Development of Strategic Fit Model of Manufacturing Unit for Garments Industry

by

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Declaration

This is to certify that the thesis work entitled "*Development of Strategic Fit Model of Manufacturing Unit for Garments Industry*" has been carried out by *Md. Habibur Rahman* in the Department of *Industrial Engineering and Management*, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Abstract

Though Bangladesh is one of the largest garments manufacturing country in the world and there happened revolutionary changes more than four decades ago, they couldn’t achieve sustainable platform yet. The failure to achieve up to the requirement level for the competitive capabilities/manufacturing metrics is the common phenomenon for the manufacturers. Even there is an alarming issue that the manufactures yet don’t know how they are affected by these failures and also can’t measure how much they are statistically fit. The manufacturers fail to compete with their competitors, since they can’t achieve their manufacturing metrics up to the requirements. To proceed towards world class manufacturing and to create a sustainable platform considering highly competitive business market, the manufacturer should aware about their metrics capabilities, competitive capabilities and reasons of metrics failure. By being motivated from manufacturer’s failure, we worked on a manufacturing unit of a garments industry where we aggregated manufacturing metrics and determined how the manufacturers are affected by the failure of these metrics. This research work will conclude by proposing few models with their mathematical and graphical explanation. By using these models, the manufacturers will be able to determine their strategic fitness, security level and associated loss/penalty.

Keywords: manufacturing metrics, strategic manufacturing fit, manufacturing metrics prioritization, strategic fit model

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CHAPTER 1

Introduction

1.1 Definition of 'Strategic fit'

'Strategic fit' means the meeting of the organizational external environment (requirements or demands to the organization by the buyers or customers) with their resources and capabilities (Swink et al. 2005; Swink et al. 2007; Amoako-Gyampah et al., 2008; Karim et al. 2008; da Silveira et al. 2010; Wagner et al. 2012). This strategy execute the organizational capability that indicates the organization how much utilizes its resources and its capabilities (Anand et al., 2004; Brown et al., 2007; Gonzalez et al., 2012; Gonzalez-Benito et al., 2014; Dubey et al., 2015). In the case of a garment industry, the organizational performance is mostly depended on its manufacturing units (Chowdhury et al. 2006; Haider, 2007). The present situation of garments sectors requires more competitive capabilities, developed industries, and better performance (World Trade Organization, 2011). To compete with the competitive world, the manufacturers should know about manufacturing metrics, manufacturing fitness, and should also know how the metrics affect manufacturing fitness. Strategic fit evaluates the current performance of an organization/industry. This is necessary to realize easily that the organization how much capable to achieve its external environment. To make easy this evaluation process this research has developed a model of strategic fit which will measure the strategic achievement compared to strategic capabilities.

The links among competitive strategy, manufacturing strategy, and performance are addressed by Vickery et al. (1993). Again, Porter (1996) claims that a proper link between strategy and manufacturing operations is a key to developing sustainable competitive advantage. To be successful in this globally competitive, rapidly changing environment, organizations must formulate strategic plans that are consistent with their capabilities and use of manufacturing strategies (Tracey et al., 1999). Expanding global competition, rapidly changing markets and technology, and increasing complexity and uncertainty are creating a new competitive environment (Bayus, 1994). These changes are causing manufacturing firms to carefully examine a shift from industrial systems driven by efficiency and enabled by strategy based manufacturing systems where success depends on high quality products, better customized (Skinner, 1986; Hayes et al., 1988; Doll and Vonderembse, 1991; Goldhar et al., 1991; McCutcheon et al., 1994; Roth, 1996). High quality and reliability, timely delivery, enhanced customer service, rapid new product introduction, flexible systems, and efficient capital deployment, not cost reduction, are the primary sources of competitive advantage (Skinner, 1986).

Success depends on close and careful linkages between a firm's manufacturing strategy and its overall strategy. These linkages help to guide decisions about how manufacturing technologies, and strategies are applied, which competitive capabilities are achieved and, ultimately, how well firms perform (Skinner, 1969; Porter, 1996). The design of manufacturing systems should focus on developing competitive capabilities that satisfy customer needs and improve performance (Ward et al., 1994).

1.2 Research objectives

To determine manufacturing fitness, and to show the effect of manufacturing metrics on fitness we have fixed two goals/objectives and they are

(a) Strategic fitness, security level, and loss/penalty calculation of unit 4 and

(b) Their (strategic fitness, security level achievement, and loss/penalty) model development for a manufacturing unit of a garments industry.

To make visualized these manufacturing metrics, manufacturing fitness, and their effect on fitness we have focused on manufacturing unit 4 and it has 6 manufacturing lines (16, 17, 18, 19, 20, and 21). The management of this unit only deals the orders of buyer TOM TAYLOR, WOOL WORTH, PRIMARK, H&M, C&A and SOliver.

1.3 Organization of this research

This article is organized into seven chapters for the completion its objectives and the organization is

Chapter 1- Introduction: Concept of 'Strategic fit', research objectives and organization of this work had been aggregated in this chapter.

Chapter 2-Background study and concept development of manufacturing fitness: In this chapter, the concept of 'strategic fit' of a manufacturing unit is generated by literatures/articles reviewing. This chapter also shows the summary of previous research works.

Chapter 3- Research methodology: In this chapter, a research methodology is adopted for the completion of its objectives. The adopted methodology shows the sequences to complete its objectives that will make the readers easy to understand the adopted methods.

Chapter 4- Data calculation and analysis: In this chapter, all the data had been calculated according to the sequences of methodology.

Chapter 5- Development of strategic fit model: A conceptual model and mathematical model had been developed in this chapter based on the calculation of chapter 4. This chapter summarized the previous chapter's calculations and will make visualized the developed conceptual model & mathematical model to the readers easily.

Chapter 6- Analysis of metrics significance on manufacturing fitness: This chapter shows the list of aggregated sub-metrics for each metric and also shows how they are related to manufacturing fitness by LISREL analysis and structural modelling.

Chapter 7- Discussions and conclusions: Comparison to others research results, significance of this research, recommendations, limitations, and scope of further research had been integrated in this chapter.

CHAPTER 2

Background Study and Concept Development of Manufacturing Fitness

It is necessary to discuss in brief the previous literatures on the relevant topics prior to proceeding the concept of manufacturing fitness. There are many research articles on the ready-made garments (RMG) sectors related to performance factors where they showed how performance factors affect the manufacturing efficiency. Rahman & Amin (2016) analyzed that problems in a production line such as raw materials problems, accessories problems, production related problems (machine problems, order variation problems, sewing problems etc.) decreased the efficiency of a production line where availability of materials, order variation handling capability, problem handling capability are considered as performance factors (manufacturing metrics) of a production line. They also analyzed and measures how the production efficiency of a production line falls. Finally, they also advised to the manufacturers to overcome these problems and to increase efficiency. Their advises are (1) they can easily identify their root causes of production loss because this research listed all the problems of production (2) can realize the production fall from process to process (3) will provide training for all the departments to make them conscious and finally (4) will be helpful to take actions against the production loss from the list of effective ways to mitigation production problems.

Nuruzzaman (2013) showed that failure to due time shipment/late shipment is associated with loss/penalty. Wong et al. (2011) examined delivery, production cost, product quality, and production flexibility as four factors of operational performance and these factors reflect the four key capabilities of a local firm (Schmenner and Swink, 1998). From the production literature, internal integration of the performance factors enables better coordination of production capacity to improve production flexibility (Sawhney, 2006) and delivery performance (Droge et al., 2004). They proposed a model that not only articulates an effective use of flexibility concurrently for both proactive and reactive purposes, it also allows a simultaneous view of the opportunities and uncertainties along the value-chain. By embracing the entire value-chain, this model considers the implications of the inter-relating feedback loops within the supply-chain, which to-date has been overlooked in the flexibility literature. Such an approach provides managers with a tool that allows them to consider more options in configuring flexibility between its two competing uses.

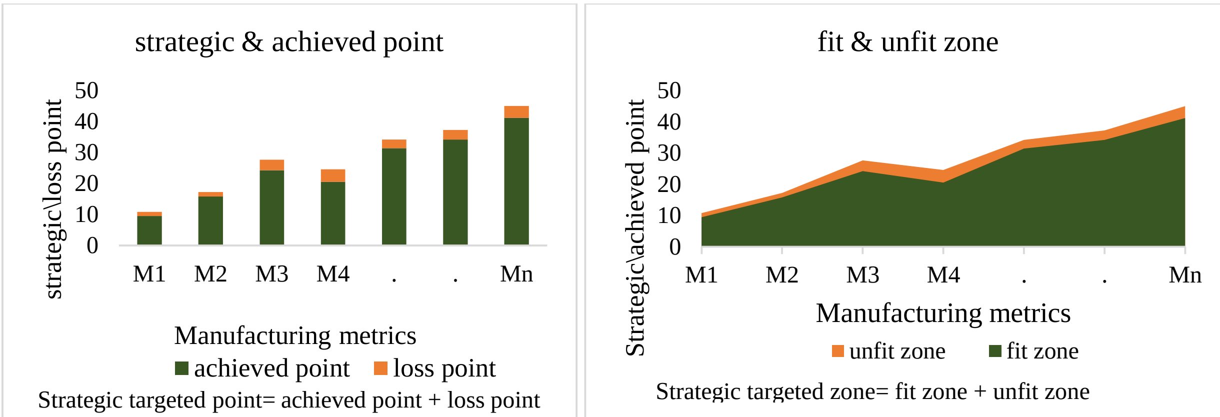
These theoretical arguments had been supported by numerous studies which demonstrates positive associations between internal integration and process efficiency (Saeed et al., 2005; Swink et al., 2007), delivery performance and quality performance (Swink et al., 2007). Tracey et al. (1999) considered quality of products, order fill rate, order cycle time, order/shipment time, and delivery frequency as competitive capabilities during linking technology and strategy to create competitive capabilities and improve performance. Upton (1994) contends that firms must match with these manufacturing systems capabilities to their competitive priority in order to be successful. According to Upton (1994) flexibility is an elusive quality in manufacturing and operations. This term is used for many purposes, each of which involves different qualities and capabilities of a system. Flexibility problem has become big concerns among the top managements and continuously growing its importance. This operational flexibility and manufacturing flexibility is related to the overall performance (fitness) of a manufacturing unit. That means this flexibility is one of the importance metrics related to manufacturing fitness.

Brown et al. (2007), and Amoako-Gyampah et al. (2008) showed the contribution of manufacturing strategy and competitive strategy on firm's manufacturing performance. Brown et al. (2007) linked strategic alignment and manufacturing strategy process to be fit with world class manufacturing practices and performance and more generally to the best practices and practice-performance debates to world-class manufacturing performance. Amoako-Gyampah et al. (2008) confirmed that competitive strategies can be implemented by means through manufacturing strategies cost, delivery, flexibility, and quality. Among these four strategies only quality influence firm's performance. Manufacturing lead time, rework time spend, material rejection can be reduced by improving quality and improves delivery time, flexibility, and unit cost performance. They significant and positive relationships competitive strategy and manufacturing strategies. Their findings also indicate quality is the only manufacturing strategy component that influences performance. Again, Porter (1996) claimed that a proper link between strategy and operations is a key to developing sustainable competitive advantage.

From the previous study, we can summarize that order fill rate, quality perfection, availability of materials, problem handling/manufacturing flexibility, order variation handle, cost performance and shipment time/ delivery time are the competitive capabilities/manufacturing metrics for a manufacturing unit. Previous studies also indicated contribution to manufacturing metrics is the firm's performance, since firm's performance is directly related to the performance of manufacturing metrics. Again, metrics performance fluctuates firm's overall fitness (performance).

The authors of this article are interested to determine this fluctuation of manufacturing fitness by determining strategic achievement compared to strategic capabilities with graphical representation (fit zone/unfit zone). A simple question 'what is strategic fit zone/unfit zone?' may arise at first. The zone that represents the requirement fulfillment/requirement achieved compared to its capabilities can be defined as fit zone and the remaining zone can be called as unfit zone. For an example, figure 2.1 is the graphical representation of strategic fitness of a manufacturing unit, there are n manufacturing metrics and they are

M1, M2, M3, M4,……..Mn. Each metric has a target which is determined by the management team according to their capabilities. The figure 2.1 (a) shows strategic capabilities (targeted) & achievement and figure 2.1 (b) shows the fit zone and unfit zone of that unit.



(a) Strategic point & achieved point (b) Fit zone & unfit zone

Figure 2. 1 graphical representation of strategic fitness

To calculate strategic fit this research selected a manufacturing unit of Fakir Apparels Ltd. Organizational fitness depends on all units of an organization. Here, we selected only one unit (unit 4) and determined the fitness of this unit. By the similar way it is possible to determine the fitness of all units of an organization/industry. From where, it is possible to determine the overall fitness of an organization/industry. If there are n manufacturing metrics of a manufacturing unit in an industry, strategic fitness can be determined by the following proposed equation.

$$Strategic\ fit = \left[\left[\frac{\left(\sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}\right)}{\left(\sum_{i=1}^{i=n} S_{p(b)i} * W_{m(i)}\right)}\right] * 100\%\right]$$

$$= \left[\left[\frac{\sum_{i=1}^{i=n}\left\{\frac{M_{i\ (Strategic\ Achievement)}}{M_{i\ (Strategic\ Capability)}}\right\}}{n}\right] * 100\%\right]$$

This research also compares this fitness to its security level/lowest tolerance level. Since the metrics are related with the manufacturing fitness that means manufacturer's profit/loss is related with the ups and downs of the metrics. For this reason, the manufacturers should strictly follow a security level for each metrics. The more metrics achievement above the security level the more satisfactory fitness to the manufacturers. Below the security level, the metric will be associated with a loss/penalty from the strategic achievement. A manufacturing unit how much achieved the security level can be calculated easily by the following proposed equation.

$$Security\ level = \left[\sum_{i=1}^{i=n} M_{\max(Strategic\ point)(i)} * S_{L(i)} * W_{m(i)}\right]$$

$$Security\ level\ achievement = \left[\left[\frac{\left(\sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}\right)}{\left(\sum_{i=1}^{i=n} M_{\max(Strategic\ point)(i)} * S_{L(i)} * W_{m(i)}\right)}\right] * 100\%\right]$$

CHAPTER-3

Research Methodology

This section represents a methodology to calculate the strategic fitness, and to determine metrics significance on manufacturing fitness of a manufacturing unit that is shown by the figure 3.1. This figure shows the sequence for the determination of manufacturing fitness, security level, and also associated loss/penalty of a manufacturing unit.

Step 1: Manufacturing metrics aggregation and their categorization is shown in section 3.1	→	Step 2: Hypotheses proposed among the metrics is shown in section 3.2, and Development of relationship diagram among these metrics is shown in section 4.1	→	Step 3: Metrics weight calculation method selection is shown in section 3.3, and Their weight calculation by FAHP is shown in section 4.2	→	Step 4: Strategic-security level, & scale development are shown in section 3.4, and Calculation of strategic manufacturing fit & their model development is shown in section 4.3 and chapter 5	→	Step 5: Aggregation of manufacturing sub-metrics is shown in section 3.5, and significance of the generated items is shown in chapter 6

Figure 3. 1 Research framework

3.1 Manufacturing metrics aggregation and categorization

3.1.1 Metrics aggregation

This section aggregated the metrics for garments manufacturing industries based on the literatures/articles reviewing that is shown in table 3.1.

Table 3. 1 Aggregation of manufacturing metrics

Manufacturing metrics for a manufacturing unit	
Manufacturing metrics	Researcher (year)
Order fill rate (OF)	Wheel Wright (1984); Tracey et al. (1999); Majukwa & Haddud (2016)
Quality perfection (QP)	Noble (1995); Tracey et al. (1999); Ward & Duray (2000); Zhou et al. (2010)
Availability of materials (AM)	Haider, M. Z. (2007); Islam et al. (2012); Karmaker & Saha (2016)
Problem handling/manufacturing flexibility (PH)	Swamidass & Newell (1987); Gerwin (1993); Noble (1995); Hayes & Pisano (1996); Gupta & Lonial (1998)
Order variation handle (OVH)	Wheel Wright (1984); Ward & Duray (2000); Majukwa & Haddud (2016), Zhou et al. (2010)
Cost performance (CP)	Swamidass & Newell (1987); Noble (1995); Hayes & Pisano (1996); Ward & Duray (2000), Zhou et al. (2010)
Shipment time/delivery time (ST)	Swamidass & Newell (1987); Noble (1995); Tracey et al. (1999); Ward & Duray (2000)

3.1.2 Metrics categorization

There are seven manufacturing metrics those can be divided into the following three categories. The metrics of first category have an effect on the second category metrics. Similarly, the second category metrics have an effect on third category metrics and the third category metrics have an effect on strategic fit (SF) that is shown by Figure 3.2 and this effect from one category to next category had been shown in section 4.1 with their significance results.

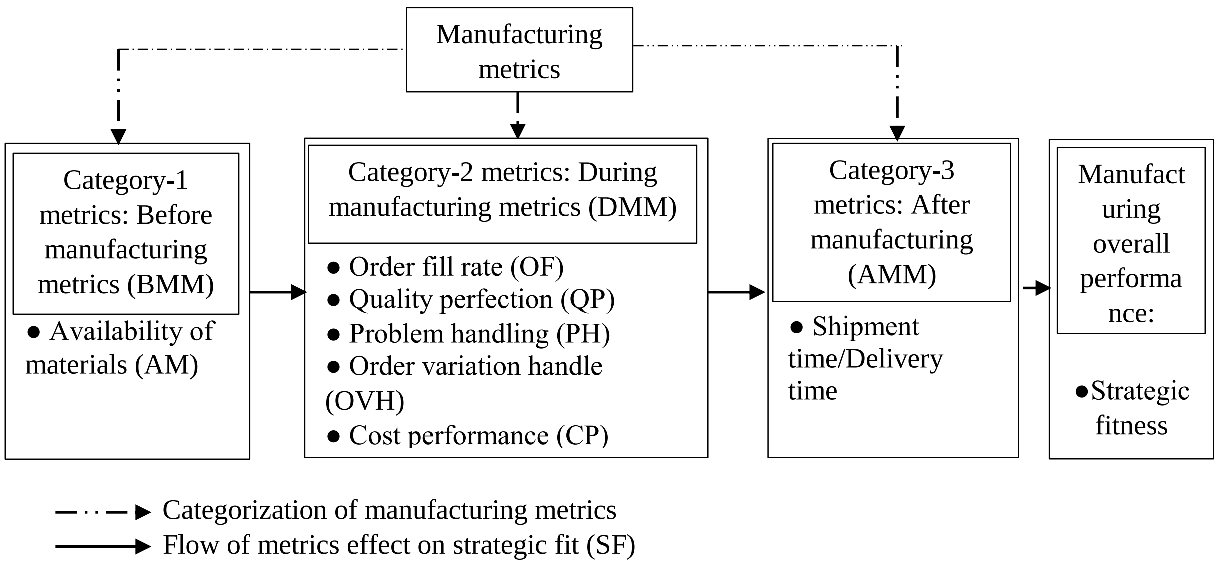


Figure 3. 2 Manufacturing metrics categorization and their effect on strategic fit

3.2 Hypotheses proposed among the metrics

3.2.1 Hypotheses proposed between BMM and DMM

Availability of materials (AM) is required before starting the manufacturing and so this is considered as the metric of first category. There is a great contribution of AM to overall performance of a manufacturing unit and the manufacturers think that shortage of materials directly affect the metrics of second category (DMM) (Han, J. 2009; Jaafreh & Al-abedallat, 2012). Effect of AM to during manufacturing metrics (DMM) had been analyzed by the previous researches. Like, Rahman and Amin (2016) analyzed the effect of AM to problem handling (PH), cost performance (CP), and order fill rate (OF); Swink et al. (2005), Tracey et al. (1999) analyzed the effect of manufacturing practices to cost efficiency (cost performance-CP), process flexibility (problem handling-PH, order variation handle-OVH), quality perfection (QP). Based on the previous researches, this research considered the direct effect of AM to DMM; therefore, the following hypotheses were proposed:

H1a: Order Variation Handle (OVH) is positively related to Availability of materials (AM)

H1b: Problem Handling (PH) is positively related to Availability of materials (AM)

H1c: Quality Perfection (QP) is positively related to Availability of materials (AM)

H1d: Cost performance (CP) is positively related to Availability of materials (AM)

H1e: Order Fill Rate (OF) is positively related to Availability of materials (AM)

3.2.2 Hypotheses proposed among DMM

From figure 3.2**,** there are five manufacturing metrics in second category those are related among themselves and also has positive relation with AMM. Besides the relation with BMM and AMM, these have internal relation from OVH to OF (Surana et al. 2005; Pathak et al. 2007; Swink et al. 2007). Previous researches showed an internal linkage among these metrics such as M. Tracey et al. (1999) determined the relation between quality of products (QP) and order fill rate (OF), Doll and Vonderembse (1987), Roth and Miller (1992), Handfield and Pagell (1995), Tracey et al. (1999) determined the relation between product quality (QP) and delivery time/shipment time (ST) and they also showed their effect on the overall performance of a manufacturing unit. Considering these relations during manufacturing metrics, this research considered the following hypotheses.

H2a: Problem Handling (PH) is positively related to Order Variation Handle (OVH)

H2b: Quality Perfection (QP) is positively related to Problem Handling (PH)

H2c: Cost Performance (CP) is positively related to Quality Perfection (QP)

H2d: Order Fill Rate (OF) is positively related to Cost Performance (CP)

3.2.3 Hypotheses proposed between DMM and AMM

There is only one manufacturing metric (shipment time/delivery time) in the third category which is related with the metrics of previous category and the fitness of a manufacturing unit. The failure of due time shipment affect the manufacturing overall fitness (Surana et al. 2005; Swafford et al. 2006; Mondal et al. 2017). Senior management suggested to keep focus on the due time shipment. Due time shipment gives the evidence of proper handling of the previous metrics and it motivates & encourages the employees for the better performance & better growth of an organization (Swink et al., 2005; Vollmann et al. 2005; Meryem et al. 2016). Based on the previous researches (Swink et al., 2005; Vollmann et al. 2005; Meryem et al. 2016), this research proposed the following hypotheses.

H3a: Shipment Time (ST) is positively related to Order Variation Handle (OVH)

H3b: Shipment Time (ST) is positively related to Problem Handling (PH)

H3c: Shipment Time (ST) is positively related to Quality Perfection (QP)

H3d: Shipment Time (ST) is positively related to Cost Performance (CP)

H3e: Shipment Time (ST) is positively related to Order Fill Rate (OF)

Hypotheses of different categories had been integrated and visualized by the following figure 3.3. This figure showed that there is an effect from the metrics of first category to strategic fitness of a manufacturing unit. How much these hypotheses are related with one another and with manufacturing fitness of a manufacturing unit had been analyzed in this section 4.1.

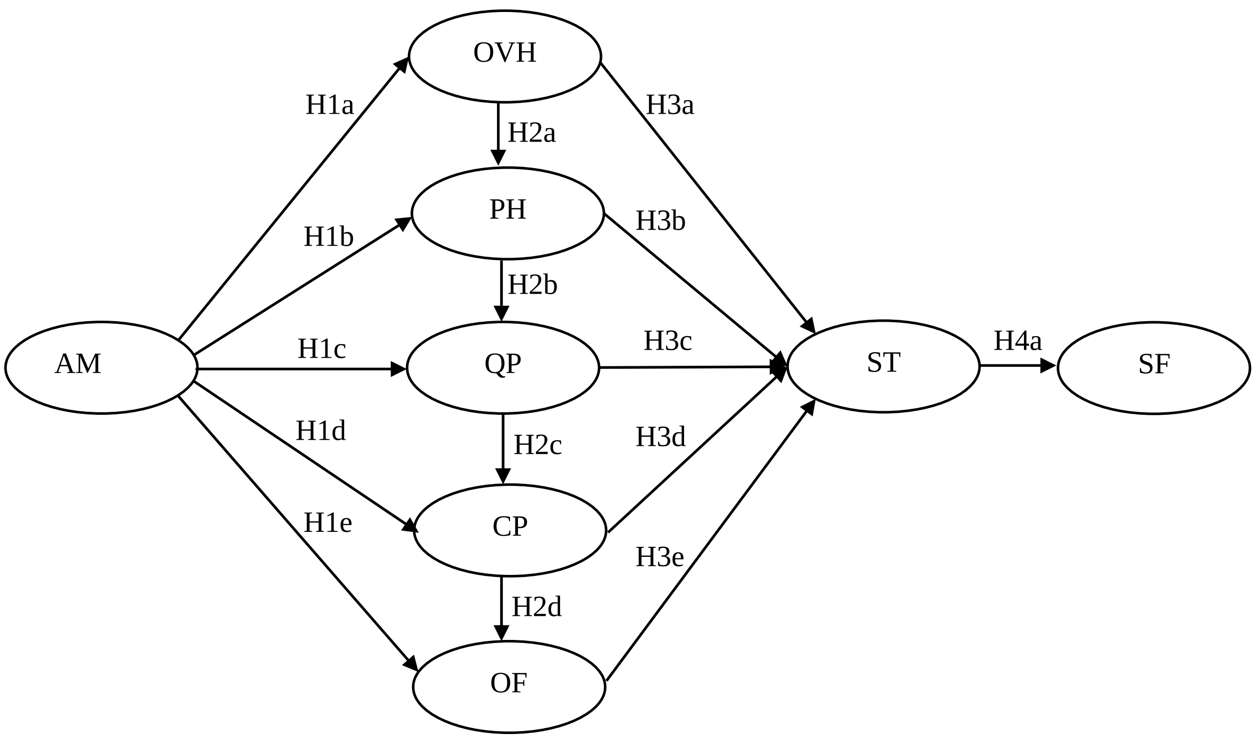


Figure 3. 3 Initially considered/proposed relationship diagram/model among the manufacturing metrics

3.2.4 Hypothesis proposed between AMM and SF

Strategic fitness of a manufacturing unit defines the overall performance of that unit. To determine this fitness of a garments manufacturing unit, we selected a manufacturing unit (unit 4) of Fakir Apparels Ltd. From figure 3.3, manufacturing fitness (SF) is directly related to the metrics of third category (due time shipment/due time delivery). Management think, it is necessary to give more importance to the previous metrics prior to third category metric (shipment time) (Jaafreh, & Al-abedallat, 2012; Meryem et al., 2016). The better performance of the previous metrics results better performance of SF. The strategy of getting better fitness creates an environment of more empowered employees and more developed systems (Ebrahimi & Sadeghi, 2013). Therefore, this research had also proposed another hypotheses.

H4a: Strategic Fit (SF) is positively related to Shipment Time (ST)

It is necessary to verify the relation diagram shown in figure 3.3 whether all the hypotheses support the model. This can be verified by regression and correlation analysis and this verification had been shown in section 4.1. This analysis determines how much two variables are linearly related and this analysis also reduces the model complexity. This regression analysis also finds the statistical relation between two variables rather than theoretical analysis (Teo, 2014). Initially we considered 14 hypotheses (H1a-H1e, H2a-H2d, and H3a-H3e) among the three stages manufacturing metrics and another hypothesis is H4a which defines shipment time (ST) is related to strategic fit (SF).

3.3 Metrics weight calculation method selection

In this research, Fuzzy AHP had been preferred in the prioritization of manufacturing metrics since this method is the only one using a hierarchical structure among goals, attributes and alternatives. Usage of pair-wise comparisons is another asset of this method that lets the generation of more precise information about the preferences of decision makers. Moreover, since the decision-makers are usually unable to explicit about their preferences due to the fuzzy nature of the decision process, this method helps them providing an ability of giving interval judgments instead of point judgments.

In the following, the outlines of the extent analysis method on Fuzzy AHP are given: Let X = {x_1, x_2, ……., x_n} be an object set, and U = {u_1, u_2, ……., u_m} be an goal set. According to Chang's (1992, 1996) extent analysis, each object is taken and extent analysis for each goal, g_i, is performed respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M_{gi}^1, M_{gi}^2, \dots\dots\dots\dots\dots, M_{gi}^n, \qquad \text{i} = 1, 2, 3, \dots\dots\dots, \text{n} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where all the M_{gi}^j (j = 1, 2, 3, ………., m) are triangular fuzzy numbers (TFNs) whose parameters are a, b, and c. they are the lowest possible value, the most possible value, and the largest possible value respectively. A TFN is represented as (a, b, c) as illustrated in figure 3.4.

The steps of Chang's extent analysis can be given as in the following:

Step 1**:** The value of fuzzy synthetic extent with respect to the *i*th object is defined as

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} a_{ij}, \sum_{j=1}^{m} b_{ij}, \sum_{j=1}^{m} c_{ij}\right), \quad i = 1, 2, 3, \ldots\ldots, n \quad \ldots\ldots\ldots\ldots (3)$$

And to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$, perform the fuzzy addition operation of M_{gi}^{j} (j = 1,2,……..,m) values such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} b_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

And then compute the inverse of the vector in eqn. (4) such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} b_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij}}\right) \ldots\ldots\ldots (5)$$

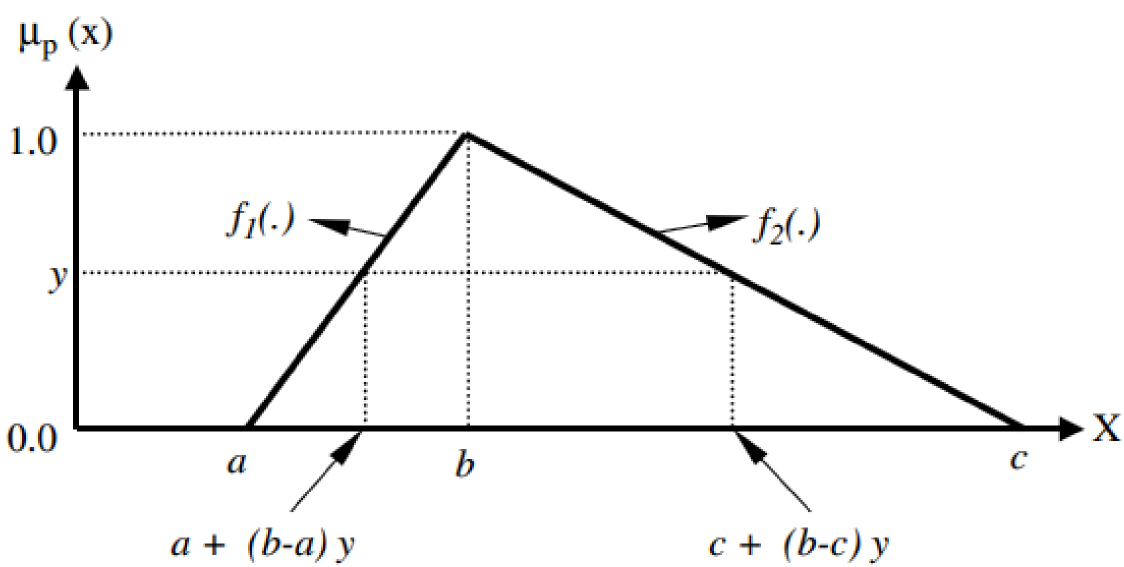


Figure 3. 4 A triangular fuzzy number, P ˇ= (a, b, c)

Step 2. The degree of possibility of $M_2 = (a_2, b_2, c_2) \geq M_1 = (a_1, b_1, c_1)$ in defined as

$$V\ (M_2\ \geq\ M_1) = \sup_{y \geq x}[\min(\mu_{M_1}(x), \mu_{M_2}(y))] \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . (6)$$

And can be equivalently expressed as follows:

$$V\ (M_2\ \geq\ M_1) = hgt\ (M_1\ \cap\ M_2) = \ \mu_{M_2}(d) = \begin{Bmatrix} 1, & if\ b_2 \geq\ b_1 \\ 0, & if\ a_1 \geq\ c_2 \\ \dfrac{a_1 -\ c_2}{(b_2 - c_2) -\ (b_1 - a_1)}, & otherwise \end{Bmatrix} \dots . . (7)$$

Where d is the ordinate of the largest intersection point D between μ_{M_1} and μ_{M_2} (see Fig. 3.5). To compare M_1 and M_2, we need both the values of $V\ (M_1\ \geq\ M_2)$ and $V\ (M_2\ \geq\ M_1)$.

Step 3: The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i\ (i =\ \ 1, 2, \dots \dots \dots . , k)$ can be defined by

$$V\ (M\ \geq M_1, M_2, \dots \dots \dots , M_k) = \ V[(\ M\ \geq\ M_1)\ and\ (M\ \geq\ M_2)\ and\ \dots \dots . and\ (M\ \geq\ M_k)]$$
$$= \min\ V\ \ (\ M\ \geq\ M_i),\ \ i = 1, 2, 3, \dots \dots \dots , k. \qquad \dots \dots \dots \dots \dots \dots \dots \dots . . \dots \dots . . (8)$$

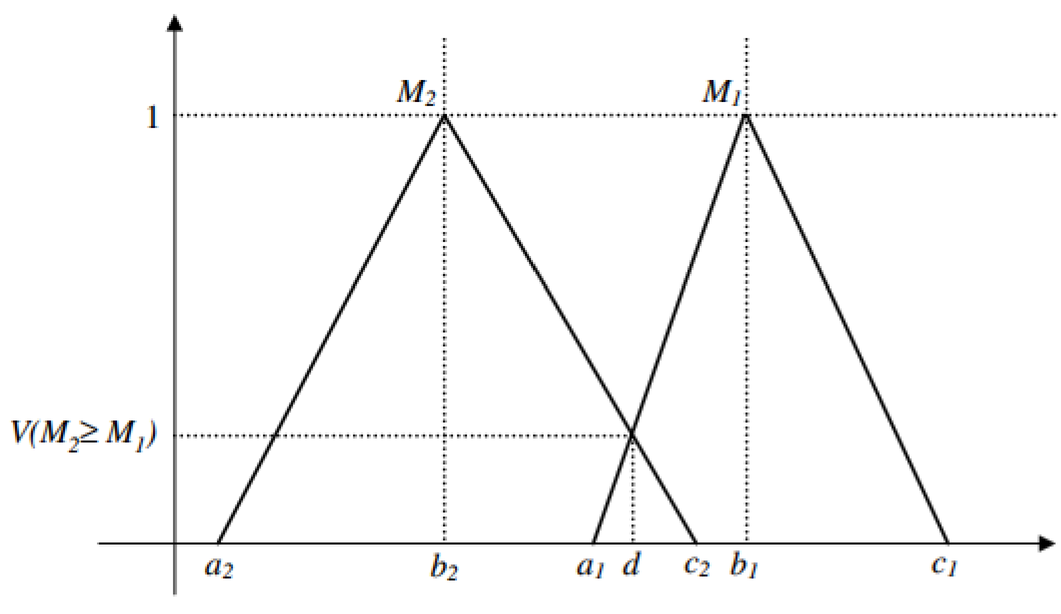


Figure 3. 5 The intersection between M_1 and M_2

Assume that

$$d'\ (\ A_1) = \min\ V\ \ (S_i\ \geq\ S_k) \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . . (9)$$

For $k\ = 1, 2, 3, \dots \dots \dots , n;\quad k\ \neq i.$ Then the weight vector is given by

$$W^i = (d' (A_1), d' (A_2), \dots \dots \dots \dots .., d' (A_n))^T \quad \dots \dots \dots \dots \dots . (10)$$

Where A_i $(i = 1, 2, \dots .., n)$ are n elements.

Step 4: Via normalization, the normalized weight vectors are

$$W = (d (A_1), d (A_2), \dots \dots \dots \dots .., d (A_n))^T \quad \dots \dots \dots \dots \dots . (11)$$

Where, W is a non-fuzzy number.

3.4 Strategic level, security level, and scale development

3.4.1 Strategic level and security level determination

The manufacturing capabilities varies depending on variation of order (Majukwa & Haddud, 2016). Manufacturers set a strategic target based on the manufacturing capabilities. Again, strategic targets depends on their capabilities and previous experiences (Hayes & Pisano, 1996; Islam et al., 2012). The manufacturing unit 4 also has the different capabilities and targets determined by the management team that is shown by table 3.2.

Table 3. 2 Manufacturing matrices with strategic target, and security level

Manufacturing metrics for a manufacturing unit		For unit 4 of Fakir Apparels Ltd.	
Manufacturing metrics	Manufacturing capabilities	Strategic target	Security level
Order fill rate (OF)	Completely filled (100%)	Order filling target: 100%	100%
	Partially filled (80%-99%)		
	Partially filled (50%-79%)		
	Partially filled (<50%)		
	Failed to delivery		
Quality perfection (QP)	High	Quality perfection fulfillment according to the buyer's requirements: 100%	85%
	Moderate		
	Low		
Availability of materials (AM)	Availability of all materials	Availability of materials to start the production of an order: At least 90%	At least 80%
	Not availability of all materials (<100%)		
Problem handling/manufacturing flexibility (PH)	High	Problem solving ability with high performance: 100%	100%
	Moderate		
	Low		
Order variation handle (OVH)	High	Order variation handle ability with high performance: At least 90%	At least 80%
	Moderate		
	Low		
Cost performance (CP)	High	Cost performance ability with high performance: At least 95%	At least 85%
	Moderate		
	Low		
Shipment time/delivery time (ST)	Due time shipment	Due time shipment: 100%	100%
	Late shipment		

3.4.2 Weight scale development

To determine strategic manufacturing fit it is necessary to develop a weight scale for the manufacturing metrics. Scale may vary for the case of manufacturing units of other industries. According to the manufacturer's suggestions and explanations of unit 4 of Fakir Apparels Ltd., we developed a scale that ranges from 0 to 5. Their suggestions and explanations had been summarized in the below table 3.3. This table also incorporates the views of researchers with manufacturer's suggestions and explanations.

Moderate importance

Worst importance — 0 — 1 — 2 — 3 — 4 — 5 → Best importance

Here,

$$\begin{cases} \quad 0, \ \textit{no importance} \\ 0 < W_d \leq 1, \ \textit{very low importance} \\ 1 < W_d \leq 2, \ \textit{low importance} \\ 2 < W_d \leq 3, \ \textit{moderate importance} \\ 3 < W_d \leq 4, \ \textit{good importance} \\ 4 < W_d \leq 5, \ \textit{very good importance} \\ \quad W_d = \textit{Scale weight} \end{cases}$$

Table 3. 3 Weight scale set according to researcher and senior management explanations

Manu. metrics	Manufacturing capabilities	W_d	Researchers and senior management explanations
OF	Completely filled (100%)	5	Management prefers to give the most importance (5) when order is fulfilled in time since this helps for due time shipment. For this reason, they gave the most importance value (5) for due time shipment. Again, failure to due time production sometimes fails to due time shipment and this causes a great penalty/discount for the manufacturers (Roth & Miller, 1992; Rahman & Amin, 2016; Sampaio et al., 2016; Mondal et al. 2017). Hence, they preferred to give no importance (0) for late order fill i.e. late production and late shipment.
	Partially filled (80%-99%)	0	
	Partially filled (50%-79%)		
	Partially filled (<50%)		
	Failed to delivery		
ST	Due time shipment	5	
	Late shipment	0	
AM	Availability of all materials	5	Management preferred to give weight value (5) for availability of 100% materials, (3) for availability of >80% materials and (1) for availability of >60% materials at the beginning of an order.
	Not availability of all materials (<100%)	3 1	

QP	High	5	"Quality" or "quality performance" is a controversial construct for a variety of conceptual and empirical reasons (Soares et al. 2017) and the quality performance depends on quality management practices (Soltani and Wilkinson, 2010; Uluskan et al. 2016) and better problem handling capabilities. The better problem solution helps the management for their industries for good quality control capabilities (Taylor, 1995; Gereffi, 1999; Bair & Gereffi, 2001; Sila et al. 2006; Azar et al., 2010). For this reason, the management gave the maximum weight value (5) for good quality and good problem handling, moderate weight value (3) for moderate quality and moderate problem handling and poor weight value (1) for low quality and low problem handling.
	Moderate	3	
	Low	1	
PH	High	5	
	Moderate	3	
	Low	1	
OVH	High	5	Management preferred to give maximum weight value (5) for good order variation. When management fails to solve order variation or show poor performance to solve order variation this causes the failure of order shipment and due time production (Roth & Miller, 1992; Masud, 2010; Mohan Kathuria, 2013; Nuruzzaman, 2013; Rahman & Amin, 2016; Mondal et al. 2017). Hence, they gave low weight value (1) for moderate order variation capabilities and no weight (0) for low order variation capabilities.
	Moderate	1	
	Low	0	
CP	High	5	There is a great importance of cost performance for a manufacturing unit (Schmalensee, 1989; Arauz & Suzuki, 2004). The management preferred to give the maximum weight value (5) for the good or high cost performance, moderate weight value (1) for average cost performance and no weight value (0) for low cost performance. Because they think that the cost performance is directly related with the organizational profit.
	Moderate	1	
	Low	0	

The manufacturer works for the achievement most important value (5) by setting 100% strategic target so that they can achieve the maximum strategic point. For an example, the manufacturers of unit 4 always tried to fulfil 100% order quantity (100% OF) by the due time so that they could achieve the maximum strategic point 165 (33 due time production*most important weight value, 5) for OF. But they failed 4 times that resulted in 145 points. The partial production or interruption in the production sometimes stops a running production and compels for the next month production and this is a reason against strategic target (Ferdousi, 2009; Biswas, 2015; Rahman & Amin, 2016).

3.5 Aggregation of manufacturing sub-metrics

Aggregated manufacturing metrics had been shown by the table 3.1 and corresponding sub metrics also had been aggregated by literature/article reviewing that is shown by table 3.4, since it is necessary to aggregate all the items for each metric for their significance analysis to manufacturing fitness. The sub-metrics those are related & not related to manufacturing fitness had been analyzed and shown in chapter 6.

Table 3. 4 List of manufacturing metrics with their sub metrics

Manufacturing metrics	Manufacturing sub metrics	Manufacturing capabilities Manufacturing capabilities on availability of materials (AM)	Researcher (year) & survey result
Availability of materials (AM)	AM1	Storing all the materials before starting the order	Michalska & Szewieczek (2007); Filip & Marascu-Klein, (2015)
	AM2	Collecting the remaining materials for that case when there is not available 100% materials but order has been started	Haque (2009); Yunus & Yamagata (2012)
	AM3	Availability of all the accessories	Abdel-Latif (1993); Haque (2009); Hossan et al., (2012); Yunus & Yamagata (2012)
	AM4	Sending the list of materials in the cutting department and stores for the associated orders with a good lead time	Hossan et al., (2012)
Order fill rate (OF)	OF sub metrics	Manufacturing capabilities on order fill rate (OF)	
	OF1	Availability of all materials	Abdel-Latif (1993); Haque (2009); Yunus & Yamagata (2012)
	OF2	Workers and employees performance	Kopacek et al. (1990); Morshed (2007); Hossan et al., (2012); Bhuiyan (2013)
	OF3	Production time	Haque (2009); Yunus & Yamagata (2012)
	OF4	Automated machine instead of manual machines	Kopacek et al.,(1990); Rahman & Amin (2016)
	OF5	Supervising	Absar (2001); Yunus & Yamagata (2012); Saha & Mazumder (2015)
Quality perfection (QP)	QP sub metrics	Manufacturing capabilities on quality perfection (QP)	
	QP1	Availability of all materials	Abdel-Latif (1993); Haque (2009); Yunus & Yamagata (2012)
	QP2	Pre-production activities (Dying, washing, printing and cutting)	Based on survey
	QP3	Materials quality	Abdel-Latif (1993); Flynn et al. (1994); Flynn et al. (1995)

	QP4	Workers and employees performance	Kopacek et al.(1990); Flynn et al. (1994); Morshed (2007)
	QP5	Quality inspection by quality control department	Ebrahimpour (1986); Duncalf & Dale (1988); Abdel-Latif (1993); Ahmed & Hossain (2009); Haque (2009)
	QP6	Automated machines instead of manual machines	Kopacek et al. (1990); Masud, J. P. (2010); Rahman & Amin (2016)
	QP7	Supporting the operators by helpers	Berg et al.(1996); Absar (2001)
	QP8	Post production activities (Ironing, Embroidery and printing)	Based on survey
Problem handling (PH)	PH sub metrics	Manufacturing capabilities on problem handling (PH)	
	PH1	Availability of all materials	Abdel-Latif (1993); Haque (2009); Yunus & Yamagata (2012)
	PH2	Automated machines	Bakht et al. (2009); Masud, J. P. (2010); Rahman & Amin (2016)
	PH3	Skilled operators and workers	Kopacek et al. (1990); Bakht et al., (2009); Masud (2010)
	PH4	Proper power supply	Based on survey
	PH5	Differentiate the production lines according to order size and product item	Based on survey
	PH6	Sufficient expert technician	Masud. (2010); Hasan, et al. (2017)
Order variation handle (OVH)	OVH sub metrics	Manufacturing capabilities on order variation handle (OVH)	
	OVH1	Availability of all materials	Abdel-Latif (1993); Haque (2009); Yunus & Yamagata (2012)
	OVH2	Differentiate the production lines based on order size and product item	Kabeer & Mahmud (2004); Rodríguez & Rodríguez (2005)
	OVH3	Production in a single time	Based on survey
	OVH4	Don't start the another order by breaking the running order	Based on survey
	OVH5	Maximum production for different orders by not changing the existing layout (if possible)	Kabeer & Mahmud (2004); Rodríguez & Rodríguez (2005); Uddin (2009)
Cost performance (CP)	CP sub metrics	Manufacturing capabilities cost performance (CP)	
	CP1	Availability of all materials	Abdel-Latif (1993); Haque (2009); Yunus & Yamagata (2012)
	CP2	Skilled operator	Kopacek et al.(1990); Bakht et al. (2009); Uddin. (2009)
	CP3	Automated machines	Kopacek et al. (1990); Bakht et al. (2009); Rahman & Amin (2016)
	CP4	Try to avoid overtime schedule	Ali et al. (2008); Uddin (2009); Hossan et al. (2012)
	CP5	Avoid subcontracting production system	Ali et al. (2008); Uddin (2009); Haque, & Azad (2010)
	CP6	Training programs among the operators on production techniques	Flynn et al., (1995); Chowdhury et al. (2006)
	CP7	Due time shipment	Chowdhury et al. (2006); Bhuiyan, (2013); Ahmed et al. (2014)
	ST sub metrics	Manufacturing capabilities on shipment time (ST)	

Shipment time (ST)	ST1	Order fill rate	Wheel Wright (1984); Tracey et al. (1999); Majukwa & Haddud (2016)
	ST2	Quality perfection	Noble (1995); Tracey et al. (1999); Ward & Duray (2000)
	ST3	Problem handling	Noble (1995); Hayes & Pisano (1996); Gupta & Lonial (1998)
	ST4	Order variation handle	Ward & Duray (2000); Majukwa & Haddud (2016)
	ST5	Cost performance	Noble (1995); Hayes & Pisano (1996); Ward & Duray (2000)
	ST6	Complete the production in time	Chowdhury et al. (2006); Ahmed et al. (2014)
	ST7	Time interval between the production time and shipment time	Chowdhury et al. (2006); Haque et al. (2012); Kader & Akter (2014)
	ST8	Problem handling capability	Haque & Azad (2010); Rahman & Amin (2016)
	ST9	Order variation handle capability	Masud (2010); Hossan et al. (2012)
Strategic fitness (SF)	SF sub metrics	Management capabilities by strategic fitness (SF)	
	SF1	Shipment time/delivery time	Noble (1995); Tracey et al. (1999); Ward & Duray (2000)
	SF2	Utilization of maximum manufacturing capabilities	Kelegama (2009); Chowdhury & Quaddus (2015)
	SF3	Utilization of employee's and worker's capabilities	Haider (2007); Asgari at al. (2013); Ansary, & Barua (2015)
	SF4	Earning foreign exchange	Demidova et al. (2012); Mohan (2013); Rahman et al. (2016)
	SF5	Better growth of the organization	Mukherjee et al. (2007); Islam et al. (2012); Mondal et al. (2017)

CHAPTER 4

Data Calculation and Analysis

4.1 Metrics relationship diagram development

4.1.1 Regression and correlation analysis

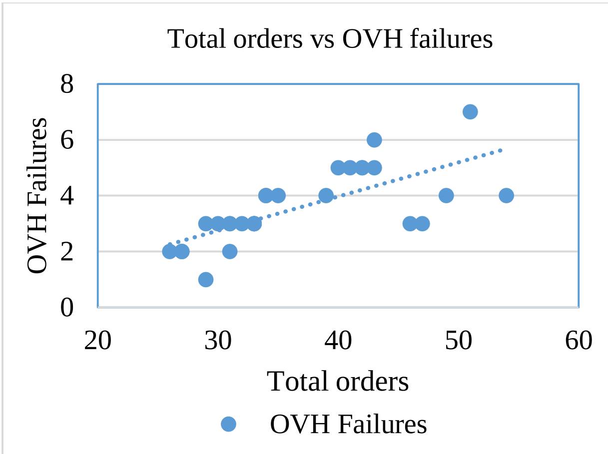
Regression analysis finds the linear relationship between two variables and regression analysis measures the strength of that linear relationship. Regression and correlation analyses verify the validity of hypotheses. For these analyses, we aggregated orders and metrics failures from January to June for different garments industries (Fakir Apparels Ltd., Young one- Dhaka EPZ, LIZ Fashion Ltd., and FCI BD Ltd.-Dhaka EPZ) shown in Table 4.1. These were collected with the help of Industrial Engineer (IE), Assistant Production Manager, and Production Manager of different garments industries by a survey form that is shown by the table A-1 in Appendix section. This survey form was sent to them through mailing. For the purpose of verifying the proposed hypotheses shown in figure 3.3 by regression and correlation analysis, we plotted scatter diagram with their linear relationship shown by the figures 4.1 - 4.4 using the data of table 4.1. Scatter diagram determines whether there is a relationship between two variables. The fairly linear scatter plot indicates there is a 'strong/moderate' correlation between two variables and nonlinear or distributed plot indicates there is 'weak/no' relation between two variables.

Table 4. 1 Aggregation of orders & metric's failures from January to June for different garments industries

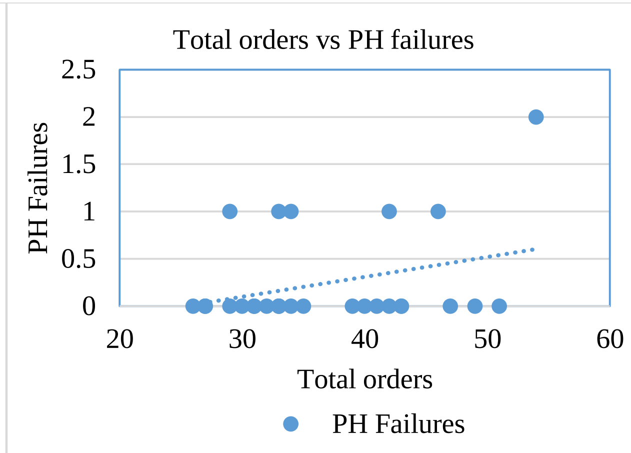
Name of Garment Industries	Months in 2016	Total order	Effect of category 1 metrics to category 2 (Effect of BMM to DMM)					Among the metrics of category 2				Effect of category 2 metrics to category 3 (Effect of DMM to AMM)					Effect of ST to SF
			Couldn't control OVH due to lack of AM	Couldn't control PH due to lack of AM	Couldn't meet QP due to lack of AM	Couldn't achieve CP due to lack of AM	Couldn't meet OF due to lack of AM	Couldn't control PH due to failure of OVH	Couldn't achieve QP due to failure of PH	Couldn't achieve CP due to failure of QP	Couldn't meet OF due to failure of CP	Couldn't meet ST due to failure of OVH	Couldn't meet ST due to failure of PH	Couldn't meet ST due to failure of QP	Couldn't meet ST due to failure of CP	Couldn't meet ST due to failure of OF	Couldn't meet SF due to failure of ST
Fakir Apparels Ltd. (Unit 4)	January	27	2	0	0	0	3	2	2	2	0	2	0	0	0	2	2
	February	29	3	1	0	1	3	2	2	2	0	2	1	0	0	2	2
	March	31	3	0	0	0	4	3	3	3	0	2	0	0	0	3	3
	April	30	3	0	1	0	4	3	3	3	1	1	1	0	0	3	2
	May	34	4	1	0	0	5	4	4	4	0	4	0	0	0	4	3
	June	27	2	0	0	1	3	2	3	2	0	2	1	0	0	2	2
Young one (Dhaka EPZ)	January	32	3	0	0	0	5	3	2	3	0	3	3	0	0	4	4
	February	33	3	0	1	0	5	3	2	2	0	3	4	1	0	5	4
	March	31	2	0	0	0	4	2	1	2	0	2	3	1	0	3	4
	April	35	4	0	0	0	6	4	3	5	0	4	5	0	0	4	5
	May	34	4	0	0	1	5	4	3	5	0	3	5	0	0	5	4
	June	33	3	0	0	0	5	3	3	4	0	3	4	0	0	4	3
Fakir Apparels Ltd. (Unit 5)	January	26	2	0	0	0	3	2	2	2	0	2	0	0	0	2	2
	February	29	1	0	0	0	4	3	3	3	0	2	0	0	0	3	3
	March	27	2	0	0	1	3	2	2	2	0	1	0	1	0	2	2
	April	33	3	1	0	0	5	3	3	3	0	3	0	0	0	4	3
	May	31	3	0	1	0	4	2	2	2	1	2	0	0	0	3	2
	June	33	3	0	0	1	5	4	3	4	0	3	1	0	0	4	3
LIZ Fashion Ltd.	January	42	5	1	0	0	6	5	2	4	0	5	2	0	0	4	4
	February	41	5	0	0	2	6	5	4	4	0	5	2	2	0	4	4
	March	39	4	0	0	0	5	4	3	3	0	3	2	0	0	3	2
	April	40	5	0	0	0	6	5	2	4	0	3	3	1	0	3	3
	May	43	6	0	0	0	6	5	2	5	0	5	3	0	1	4	4

	June	42	5	0	0	1	5	4	2	4	0	5	3	0	0	4	3
FCI (BD) Ltd. (Dhaka EPZ)	January	46	3	1	0	0	7	5	6	2	0	6	5	0	0	6	6
	February	43	5	0	0	1	5	4	4	5	0	4	5	1	1	5	4
	March	51	7	0	0	0	8	7	7	6	0	6	6	0	0	7	7
	April	49	4	0	2	1	7	6	7	6	0	5	5	2	0	6	7
	May	54	4	2	0	0	9	8	8	7	0	5	6	0	0	8	8
	June	47	3	0	2	1	8	6	7	6	2	3	5	2	0	6	7
Pearson correlation coefficient (r)			.71	.33	.24	.05	.93	.95	.76	.79	.10	.85	.76	.31	.23	.86	.84

The regression line (linear relationship) that meets the maximum points defines the strong relationship between the two variables. For an example, the regression line of figure 4.1 (a) & (e) meets with maximum points and they define, two variables of each figure are strongly related to each other's i.e. there is a correlation between these two variables. Similarly, figure 4.1 (b), (c) & (d); figure 4.2 (d); figure 4.3 (c) & (d) defines, two variables of each figure are not related (weak correlation) to each other's since their regression lines (linear relationship) couldn't meet with the diagram points.



(a)



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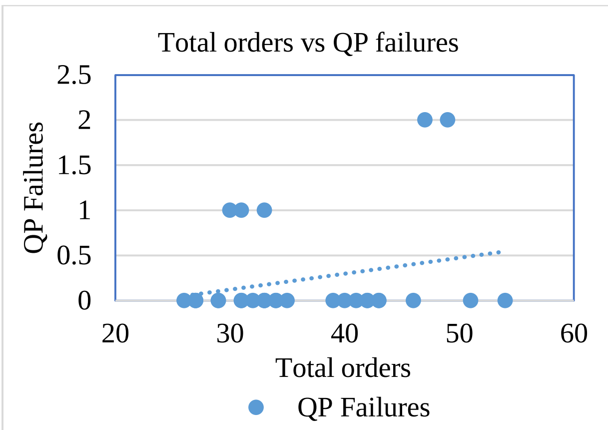
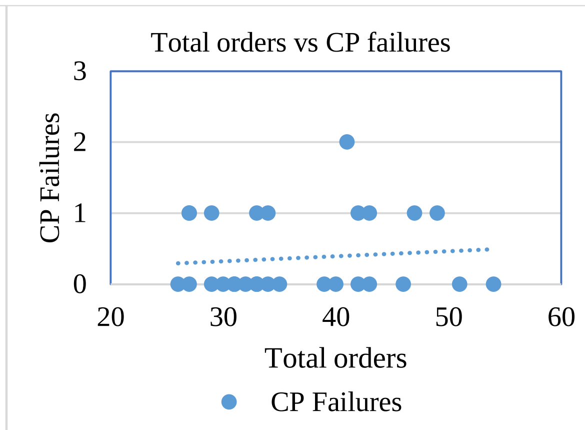


(c)



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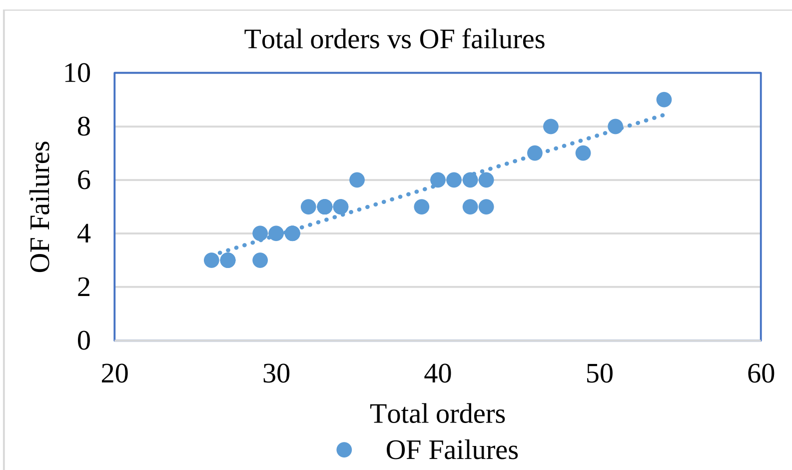
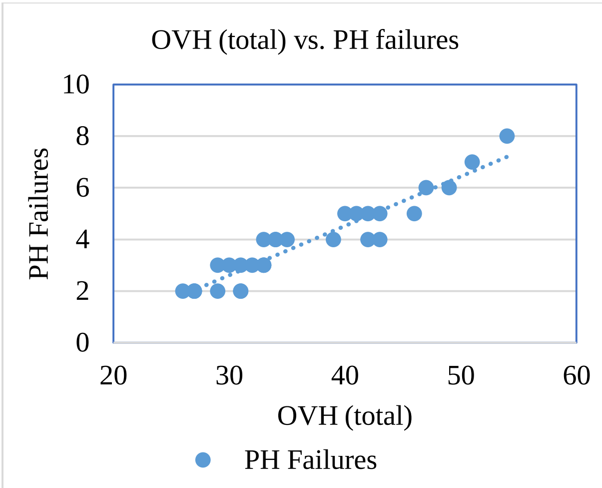
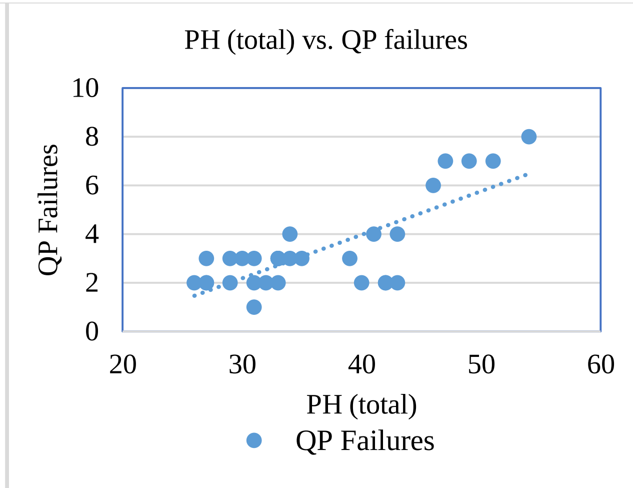


(e)

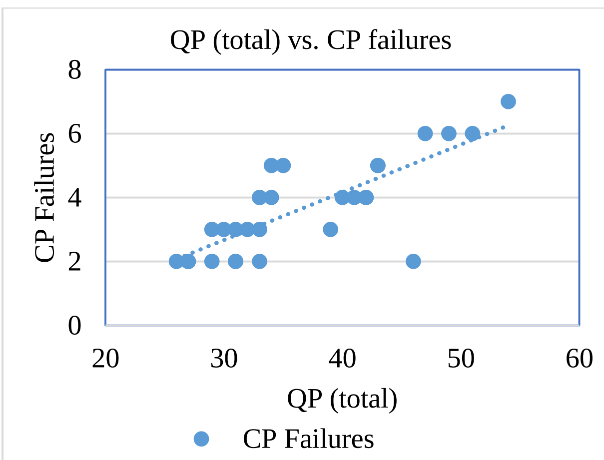
Figure 4. 1 Scatter diagram and correlation of (a) total orders vs. OVH failures (b) total orders vs. PH failures (c) total orders vs. QP failures (d) total orders vs. CP failures and (e) total orders vs. OF failures



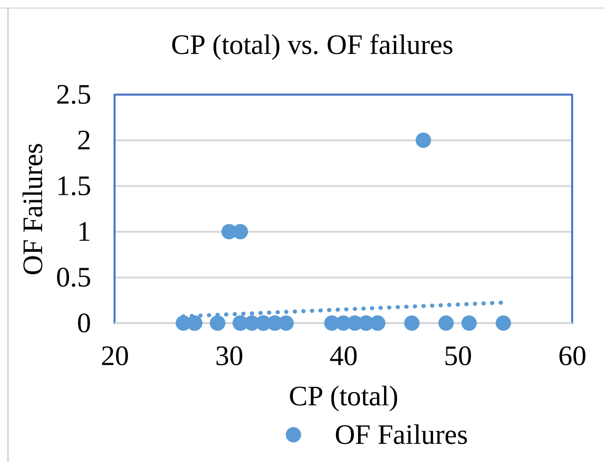
(a)



(b)

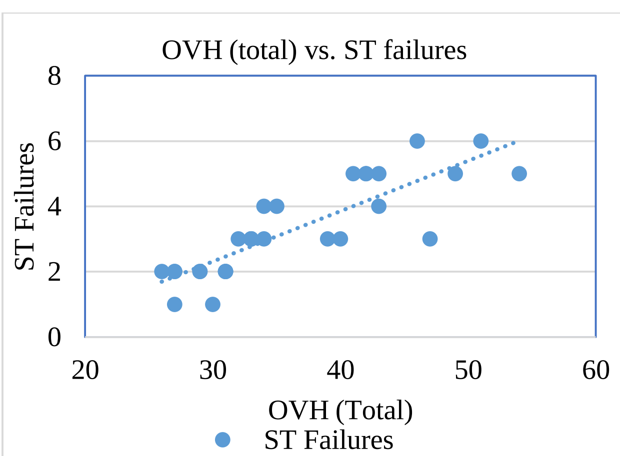


(c)

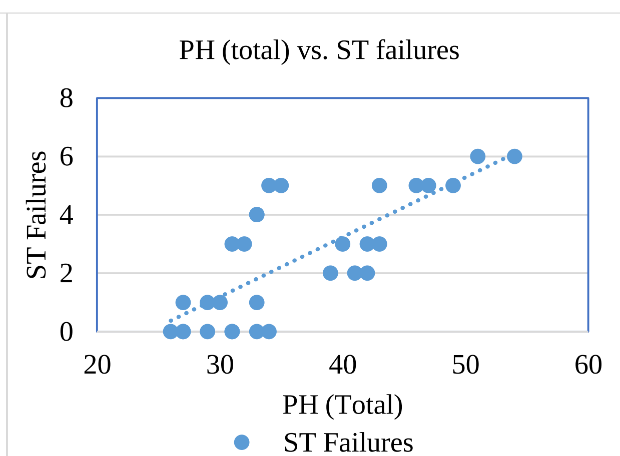


(d)

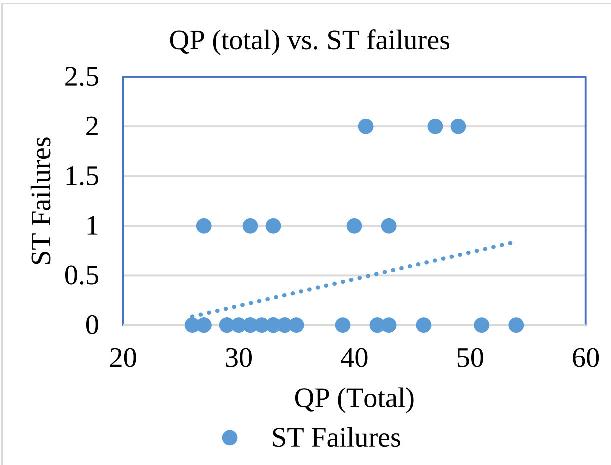
Figure 4. 2 Scatter diagram and correlation of (a) OVH (total) vs. PH failures (b) PH (total) vs. QP failures (c) QP (total) vs. CP failures (d) CP (total) vs. OF failures



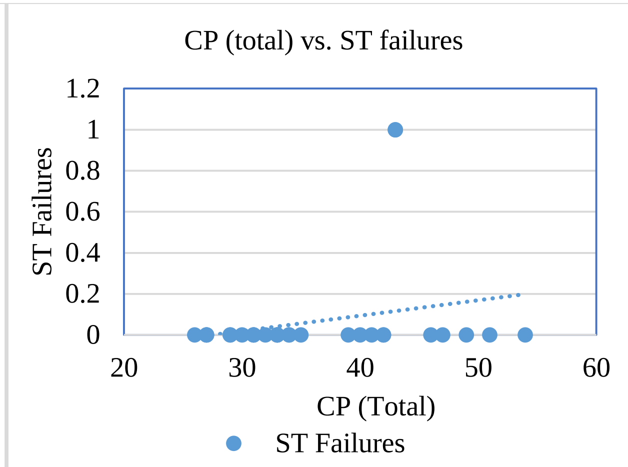
(a)



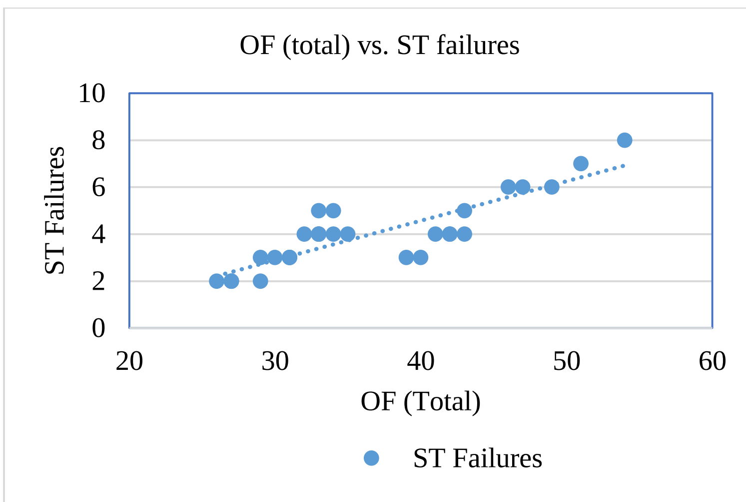
(b)



(c)



(d)



(e)

Figure 4. 3 Scatter diagram and correlation of (a) OVH (total) vs. ST failures (b) PH (total) vs. ST failures (c) QP (total) vs. ST failures (d) CP (total) vs. ST failures and (e) OF (total) vs. ST failures

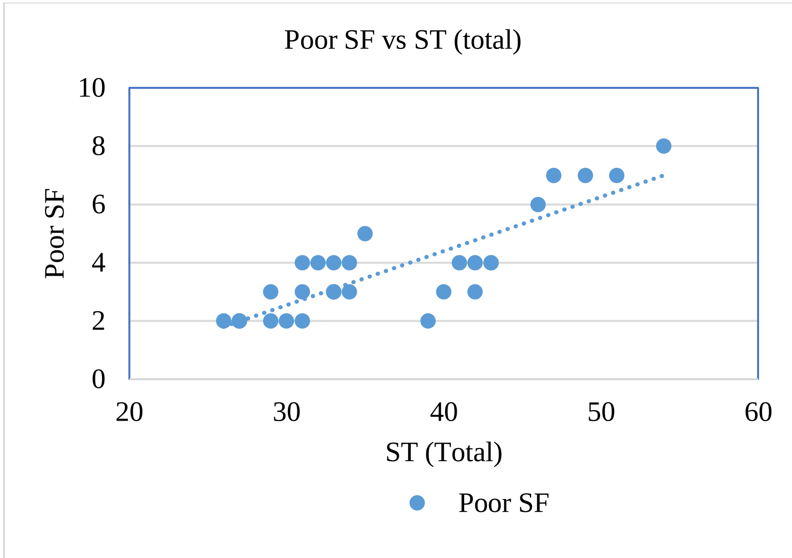


Figure 4. 4 Scatter diagram and correlation of ST (total) vs. poor SF

Table 4.3 shows the summarization results on proposed hypotheses based on scatter plot and Pearson correlation coefficient (r). This correlation value (r) defines the strength of a hypothesis. Evans (1996) suggested scale of (r) is shown in table 4.2 that determines the strength of a hypothesis.

Table 4. 2 Hypotheses strength with correlation value (r)

Correlation value (r)	Hypotheses strength
0.00-0.19	Very weak
0.20-0.39	Weak
0.40-0.59	Moderate
0.60-0.79	Strong
0.80-1.00	Very strong

From table 4.3, six hypotheses are rejected since their (r) value indicates weak/ very weak relationship between their associated variables of these hypotheses. Similarly, the (r) value also indicates the acceptance of another nine hypotheses since they have strong/ very strong relationship between their associated variables. From this result, we can develop a relationship diagram among the manufacturing metrics showing their corresponding hypotheses and figure 4.5 is the developed model.

Table 4. 3 Validation results of proposed hypotheses

Relationship	Hypotheses	r value	t value	ρ value	Significance	Validation results of proposed hypotheses (Fig. 3.3)
BMM to DMM						
AM→OVH	H1a	0.715	5.411	0.000	Yes	Order variation handing (OVH) capability is strongly related to AM
AM→PH	H1b	0.326	1.825	0.079	No	Problem handling (PH) capability is weakly related to AM
AM→QP	H1c	0.243	1.326	0.197	No	Quality perfection (QP) is weakly related to AM
AM→CP	H1d	0.100	0.532	0.599	No	Cost performance (CP) is very weakly related to AM
AM→OF	H1e	0.933	13.72	0.000	Yes	Order fill rate (OF) is very strongly related to AM
Among during manufacturing metrics (DMM)						
OVH→PH	H2a	0.946	15.44	0.000	Yes	Problem handling (PH) is very strongly related to OVH
PH→QP	H2b	0.765	6.29	0.000	Yes	Quality perfection (QP) is strongly related to PH
QP→CP	H2c	0.790	6.82	0.000	Yes	Cost performance (CP) is strongly related to QP
CP→OF	H2d	0.096	0.51	0.615	No	Order fill rate (OF) is very weakly related to CP
DMM to AMM						
OVH→ST	H3a	0.849	8.50	0.000	Yes	Shipment time (ST) is very strongly related to OVH
PH→ST	H3b	0.761	6.21	0.000	Yes	Shipment time (ST) is strongly related to PH
QP→ST	H3c	0.314	1.75	0.091	No	Shipment time (ST) is weakly related to QP
CP→ST	H3d	0.230	1.25	0.222	No	Shipment time (ST) is weakly related to CP
OF→ST	H3e	0.862	9.00	0.000	Yes	Shipment time (ST) is strongly related to OF
AMM (ST) to SF						
ST→SF	H4a	0.843	8.29	0.000	Yes	Strategic fitness (SF) is strongly related to ST

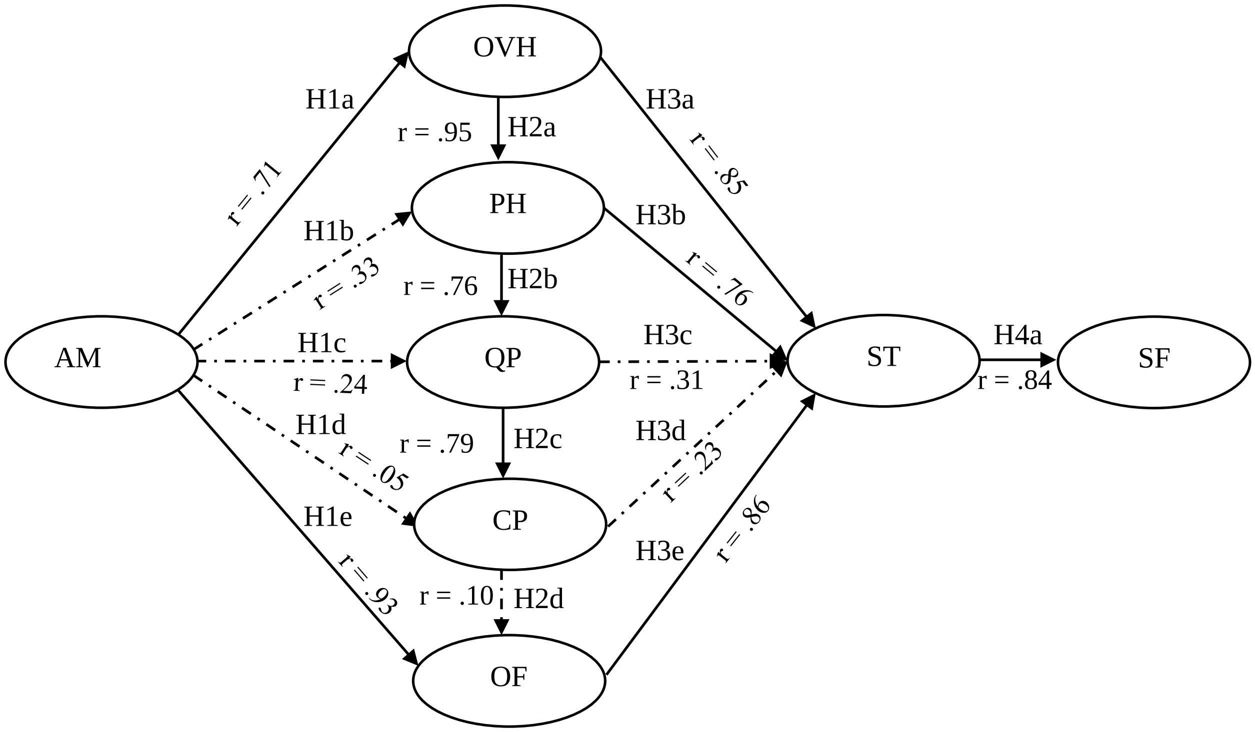


Figure 4. 5 Developed relation diagram among the manufacturing metrics

4.1.2 Hypotheses validity analysis

Table 4.3 shows the statistical verification of the proposed model that had been showed in Figure 3.3. t-value, and ρ value judge the statistical significance of the theorized relationship (hypotheses), and they have positive significance those have the t-value above 2.00. The t-values and ρ values provide the hypotheses acceptance/ rejection strength at 5% significance level ($\alpha = 0.05$). From table 4.3 hypotheses H1b, H1c, H1d, H2d, H3c, and H3d are not accepted since their t-value, and ρ value don't provide sufficient strength for their acceptance. On the other hand, hypotheses H1a, H1e, H2a, H2b, H2c, H3a, H3b, H3e, and H4a are accepted since their t-value, and ρ value provide sufficient strength for their acceptance. From the ρ values ($\rho < 0.05$) and t-values (t value > 2.00) of H1a & H1e for a garments manufacturing unit, we can say that availability of materials (AM) has strong contribution to order fill rate (OF) and order variation handle (OVH). This means that before manufacturing metric (AM) is linked with during manufacturing metrics (OVH, PH, QP, CP, ST) and the metrics of during manufacturing will be fluctuated/influenced with the shortage of AM. Again, ρ values ($\rho < 0.05$) and t-values (t-value > 2.00) of H2a, H2b, & H2c for a garments manufacturing unit define that they are strongly linked sequentially without H2d since its ρ value (> 0.05) & t-value (< 2.00) do not provide sufficient strength for acceptance. It means that OVH related to problem handling PH, PH is related to QP, and QP is related to CP but CP is not related to OF. Again, the ρ values (< 0.05) and t-values (> 2.00) for the hypotheses of H3a, H3b, & H3e without H3c & H3d define that they have strong contribution to ST. Besides this strong linkage of DMM to AMM, the ρ value (< 0.05) and t-value (> 2.00) of H4a also indicates that strategic fit (SF) is strongly linked to ST.

4.2 Metrics weight calculation by Fuzzy AHP

Fuzzy logic is a suitable method for simulating decision making procedure. To proceed through Fuzzy AHP 30 professional's opinions (opinions of production managers of different garments industries) were collected through a questionnaire. The questionnaire was sent to more than 100 production managers of different garments industries through mailing and we received only 30 professional's responses. Common linguistic terms were used in the questionnaire. To analyze their opinions, converting the qualitative terms into quantitative terms is required. It is not possible to make mathematical operations on linguistic values directly. This is why, the linguistic scale must be converted into fuzzy scale. The triangular fuzzy conversion scale given in table 4.4 had been used in the evaluation model of this research adopted from Chang (1996).

Table 4. 4 Triangular fuzzy conversion scale

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1,1,1)	(1,1,1)
Equally important	(1/2,1,3/2)	(2/3,1,2)
Weakly more important	(1,3/2,2)	(1/2,2/3,1)
Strongly more important	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more important	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more important	(5/2,3,7/2)	(2/7,1/3,2/5)

The questionnaire & comparison table (table A-2) added in appendix section (Appendix A) was provided to more than 100 professionals to get the comparison matrix (table 4.5) which is the first step of the analysis was built by taking the arithmetic mean of their evaluations.

Table 4. 5 Integrated pairwise comparison between main criteria

Criteria	OF	QP	AM	PH	OVH	CP	ST
OF	(1,1,1)	(0.75,1.25, 1.75)	(2.25, 2.75, 3.25)	(1, 1.5, 2)	(0.47, 0.63, 1.06)	(0.75, 1.25, 1.75)	(1.75, 2.25, 2.75)
QP		(1,1,1)	(0.75, 1.25, 1.75)	(0.5, 0.69, 1.17)	(1, 1.5, 2)	(1.25, 1.75, 2.25)	(0.45, 0.58, 0.83)
AM			(1,1,1)	(1.75, 2.25, 2.75)	(0.37, 0.45, 0.58)	(0.75, 1.25, 1.75)	(2.25, 2.75, 3.25)
PH				(1,1,1)	(1.75, 2.25, 2.75)	(0.75, 1.25, 1.75)	(1.75, 2.25, 2.75)
OVH					(1,1,1)	(1.25, 1.75, 2.25)	(0.37, 0.45, 0.58)
CP						(1,1,1)	(0.75, 1.25, 1.75)
ST							(1,1,1)

For the first level (i.e. for manufacturing metrics), the values of fuzzy synthetic extents with respect to the main attributes are calculated as follows (see Eq. (2)):

$$S_{OF} = (7.97, 10.63, 13.56) \otimes \left({}^{1}/_{74.25}\, , {}^{1}/_{57.29}\, , {}^{1}/_{43.50} \right) = (0.107, 0.186, 0.312)$$

$$S_{QP} = (5.52, 7.57, 10.33) \otimes \left({}^{1}/_{74.25}\, , {}^{1}/_{57.29}\, , {}^{1}/_{43.50} \right) = (0.074, 0.132, 0.238)$$

$$S_{AM} = (7, 8.86, 11.108) \otimes \left({}^{1}/_{74.25}\, , {}^{1}/_{57.29}\, , {}^{1}/_{43.50} \right) = (0.094, 0.155, 0.255)$$

$$S_{PH} = (6.96, 9.31, 11.82) \otimes \left({}^{1}/_{74.25}\, , {}^{1}/_{57.29}\, , {}^{1}/_{43.50} \right) = (0.094, 0.163, 0.272)$$

$$S_{OVH} = (6.15, 8.12, 10.23) \otimes \left({}^{1}/_{74.25}\, , {}^{1}/_{57.29}\, , {}^{1}/_{43.50} \right) = (0.083, 0.142, 0.235)$$

$$S_{CP} = (4.35, 5.79, 8.35) \otimes \left({}^{1}/_{74.25}\, , {}^{1}/_{57.29}\, , {}^{1}/_{43.50} \right) = (0.059, 0.101, 0.192)$$

$$S_{ST} = (5.54, 7, 8.85) \otimes \left({}^{1}/_{74.25}\, , {}^{1}/_{57.29}\, , {}^{1}/_{43.50} \right) = (0.075, 0.122, 0.203)$$

The degrees of possibility are calculated as below (see Eq. (7)):

$$V\left(S_{OF} \geq S_{QP}\right) = 1, \quad V\left(S_{OF} \geq S_{AM}\right) = 1, \quad V\left(S_{OF} \geq S_{PH}\right) = 1, \quad V\left(S_{OF} \geq S_{OVH}\right) = 1, \quad V\left(S_{OF} \geq S_{CP}\right) = 1, \quad V\left(S_{OF} \geq S_{ST}\right) = 1$$

$$V\left(S_{QP} \geq S_{OF}\right) = 0.709, \quad V\left(S_{QP} \geq S_{AM}\right) = 0.864, \quad V\left(S_{QP} \geq S_{PH}\right) = 0.825, \quad V\left(S_{QP} \geq S_{OVH}\right) = 0.942, \quad V\left(S_{QP} \geq S_{CP}\right) = 1, \quad V\left(S_{QP} \geq S_{ST}\right) = 1$$

$$V\left(S_{AM} \geq S_{OF}\right) = 0.828, \quad V\left(S_{AM} \geq S_{QP}\right) = 1, \quad V\left(S_{AM} \geq S_{PH}\right) = 0.954, \quad V\left(S_{AM} \geq S_{OVH}\right) = 1, \quad V\left(S_{AM} \geq S_{CP}\right) = 1, \quad V\left(S_{AM} \geq S_{ST}\right) = 1$$

$$V\left(S_{PH} \geq S_{OF}\right) = 0.877, \quad V\left(S_{PH} \geq S_{QP}\right) = 1, \quad V\left(S_{PH} \geq S_{AM}\right) = 1, \quad V\left(S_{PH} \geq S_{OVH}\right) = 1, \quad V\left(S_{PH} \geq S_{CP}\right) = 1, \quad V\left(S_{PH} \geq S_{ST}\right) = 1$$

$$V\left(S_{OVH} \geq S_{OF}\right) = 0.745, \quad V\left(S_{OVH} \geq S_{QP}\right) = 1, \quad V\left(S_{OVH} \geq S_{AM}\right) = 0.916, \quad V\left(S_{OVH} \geq S_{PH}\right) = 0.872, \quad V\left(S_{OVH} \geq S_{CP}\right) = 1, \quad V\left(S_{OVH} \geq S_{ST}\right) = 1$$

$$V\left(S_{CP} \geq S_{OF}\right) = 0.500, \quad V\left(S_{CP} \geq S_{QP}\right) = 0.791, \quad V\left(S_{CP} \geq S_{AM}\right) = 0.646, \quad V\left(S_{CP} \geq S_{PH}\right) = 0.615, \quad V\left(S_{CP} \geq S_{OVH}\right) = 0.729, \quad V\left(S_{CP} \geq S_{ST}\right) = 0.848$$

$$V\left(S_{ST} \geq S_{OF}\right) = 0.602, \quad V\left(S_{ST} \geq S_{QP}\right) = 0.928, \quad V\left(S_{ST} \geq S_{AM}\right) = 0.770, \quad V\left(S_{ST} \geq S_{PH}\right) = 0.730, \quad V\left(S_{ST} \geq S_{OVH}\right) = 0.860, \quad V\left(S_{ST} \geq S_{CP}\right) = 1$$

For each pair-wise comparison, the minimum of the degrees of possibility is found as below (see Eq. (8)):

$$Min\, V\left(S_{OF} \geq S_i \right) = 1$$

$$Min\, V\left(S_{QP} \geq S_i \right) = 0.709$$

$$Min\, V\left(S_{AM} \geq S_i \right) = 0.828$$

$$Min\, V\left(S_{PH} \geq S_i \right) = 0.877$$

$$Min\,V\;(\,S_{OVH}\;\geq\;S_i\,) = 0.745$$

$$Min\,V\;(\,S_{CP}\;\geq\;S_i\,) = 0.500$$

$$Min\,V\;(\,S_{ST}\;\geq\;S_i\,) = 0.602$$

These values yield the following weights vector:

$$W' = (1,\;\; 0.709,\;\; 0.828,\;\; 0.877,\;\; 0.745,\;\; 0.500,\;\; 0.602)^T$$

Via normalization, the importance weights (i.e. eigenvalues) of the main attributes (manufacturing metrics) are calculated as follows:

$$\text{Normalized weight matrix, W} = \begin{bmatrix} w_{OF} \\ w_{QP} \\ w_{AM} \\ w_{PH} \\ w_{OVH} \\ w_{CP} \\ w_{ST} \end{bmatrix} = \begin{bmatrix} 0.1895 \\ 0.1349 \\ 0.1571 \\ 0.1664 \\ 0.1416 \\ 0.0957 \\ 0.1148 \end{bmatrix}$$

The matrix W shows order fill rate (OF), problem handling (PH), and availability of materials (AM) have comparatively more weight among the seven manufacturing metrics. This (W) also indicates that these three metrics are more important for a manufacturing unit. On the other hand, order variation handle (OVH), quality perfection (QP), shipment time (ST) and cost performance (CP) have comparatively lower weight. For the explanation of lower values of these metrics, the management replies that their performance is depended on the performance of OF, PH, and AM.

4.3 Calculation of strategic manufacturing fit, security level achievement, and associated loss/penalty

4.3.1 Data collection

Table 4.6 is the summary of order details aggregation (table A3-A8) of unit 4 of Fakir Apparels Ltd. for six months from July to December of 2016. This table shows, there are due time production 29, late production 4 and late shipment 1 (in December). When the manufacturers fails to fill the order quantity by extending the production time more than two times or three times, that results in late shipment. In September, November and December, there are 1, 1, and 2 late productions respectively. The management teams succeeded to achieve their production target by extending the production time once, that resulted late production but not late shipment (September, November, & December). But another order in December resulted late shipment.

Table 4. 6 Summary of order details from the month July to December

Months	Order details						
	Due time production	More than 80% material availability	More than 60% material availability	Late production	Late shipment	Production stopped due to lack of raw materials	Order continued to the next month
July	5	1				1	5
August	6		1				3
September	5			1		1	5
October	4	1	1			2	5
November	6			1			6
December	3			2	1		6

4.3.2 Calculation of strategic point and achieved point for OF, AM and ST

Since availability of materials (AM) has a direct effect on order fill rate (OF) and shipment time (ST) (Wagner et al. 2012; Rahman & Amin, 2016), the failure of AM will cause the failure of OF, and ST. Table 4.7 makes it easy to understand that, insufficient AM (>80% even > 60%) made it failure due time OF 4 times and due time shipment 1 time. This is one of the causes of failure for the achievement of 100% strategic fit. The fall of strategic point for the metrics OF, AM, and ST had been calculated and shown in table 4.9.

Table 4. 7 Calculation of strategic point and achieved point for OF, AM and ST

Manu. metrics	Manufacturing Capabilities	Weight	No. of orders	Strategic point	Achieved point	Total achieved point	Security level
Order fill rate (OF)	Due time order fill (due time production)	5	29	(33*5)*1.0 =165	145	145*1.0 =145	165*1.0 =165
	Late order fill (late production)	0	4		0		
Availability of materials (AM)	Availability of 100% materials at the beginning of order	5	29	(33*5)*.90 =148.5	145	153*.90 =137.7	165*.80 =132
	Availability of >80% materials at the beginning of order	3	2		6		
	Availability of >60% materials at the beginning of order	1	2		2		
Shipment time (ST)	Due time shipment	5	32	(33*5)*1.0 =165	160	160*1.0 =160	165*1.0 =165
	Late shipment	0	1		0		

4.3.3 Calculation of strategic point and achieved point for QP, PH, OVH and CP

The remaining four metrics (QP, PH, OVH, & CP) with their achievement level (high, moderate and low) had been shown in table 4.8 which is the summarization of table A-9. Since QP, PH, OVH and CP are related with each other (Berg et al. 1996; Wagner et al. 2012; Rahman & Amin, 2016), it sometimes becomes very difficult for the manufacturers to achieve the highest weight value always for all of them (Geršak, 2002; Ferdousi, 2009). When the manufacturers fail to handle order variation, they fail to achieve better quality and ultimately fails to achieve better cost performance (Wagner et al. 2012).

Table 4. 8 Calculation of strategic point and achieved point for QP, PH, OVH and CP

Metrics & its classification with weight value	Manufacturing Metrics											
	QP			PH			OVH			CP		
	High	Mod.	Low	High	Mod.	Low	High	Mod.	Low	High	Mod.	Low
	13	19	1	18	13	2	18	12	3	23	10	0
Scale value (weight)	5	3	1	5	3	1	5	1	0	5	1	0
Achieved Point	65	57	1	90	39	2	90	12	0	115	10	0
Sum of achieved Point	123			131			102			125		
Possible highest strategic point	33*5=165			33*5=165			33*5=165			33*5=165		
Strategic point	165*1.0=165			165*1.0=165			165*0.90=148.5			165*.95=156.75		
Achieved point	123*1.0=123			131*1.0=131			102*0.90=91.8			125*0.95=118.75		
Security level	165*.85=140.25			165*1.0=165			165*.80=132			165*.85=140.25		

4.3.4 Fitness, security level achievement, and loss/penalty calculation of unit 4

Table 4.9 shows the aggregated strategic points, achieved points, and also security level for all manufacturing metrics. From this table 4.10 and figure 4.6, we can see that only one manufacturing metric (AM) is above the security level and others are below the security level. That means the manufacturers succeeded to maintain the security level for only one manufacturing metric (AM) during the production period from July to December, 2016. Here, total strategic point is 159.281 and total achieved point is 130.232 i.e. strategic fitness 130.232/159.281=81.76% and security level achievement 87.15% (130.232/149.435). We can visualize the strategic fit/unfit zone by figure 4.7 and figure 4.8.

Table 4. 9 Calculation of strategic fit

<table>
<tr><th rowspan="2">Types of point</th><th colspan="7">Manufacturing metrics</th><th rowspan="2">Total point</th></tr>
<tr><th>OF</th><th>AM</th><th>ST</th><th>QP</th><th>PH</th><th>OVH</th><th>CP</th></tr>
<tr><td>Strategic point</td><td>165</td><td>148.5</td><td>165</td><td>165</td><td>165</td><td>148.5</td><td>156.75</td><td>1113.75</td></tr>
<tr><td>Achieved point</td><td>145</td><td>137.7</td><td>160</td><td>123</td><td>131</td><td>91.8</td><td>118.75</td><td>907.25</td></tr>
<tr><td>Security level</td><td>165</td><td>132</td><td>165</td><td>140.25</td><td>165</td><td>132</td><td>140.25</td><td rowspan="2"></td></tr>
<tr><td>Metrics weight</td><td>0.1895</td><td>0.1571</td><td>0.1148</td><td>0.1349</td><td>0.1664</td><td>0.1416</td><td>0.0957</td></tr>
<tr><td>Strategic point</td><td>31.267</td><td>23.329</td><td>18.942</td><td>22.258</td><td>27.456</td><td>21.027</td><td>15.000</td><td>159.281</td></tr>
<tr><td>Achieved point</td><td>27.477</td><td>21.632</td><td>18.368</td><td>16.592</td><td>21.798</td><td>12.998</td><td>11.364</td><td>130.232</td></tr>
<tr><td>Point differences</td><td>3.79</td><td>1.697</td><td>0.574</td><td>5.666</td><td>5.658</td><td>8.029</td><td>3.636</td><td>29.049</td></tr>
<tr><td>Security level</td><td>31.267</td><td>20.737</td><td>18.942</td><td>18.919</td><td>27.456</td><td>18.691</td><td>13.421</td><td>149.435</td></tr>
<tr><td>Security level sustainability</td><td>Break</td><td>Sustain</td><td>Break</td><td>Break</td><td>Break</td><td>Break</td><td>Break</td><td></td></tr>
<tr><td>Strategic fitness (SF)</td><td colspan="3">130.232/159.281=0.8176
i.e., 81.76%</td><td colspan="2">Security level achieved</td><td colspan="3">130.232/149.435= 0.8715
i.e. 87.15%</td></tr>
<tr><td>Net achievement</td><td colspan="3">0.8176*0.8715= 71.26%</td><td colspan="2">Loss/penalty from achievement</td><td colspan="3">(81.76-71.26)%
= 10.50%</td></tr>
</table>

Table 4. 10 Achievement summary for manufacturing unit 4

Criteria	Metrics above security level	Metrics below security level	Strategic fitness	Security level achievement	Net achievement	Loss/ penalty
Achievement	1/7	6/7	81.76%	87.15%	71.26%	10.50%

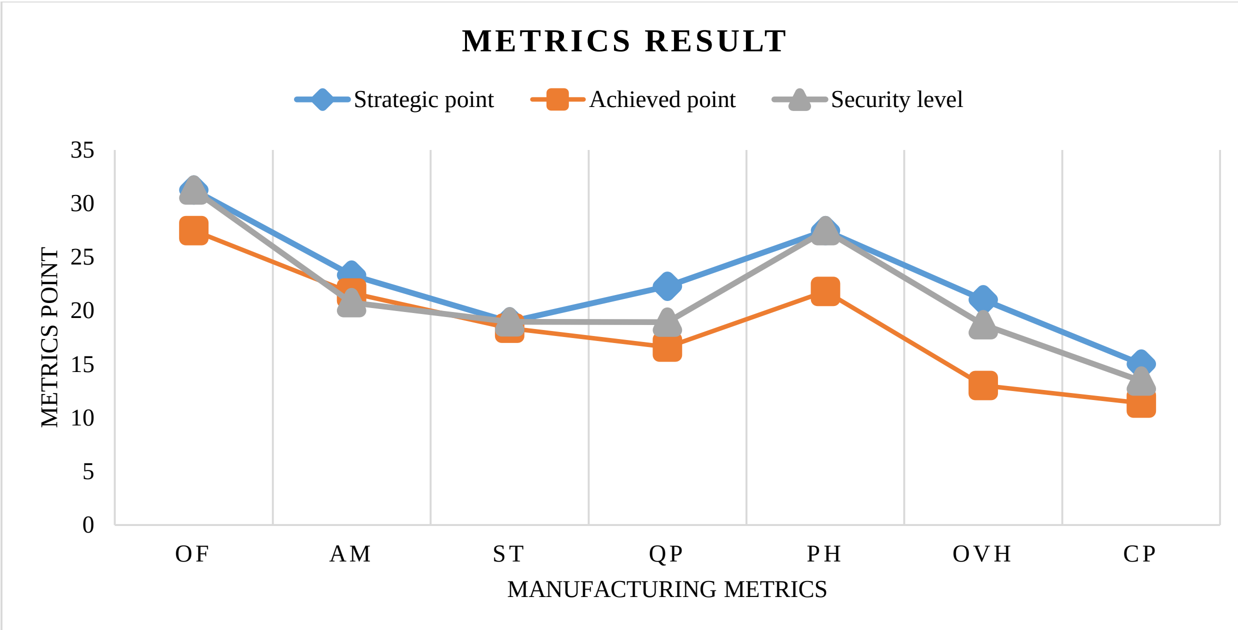


Figure 4. 6 Manufacturing metrics sustainability

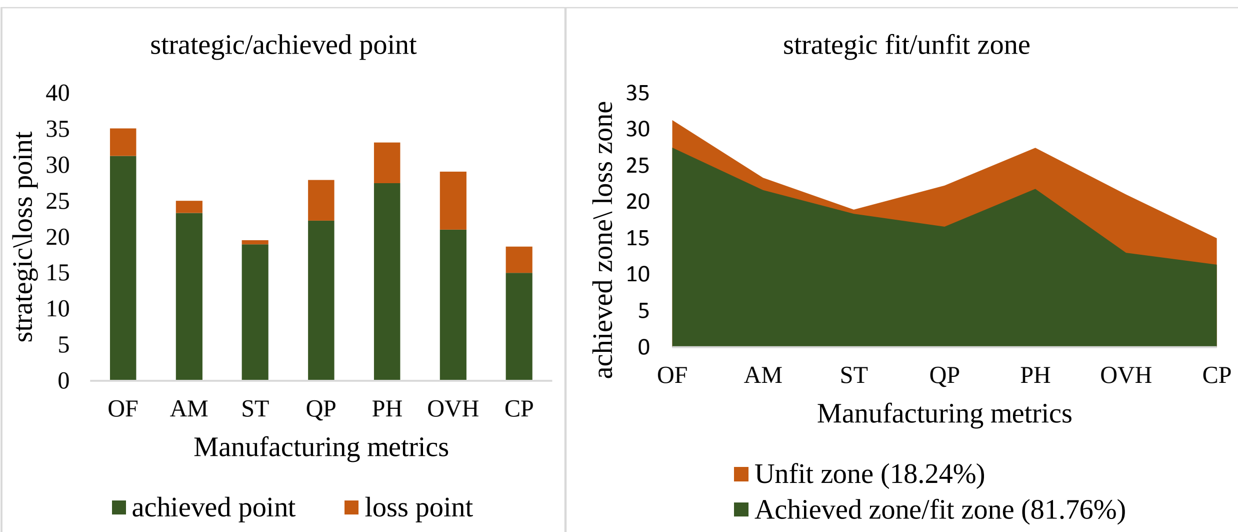


Figure 4. 7 Strategic fit and unfit zone

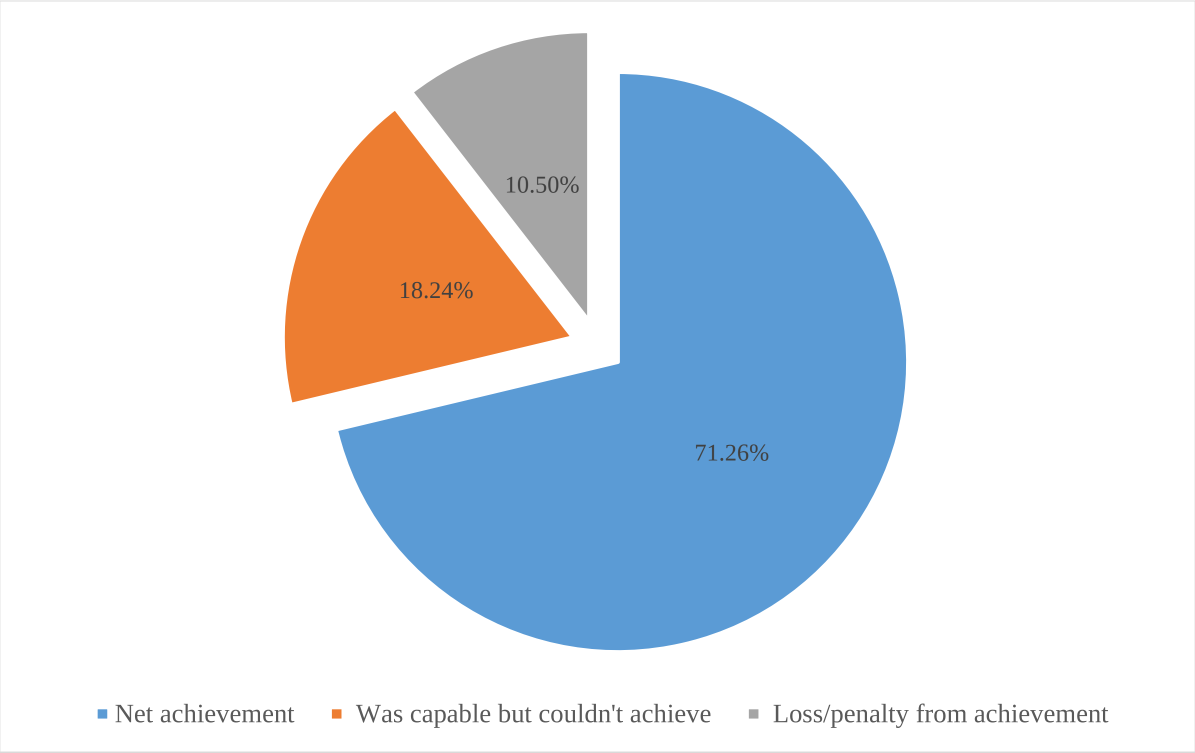


Figure 4. 8 Achievement summary of manufacturing unit 4

From this results, we can see that the manufacturers failed to achieve 100% security level. Failure to achieve up to the security level causes loss/penalty from the net achievement. Here, security level achievement is 87.15% for unit 4. This failure of the manufacturers reduced their strategic fitness from 81.76% to 71.26%. That means the manufacturers had to face (81.76-71.26) % = 10.50% loss/penalty from their net achievement. This is a big penalty for the manufacturers. Behind this penalty from manufacturing achievement and fall of security level of unit 4, manufacturing metrics OVH, QP, PH, & CP have the worst effect. Besides this, there is an alarming issue that 6 metrics out of 7 couldn't achieve the security level. Only one metric achieved the security level. So, this can be stated that the manufacturers of unit 4 failed to achieve their satisfactory results.

This result was shown to the manufacturers of unit 4 of Fakir Apparels Ltd. and they gave their positive consent to this results. From their positive consent, we inspired to develop a conceptual and mathematical model of strategic fit of a manufacturing unit. Chapter 5 shows a conceptual model and few mathematical models for the determination of manufacturing fitness.

CHAPTER 5

Development of Strategic Fit Model

5.1 Conceptual model of strategic fit

Previous sections show the details calculation of all processes to determine strategic fitness of a manufacturing unit. These calculations can be summarized and visualized by the following six stepped conceptual model represented by figure 5.1.

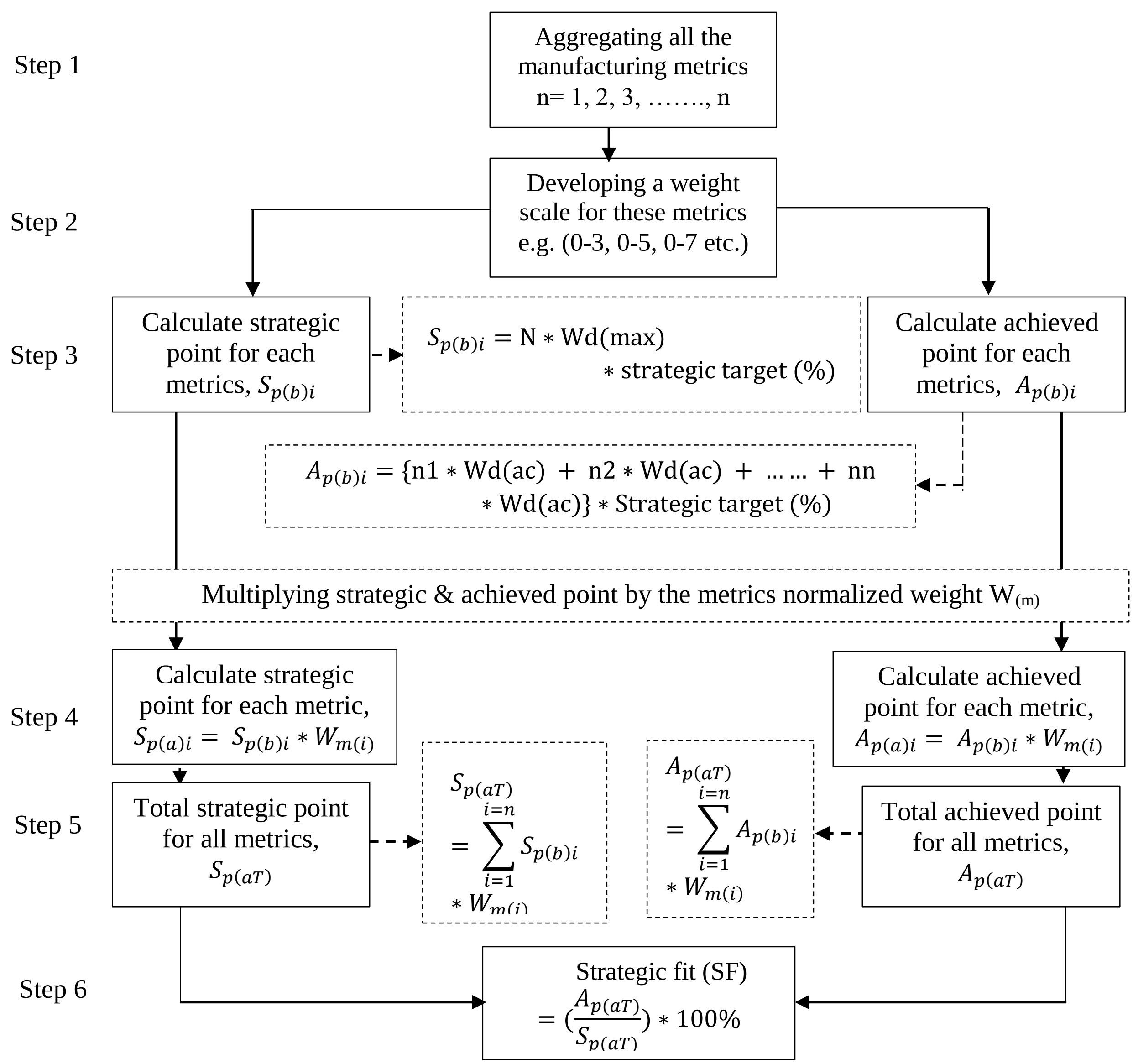


Figure 5. 1 Strategic fit conceptual model

5.2 Mathematical model of strategic fitness, security level achievement, and loss/penalty

Step 1 (Aggregating all the manufacturing metrics)

In this step, manufacturers have to aggregate all the manufacturing metrics for a manufacturing unit. This research shows that there are 7 (n=7) manufacturing metrics for a garments manufacturing industry and they are AM, OF, QP, PH, OVH, CP, and ST.

Step 2 (Set a weight scale for the metrics)

The manufacturers have to set a weight scale after aggregating the manufacturing metrics. The manufacturers of Fakir Apparels Ltd. preferred to set a scale ranges 0-5 and also preferred to give different values for different metrics based on their capabilities and metrics importance.

Step 3 (Calculation of strategic point and achieved point for each metric)

Strategic point,

$$S_{p(b)i} = \mathrm{N} * \mathrm{Wd(max)} * \text{strategic target (\%)}$$

Achieved point,

$$A_{p(b)i} = \{\mathrm{n1} * \mathrm{Wd(ac)} + \mathrm{n2} * \mathrm{Wd(ac)} + \dots\dots\dots\dots\dots\dots + \mathrm{nn} * \mathrm{Wd(ac)}\} * \text{Strategic target (\%)}$$

Where, $\mathrm{N} = \text{Total number of orders and } \mathrm{N} = \mathrm{n1} + \mathrm{n2} + \dots\dots\dots + \mathrm{nn}$

$\mathrm{Wd(max)} = \text{maximum scale weight}$

$\mathrm{Wd(ac)} = \text{achieved scale weight}$

For an example, Strategic point for OF,

$$S_{p(b)1} = \mathrm{N} * \mathrm{Wd(max)} * \text{strategic target (\%)} = 33 * 5 * 1.0 = 165$$

And achieved point for OF,

$$A_{p(b)1} = \{\mathrm{n1} * \mathrm{Wd(ac)} + \mathrm{n2} * \mathrm{Wd(ac)} + \dots\dots\dots\dots\dots\dots + \mathrm{nn} * \mathrm{Wd(ac)}\} * \text{Strategic target (\%)}$$

$$= (29 * 5 + 4 * 0) * 1.0 = 145$$

The management can aggregate total strategic point and achieved point before multiplying by the metrics weight (W_m)

Total strategic point,

$$S_{p(bT)} = \sum_{i=1}^{i=n} S_{p(b)i}$$

$$= S_{p(b)1} + S_{p(b)2} + \dots\dots\dots\dots\dots.. + S_{p(b)7}$$

$$= S_{p(b)AM} + S_{p(b)OF} + \dots\dots\dots\dots\dots.. + S_{p(b)ST}$$

Total achieved point,

$$A_{p(bT)} = \sum_{i=1}^{i=n} A_{p(b)i}$$

$$= A_{p(b)1} + A_{p(b)2} + \dots\dots\dots\dots\dots.. + A_{p(b)7}$$

$$= A_{p(b)AM} + A_{p(b)OF} + \dots\dots\dots\dots\dots.. + A_{p(b)ST}$$

Step 4 (Calculate strategic point & achieved point by multiplying, W_m for each metric)

In this step, strategic point and achieved point had been calculated by multiplying the strategic point and achieved point with its corresponding normalized weight(W_m).

Strategic point,

$$S_{p(a)i} = S_{p(b)i} * W_{m(i)}$$

Achieved point,

$$A_{p(a)i} = A_{p(b)i} * W_{m(i)}$$

For an example, strategic point for OF,

$$S_{p(a)1} = S_{p(b)1} * W_{m(1)} = 165 * 0.1895 = 31.267$$

Achieved point for OF,

$$A_{p(a)1} = A_{p(b)1} * W_{m(1)} = 145 * 0.1895 = 27.477$$

Step 5 (Aggregating the strategic point & achieved point for all metrics)

The strategic point and achieved point for the metric OF are 31.267 and 27.477. By the similar way we can determine the strategic point and achieved point for all manufacturing metrics and this step aggregating these points for all manufacturing metrics.

Total strategic targeted point,

$$S_{p(aT)} = \sum_{i=1}^{i=n} S_{p(b)i} * W_{m(i)}$$

$$For\ unit\ 4, \qquad S_{p(aT)} = \sum_{i=1}^{i=7} S_{p(b)i} * W_{m(i)} = 159.281$$

Total strategic achieved point,

$$A_{p(aT)} = \sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}$$

$$For\ unit\ 4, \qquad A_{p(aT)} = \sum_{i=1}^{i=7} A_{p(b)i} * W_{m(i)} = 130.232$$

Step 6 (Determination of strategic fitness)

From the aggregated values of total strategic point and achieved point, we can determine the strategic fitness of a manufacturing unit. For unit 4 of Fakir Apparels Ltd. total strategic point and achieved point is 159.281 and 130.232. The strategic fitness of the unit 4 can be determined by the following equation (1).

Strategic fitness

$$SF = \left(\frac{A_{p(aT)}}{S_{p(aT)}}\right) * 100\%$$

$$= \left(\frac{\sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}}{\sum_{i=1}^{i=n} S_{p(b)i} * W_{m(i)}}\right) * 100\%$$

$$Again, \qquad SF = \left[\frac{\sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}}{\sum_{i=1}^{i=n} S_{p(b)i} * W_{m(i)}}\right] * 100\%$$

$$= \left[\frac{\sum_{i=1}^{i=n} \left\{\frac{M_{i\ (Strategic\ Achievement)}}{M_{i\ (Strategic\ Capability)}}\right\}}{n}\right] * 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$= \frac{130.232}{159.281} * 100\% = 81.76\%$$

Equation (1) is the mathematical model of manufacturing fitness that evaluates the fitness of a manufacturing unit. By using this model, we got 81.65% fitness for unit 4. The manufacturers also can evaluate security level and security level achievement by using the equations (2) and (3) respectively.

$$Security\ level$$

$$= \left[\sum_{i=1}^{i=n} M_{\max(Strategic\ point)(i)} * S_{L(i)} * W_{m(i)}\right] \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$For\ unit\ 4, \qquad Security\ level = \left[\sum_{i=1}^{i=7} M_{\max(Strategic\ point)(i)} * S_{L(i)} * W_{m(i)}\right]$$

$$= 149.435$$

$$Security\ level\ achievement = \left[\frac{\left(\sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}\right)}{\left(\sum_{i=1}^{i=n} M_{\max(Strategic\ point)(i)} * S_{L(i)} * W_{m(i)}\right)}\right] * 100\% \ \ldots.(3)$$

$$For\ unit\ 4, \quad Security\ level\ achievement = \left[\frac{\left(\sum_{i=1}^{i=7} A_{p(b)i} * W_{m(i)}\right)}{\left(\sum_{i=1}^{i=7} M_{\max(Strategic\ point)(i)} * S_{L(i)} * W_{m(i)}\right)}\right] * 100\%$$

$$= \frac{130.232}{149.435} = 87.15\%$$

$where, S_L = Security\ level\ (in\ percentage)$

Since the manufacturers couldn't achieve 149.435 point, they couldn't achieve 100% security level. They only achieved 87.15% security level. This lack of security level decreases the strategic achievement. From the below equation (4), manufacturers of unit 4 acquired only 71.26% achievement. The penalty due to lack of security level achievement can also be evaluated by using the equation (5).

$$Net\ achieved = SF * Security\ level\ hold$$

$$= \left[\left[\frac{\sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}}{\sum_{i=1}^{i=n} S_{p(b)i} * W_{m(i)}}\right] * \left[\frac{\left(\sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}\right)}{\left(\sum_{i=1}^{i=n} M_{\max(Strategic\ point)(i)} * S_{L(i)} * W_{m(i)}\right)}\right]\right] * 100 \ldots \ldots (4)$$

$$= 81.76\% * 87.15\% = 71.26\%$$

$$Loss\ or\ penalty\ (Loss\ from\ net\ revenue) = strategic\ fitne - net\ achievement$$

$$= \left[\left[\frac{\sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}}{\sum_{i=1}^{i=n} S_{p(b)i} * W_{m(i)}}\right] * 100\%\right] - \left[\left[\frac{\sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}}{\sum_{i=1}^{i=n} S_{p(b)i} * W_{m(i)}}\right] * \left[\frac{\left(\sum_{i=1}^{i=n} A_{p(b)i} * W_{m(i)}\right)}{\left(\sum_{i=1}^{i=n} M_{\max(Strategic\ point)(i)} * S_{L(i)} * W_{m(i)}\right)}\right]\right] * 100\% \ldots \ldots (5)$$

$$= 81.76\% - 71.26\% = 10.50\%$$

CHAPTER 6

Analysis of Metrics Significance on Manufacturing Fitness

From the results of manufacturing unit 4, we can understand that the cumulative achieved point decreased gradually by the fall of metrics. The fall of metrics OVH, QP, PH, and CP is more comparatively than the other metrics. Besides according to the manufacturers, the metrics availability of materials (AM), order fill rate (OF) and problem handling (PH), and order variation handle (OVH) are very crucial for a manufacturing unit because they are related to the other metrics quality perfection (QP), cost performance (CP), and shipment time (ST). Achievement fluctuations for the metrics AM, OF, PH, and OVH fluctuated the achievement of QP, CP, and ST that eventually make a fluctuation to manufacturing fitness achievement.

This is necessary to verify the effect of the metrics on the manufacturing fitness statistically. For this purpose, this research has integrated all the manufacturing sub metrics for each metrics by literature reviewing and manufacturer's suggestions that is shown in table 3.4.

6.1 Item generation

The list of metrics (aggregated in table 3.1) and sub metrics (aggregated in table 3.4) with their proper definition was presented to their manufacturers of different garments manufacturing firms such as *Fakir Apparels Ltd., Liz Fashion Ltd., FCI BD Ltd., Epyllion Group, and SQ Birichina Ltd*. The questionnaire set was interactive, easy and relevant so that the reader can understand easily. They were requested to add or drop any metrics or sub metrics if they feel necessary or redundant/unnecessary. Finally, the aggregated set of metrics and sub metrics with the related questionnaire were discussed with academic experts of supply chain and logistic, operations management and manufacturing technologies. This was also mailed to the manufacturing experts of *Fakir Apparels Ltd., Liz Fashion Ltd., FCI BD Ltd., Epyllion Group, and SQ Birichina Ltd*. After their modification, table 3.4 was selected as final and these are the generated items for significance analysis again shown in table 6.1.

Five point (1-5) Likert scales were used for the evaluation of questionnaire set (table A-11) related to manufacturing metrics and their sub metrics with their proper definition (table A-10) where 1-2 = low impact, 2-4 = moderate impact, and 5 = most importance. There are some cases, where the management team and executives preferred to give very low point (1) since these cases don't add any contribution to manufacturing fitness even create loss/penalty for the manufacturers. For an example, failure to due time shipment has no contribution in manufacturing fitness. Even, it creates discount or losses for the company.

Table 6. 1 Item generation for significance analysis

Manufacturing metrics	Manufacturing sub metrics	Manufacturing capabilities
		Manufacturing capabilities on availability of materials (AM)
Availability of materials (AM)	AM1	Storing all the materials before starting the order
	AM2	Collecting the remaining materials for that case when there is not available 100% materials but order has been started
	AM3	Availability of all the accessories
	AM4	Sending the list of materials in the cutting department and stores for the associated orders with a good lead time
Order fill rate (OF)	OF sub metrics	Manufacturing capabilities on order fill rate (OF)
	OF1	Availability of all materials
	OF2	Workers and employees performance
	OF3	Production time
	OF4	Automated machine instead of manual machines
	OF5	Supervising
Quality perfection (QP)	QP sub metrics	Manufacturing capabilities on quality perfection (QP)
	QP1	Availability of all materials
	QP2	Pre-production activities (Dying, washing, printing and cutting)
	QP3	Materials quality
	QP4	Workers and employees performance
	QP5	Quality inspection by quality control department
	QP6	Automated machines instead of manual machines
	QP7	Supporting the operators by helpers
	QP8	Post production activities (Ironing, Embroidery and printing)
Problem handling (PH)	PH sub metrics	Manufacturing capabilities on problem handling (PH)
	PH1	Availability of all materials
	PH2	Automated machines
	PH3	Skilled operators and workers
	PH4	Proper power supply
	PH5	Differentiate the production lines according to order size and product item
	PH6	Sufficient expert technician
Order variation handle (OVH)	OVH sub metrics	Manufacturing capabilities on order variation handle (OVH)
	OVH1	Availability of all materials
	OVH2	Differentiate the production lines based on order size and product item
	OVH3	Production in a single time
	OVH4	Don’t start the another order by breaking the running order
	OVH5	Maximum production for different orders by not changing the existing layout (if possible)
Cost performance (CP)	CP sub metrics	Manufacturing capabilities cost performance (CP)
	CP1	Availability of all materials
	CP2	Skilled operator
	CP3	Automated machines
	CP4	Try to avoid overtime schedule

	CP5	Avoid subcontracting production system
	CP6	Training programs among the operators on production techniques
	CP7	Due time shipment
Shipment time (ST)	ST sub metrics	Manufacturing capabilities on shipment time (ST)
	ST1	Order fill rate
	ST2	Quality perfection
	ST3	Problem handling
	ST4	Order variation handle
	ST5	Cost performance
	ST6	Complete the production in time
	ST7	Time interval between the production time and shipment time
	ST8	Problem handling capability
	ST9	Order variation handle capability
Manufacturing fitness (MF)	MF sub metrics	Management capabilities by manufacturing fit (MF)
	MF1	Shipment time/delivery time
	MF2	Utilization of maximum manufacturing capabilities
	MF3	Utilization of employee's and worker's capabilities
	MF4	Earning foreign exchange
	MF5	Better growth of the organization

6.2 Pilot study

A pilot study was conducted among the targeted respondents. About 160 executives (manufacturing managers/assistant managers, supply chain managers/assistant managers, merchandizing managers/assistant managers, facility/plant managers/assistant managers, materials managers/assistant managers etc.) were mailed for the evaluation. 52 responses were received and that was the sample for the pilot study. The sample size 52 is large enough for the pilot study stage (Hair et al. 1995; pp 373). The sample adequacy was measured with the help of Kaiser-Meyer-Olkin (KMO) adequacy measurement which determines the appropriateness of factor analysis (Kaiser, 1970). In this case, factor analysis was appropriate.

6.3 Scale development for Before Manufacturing Metrics (BMM), During Manufacturing Metrics (DMM) and After Manufacturing Metrics (AMM)

Table 6.2 shows the results of purification of the manufacturing sub metrics by using the CITCs and Cronbach's alpha. The item inter-correlation matrices provided by SPSS®. The items those does not strongly contribute to Cronbach alpha (Cronbach, 1951) was eliminated/dropped down that resulted table 6.2 and this table shows the list of retained items. The retained items were carried for the further calculation that will indicate sound construct validity.

Table 6. 2 CITCs and reliabilities of the manufacturing metrics after purification (n=178)

Item	CITC	Cronbach's α for the retained items
Before manufacturing metrics (BMM)		
Availability of materials (AM)		
AM1: Storing all the materials before starting the order	0.699	
AM2: Collecting the remaining materials for that case when there is not available 100% materials but order has been started	0.706	
AM3: Availability of all the accessories	0.744	α = 0.747
[a]**AM4:** Send the list of materials in the cutting department and stores of the associated orders with a good lead time	0.215	
During manufacturing metrics (DMM)		
Order fill rate (OF)		
OF1: Availability of all materials	0.698	
OF2: Workers and employees performance	0.759	
OF3: Production time	0.685	α = 0.708
[a]**OF4:** Automated machine instead of manual machines	0.206	
[a]**OF5:** Supervising	0.070	
Quality perfection (QP)		
[a]**QP1:** Availability of all materials	0.076	
QP2: Pre-production activities (Dying, washing, printing and cutting)	0.738	
QP3: Materials quality	0.828	
QP4: Workers and employees performance	0.876	α = 0.763
QP5: Quality inspection by quality control department	0.711	
QP6: Automated machines instead of manual machines	0.639	
[a]**QP7:** Supporting the operators by helpers	-0.158	
QP8: Post production activities (Ironing, Embroidery and printing)	0.709	
Problem handling (PH)		
[a]**PH1:** Availability of all materials	0.275	
PH2: Automated machines	0.740	
PH3: Skilled operators and workers	0.604	
[a]**PH4:** Proper power supply	0.137	α = 0.703
[a]**PH5:** Differentiate the production lines according to order size and product item	0.313	
PH6: Sufficient expert technician	0.708	
Order variation handle (OVH)		
[a]**OVH1:** Availability of all materials	0.109	
OVH2: Differentiate the production lines based on order size and product item	0.762	
OVH3: Production in a single time	0.679	
OVH4: Don't start the another order by breaking the running order	0.602	α = 0.719
[a]**OVH5:** Maximum production for different orders by not changing the existing layout (if possible)	0.421	
Cost performance (CP)		
[a]**CP1:** Availability of all materials	0.140	
CP2: Skilled operator	0.923	
CP3: Automated machines	0.763	

CP4: Try to avoid overtime schedule	0.595	α = 0.838
CP5: Avoid subcontracting production system	0.770	
[a]**CP6:** Training programs among the operators on production techniques	0.287	
CP7: Due time shipment	0.763	
After manufacturing metrics (AMM)		
Shipment time (ST)		
ST1: Order fill rate	0.651	α = 0.746
[a]**ST2:** Quality perfection	0.322	
ST3: Problem handling	0.688	
ST4: Order variation handle	0.604	
[a]**ST5:** Cost performance	0.162	
ST6: Complete the production in time	0.633	
ST7: Time interval between the production time and shipment time	0.629	
Strategic fit (SF)		
[a]**SF1:** Shipment time/delivery time	0.373	α = 0.726
SF2: Utilization of maximum manufacturing capabilities	0.709	
SF3: Best performance based on their capabilities	0.679	
[a]**SF4**: Earning maximum FOB	0.244	
SF5: Better growth of the organization	0.512	

[a] Item dropped

Table 6.3 shows the list of remaining items after purification of the redundant items. 16 items had been dropped out from table 6.2 because their CITC value is less than 0.5. Before proceeding to the table 6.3, we discussed with senior management/management experts and manufacturers of different garments manufacturing units. Most of them gave positive consent and inspired us for the next proceedings. Based on the value of Cronbach alpha (α), the manufacturing metrics were prioritized/ranked sequentially that is shown in table 6.3.

Table 6. 3 Factors, loading, and reliabilities of the manufacturing metrics after factor analysis (n=178)

Item	Before manufacturing	During manufacturing					After manufacturing		α for retained items
	Availability of materials (AM)	Order fill rate (OF)	Quality perfection (QP)	Problem handling (PH)	Order variation handle (OVH)	Cost performance (CP)	Shipment time (ST)	Manufacturing fit (MF)	
		Ranking among the DMM based on α value							
		1st	2nd	4th	5th	3rd			
	KMO-0.709	KMO-0.761					KMO-0.807	KMO-0.703	
AM1	0.887								0.917
AM3	0.875								
AM2	0.745								
OF2		0.916							0.945
OF1		0.894							
OF3		0.850							
QP3			0.927						0.934
QP4			0.884						
QP2			0.814						
QP8			0.776						
QP5			0.756						
QP6			0.687						
PH6				0.826					0.880
PH2				0.817					
PH3				0.677					
OVH2					0.870				0.869
OVH4					0.737				
OVH3					0.657				
CP2						0.874			0.927
CP7						0.868			
CP5						0.839			
CP3						0.759			
CP4						0.704			
ST3							0.848		0.866
ST1							0.801		
ST7							0.648		
ST4							0.627		
ST6							0.539		
SF2								0.777	0.845
SF5								0.701	
SF3								0.662	
Eigen value	2.586	2.705	4.536	2.442	2.379	3.879	3.296	2.290	

[a] Item dropped

6.4 LISREL analysis and structural modeling

Figure 6.1 and Figure 6.2 shows the restatement of the model shown in Figure 3.3. The items (AM1, AM2, and AM3) from the scale development were utilized as the direct indicators of the exogenous latent variable of BMM. Composite scores for the factors OF, QP, PH, OVH and CP were shown as the observable indicators of the endogenous latent variable, DMM. The composite measures were calculated by summing the individual scores for each item in a dimension and then dividing by the number of items. For example, the responses to OF1, OF2, and OF3 were summed and then divided by three to determine the composite measure OF. Pearson product-moment correlation coefficient (r) determines predict validity of a relationship. Figure 6.1 shows a relationship among the metrics. Composite measures of the metrics were constructed and then submitted to SPSS® to determine Pearson product-moment correlation coefficient (r). The coefficient value of BMM to DMM is 0.942, DMM to ST (AMM) is 0.881 and ST to SF is 0.843 and these coefficient are significant at α=0.05. This indicates the validity the possible relationship of Figure 6.1.

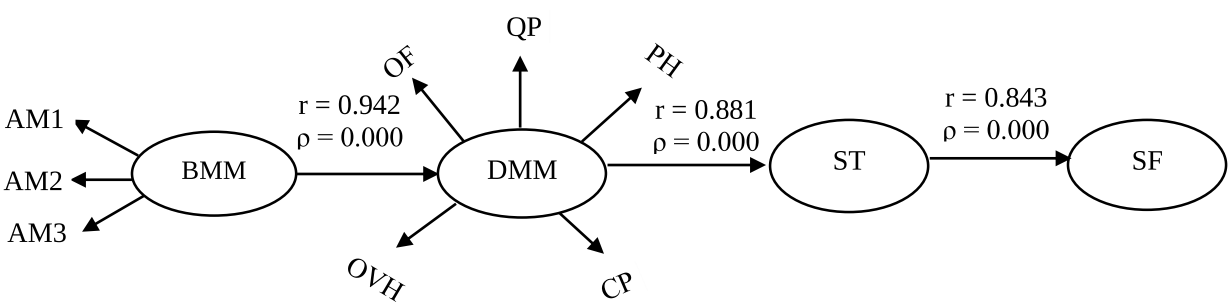
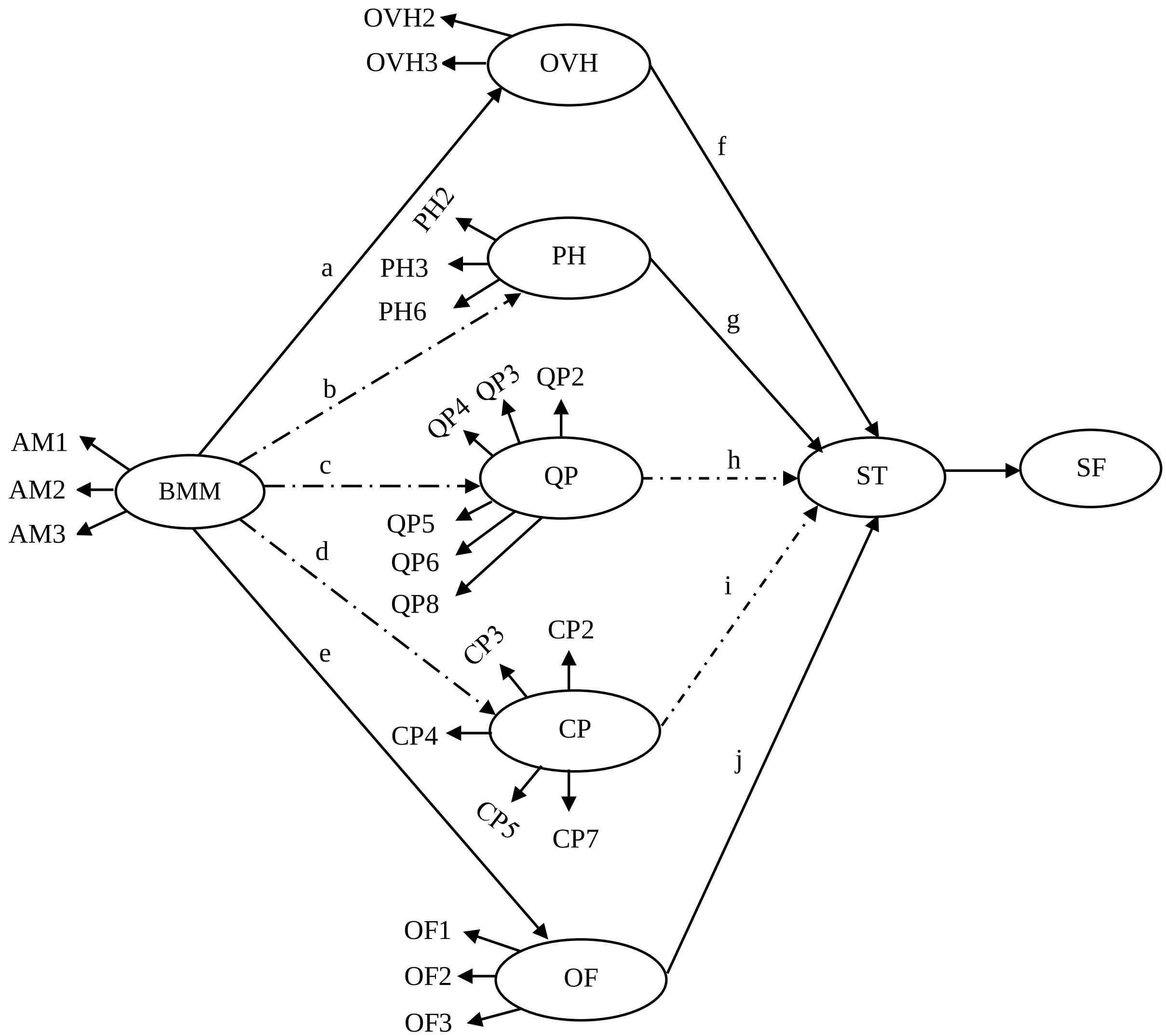


Figure 6. 1 Significance of AM to DMM, DMM to AMM and AMM to SF

Manufacturing metrics OF, PH, & OVH have strong contribution to ST and QP, & CP have less contributions that is shown in Figure 6.2. The t-value and ρ value justifies the strength of their contributions. QP and CP have weak contributions to ST since their t-value is less than 2.00 and their ρ value is not significant at α=0.05. According to the senior management/ management expert, QP and CP are hardly responsible for due time shipment. On the other hand, the remaining metrics OVH, PH, and OF have strong contributions to ST since the t-values are much greater than 2.00 and ρ values are significant at α=0.05.

The goodness-of-fit index (GGI) is used to evaluate the fitness of the models tested. GFI provides a measure the ranging from 0 to 1. The GFI value near to 1 justifies a 'good' model (Dillion and Goldstein, 1984). The GFI for this model is 0.931 and goodness-of-fit index adjusted for the degree of freedoms (AGFI) is 0.892 which is also good. Both of them evaluate the fitness of this model.



a	t = 5.411& ρ = 0.000	Significant	f	t = 8.50 & ρ = 0.000	Significant	Results: GFI =0.931 AGFI =0.892 n = 178
b	t = 1.825 & ρ = 0.079	Not Significant	g	t = 6.21 & ρ = 0.000	Significant	
c	t = 1.326 & ρ = 0.197	Not significant	h	t = 1.75 & ρ = 0.091	Not significant	
d	t = 0.532 & ρ = 0.599	Not significant	i	t = 1.25 & ρ = 0.222	Not significant	
e	t = 13.72 & ρ = 0.000	Significant	j	t = 9.00 & ρ = 0.000	Significant	

Figure 6. 2 Significance of sub metrics to DMM, and DMM to ST

From table 4.10 and figure 4.8, we can see that the manufacturers of unit 4 couldn't achieve their satisfactory results. To make easy the reasons why they couldn't achieve up to their satisfactory results, we analyzed Linear Structural Relations (LISREL) with structural modeling by integrating sub metrics for each manufacturing metric. 47 sub metrics (4 sub metrics for AM, 5 sub metrics for OF, 8 sub metrics for QP, 6 sub metrics for PH, 5 sub metrics for OVH, 7 sub metrics for CP, 7 sub metrics for ST, 5 sub metrics for

SF) for 7 metrics were integrated for scale development and LISREL analysis. During scale development 16 sub metrics dropped and the remaining 31 sub metrics sustained since the value of Cronbach alpha (α) for them was above the satisfied level (α=0.7). Scale development also showed the important variables/items to exogenous latent variables and endogenous latent variables. Latent variables, and composites measured variables for each exogenous latent variable (BMM) and endogenous latent variable (DMM, ST, & SF) after LISREL analysis had been shown by the figure 6.1.

Pearson product-moment correlation coefficient (r) and ρ values give the evidence that availability of materials (AM) is related to the metrics of during manufacturing (OF, QP, PH, OVH, and CP), especially it is strongly related to OF & PH. Again, these metrics of DMM are strongly related to ST, since shipment time depends on all the metrics of DMM. This will be affected due to the failure of any metrics of DMM. Finally ST is strongly related to SF. That means strategic fitness of a manufacturing unit is depended on all the metrics of its previous stages (ST, DMM, & BMM). The fitness of a unit will definitely fluctuate due to the ups and downs of its any manufacturing metrics. The above figure 6.1 shows that how strategic fitness of a manufacturing fitness is related to its metrics.

CHAPTER 7

Discussions and Conclusions

7.1 Discussions

One of the main contributions to this research work is aggregation of manufacturing metrics/competitive strategies those had been used in the previous researches separately. Such as, Amoako-Gyampah et al. (2008) examined the relationship between manufacturing strategy and competitive strategy and their influence on firm performance. They also found significant and positive relationships between competitive strategy and the manufacturing strategies of cost, delivery, flexibility, and quality. The findings also indicated that quality is the only manufacturing strategy component that influences performance. Their results further showed that although competitive strategy does not directly affect firm performance, it does so indirectly through quality. Gupta et al. (1996) showed the effect of manufacturing flexibility on organizational performance. Strategic flexibility supports the adaptive use of resources (Zhou and Wu, 2010), and thus, the ability to quickly respond to dynamically changing environments (Nadkarni and Narayanan, 2007; Schreyögg and Sydow, 2010). Chang et al. (2003) investigated the practice of manufacturing flexibility in small and medium sized firms. Swink et al. (2007) aggregated four types of strategies and showed the effect on manufacturing plant performance and their results provide implications for manufacturing managers who seek to design integration policies and associated resource deployments. Anand et al. (2004) & Kortmann et al. (2014) showed the results of fit, flexibility and performance in manufacturing to cope with the dynamic environment. Goyal et al. (2012) found the relationship between flexibility and demand correlation. Kazan et al. (2006) found the effect of quality and cost flexibility on financial performance. Vickery et al. (1993), found covariance between competitive strategy and production competence with business performance. In their study of firms in the textile industry, Williams et al. (1995) found a relationship between competitive strategy and manufacturing strategy and also between manufacturing strategy and performance. Gupta and Lonial (1998) linked among business strategy, manufacturing strategy, and organizational performance.

Here, this research has focused on fitness of a manufacturing unit and for this purpose we aggregated all the manufacturing metrics. It is already clear to us that manufacturing fitness is depended on its associated all metrics. From the results of unit 4, fall of metrics reduces the fitness gradually. For this reason, they achieved only 81.76% fitness. Besides this, 6 metrics within 7 failed to achieve the security level and this demanded a big loss/penalty (10.50%) which was deducted from their achievement. That resulted only 71.26% achievement for the manufacturers. So, this makes us clear that the manufacturing fitness fell due to the fall of its metrics, and this proved that manufacturing fitness is depended on its metrics. This achievement will fluctuate by the fluctuation of its metrics achievements.

7.2 Conclusions

From the above discussions, we can give this message to the manufacturers that they have to emphasis on the achievement of each manufacturing metric to prevent this fall of achievement. We also uncovered a new concept strategic fit with mathematical and graphical explanation in the field of manufacturing industries that recovers strategic fitness, security level, & loss/penalty of a manufacturing unit. We hope this will create an inspiration among the manufacturers to find out those causes by which the metrics are far below the security level and also the strategic targeted level. This will also create an awareness among them to take corrective actions and preventive solutions against these adverse balances to meet the maximum fitness.

7.3 Recommendations and scope of further research

Finally, this research creates a scope of further research to develop the fitness model for the units of other manufacturing industries like manufacturing units of plastic industries/furniture industries/food & beverage industries etc. based on their manufacturing strategies and metrics. And the limitation of this research is the effect of unusual issues like political violence, ups and downs of global/national economic, social value changing, and technology changing had not been considered.

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APPENDIX

Figure A-1 shows a relationship diagram among the manufacturing metrics. This relationship diagram makes it easy to understand the relations among BMM, DMM, AMM, and SF. Table A-1 shows a survey form to aggregate manufacturing metrics failure among the metrics from the month January to June of 2016. The management are requested to read the table carefully and put the right value of failure occurrence for each month among the metrics.

The abbreviated words used in the following Figure A-1 are elaborated here.

Before manufacturing metrics (BMM) → AM	During manufacturing metrics (DMM)→ OVH, PH, QP, CP & OF	After manufacturing metrics (AMM) → ST	SF: Strategic fit

AM: Availability of materials, OF: Order fill rate, QP: Quality perfection, PH: Problem handling, OVH: Order variation handle, CP: Cost performance, ST: Shipment time, SF: Strategic fit

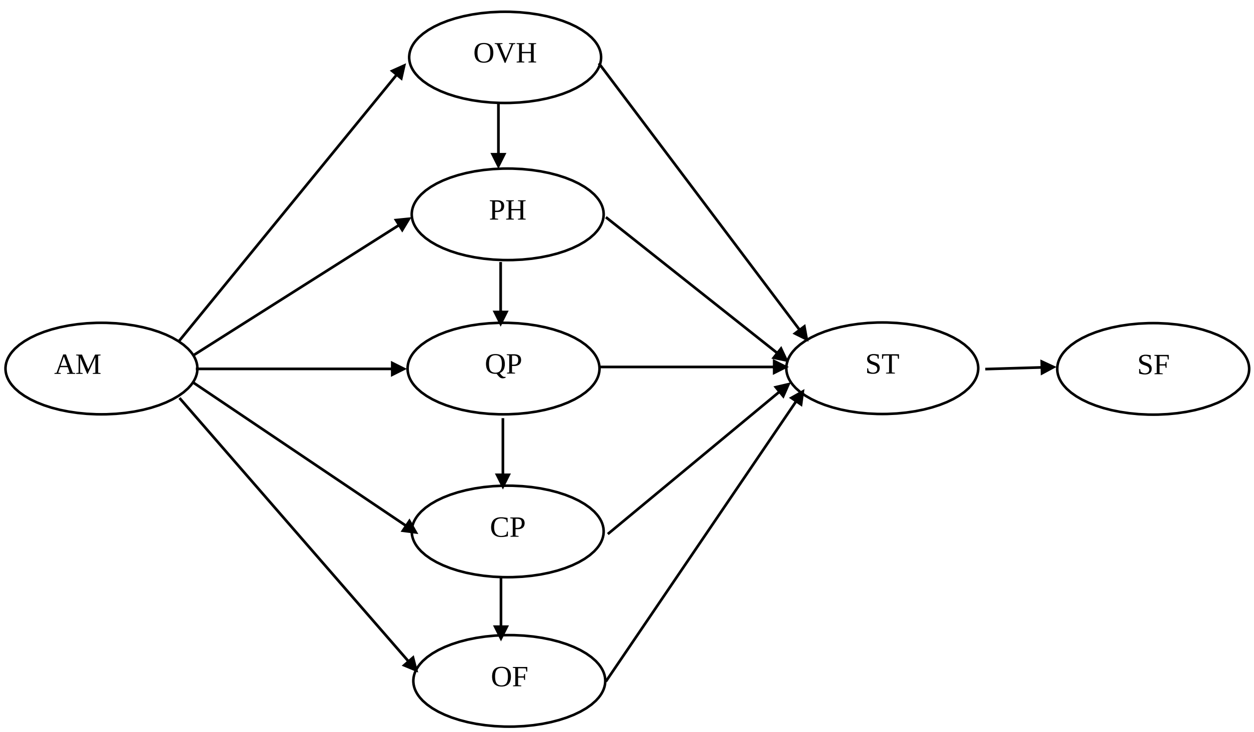

Figure A. 1 Relationship diagram among the manufacturing metrics

Table A- 1 A form of failure occurrence aggregation among the manufacturing metrics

Failure frequency of a metric due to the failure of the previous metric	Occurrence frequency					
	Total order in January	Total order in February	Total order in March	Total order in April	Total order in May	Total order in June
	Failure occurrence frequency					
	January	February	March	April	May	June
	BMM to DMM					
Couldn't handle order variation *(OVH)* due to lack of availability of materials *(AM)*						
Couldn't handle problems *(PH)* due to lack of availability of materials *(AM)*						
Couldn't achieve better quality *(QP)* due to lack of availability of materials *(AM)*						
Couldn't gain better cost performance *(CP)* due to lack of availability of materials *(AM)*						
Failure to fill order quantity *(OF)* due to lack of availability of materials *(AM)*						
Among DMM						
Couldn't handle problems *(PH)* due to lack of order variation handle *(OVH)*						
Couldn't gain better quality *(QP)* due to lack of problem handling *(PH)*						
Couldn't gain better cost performance *(CP)* due to lack of quality performance *(QP)*						
Couldn't fill order quantity *(OF)* due to lack of good cost performance *(CP)*						
DMM to AMM						
Failure of due time shipment *(ST)* due to lack of order variation handle *(OVH)*						
Failure of due time shipment *(ST)* due to lack of problem handling *(PH)*						
Failure of due time shipment *(ST)* due to lack of quality perfection *(QP)*						
Failure of due time shipment *(ST)* due to lack of better cost performance *(CP)*						

Failure of due time shipment *(ST)* due to lack of order fill *(OF)*						
AMM to SF						
Poor strategic fit *(SF)* due to lack of proper shipment *(ST)*						

Questionnaire forms used to facilitate comparisons of manufacturing metrics

QUESTIONNAIRE

Read the following questions and put the check marks (√) during comparing between two metrics. If you prefer that the left sided metric is more important compared to right sided metric, put the check mark at the left side of 'Equal' importance under the preference level that you prefer. Again if you prefer that the right sided metric is more important compared to left sided metric, put the check mark at the right side of 'Equal' importance under the preference level that you prefer.

QUESTIONS

With respect to the overall goal "*prioritization of the manufacturing metrics*",

Q1. How important is *order fill rate (OF)* when it is compared with *quality perfection (QP)?*

Q2. How important is *order fill rate (OF)* when it is compared with *availability of materials (AM)?*

Q3. How important is *order fill rate (OF)* when it is compared with *problem handling (PH)?*

Q4. How important is *order fill rate (OF)* when it is compared with *order variation handle (OVH)?*

Q5. How important is *order fill rate (OF)* when it is compared with *cost performance (CP)?*

Q6. How important is *order fill rate (OF)* when it is compared with *shipment time (ST)?*

Q7. How important is *quality perfection (QP)* when it is compared with *availability of materials (AM)?*

Q8. How important is *quality perfection (QP)* when it is compared with *problem handling (PH)?*

Q9. How important is *quality perfection (QP)* when it is compared with *order variation handle (OVH)?*

Q10. How important is *quality perfection (QP)* when it is compared with *cost performance (CP)?*

Q11. How important is *quality perfection (QP)* when it is compared with *shipment time (ST)?*

Q12. How important is *availability of materials (AM)* when it is compared with *problem handling (PH)?*

Q13. How important is *availability of materials (AM)* when it is compared with *order variation handle (OVH)?*

Q14. How important is *availability of materials (AM)* when it is compared with *cost performance (CP)?*

Q15. How important is *availability of materials (AM)* when it is compared with *shipment time (ST)?*

Q16. How important is *problem handling (PH)* when it is compared with *order variation handle (OVH)?*

Q17. How important is *problem handling (PH)* when it is compared with *cost performance (CP)?*

Q18. How important is *problem handling (PH)* when it is compared with *shipment time (ST)?*

Q19. How important is *order variation handle (OVH)* when it is compared with *cost performance (CP)?*

Q20. How important is *order variation handle (OVH)* when it is compared with *shipment time (ST)?*

Q21. How important is *cost performance (CP)* when it is compared with *shipment time (ST)?*

Table A- 2 Manufacturing metrics pair-wise comparison form

With respect to the overall goal		Importance (or preference) of one metric over another											
Questions	Metrics	Absolutely more important	Very strongly more important	Strongly more important	Weakly more important	Equally important	Just equal	Equally important	Weakly more important	Strongly more important	Very strongly more important	Absolutely more important	Metrics
Q1	OF												QP
Q2	OF												AM
Q3	OF												PH
Q4	OF												OVH
Q5	OF												CP
Q6	OF												ST
Q7	QP												AM
Q8	QP												PH
Q9	QP												OVH
Q10	QP												CP
Q11	QP												ST
Q12	AM												PH
Q13	AM												OVH
Q14	AM												CP
Q15	AM												ST
Q16	PH												OVH
Q17	PH												CP
Q18	PH												ST
Q19	OVH												CP
Q20	OVH												ST
Q21	CP												ST

Order Details Aggregation

Table A3-A8 showed the details of order size, delivery information and materials availability of the Buyer TOM TAYLOR, WOOL WORTH, PRIMARK, H&M, C&A, SOliver and Esprite for the manufacturing unit 4 of FAKIR Apparels Ltd. These tables also showed the details of the orders from July to December. This research used some symbols to make easy to understand the order details like (●) means the quantity produced without any delay i.e. quantity of due time production, (∆) means the quantity of late production, (↓) means production is continued to next month and (◊) means the availability of materials more than 80% (i.e., 80-99%) at the starting of an order and (○) means the availability of materials more than 60% (i.e., 60-79%). In the case of less than 60% raw materials, the order is not started until the materials is available. When the materials is less than 80% or more than 60%, the order is started but sometimes it is seen that the production is not finished completely because the rest of the materials has not reached during the production. For this reason, the remaining quantity is finished after receiving the rest of the raw materials. (■) means the order has been stopped due to lack of materials. (♂) means the stopped order has been started again after receiving the remaining materials and (⌂) means late shipment.

Table A- 3 Order details for the month of July

Month	Product Category	Line -16		Line-17		Line-18		Line-19		Line-20		Line-21	
July	T-Shirt	10,500	●	8,500	●	1,300	●			5,100	●	7,200	●
		10,500		8,500		1,300				5,100		7,200	
	Order												
		Orders from the previous month (June)											
	Buyer	Tom Taylor		Wool Worth		Wool Worth				SOliver		Esprite	
	Leggings					25,250	◊	13,200	●	25,800		21,500	
						21,465		13,200		15,390		6,700	
						3,785	■			10,410	↓	14,800	↓
	Order					CA-SL-4530		SO-SL-5633		SO-SL-5631		TT-LL-2324	
	Buyer					C&A		SOliver		SOliver		Tom Taylor	
	Tops	30,250		50,000				15,500		4,300	●	16.500	●
		27,150		16,390				9,320		4,300		16.500	
		3,100	↓	33,610	↓			6,180	↓				
	Order	TT-SSRN-2327		TT-SSVN-2334				CA-LSRN-4534		ESP-SSRN-6329		ESP-SSRN-6330	
	Buyer	Tom Taylor		Tom Taylor				C&A		Esprite		Esprite	
	Order details	Due time production =5 times, more than 80% material availability (◊)=1 time, production stopped due to lack of raw materials= 1 time, order continued to the next month (August)= 5 times											

Table A- 4 Order details for the month of August

Aug.	T-Shirt	25,400	●			25,500				7,300	●		
		25,400				2,545				7,300			
						22,955	↓						
	Order	TT-SSRN-2329				WW-LSVN-3419				SO-SSVN-5637			
	Buyer	Tom Taylor				Wool Worth				SOliver			
	Leggings							35,000		10,410	●	14,800 (8500)	●
								23,830		10,410		14,800 (7900)	
								11,170	↓			600	↓
	Order							TT-SL-2338		SO-SL-5631		TT-LL-2324 &WW-LL-3422	
	Buyer							Tom Taylor		SOliver		Tom Taylor (Wool Worth)	
	Tops	3,100	●	33,610		17,300	●	6,180	●	27,300	○		
		3,100		26,900		17,300		6,180		7,100			
				6,710	↓					20,200	↓		
	Order	TT-SSRN-2327		TT-SSVN-2334		CA-SSVN-4538		CA-LSRN-4534		CA-SSRN-4539			
	Buyer	Tom Taylor		Tom Taylor		C&A		C&A		C&A			
	Order details	Due time production =6 times, more than 60% material availability (○)=1 time, order continued to the next month (September)= 3 times											

Table A- 5 Order details for the month of September

Sep.	T-Shirt	12,300	●			22,955	●	25,800	◊	8,950	●		
		12,300				22,955		8,800		8,950			
								17,000	↓				
	Order	WW-SSRN-3426				WW-LSVN-3419		TT-LSRN-2341		CA-SSVN-4543			
	Buyer	Wool Worth				Wool Worth		Tom Taylor		C&A			
	Leggings	23,000		47,500		3,785	Δ	11,170	●			600	●
		20,100		22,400		3,785	♂	11,170				600	
		2,900	↓	25,100	↓		⌂						
	Order	WW-LL-3429		PRI-LL-7251		CA-SL-4530		TT-SL-2338				WW-LL-3422	
	Buyer	Wool Worth		PRIMA RK		C&A		Tom Taylor				Wool Worth	
	Tops			6,710	●	22,000				20,200	○	24,500	
				6,710		300				10,100		13,900	
						21,700	↓			10,100	■	10,600	↓
	Order			TT-SSVN-2334		HM-SSVN-8185				CA-SSRN-4539			
	Buyer			Tom Taylor		H&M				C&A		Esprite	
	Order details	Due time production =5 times, late production (Δ) = 1 time & it causes late shipment (⌂) i.e., late shipment = 1 time, production stopped due to lack of raw materials= 1 time, order continued to the next month (October)= 5 times											

Table A- 6 Order details for the month of October

Oct.	T-Shirt							17,000	◊				
								11,066					
								5,934	■				
	Order							TT-LSRN-2341					
	Buyer							Tom Taylor					
	Leggings	2,900	●	25,100	●	5,500		45,000					
		2,900		25,100		5,020		13,550					
						480	↓	31,450	↓				
	Order	WW-LL-3429		PRI-LL-7251		TT-LL-2346		HM-LL-8178					
	Buyer	Wool Worth		PRIMARK		Tom Taylor		H&M					
	Kids sweater	32,250	○	24,200						23,500		34,400	
		20,175		3,275						19,540		16,800	
		12,075	■	20,925	↓					3,960	↓	17,600	↓
	Order	WW-LSRN-3434		WW-LSRN-3436						WW-LSVN-3437		HM-SLRN-8181	
	Buyer	Wool Worth		Wool Worth						Wool Worth		H&M	
	Tops					21,700	●					10,600	●
						21,700						10,600	
	Order					HM-SSVN-8185						ESP-SSRN-6335	
	Buyer					H&M						Esprite	
	Order details	Due time production =4 times, more than 80% material availability (◊)=1 time ,more than 60% material availability (○)=1 time, production stopped due to lack of raw materials= 2 times, order continued to the next month (November)= 5 times											

Table A- 7 Order details for the month of November

Nov.	T-Shirt	13,500	●							13,400		25,200	
		13,500								4,520		8,300	
										8,880	↓	16,900	↓
	Order	WW-LSRN-3439								TT-SLVN-2349		ESP-SLVN-6337	
	Buyer	Wool Worth								Tom Taylor		Esprite	
	Kids sweater	12,075	Δ	20,925	●	40,300				3,960	●	17,600	●
		5,180	♂	20,925		8,240				3,960		17,600	
		6,895	↓			31,760	↓						
	Order	WW-LSRN-3434		WW-LSRN-3436		HM-LSRN-8188				WW-LSVN-3437		HM-SLRN-8181	
	Buyer	Wool Worth		Wool Worth		H&M				Wool Worth		H&M	
	Leggings					480	●	31,450					
						480		23,300					
								8,150	↓				
	Order					TT-LL-2346		HM-LL-8178					
	Buyer					Tom Taylor		H&M					
	Tops			33,500		8,500	●			10,100	Δ		
				5,350		8,500				10,100	♂		
				28,150	↓								
	Order			CA-SLVN-4548		TT-SLVN-2355				CA-SSRN-4539			
	Buyer			C&A		Tom Taylor				C&A			
	Order details	Due time production =6 times, late production (Δ) = 1 time, order continued to the next month (December)= 6 times											

Table A- 8 Order details for the month of December

Dec.	T-Shirt							5,934	∆	8,880 (33400)	●	16,900	●
								5,934	♂	8,880 (14350)		16,900	
										19,050	↓		
	Order							TT-LSRN-2341		TT-SLVN-2349 & TT-SLVN-2361		ESP-SLVN-6337	
	Buyer							Tom Taylor		Tom Taylor		Esprite	
	Leggings	25,400						8,150	●				
		18,200						8,150					
		7,200	↓										
	Order	PRI-SL-7261						HM-LL-8178					
	Buyer	PRIMARK						H&M					
	Tops			28,150				25,000				18,300	
				23,120				5,500				6,800	
				5,030	↓			19,500	↓			11,500	↓
	Order			CA-SLVN-4548				CA-SLVN-4554				PRI-LSRN-7268	
	Buyer			C&A				C&A				PRIMARK	
	Kids sweater	6,895	∆			31,760							
		6,895	♂			26,220							
			⌂			5,540	↓						
	Order	WW-LSRN-3434				HM-LSRN-8188							
	Buyer	Wool Worth				H&M							
	Order details	Due time production =3 times, late production (∆) = 2 times, late shipment (⌂) = 1 time, order continued to the next month (January)= 6 times											

Here, this research abbreviating the details of a product item. Like SSRN means short sleeve round neck, SSVN means short sleeve V-neck for T-shirt, tops and kid's sweater, SL means short leggings and LL means long leggings for leggings. Order TT-LL-2346 represents buyer Tom Taylor (TT), product type long leggings (LL) and the numerical digit 2346 is the order identification number. By the similar way, table A-9 represents the details of all orders with their respective buyer.

The manufacturers achieved different weight values for different manufacturing metrics that is denoted by the symbol check mark (√) that resulted total achieved point by multiplying the cumulative value of achieved point by the scale value that is also shown by the following table A-9.

Table A- 9 Calculation of strategic point and achieved point for QP, PH, OVH and CP

Buyer	Product Category	Style	Manufacturing Metrics											
			QP			PH			OVH			CP		
			High	Mod.	Low	High	Mod.	Low	High	Mod.	Low	High	Mod.	low
Tom Taylor	T-Shirt	TT-SSRN-2324	√				√			√		√		
		TT-SSRN-2329	√			√			√			√		
		TT-LSRN-2341 ◊	√				√			√			√	
		TT-SLVN-2349		√			√			√		√		
	Leggings	TT-SL-2338		√			√			√		√		
		TT-LL-2346		√		√			√			√		
	Tops	TT-SSRN-2327	√			√			√				√	
		TT-SSVN-2334		√		√			√			√		
		TT-SLVN-2355		√		√			√				√	
Wool Worth	T-Shirt	WW-LSVN-3419	√				√			√		√		
		WW-SSRN-3426		√		√			√			√		
		WW-LSRN-3439	√			√			√			√		
	Leggings	WW-LL-3422		√			√			√		√		
		WW-LL-3429		√			√				√		√	
	Kids sweater	WW-LSRN-3434 ○		√		√			√			√		
		WW-LSRN-3436	√				√			√			√	
		WW-LSVN-3437	√			√			√				√	
PRIMARK	Leggings	PRI-LL-7251			√			√			√		√	
	T-Shirt	CA-SSVN-4543	√				√			√			√	
	Leggings	CA-SL-4530 ◊		√			√			√		√		

C&A	Tops		√				√			√		√	
		CA-LSRN-4534											
			√		√			√			√		
		CA-SSVN-4538											
			√		√			√			√		
		CA-SSRN-4539 ○											
H&M	Leggings	√			√			√			√		
		HM-LL-8178											
	Kids sweater	√			√			√			√		
		HM-SLRN-8181											
	Tops	√				√			√		√		
		HM-SSVN-8185											
SOliver	Leggings	√			√			√			√		
		SO-SL-5631											
			√		√			√			√		
		SO-SL-5633											
	T-shirt		√			√			√			√	
		SO-SSVN-5637											
Esprite	T-shirt		√			√			√		√		
		ESP-SLVN-6337											
	Tops		√		√			√			√		
		ESP-SSRN-6329											
			√		√			√			√		
			ESP-SSRN-6330										
			√		√			√			√		
		ESP-SSRN-6335											
Achieved Point		13*5	19*3	1*1	18*5	13*3	2*1	18*5	12*1	3*0	23*5	10*1	0
Sum of achieved Point		123			131			102			125		
Total achieved point		481											
Possible highest point		33*5=165			33*5=165			33*5=165			33*5=165		
Strategic target		100%			100%			90%			95%		
Strategic point		165*1.0=165			165*1.0=165			165*0.90=148.5			165*.95=156.75		
Total strategic point		635.25											

Table A- 10 List of Manufacturing Metrics with Sub-metrics

Manufacturing metrics	Manufacturing sub metrics	Manufacturing sub metrics
Availability of materials (AM)	AM1	Storing all the materials before starting the order
	AM2	Collecting the remaining materials for that case when there is not available 100% materials but order has been started
	AM3	Availability of all the accessories
	AM4	Sending the list of materials in the cutting department and stores for the associated orders with a good lead time
Order fill rate (OF)	OF1	Availability of all materials
	OF2	Workers and employees performance
	OF3	Production time
	OF4	Automated machine instead of manual machines
	OF5	Supervising
Quality perfection (QP)	QP1	Availability of all materials
	QP2	Pre-production activities (Dying, washing, printing and cutting)
	QP3	Materials quality
	QP4	Workers and employees performance
	QP5	Quality inspection by quality control department
	QP6	Automated machines instead of manual machines
	QP7	Supporting the operators by helpers
	QP8	Post production activities (Ironing, Embroidery and printing)
Problem handling (PH)	PH1	Availability of all materials
	PH2	Automated machines
	PH3	Skilled operators and workers
	PH4	Proper power supply
	PH5	Differentiate the production lines according to order size and product item
	PH6	Sufficient expert technician
Order variation handle (OVH)	OVH1	Availability of all materials
	OVH2	Differentiate the production lines based on order size and product item
	OVH3	Production in a single time
	OVH4	Don’t start the another order by breaking the running order
	OVH5	Maximum production for different orders by not changing the existing layout (if possible)
Cost performance (CP)	CP1	Availability of all materials
	CP2	Skilled operator
	CP3	Automated machines
	CP4	Try to avoid overtime schedule
	CP5	Avoid subcontracting production system
	CP6	Training programs among the operators on production techniques
	CP7	Due time shipment
Shipment time (ST)	ST1	Order fill rate
	ST2	Quality perfection
	ST3	Problem handling
	ST4	Order variation handle

	ST5	Cost performance
	ST6	Complete the production in time
	ST7	Time interval between the production time and shipment time
	ST8	Problem handling capability
	ST9	Order variation handle capability
Strategic fitness (SF)	SF1	Shipment time/delivery time
	SF2	Utilization of maximum manufacturing capabilities
	SF3	Utilization of employee's and worker's capabilities
	SF4	Earning foreign exchange
	SF5	Better growth of the organization

Please give the check mark (√) in one cell for each manufacturing sub-metrics according to its relation/importance to manufacturing metrics.

Table A- 11 Survey questionnaire

Manufacturing metrics	Manufacturing sub metrics	Survey questionnaire	Low impact		Moderate Impact		Extreme impact
			1	2	3	4	5
Availability of materials (AM)	*Impact of (AM1-AM4) on Availability of materials (AM)*						
	AM1	What is the importance of sorting all the materials before starting the order to AM?					
	AM2	How much collection of remaining materials is important during manufacturing?					
	AM3	How much collection of accessories is important before manufacturing?					
	AM4	How much sending of materials list in the cutting department is important before manufacturing?					
Order fill rate (OF)	*Impact of OF1-OF5 on Order fill rate (OF)*						
	OF1	How much availability of materials is important for OF?					
	OF2	How much employee's and worker's performance are important for OF?					
	OF3	What is the effect of allocated production time on OF?					
	OF4	What is the effect of automated machines on OF?					
	OF5	What is the effect of good supervising on OF?					
Quality perfection (QP)	*Impact of QF1-QF8 on Quality perfection (QP)*						
	QP1	What is the importance of availability of materials to get QP?					
	QP2	How much pre-production activities are important to get QP?					

	QP3	How much materials quality are important to get QP?					
	QP4	How much employee’s and worker’s performance are important to get QP?					
	QP5	What is the effect of quality inspection to get QP?					
	QP6	What is the effect of automated machines to get QP?					
	QP7	How much helpers help to get QP?					
	QP8	How much post-production activities are important to get QP?					
Problem handling (PH)	*Impact of PH1-PH6 on Problem handling (PH)*						
	PH1	How much availability of materials help to solve PH?					
	PH2	What is the importance of automated machines to solve PH?					
	PH3	What is the significance of operator’s and helper’s skills to solve PH?					
	PH4	How much proper power supply help to solve PH?					
	PH5	What is the importance of production lines differentiation to solve PH?					
	PH6	How much sufficient expert technicians help to solve PH?					
Order variation handle (OVH)	*Impact of OVH1-OVH5 on Order variation handling (OVH)*						
	OVH1	What is the importance of availability of all materials to handle order variation?					
	OVH2	What is the importance of production lines differentiation to handle order variation?					
	OVH3	How much single line production help to handle order variation?					
	OVH4	What is the significance of not breaking the running lines to handle order variation?					
	OVH5	What is the importance of production without changing the layout to handle order variation?					
Cost performance (CP)	*Impact of CP1-CP7 on Cost performance (CP)*						
	CP1	What is the significance of availability of all materials to CP?					
	CP2	What is the significance of skilled operator to CP?					
	CP3	What is the significance of automated machines to CP?					
	CP4	How much overtime production affect CP?					
	CP5	How much subcontracting production affect CP?					
	CP6	What is the importance of training programs for better CP?					
	CP7	How much importance due time shipment for CP?					
	Impact of ST1-ST9 on Shipment time (ST)						

Shipment time (ST)	ST1	What is the importance of order fill rate for due time shipment?					
	ST2	What is the effect of quality perfection for due time shipment?					
	ST3	What is the effect of problem handling to ST?					
	ST4	How much order variation handle affect to ST?					
	ST5	How much cost performance affect to ST?					
	ST6	What is the significance of due time production to ST?					
	ST7	What is the significance of time gap between production and shipment to ST?					
	ST8	How much problem handling capability affect to ST?					
	ST9	What is the importance of order variation handle to ST?					
Strategic fitness (SF)	*Impact of SF1-SF5 on Strategic fitness (SF)*						
	SF1	What is the importance of due time shipment to achieve SF?					
	SF2	How much utilization of manufacturing capabilities help to achieve SF?					
	SF3	How much utilization of employee's and worker's capability help to achieve SF?					
	SF4	How much earning of foreign exchange help to achieve SF?					
	SF5	How much better growth of organization help to achieve SF?					