve performance of the process by eliminating causes of its variations. Use of data obtained from SPC is the way of scientific management in which decisions are made based on actual data, not based on conjecture or experience. SPGs prove the effective method of management by enterprises all over the world.

All seven CSFs (i) Top management commitment; (ii) Team work; (iii) SPC training and education; (iv) Process focus; (v) Role of quality department; (vi) Deployment SPC and (vii) Documentation and update of knowledge) are tested and proved important in SPC implementation in Vietnamese enterprises in mechanic and manufacturing industries. For successful implementation of SPC in Vietnamese enterprises it must be taken step by step starting from smaller, easier and advantageous fields to ensure smooth and effective implementation before deployment it on a large scale. Top management commitment the first CSF. Top managers determine quality goals and directions for achieving them by strong commitments to provide human and financial resources. Training and education on SPC should be carried out continuously, employees training each other using knowledge and data on the production process of the enterprise and benefits of SPC implementation must be pointed out. Quality Department need to play its role in guiding and supporting SPC practicing, and organize discussion to find bad and good points and select divisions as a pilot for SPC.

Managers also need to seriously consider following factors; Control charts; identification of importance of quality; Analysis of the measurement system; Exchange knowledge; Use SPC software. A lot of previous studies have also shown that these factors still have a positive effect on the implementation of SPC. Special attention have to paid on the application of information technology, or apply SPC software to data management such as Microsoft Excel, or specific software of each company to create and analyze control charts making data easily understandable and comparable. However, the application of computer software packages should only be allowed after the basic principles of SPC have been understood and the participants have gained skills to interpret control charts.

4.1. Policy implications

In order to encourage the successful application of SPC in businesses in addition to the efforts of each business, appropriate macro policies should be in effect. Firstly, specific guidances, policies and action programs needed to be introduced in order to universalizing SPC knowledge and training formally. Incentives must be provided for vocational schools and universities to include SPC into their training curriculum on administration in general and enterprise administration in particular, with increased theoretical and practical volume, and training time. Conferences and researches on this topic should be encouraged at Vietnamese enterprises. Secondly, the SPC implementation and other methods such as SS Kaizen, Lean in business management should be encouraged, in the initial phase the stateshould create favorable conditions for businesses to visit and learn from good practices, especially enterprises in FDI sector like Toyota, Honda, or Panasonic; technical, financial and advisory supports are needed for SPC deployment.

Thirdly, the government’s recommendation about product quality differences between groups by ownership is needed. Indeed, most state-owned enterprises have paid not enough attention on SPC. Therefore, for state-owned enterprises, a specific roadmap for SPC must be developed by the government. To promote SPC implementation local governments should provide state-owned enterprises with supports relating to SPS consultancy and training.

4.2. Limitations

The research was made on mechanical and manufacturing fields in Hanoi. Further researches should be done on other regions (HoChiMinh city, Haiphong, DongNai, BinhDuong) and fields (electronics, garment, foodstuff, healthcare, hospitality), and include other factors influencing success of SC implementation, such as control charts; Identification of important characteristics of quality; Analysis of the measurement system; Exchange and share knowledge.

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