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ORIGINAL ARTICLE

Customer-focused and product-line-based manufacturing performance measurement

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Abstract Until the 1980s, manufacturing companies relied solely on performance measurement systems based on traditional cost accounting systems to control, monitor, and improve operations. However, it has been shown that these systems do not capture the relevant performance issues for today's manufacturing environment. Pre-80s systems focused on monitoring and controlling instead of supporting process improvements, promoting overall system optimization and addressing the dynamics of changing systems. A variety of integrated systems were proposed to overcome the limitations of the traditional performance measurements systems. However, these systems have not yet fully addressed the performance measurement system requirements for today's manufacturing environment. This paper presents an integrated dynamic performance measurement system (IDPMS) developed in conjunction with the D Company Plant of Chungli, Taiwan. IDPMS integrates three main areas; company management, process improvement, and the factory shop floor. To achieve an integrated system, these three areas are linked through specifications, reporting and dynamic defined success area updating, performance measures, and performance standards. This study is undertaken to specify the interaction and movement among the three groups in the process from production planning to customer, "planning-manufacturing-customer". The results from these stages, production planning, manufacturing, and customer service, are integrated. These factors are transformed into measurable, quantitative, and JIT (just-in-time) parameters utilized along with management by objectives (MBO) principles in planning and establishing a manufacturing performance measurement system focused on satisfying both internal and external customers. An example is given that illustrates how the IDPMS addresses the current performance measurement system requirements.

Keywords Performance measurement · Management by objective · Process improvement · Customer satisfaction · Manufacturing

1 Introduction

In today's highly competitive business environment, innovative product manufacturers must provide customized and innovative products. Thus, innovative manufacturers also need to achieve innovative performance dimensions. To measure manufacturing performance, participants were asked to compare their plant with other manufacturing plants in the industry on customer satisfaction, product quality, speed to complete manufacturing orders, productivity, diversity of product line, and flexibility to manufacture new products [1].

Performance measures are defined as a tool for assessing how well the activities within a process or the process outputs achieve a specified goal. Performance measures have been defined as a tool to compare actual results with a pre-determined goal and measure the extent of any deviation. A target performance level is expressed as a quantitative standard, value, or rate [2]. The selection of a range of performance measures appropriate to a particular company should be made in the light of the company's strategic intentions to suit the competitive environment in which the company operates. For example, if technical

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leadership and product innovation are key source of a manufacturing company's competitive advantage, performance in this area must be measured relative to the competitors. However, if a service company decides to differentiate itself in the marketplace on the basis of quality of service, then, among other things, it should be monitoring and controlling the desired level of quality [3].

Whether the company is in the manufacturing or service sector, choosing an appropriate range of performance measures is necessary and these measures must be balanced to ensure that one performance or set of performance dimensions is not stressed to the detriment of others. The mix chosen will in almost every instance be different. Incomplete metrics may lead to inappropriate action [3]. Performance areas must be made measurable in the form of performance indicators that allow the company to monitor performance and goal realization [4]. To achieve and maintain a competitive edge in the world marketplace, manufacturing companies must produce high-quality products at a low cost with increasing variety, over shorter lead times. To achieve these objectives, many companies are adopting recently developed management, production, and quality philosophies such as: total quality management (TQM), just-in-time (JIT), computer integrated manufacturing (CIM), and optimized production realization (OPR). To assess their success when adopting these philosophies, manufacturing companies use performance measures. A business can achieve success only by understanding and fulfilling the needs of its customers. Most studies ignored the quality factors at different stages in the process and the consequential cost that could cause a huge potential loss [5]. As defined in the context of quality management, customer-focus practices involve the establishment of links between customer requirements, satisfaction, and internal processes [6, 7]. Having a customer focus means shifting from a goal of maximizing our profits in one project by optimizing the utilization of our resources to goal of superior service to the customer to maximize the customer's value by meeting the jointly agreed project goals [8]. However, many companies use performance measures that are based on traditional management cost systems that are now outdated and incompatible with their new operating philosophies. Consequently, many researchers are suggesting new performance measurement approaches that support day-to-day operations and provide managers, supervisors, and operators with information that is both timely and relevant [9].

To provide an overall view of company performance and prevent local optimization, researchers have tried to combine more than one performance aspect through integrated performance measurement systems. These integrated systems address many of the shortcomings of past performance measurement systems, however, there are still issues associated with today's manufacturing environment that must be considered. For example, these systems work primarily as monitoring and controlling tools that fail to incorporate an explicit feedback loop that supports performance measure improvement. In addition, these systems are not dynamic and therefore cannot update critical success areas and do not provide mechanisms for adapting to a changing manufacturing environment. To address these shortcomings, this paper presents an integrated dynamic performance measurement system (IDPMS), developed in collaboration with the D Company in Taiwan. The proposed system focuses on improving manufacturing competitiveness by overcoming the limitations of existing performance measurement systems and motivating continuous improvement [10]. The object of this research is to establish an integrated dynamic performance measurement system for manufacturing from the customer satisfaction orientation using objective-oriented factors that specifies the interaction and mutual movement among these three groups; management (production planning), manufacturing, and the customer. The meaning of these indicators is discussed. The suitability of this system is verified using actual case simulation.

Section 2 reviews the literature pertaining to performance measurement. Section 3 presents the development of the integrated dynamic performance measurement system. Section 4 illustrates how the system would be applied. Sections 5 and 6 provide a result comparison and summarize the benefits of IDPMS with respect to the existing performance measurement systems.

2 Literature and recent models review

The literature on manufacturing performance evaluation models, customer-oriented measurement system concepts, and management by objective (MBO) applications is varied. In this section, literature that closely relates to the topic of interest is reviewed, leading to the development of our research focus.

In formulating performance measurement system (PMS) design characteristics to effectively support strategy implementation, particular challenges are apparent in the manufacturing industry. Rapid global manufacturing competitive change has brought new doctrines (e.g., JIT, TQM, and the flexible factory), and required new approaches to performance measurement. The importance of quality, flexibility and responsiveness has challenged the relevance of conventional manufacturing efficiency measures. One way in which this challenge has been met is PMS expansion. The literature has established significant associations between the pursuit of specific strategies, such as TQM, JIT or manufacturing flexibility and the expansion of traditional efficiency-focused manufacturing PMSs to embrace new manufacturing performance measures [11–13]. However, there have been few positive performance outcomes associated with such expansions. Ittner and Larcker [14] suggested that the resultant widespread use of multiple measures raises several implementation issues including the likelihood of ineffective managerial effort [15]. Choe [16] noted the ultimate goals that can be attained through advanced manufacturing technology (AMT) are low cost, improved quality, increased flexibility and high dependability of supply. The measurements of manufacturing performance in AMT should reflect the degree of the realization of these four strategic goals. It has been well recognized that one of the important tenets of good manufacturing practice is the appropriate use of performance measures. There has been quite a bit of literature published in the form of books and articles on the subject of measuring performance in manufacturing companies. There has been a lot research focused on the financial and managerial accounting measures used in determining organization performance. The recent work of Gunasekharan et al. [17], and Gupta and Galloway [18] are two examples (in a plethora of articles) that focus on using financial and cost-based performance measures in manufacturing operations [19].

A customer-focused manufacturing strategy may be seen as comprising the cost, quality, flexibility, and supply dependability dimensions [3]. Narver and Slater [20] defined customer orientation as "a sufficient understanding of one's target buyers that allows continuously creating superior value for them". Similarly, customer orientation is defined as "a set of beliefs that puts the customer's interest first" [21], or "firm's ability and will to identify, analyze, understand, and answer user needs" [22, 23]. Customer focus is the underpinning principle in the TQM philosophy. TQM is concerned with how the organization designs and introduces products and services, integrates production and delivery requirements and manages supplier performance [24]. Mohr-Jackson [25] proposed an extended customer-orientation concept that includes internal customers and notes that this requires additional activities. These include (1) understanding the internal customers' requirements for the effective delivery of needs and preferences of external customers, (2) obtaining information about external customers' needs and preferences through effective interdepartmental communication, and (3) creating additional final buyer value by increasing internal customer benefits. To provide superior value to the external customer, it is important that superior value is provided at each point of the value chain. Hence, internal suppliers need to have customer orientation. This will ensure the development of a customer and market orientation throughout the organization [26] and not limit this orientation to the point of customer contact [27]. From a total quality perspective, all strategic decisions a company makes are "customer-driven" [28]. Knowing the customer begins with a detailed evaluation of what is known about the customer. Knowing the customer is basically a customer satisfaction measurement process [29]. Breyfogle et al. [30] noted that a good performance measurement system addresses both external and internal quality views. Neither internal nor external measures are inherently bad. Liu et al. [31] emphasized that customer orientation is a set of beliefs that customer needs and satisfaction are the priority of an organization. It focuses on dynamic interactions between the organization and customers as well as competitors in the market and its internal stakeholders. Customer orientation refers to the extent to which an organization and individuals within an organization focus their efforts on understanding and satisfying customers [32].

Bhote [33] noted, "If performance isn't being measured, it isn't being managed." "Management by objectives" (or MBO), introduced to industry in the early 1950s by the management guru Peter F. Drucker, has been used effectively to measure senior management. In companies where MBO is more than a game, the goals are carefully crafted, the measurement system finely tuned, and progress against goals meticulously monitored. The first step is to establish objective measurements. The objective of performance measurements is to establish which road you want to take, where you currently are on that road and where you ultimately want to end up. The best measures are customer-focused and goal-oriented. Goals should also reflect current realities. Measurements are a starting point. They help people learn how to improve performance by pointing out where they are deficient and by establishing achievable timetables to reach desired levels. In this way, they can be used as a basis for improved performance [34]. Ahmad et al. [2] specified that the concept of performance measures is the process of comparing actual operation results with established performance targets. It agreed that the target value is used to evaluate performance measurement data, usually to assess performance achieved compared to performance expected. The six-sigma [35] and balanced scorecard (BSC) [36], approaches both offer frameworks for business improvement. The improvement approaches in the foregoing start from business goal definition and goal decomposition and are oriented on quantitative performance measurement. They offer frameworks for improvement, starting from business strategy, pre-defined types of business goals and pre-defined type of metrics [37].

2.1 Recent manufacturing performance concepts and practices

Summaries of recent manufacturing performance concepts and practices are presented as follows:

The manufacturing performance assessment and analysis introduced in Ahmad and Benson [38] covered the areas of quality, delivery reliability, cost (price minus profit margin) and delivery lead time. The KPIs within manufacturing strategy are cost, quality, inventory, flexibility, and delivery [39]. A part of a project survey was carried out to identify which performance indicators companies use and which ones they characterize as important. The top five were: profitability, conformance to specifications, customer satisfaction, return on investment, and materials/overhead cost. When looking at the performance areas to which the specific indicators are related considering their relative importance, it was also possible to rank the importance of these performance areas (from top to bottom): efficiency, quality, competence (technical), flexibility, innovativeness, and speed and capacity [4]. The measured KPIs are normally split into six sections: (1) safety and environment (2) flexibility (3) innovation (4) performance (5) quality (6) dependability [3]. A six-item scale is used to measure the operational performance of a manufacturing plant after different levels' lean manufacturing practice. The items include 5-year changes in scrap and rework costs, manufacturing cycle time, first pass yield, labor productivity, unit manufacturing cost, and customer lead time [9]. Global competition demands that manufacturing organizations improve quality, reduce delivery time, and minimize costs. In response to this, many manufacturing organizations have implemented different excellence programs to improve their performance. Lean manufacturing techniques, performance measurement, and benchmarking, were included in many of those excellence programs [2].

2.1.1 Popular model review

D Company was supported to establish the manufacturing performance evaluation through integrating "quality", "cost", and "delivery" by the Corporate Synergy Development center (CSD), Taiwan. The manufacturing performance (Y) is measured by:

$$Y = WqQ + WcC + WdD \tag{1}$$

Where

Q: score of quality

$$= \frac{\text{Good production}}{\text{Good production} + \text{Failed QC (quality control)}} \tag{2}$$

W_q: weight of quality

$$\text{C: score of cost} = \left| \frac{\sum(\text{actual cost} - \text{target cost})}{\sum \text{target cost}} - 0.60 \right| \tag{3}$$

W_c: weight of price

$$\text{D: score of delivery} = 1 - \frac{\text{number of delayed lots}}{\text{number of delivered lots}} \tag{4}$$

W_d: weight of delivery

$$Wq + Wc + Wd = 100 \tag{5}$$

From the rating system defined by the D Company, we can find three factors are usually considered when the manufacturer adopts the formula of grading to measure the manufacturing performance.

a. Quality (Q)-quality of product
b. Cost (C)-price of product
c. Delivery (D)-delivery time of product

The weight of each factor can be adjusted when the grading calculations that depend on the needs of manufacturers are applied. Some specific manufacturers just consider quality, while others put quality and cost into consideration. Some of them consider all three, quality, service, and delivery. Two example equations are provided for the score calculations of manufacturing performance:

$$\text{Score of manufacturing performance} = 40Q + 35C + 25D \tag{6}$$

$$\text{or} = 40Q + 40C + 20D \tag{7}$$

In practice, these manufacturing performance measurement systems were unable to quantify the customer orientation and objective orientation requirement levels in the past decade. These measurement systems cannot highlight the quality or business concerns in a just-in-time manner that will promote the effectiveness of improvements. The advantages of establishing a new model is obvious after analyzing the concerns listed below.

a. Internal failure: These models do not reflect the rework, scrap, and sorting that could occur on the production line due to manufacturing quality problems.
b. Customer voice: These models do not help highlight customer complaints and their possible impact on the organization.
c. Equipment effectiveness and engineering efficiency: These models do not evaluate the efficiency of engineering maintenance programs caused by poor manufacturing management. Potential programmatic impacts, such as schedule and cost impacts, should also be brought to management's attention.

d. Quality level: The percentage of defects inside lots from various process stages are sometimes extremely different and may significantly impact profits.
e. Customer orientation: These models do not involve full satisfaction levels or views from actual product users.
f. Objective orientation: If indicators are applied to manufacturing project performance measures with different characteristics, arguments will always ensue. Setting a target for each performance measurement using "achievement level (or AL) will be one of the solutions.

This study attempts to highlight suitable factors that if applied day-to-day, year-to-year and product-to-product in industry performance measurement systems that could help transform these factors into measurable, quantitative, just-in-time (JIT) parameters. These parameters could be utilized in planning and establishing a manufacturing performance rating system based on our work with an international electronics firm (D company). The relevance of the proposed system to a manufacturing team, product line (internal customer) and external customers is presented. The system logic is then detailed. In addition to describing the system, applications and conclusions are drawn.

3 The new model with customer-focused

Based on the above-mentioned concerns, our research studied a set of integrated and dynamic "manufacturing" performance rating models. Central to all measurement systems is the decision about what to measure and how to weight the performance categories. This decision is probably the most important decision made during manufacturing performance measurement system design. A firm must decide which performance criteria are objective (quantitative) measures and which criteria are subjective (qualitative). However, most of the objective, quantitative variables in manufacturing performance refer to some previously specified aspects. Management could also use a number of qualitative factors including: problem resolution ability, technical ability, and corrective action response support to assess manufacturing performance. Although these factors are usually subjective in nature, management can still assign each factor a score or rating.

3.1 Satisfaction indicators in manufacturing

An integrated dynamic performance measurement system (IDPMS) [10] developed in conjunction with the D Company in Chungli, Taiwan was developed. The IDPMS integrates three main company areas management, process improvement team, and factory shop floor. To achieve an integrated system, the three areas are linked through the specification, reporting and dynamic updating of the defined success, performance measures, and performance standards. Four main indicators established in this study were based and adjusted partially from Ahmad and Dhafr's [3] defined in "establishing and improving manufacturing performance measures": Cc (customer complaint), Od (on-time delivery), Ee (equipment effectiveness) - "Ee will be divided to two sub-indicators, quality rate and availability", and Cq (cost of quality). These performance indicators were selected because they indicate important manufacturing performance areas and are usually critically linked between business strategy, internal organizational and technological basis and fairly easy to measure or estimate. The company's relative performance indicators in each area for a plant or specific product (line) can be assessed through comparing the relevant performance indicators with internal goals/ standards, competitors and customer demand. After comparisons were made for all performance areas, an overview of the performance gaps could be made. Since the importance of each gap depends on the organization's environment, customer requirements, specific company policy and market situation, the company must set priorities. The definition of each indicator is given as follows:

(1) Cc - customer complaint:

A customer complaint is defined as a quality or reliability issue occurring at the external customer end and confirmed as being caused by manufacturing failure. Normally, a formal notification and a formal corrective action report (CAR) from the customer are required and can be tracked. A measurement that identifies operational problems might be avoided in future. This will be determined by the number and nature of customer's complaint to identify operational improvement projects. Written, verbal, and anecdotal information will be recorded. This data will be shared to avoid repeat problems at other sites. The quality assurance department will be responsible for providing the information required on a regular basis.

The goal will be to achieve < x% (x lower than 1 is suggested.) complaints on dispatches. The KPIs measured are normally the number of customer complaints received, normally expressed as an absolute number or as a percentage of the dispatches. These complaints are related not only to dispatches and could arise from any business area.

(2) Od - on-time delivery:

The purpose of this KPI is to measure the on-time, in full product delivery with no product, packaging, transport arrangement, or supporting documentation defects. This measures the ability to adhere to the first agreed demand date for each order, and whether any problems occurred with the materials shipped. The commonly used due date performance measures are unit penalty, mean tardiness, and maximum and minimum lateness. It is known that tardy jobs may incur tardiness costs, such as contractual penalties, depending on how late they are. For this performance, the minimizing mean absolute and square lateness measurements are used. Due-date-related performance measures are well known [40]. Defining dj as the due date and cj as the completion time of job j is given by Eq. (8)

$$\mathrm{Lj} = \mathrm{cj} - \mathrm{dj} \tag{8}$$

Lateness can be positive (indicating a late job) or negative (indicating an early job). Therefore if earliness is important, then the mean absolute lateness or mean squared lateness is considered. Job tardiness, a related criterion, is defined based on lateness using Eq. (9)

$$\mathrm{Tj} = \max(0, \mathrm{Lj}) \tag{9}$$

Supporting such a measure requires a rigorous recording system by the plant or the distribution company if this aspect is out-sourced. The goal of this KPI is to achieve a value > y% (y higher than 99 is suggested.).

(3) Ee - equipment effectiveness:

This measure is designed to determine just how reliable our assets are and their capability to deliver the outstanding performance expected from a world-class operation.

$$\mathrm{Ee} = \text{Quality rate} \times \text{Availability} \tag{10}$$

Ee works on the principle that the best manufacturing performance is when a site operates to full capacity, always produces perfect product, and never breaks down. Capacity usage, quality performance and breakdown data will therefore be recorded to determine the Ee. The manufacturing manager at the site will be responsible to provide the information required on a timely basis.

It is suggested that an Ee of 99.5% on the critical equipment will be the future target. This can be achieved by

Quality Rate >99.9%, availability >99.6%

To achieve this goal, the following practices should be implemented.

Six-sigma performance, fully automatic start-up, shutdown and fail-safe, intelligent measurement, total accurate dynamic models, multivariate statistical process control, design for success not failure, and predictive maintenance.

Quality rate.

This is the amount of product that is right the first time with out adjustment, recycles and so on. To achieve the six-sigma performance described previously, it is necessary to achieve a very high first-time-right rate.

$$\text{Quality rate} = \frac{\text{Good production}}{\text{Good production} + \text{Failed QC}} \tag{11}$$

Availability.

The availability is defined as the number of hours the plant operates divided by the number of hours in a month (22 hours/day × 25 days/month = 550 hours/month).

$$\text{Availability} = \frac{550 - (\text{number of hours of total shutdown})}{550} \tag{12}$$

(4) Cq - cost of quality:

Cost of quality (or more accurately, of poor quality) relating to customer behavior is sometimes mentioned in TQM (total quality management) implementations. This cost is invisible and seldom pursued. It is called “opportunity cost of sales lost” due to a customer’s poor experience with a poor quality product or because of poor satisfaction with the handling of quality delivery events. This intangible effect on quality costs is often called “hidden quality costs” [41, 42]. It is defined and called “consequential costs (or loss) of failure” (which includes engineering time, management time, shop and field downtime, delivery problems, lost orders, lost market share, customer dissatisfaction, and decreased capacity generally) in this research. Some companies have found a “multiplier effect” between the measured costs and “true failure costs” [43].

The measure is defined as the comparison in actual vs. target cost for completing specific manufacturing tasks. The goal will be to achieve < z % (z lower than 3 is suggested.) consequential costs (or loss) of failure on sales revenue. This will be an important element for customer and total cost oriented performance evaluation.

3.2 The target value of product-line-based manufacturing performance

At the end of the year, the manufacturer’s top management team will measure the performance of each manufacturing team or product line and set a target value with key customers for suitable performance indicators and announce it as a management commitment or pledge for all customers from various product lines. An example case study using a manufacturer whose actual value for the year 2003 and target value for the year 2004 for each performance indicator are given in Tables 1 and 2, will be discussed.

3.3 New performance measurement model

Our study establishes a new model through integrating four indicators: Cc, Od, Ee and Cq, with appropriate weights r_1, r_2, r_3, and r_4, respectively. “Performance, P” was obtained by matching “achievement level, AL”, a range of percentages from “actual value” and “target value” comparisons

Table 1 The actual values for various power supply product business units (B.U.), year 2003

Indicator B.U.	Desktop power	Adaptor power	Telecom. power	Server power
Cc-customer complaint	3.6% on dispatches	2.2% on dispatches	7.3% on dispatches	3.8% on dispatches
Od-On-time delivery	96.6%	97.8%	94.2%	97.1%
Ee-Equipment effectiveness	94.6%	97.1%	81.7%	95.9%
Quality rate	97.6%	99.1%	93.2%	98.5%
Availability	96.9%	98.0%	87.7%	97.4%
Cq-Cost of quality	8.1% of sales	4.7% of sales	13.6% of sales	8.5% of sales

for each indicator. This system is explained precisely based on the definitions in this study,

Actual Cc → compare with target Cc → get an AL → obtain a "PCc, Cc Performance value" through matching.

The Od, Ee and Cq (POd, PEe and PCq, respectively) performances can be measured in the same way. The details of this approach are expressed using formula-example 1, formula-example 1:

(1) PCc-Cc Performance depends on the AL of target Cc

Formula: PCc = achievement level of target CC, AL_n

$1.00 = AL_1$: Cc lower than target above 60%

$0.95 = AL_2$: Cc lower than target 41% – 60%

$0.90 = AL_3$: Cc lower than target 21% – 40%

$0.85 = AL_4$: Cc lower than 6% – 20%

$0.80 = AL_5$: Cc equivalent to target + / – 5%

$0.75 = AL_6$: Cc higher than target 6% – 20%

$0.70 = AL_7$: Cc higher than target 21% – 40%

$0.65 = AL_8$: Cc higher than target 41% – 60%

$0.60 = AL_9$: Cc higher than target above 60%

We may have many kinds of value-sets, either in the number of achievement levels or in the actual output vs. target degree range depending on the organizational requirements. Two additional value-setting examples are shown below:

Formula-example 2:

PCc-Performance of Cc:

Formula: PCc = achievement level of target CC, AL_n

$1.00 = AL_1$: Cc lower than target above 80%

$0.90 = AL_2$: Cc lower than target 61% – 80%

$0.80 = AL_3$: Cc lower than target 41% – 60%

$0.70 = AL_4$: Cc lower than target 21% – 40%

$0.60 = AL_5$: Cc equivalent to target + / – 20%

$0.50 = AL_6$: Cc higher than target 21% – 40%

$0.40 = AL_7$: Cc higher than target 41% – 60%

$0.30 = AL_8$: Cc higher than target 61% – 80%

$0.20 = Al_9$: Cc higher than target above 80%

and,

Formula-example 3:

PCc-performance of Cc:

Formula: PCc = achievement level for target Cc, AL_n

$1.00 = AL_1$: Cc lower than target above 80%

$0.80 = AL_2$: Cc lower than target 31% – 80%

$0.90 = AL_3$: Cc equivalent to target + / – 30%

$0.40 = AL_4$: Cc higher than target 31% – 80%

$0.20 = AL_5$: Cc higher than target above 80%

Table 2 The target value for various power supply product business units (B.U.), year 2004

Indicator B.U.	Desktop power	Adaptor power	Telecom. power	Server power
Cc-Customer complaint	Less than 2% on dispatches	Less than 1% on dispatches	Less than 5% on dispatches	Less than 2% on dispatches
Od-On-time delivery	Higher than 98.5%	Higher than 99.5%	Higher than 96%	Higher than 99%
Ee-Equipment effectiveness	Higher than 98.0%	Higher than 99.0%	Higher than 85.0%	Higher than 98.0%
Quality rate	Higher than 99.0%	Higher than 99.8%	Higher than 95.0%	Higher than 99.0%
Availability	Higher than 99.0%	Higher than 99.2%	Higher than 90.0%	Higher than 99.0%
Cq-Cost of quality	Lower than 6.0% of sales	Lower than 3.0% of sales	Lower than 10.0% of sales	Lower than 6.0% of sales

Table 3 Comparison of desktop power performance measurements using two different formulas, (5) and (7), time: Jan–Mar, year: 2004

Indicator	Target	Actual value	Weight of formula (7), $r_1, r_2,...,r_4$	Score using formula-example 1	Weight of formula (5), W_C, Wq, and Wd	Score using formula (5)
PCc	≦2.0%	2.3%	0.3	0.75	–	–
POd	≧98.5%	98.3%	0.3	*0.75	0.35	0.983
PEe	≧98.0%	98.5%	0.2	**0.90	–	–
Quality rate	≧99.0%	99.4%	–	–	0.4	0.994
Availability	≧99.0%	99.1%	–	–	–	–
PCq	≦6.0%	9.1%	0.2	***0.65	0.25	0.569
Total				****76.0%		*****88.39%

*On-time delivery rate ≧98.5% means delinquency of delivery against customer requirements<1.5%. The calculation of achievement level (AL) should be $(98.3\% - 98.5\%) \div (1 - 98.5\%) \times 100 = -13.3\%$ -higher delinquency than target value 13.3%
**Similarly, Ee's achievement level is $(98.5.0\% - 98.0\%) \div (1 - 98.0\%) \times 100 = 25.0\%$ -better than target value 25.0%
***The calculation of Cc's achievement level is as same as Cq's which is $(9.1\% - 6.0\% \times 100 = 51.7\%)$ -worse than target value 51.7%
****$[(0.75 \times 0.3) + (0.75 \times 0.3) + (0.90 \times 0.2) + (0.65 \times 0.2)] \times 100\% = 76.0\%$
*****$[(0.983 \times 0.35) + (0.994 \times 0.4) + (0.569 \times 0.25)] \times 100\% = 88.39\%$

Similarly, the value-setting flexibility can be applied for all other indicators, Od, Ee, and Cq, or some of them. Maintaining performance measurement consistency, continuity and flexibility is necessary.

(2) Manufacturing performance measurement formula

(a) If a manufacturing team organizes just one product group, the manufacturing performance value (Pm) will be the same as the product performance value (Pp). This value is given by

$$\mathrm{Pm} = \mathrm{Pp} = 100 \times (r_1 \times \mathrm{PCc} + r_2 \times \mathrm{POd} + r_3 \times \mathrm{PEe} + r_4 \times \mathrm{PCq}) \quad (13)$$

Where $r_1 + r_2 + r_3 + r_4 = 1,\ r_i \geq 0,\ 1 \leq i \leq 4$

(b) If a manufacturing team organize several groups of products (more than one type), the Pm is obtained using

$$\mathrm{Pm} = \frac{\mathrm{Pp}_1 + \mathrm{Pp}_2 ...... + \mathrm{Pp}_n}{n}, \text{ where } n > 1 \quad (14)$$

(c) The parameters in this formula are applied flexibly to cover all kinds of manufacturing projects with different characteristics :

For instance:

(1) If a manufacturing project is not suitable for the Ee measurement, the parameter weights can be

$$r_1 + r_2 + r_4 = 1 \quad (15)$$

Table 4 Comparison of telecom. power performance measurements using two different formulas, (5) and (7), time: Jan–Mar, year: 2004

Indicator	Target	Actual value	Weight of formula (7), $r_1, r_2,...,r_4$	Score using formula-example 1	Weight of formula (5), W_C, Wq, and Wd	Score using formula (5)
PCc	≦*5.0%	2.3%	0.3	*0.95	–	–
POd	≧96.0%	98.3%	0.3	**0.95	0.35	0.983
PEe	≧85.0%	91.0%	0.2	***0.90	–	–
Quality rate	≧95.0%	96.7%	–	–	0.4	0.967
Availability	≧90.0%	94.1%	–	–	–	–
PCq	≦10.0%	9.1%	0.2	0.85	0.25	0.609
Total				92.0%		88.31%

*$(2.3\% - 5.0\%) \div 5.0\% \times 100 = 54.0\%$
**$(98.3\% - 96.0\%) \div (1 - 96.0\%) \times 100 = 57.5\%$
***$(91.0\% - 85.0\%) \div (1 - 85.0\%) \times 100 = 40.0\%$

(2) If another manufacturing project has been adopted for program support role and is not suitable for Cq's control, the formula weights can be expressed using

$$r_1 + r_2 + r_3 = 1 \quad (16)$$

4 Comparison of results

An example is presented to demonstrate how the proposed model, formula (13) could be applied to manufacturing team performance measurement and to compare it with the popular model, formula (6). The proposed method can be compared using different achievement levels and weight values (AL) for each performance indicator. The formula-example 1 is used in this comparison. The basic manufacturing data from two product groups (Desktop power and Telecom. power) are given in Tables 3 and 4. The results from our proposed model, formula (13), and the popular model, formula (6), are shown in Tables 3 and 4, respectively. Significantly sensitive, accurate and effective manufacturing performance rating results for different achievement levels, through applying the new model, formula (13), have been obtained compared to the popular model, formula (6).

5 Conclusions

The proposed manufacturing performance measurement model with customer satisfaction orientation could be applied by firms in different industries to address all kinds of manufacturing management situations. The proposed model can assist firms in selecting and rewarding the best manufacturing teams and integrating their capabilities in developing an appropriate profit improvement program for meeting and exceeding specific customer requirements.

The merits of the proposed model can be found through comparing it with the so-called "system" requirements.

(1) Complete.

The customer satisfaction oriented system integrates four performance indicators and covers three "planning production customer" stages. The main manufacturing activities in industry are horizontally involved in this system. The system extends the customer-satisfaction concept from manufacturing vertically to the user and customer.

(2) Flexible.

This system provides four flexible weights to linearly combine performance parameters that help management formulate the most suitable measurements for several kinds of manufacturing projects/teams in different industries. To attain accuracy effectiveness, different weight combinations (r_1, r_2, r_3, r_4) can be set in this system.

(3) Effective.

The proposed method addresses the same manufacturing performance requirements found in the ISO-9000 and QS-9000 quality management systems. The main purpose of these requirements is to generate effective quality improvement. The system presented in this study provides an effective method for measuring manufacturing quality improvement (i.e., PCc, PCq and PEe) with measurable, just-in-time aspects.

Grades for manufacturing performance can be developed after the performance measurement. This supports top management in adopting suitable strategic actions to promote manufacturing team performance. The applicable strategic actions to promote the willingness and capabilities of the management and manufacturing teams could be considered as a direction of future research, including profit sharing, internal promotion programs, organizational expansion projects and so on that may be critical for performance's improvement and sustaining.

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