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# Performance Measurement and Evaluation in an Innovative Modern Manufacturing System

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**Abstract:** The main objective of this study was to measure the performances after implementation of or substitution by a modern and innovative manufacturing management system in a traditional just-in-case environment. The study was carried out in a casting based manufacturing plant of an electrical company which currently implementing the Japanese concept, Kaizen towards achieving the higher productivity. The study has focused into the Performance Indicators (PIs) currently being measured by the company. Careful investigations and observations have been undertaken and then additional tangible and intangible performance indicators have been introduced in order to show the effectiveness and efficiency of the implementation of the system in an innovative manner. After analyzing the collected data, sufficient information has been generated on various aspects of performance evaluation. The success or beauty of the process has been recognized while the weakness or grey areas are noticed. Based on the literature survey and practical consideration, a number of recommendations have been suggested to the company to overcome the problems and improve their performances. However, due to lack of financial data, monetary-based PIs could not be carried out in this study.

**Key words:** Performance measurement, performance indicators, kaizen, base value, weight method, one-piece-flow

## INTRODUCTION

In order for companies to ensure achievement of their goals and objectives, Performance Measures (PMs) are used to evaluate, review, control and improve production processes. PMs are also used to benchmark the performance of different organizations, plants, departments, teams and individuals and to assess employees. As quoted from Lord Kelvin (1824-1907)[1].

*"When you can measure what you are speaking about and express it in numbers, you know something about it... (otherwise) your knowledge is a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in thought advanced to the stage of science."*

The PM is important for the company in question as it now is in the process of kaizen/JIT implementation. The quality of the company performance is an essential determinant to make this implementation a success. The company so far hardly attempted to judge the overall performance but do the simplistic analysis on the basis of conventional performance indicators. What the company really needs is the proper measurement that manages to show them the overall performance in clear terms. Therefore, through the implementation of a performance measurement system on elements (what to measure) and selection of measuring tools (how to measure) in the company unit that have been studied, that could be communicated to their members to understand priorities, objectives and values which the company looks for in achieving its strategic objectives. The selection of appropriate measurement parameters and procedures is very important to obtaining a good method of monitoring, control and evaluation of variations and improvements. The definition of the parameters to be used as PMs depends on the specific characteristics of each case. For the studied company, the vital parameters were needed to identify the performances related to its productivity, quality, efficiency and equipment maintenance to get the overall scenario of the success and weakness.

The main purpose of this research was to study the performance measurement of a factory where Kaizen is being implemented towards achieving better performances. The conventional Just-in-case (JIC) technique was the norm earlier. The research has concentrated on a manufacturing unit of the company. The possible ways or methods that could be carried out to improve the performances are to be analyzed in order to achieve the goal of the factory. The outcomes of this study can be used by other manufacturing companies. The specific objectives of the study are:

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- To study the level of the current PMS in the factory.
- To compare organizational goals (targets) with realized (actual) performances.
- To identify and determine the factors needed to improve performances.
- To suggest possible production and PM methods to improve the factory's productivity.
- To provide information for individual and team evaluation.
- To observe if managed by fact rather by gut feeling.

Literally, performance measurement is the process of quantifying actions, where performance is the outcome that has been achieved. Measurement is the process of quantifications of the outcomes. From the point of customer focus, organizations achieve their goals that they performed if they could satisfy their customers with greater efficiency and effectiveness than their competitors. Effectiveness refers to the extent to which customer requirements are met, while efficiency is a measure of how economically the firm's resources are utilized in providing the given level(s) of customer satisfaction.

The level of performance achievement is largely "system" dependent. Firms with JIT are higher performers from firms without JIT. Firms with TQM can secure higher performance than firms without it[2]. Firms produce better quality of products and services can earn greater organizational performance[3-5]. Firms with more advanced implementation of TQM can perform better than firms with less advanced implementation of that[2,6]. Again, firms with greater implementation of TQM tools can obtain greater performance than those with less of them[7]. The empirical research on the strength of the relationship between quality practice and organizational performance conducted by Maani *et al.*[8] is considered one of the most complete studies in this area[6], which also derived the similar conclusion.

The outcome of performance measures is indicated by some metrics (or indicators). A performance has a correlation with expectations. Expectations are noticed to be fulfilled if these could be measured both in quantitative and qualitative terms. However, a short-term sparkling achievement does not speak meaningfully. The relevant actions need to be adopted if high-level performance is desired in a sustained manner. Therefore, quantified elements alone cannot represent the performance of an organization or an initiative. Thus, a Performance Measurement System (PMS) not only measures the discrete quantifiable events, but also the "system" itself being applied. Then the performance measurement can be defined as:

*The process of knowing the quantitative and qualitative achievements in terms of efficiency and effectiveness in an adopted organizational or system's environment.*

The production or manufacturing management is still dominated by traditional non-system "Just-in-case (JIC)" concept, where the people are more concerned to measure profit or loss, Return On Investment (ROI), return on sales, price variances and productivity[8]. Many authors have discussed the limitations of these traditional performance measures and traditional management accounting system, which is the basis of traditional performance measures[9-12]. These conventional parameters are not sufficient to measure the performance of a manufacturing company's engineering activities because they are product specific and do not extend beyond a single product[13]. They cannot provide enough data with which engineers can assess and improve the overall engineering process. In a diversified products manufacturing firm, where continuous improvement (kaizen) and innovation over a long-range is the way people do or need to do work-a different set of indicators is needed. These metrics should target competitiveness, provide a focus on kaizen initiatives and facilitate teamwork[14].

Further, traditional measures suffered from lagging matrices or post-active measures, irrelevant to actions or practices, inflexible, pose lack of concern about the organizational strategy, lack of customer focus, insensitive, needs large volume of data, but pays poor attention upon continuous improvement (kaizen)[12,15,16]. Therefore, the traditional performance measures are focusing into the sub-optimization instead of seeking into and bringing in the entire affairs together. For that, the available measuring elements, tools and techniques are not adequate. There is little regard to workers, customers and a distant relation is maintained with vendors. Kaplan[17] states that "traditional summary measures of local performance-purchase price variances, direct labor and machine efficiencies, ratios of indirect to direct labor, absorption and volume variances-are harmful and should be eliminated, since they conflict with attempts to improve quality, reduce inventories and increase flexibility. Direct measurement is needed for quality, process time, delivery performance and any other operating performance criterion that needs to be improved".

In advent of the modern manufacturing systems or philosophies which regard the entire organizational activities as a "process" such as Total Quality Control/Management (TQC/M) system, Just-in-time (JIT), Total Productive Maintenance (TPM), 5Ss housekeeping techniques and Theory-Z, conventional measures alone cannot display any comprehensive picture of a system.

Table 1: A comparison between traditional and non-traditional performance measures[20]

| Traditional performance measures | Non-traditional performance measures |
|---|---|
| Based on outdated traditional accounting system | Based on company strategy |
| Mainly financial measures | Mainly non-financial measures |
| Intended for middle and high managers | Intended for all employees |
| Lagging metrics (weekly or monthly) | On-time metrics (hourly, or daily) |
| Difficult, confusing and misleading | Simple, accurate and easy to use |
| Lead to employee frustration | Lead to employee satisfaction |
| Neglected at the shop floor | Frequently used at the shop floor |
| Have a fixed format | Have no fixed format (depends on needs) |
| Do not vary between locations | Vary between locations |
| Do not change over time | Change over time as the need change |
| Intended mainly for monitoring performance | Intended to improve performance |
| Not applicable for JIT, TQM, CIM, FMS, RPR, OPT, etc. | Applicable |
| Hinders continuous improvement | Help in achieving continuous improvement |

With the advancement of computer technologies, a sea of changes has been experienced in manufacturing. A short-list of them are Computer Aided Design and Manufacturing (CAD/M), Flexible Manufacturing System (FMS), Computer Aided Engineering (CAE), Computer Integrated Manufacturing (CIM), robotics, computerized Manufacturing Resources Planning (MRPII) and concurrent engineering. Technology was treated as a residual ingredient in economic activities even in until early 1970s, but now accepted as the prime-mover for economic development[18]. Now the elements of measures under the ISO 9000, ISO 14000 and Malcolm Baldrige Quality Awards are different from those of conventional measures. All these changes observed that traditional measures of performance have had many limitations and development of new performance measures has a vital place. Therefore, Globerson[19] has stated that a performance measurement system of an organization should include, a set of well-defined and measurable criteria; standards of performance for each criterion; routines to measure each criterion; procedures to compare actual performance to standards and procedures for dealing with discrepancies between actual and desired performance. Now, it is highly important to conduct comprehensive, systematic and thorough measures. The differences between traditional and non-traditional PMs are summarized in Table 1.

The modern performance measures should be characterized by the following criteria.

- Ensure high quality of products and services for survival and competitiveness[21] no or minimal customer complaints, minimum rejection rate or rework, minimum in number but higher signal-to-noise ratios, no or minimum costly mistake, low cost operations, more satisfied customer, etc.
- Continuous improvement of the overall Situation-statistical Process Control (SPC), TQM, Business Process Re-engineering (BPR) in case of technology out lever, prolonged customer satisfaction;
- Quality culture-emphasizing proactive and preventive approach, using process management instead of product quality;
- Timeliness-reduced cycle time, higher inventory turnover, quicker delivery of product/service;
- Relationship with financial performance-finally can be matched with financial measures;
- Communication, technology, education and training-transparent, modernized and people friendly;
- Productivity-focus on overall productivity improvement.

Nevertheless, non-traditional measures also indicate the merit of a particular product or a bundle of products while the traditional measures present the health of the overall company. Still the engineering performance measures must represent a quantification of mission statement, so that improvement in the engineering process will be congruent with improvement in the overall company goals[22]. Forker *et al.* [3] studied on contribution of quality to business performance with 65 furniture firms and showed that design quality was the only predictor for ROI and ROS and product improvement was the only predictor for ROI growth.

From the point of quality and productivity improvement approaches, the relevant variables can be divided into dependent and independent ones. The list of those items is presented in Table 2.

The customer focus is dominant in today's manufacturing. Customers are of two types, internal and

Table 2: Performance of dependent variables

| Dependent variables | Measure |
|---|---|
| Quality performance | Percentage of defective item |
| | Returns and warranty |
| | Training and development |
| | Waste and rework |
| | Cost of inspection |
| Operating performance | Annual employee turnover |
| | Last year's net profit as percentage of sales |
| Financial performance | Last year Return On Asset (ROA) |
| | Past three years' average ROA |
| | Last year's sales growth |
| | Past three years average sales growth |

external. For the satisfaction of the external customer, the requirements of internal customers have to be met. Performance measures also could be seen from the viewpoint of internal and external performances. The performances relating to "quality" are further differentiated into produced quality, perceived quality, in-bound quality (quality of the supplier) and quality cost[23-25].

Productivity is defined as the relationship between output and input[26,27]. The outputs are generally produced physical goods possibly valorized, while the inputs are fixed or working capital in the case of the capital productivity and labor employed (hour/cost-direct or indirect) in the case of production productivity[23]. The value-added productivity could be a newer measure where in numerator, instead of output in quantities, the value of the output less the purchasing value should be considered.

Innovativeness, both in system management and performance measurement are highly important in today's manufacturing. There is no unique JIT, TQM or Kaizen prescription for every manufacturing firm. Change may be seen as an opportunity instead of just accepting any change. This is again case specific. Nevertheless, some innovations can be generalized for a large number of firms or a few industries. For example, a company, which introduces JIT or Kaizen, has already been advanced significantly to apply the concepts of TQM. The six basic concepts of TQM are:

- A committed and involved management to provide long-term top-to-bottom organizational support.
- An unwavering focuses on the customer, both internally and externally.
- Effective involvement and utilization of the entire work force.
- Continuous improvement of the business and production process.
- Treating suppliers as partners.
- Establish performance measures for the processes.

The purpose of TQM is to provide a quality product to customers, which will, in turn, increase productivity and reduce manufacturing cost. With a higher quality product and lower price, competitive position in the marketplace will be enhanced. This series of events will allow the company to achieve the objectives of profit and growth with greater ease. In addition, the work force will have job security, which will create a satisfying place to work.

TQM requires a cultural change, as it is required for Kaizen. Indeed, Kaizen is a part of TQM. Table 3 compares the previous state with the TQM state on typical quality elements. This change is substantial and will not be accomplished in a short period of time. Small organizations will be able to make the transformation much faster than large organizations.

In a Kaizen or JIT or TQM organization, measurement of equipment effectiveness is an important performance indicator. The major equipment bound losses are measured in terms of Overall Equipment Effectiveness (OEE), which is a function of equipment Availability (A), Performance rate (P) and Quality rate (Q). The exact definition of OEE differs between applications and authors. Nakajima[28] was the original author on OEE and De Groote[29] is one of the several prominent ones. Their definitions on those items are put in Table 4.

Owing to different definitions of OEE and other varying circumstances between companies, it is difficult to identify optimum OEE figures and compare OEE between firms or shops. Some authors have tried to do it though; e.g. Nakajima[27] asserted that under ideal conditions firms should have $A>0.90$, $P>0.95$ and $Q>0.99$. These figures would result in an $OEE>0.84$ for world-class firms and Nakajima considers this figure to be a good benchmark for a typical manufacturing capability.

Table 3: New and old quality cultures

| Quality element | Previous state | TQM |
|---|---|---|
| Definition | Product-oriented | Customer-oriented |
| Priorities | Second to service and cost service and cost | First among equals of |
| Decisions | Short-term | Long-term |
| Emphasis | Detection | Prevention |
| Errors | Operations | System |
| Responsibility | Quality control | Everyone |
| Problem Solving | Managers | Teams |
| Procurement | Price | Life-cycle costs, partnership |
| Manager's Role | Plan, assign, control, and enforce | Delegate, coach, facilitate, and mentor |

Table 4: Definition of OEE variables[30]

| | Nakajima[28] | De Groote[29] |
|---|---|---|
| Availability (A) | Loading time-downtime | Planned production time-unplanned downtime |
| | Loading time | Planned production time |
| Performance (P) | Ideal cycle time x output | Actual amount of production |
| | Operating time | Planned amount of production |
| Quality (Q) | Input-volume of quality defects | Actual amount of production-non-accepted amount |
| | Input | Actual amount |
| OEE | (A) x (P) x (Q) | (A) x (P) x (Q) |

Kotze[31], on the other hand, argues that an OEE less than 0.50 are more realistic. This figure corresponds to the summary of different OEE measurements presented by Ericsson[32], where OEE varies between 0.30 and 0.80. These disparate figures indicate the difficulties of comparing OEE between processes.

This study proposes some innovations in process management and performance measurement and uses number performance indicators such as quality of products and wastage of materials, equipment effectiveness, line or plant efficiency, productivities, process capability indices as well as employee aspects. A few SPC tools like control charts, histogram and other pertinent charts have been developed.

**Study method and performance measurement framework:** The methodology of this case study based research is simplified and displayed in Fig. 1 and a performance measurement framework in Fig. 2.

The study was carried out in two steps. The first step dealt with the general PM system in manufacturing and the second step was on recommended methods Overall Equipment Effectiveness (OEE), variable control charts, process capability ($C_p$, $C_{pk}$) and six-sigma concept. Both the steps were based on field observations and experiments, interviews (primary data) and company documents (secondary data).

**The case presentation**

**Company profile and problems encountered:** The company is an ISO 9001 registered and a Kuala Lumpur

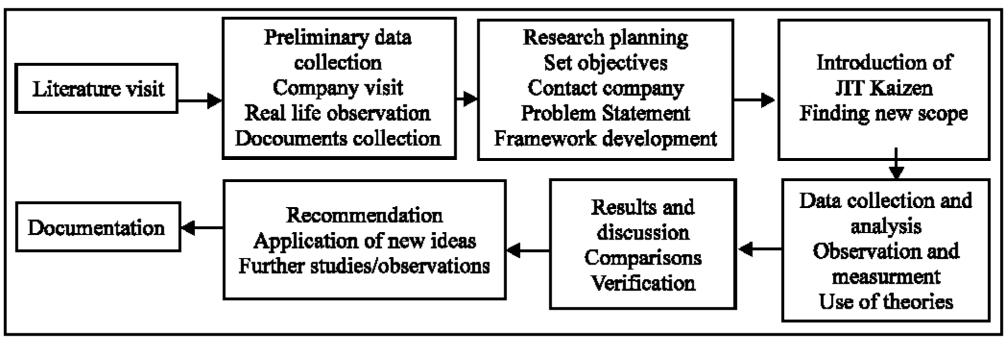


Fig. 1: Case study methodology flow chart

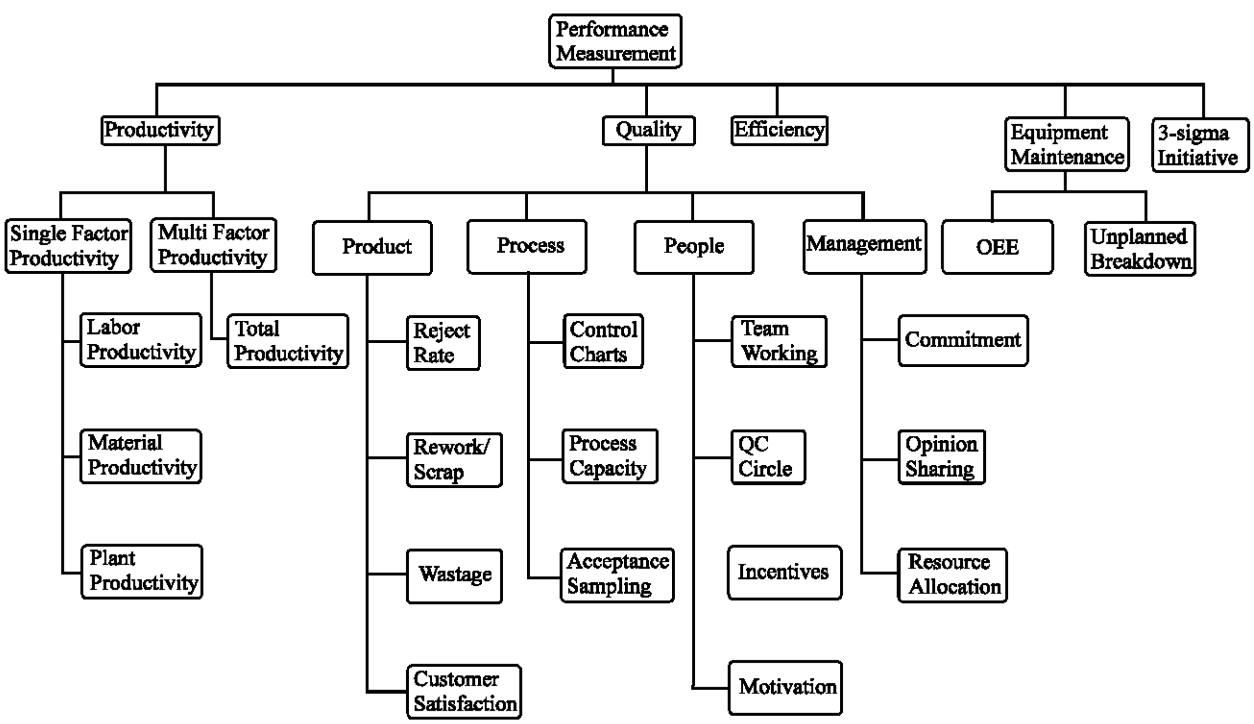


Fig. 2: Performance measurement framework

Stock Exchange Main Board listed leading manufacturer of low and medium voltage switchgear in South East Asia. Established in 1964, it has earned strength bit-by-bit during the last four decades.

This study was conducted in a unit of the company named PU Plant where manufacturing environment was governed by customer orders (produce-to-order). The manufacturing process was job shop type major. The two main processes in the unit were casting and finishing. The casting process needed skill workers to operate the injection casting guns while the finishing could be run by both skilled and semi-skilled workers to conduct the operations like grinding, drilling, filling and cleaning. The unit had both skilled workers having 15-25 experiences and newly employed semi-skilled foreign workers having a few months to three years experience.

The plant of the company was not well organized in terms of proper documentation such as time study, overall performance data, work schedules, written work procedures and records on process parameters. As there was no written work procedures, newly appointed workers had to face a number of troubles due to lack of guidelines for them. Further, they were mainly calculating productivities and no SPC methods or tools were being in use except doing some computations with Ms Excel and display the data into bar graph, line graph or pie chart.

**Introduction of Kaizen:** The company was advised to introduce the Japanese Kaizen (continuous improvement, CI) concept, which was, for the first time, successfully introduced by Toyota in Japan in the 1970s and later by many companies around the world. This was accepted for the entire company and thus for this unit as well. The PU Plant had been trying to implement the Kaizen during the last one year to improve the plant productivities. This study team joined the company at the same time of introduction of the new system. Along the Kaizen implementation, the inventory management department was practicing the basic MRP I solution. The production trend had been slowly changing to the JIT environment with the objectives to minimizing inventory, lead-time, setup time, workload, maintenance time and increasing the workers' morale and quality of the finished goods. By carrying out the Kaizen activities, now it was felt important to measure their performances, mostly from non-traditional aspects. The performance measurement could be traced from Fig. 3.

After a thorough investigation of the whole process, measures those were suggested and undertaken for implementation are briefed below:

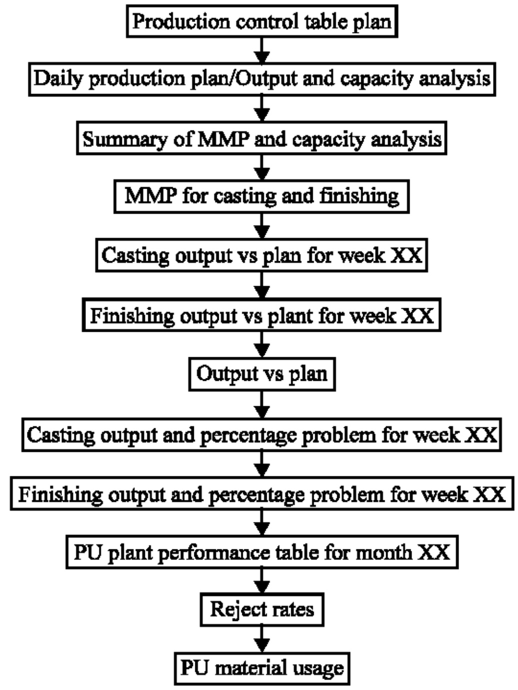


Fig. 3: Current performance measurement steps in the plant

- "One piece flow" trend-this production method was suggested and applied throughout the casting and finishing units to make sure that there were continuous jobs to do for the workers even if the mixing guns had broken down
- "Base value consideration"-as multiple products were produced in a production line, the base value concept was found proper. The base value is the ratio of standard time to the base time. The standard time of a particular product is chosen as the base time
- MRP inventory management-along the Kaizen, the inventory management department was applying this computerized solutions
- "Weight consideration"-measurement applied to calculate the percentage of reject rate by using the weight was much better and suitable than number of rejected pieces to get the performance review
- Weekly meeting of workers and supervisors-workers were allowed to raise the problems or difficulties they were being faced and decisions were made jointly;
- Hiring of modern technology-modern measurement instruments were purchased and used
- Application of SPC tools Statistical Process Control (SPC) tools like Pareto diagrams, cause-and-effect diagrams, control charts and other charts were applied to locate problems objectively

- Introduction of non-traditional performance measures-engineering or non-financial performance measures had been introduced to see the differences in the production lines
- Training and motivation-more work friendly nature of training had been imparted and revised job conditions were introduced to increase workers morale and motivation

**"One piece flow" method:** Looking into product ordering and manufacturing processes, the plant had been advised to apply the "One piece flow" production method (Fig. 4) in its casting and the finishing units. This method could make sure that there were continuous jobs to do for the workers if the mixing guns in casting unit, which was experienced critical, even had been broken. Therefore, if the casting gun would not work, the workers in the casting plant were shifted to the finishing unit, under the "one piece flow" application where there were sufficient pieces for the finishing unit (approximately the speed ratio of the casting to the finishing was 1:2 each day).

**Base value consideration:** As the company had been producing multiple products, it was suggested to use a base value concept to determine the number of pieces of each product in a time horizon. A standard time of a particular product was chosen as the base time to compare it with each product produced. In the studied company, one regularly demanded product (PDS Short T 3-ph 12 kV 1250 A) was chosen with the standard casting and standard finishing times. The base value for each product was then obtained by dividing the standard time for each product to the selected base time. The pieces of a product planned to produce could be obtained multiplying order value by the respective base value, which was different from each product in order to get the suitable quantities, because the company was manufacturing different products daily.

**Weight consideration:** Throughout the study in the PU Plant, it was found that the currently applied measurement technique of the reject rate in the plant was based on number or percentage rejects, which was a traditional measure. With respect to the physical observation, interview and discussion between the management executives and the researchers, it had been noticed that in a plant simultaneously producing different products depending on the customer orders or market demand - the products were of different sizes and there was no unique standard. Therefore, this measure was inappropriate. The weight consideration, to find the reject rate in term of

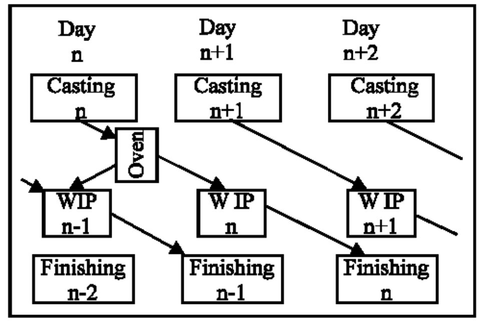


Fig. 4: "One piece flow" trend

weight (kilogram, kg), was appeared more meaningful and suitable to get better performance review for the plant. However, from the point of standard weight of a product, the number of units rejected in a time period could also be found. The percent rejected for the same product is getting the same result no matter it were calculated by using weight or units. However, there is a big difference if we want to get the total percent reject for all the variety of products produced.

If the company intention was to know the consumption of material used, then the reject rate should count in term of weight. However, if the company would like to find out the exact number of products rejected (for customer information) from each type of product produced, then it would apply the calculation in terms of unit. Since both types of calculation are showing their implications, therefore it is advisable to use both the methods.

## RESULTS AND DISCUSSION

After a few months of introduction of Kaizen with those recommended changes, a number of measures, both non-traditional and traditional, were conducted.

**Productivity measures:** The company's main target of implementation of Kaizen was to increase the overall productivity. However, the total productivity couldn't be measured because of lack of release of the financial data. A few relevant productivity measures had been carried out. In some cases they exceeded the targets. In some other cases, they fell behind. With figures, these are put below.

**Labor productivity and material productivity:** Labor productivity was one of the major areas to show how well the labor force was managed or how efficient the workers performed. A new measure called man Minute-per-piece (MMP) had been applied to show how fast a piece of product could be produced. However labor productivity

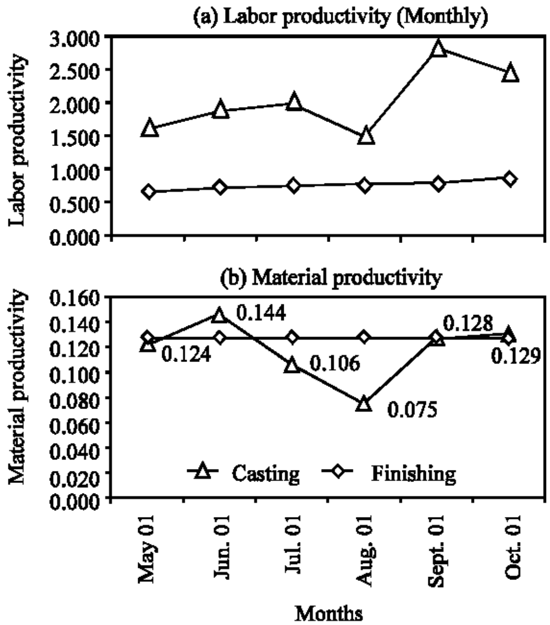


Fig. 5 a: Labor productivity achieved, b: Material productivity graph

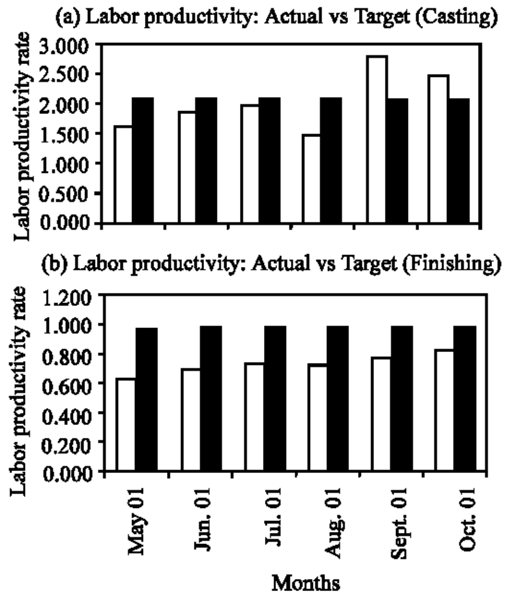


Fig. 6 a: Labor productivity actual vs. target (Casting line), b: Labor productivity actual vs Target (Finishing)

ratio could provide an easier way to understand the real trend of the production line. By having labor productivity information, we preferred to have greater values of its productivity index, while in case of MMP, we preferred lower values of MMP index.

The quality of raw material and their substitution ratios in the process can be determined by reviewing the material productivity ratio in the plant. The greater the productivity indices better the use of raw materials. The ideal ratio is as high as possible to the level of designed consumption in order to minimize the raw material wastage or cost and maximize the number of units produced.

Both labor and material productivities are depicted in Fig. 5a and 5b. Several products were produced simultaneously in the production line, therefore it was found proper to calculate the total units produced based on the “base value” method. It is evident that the casting labor and material productivities had deceased in August’01. This poor performance was due to the change of the raw materials from the supplier. The different viscosity and shrinkage of the new material caused the casting products had to cure in the oven for a longer time instead of avoiding rejection from the testing section. There was no proper testing on the new raw materials’ properties at the early stage. After the Kaizen (brainstorming) meeting between the supervisor and the executives, the solution had been carried out to change the mixing ratio of the Isocynate: Resin (Polymer) through some trial-and-error method. The trial-and-error tasks caused the wastage of the raw material for sometime. This affected the material productivity, labor productivity, plant productivity and other related measurements. However, the improvement attempt had increased the labor productivity in September’01. This attempt had saved the use of raw material. From the unstable and unfavorable material productivity ratio in the beginning, it was later found that the substitution ratio of raw material in the process was inviting. The labor performance had again decreased in October’01 during the period of new mould changing, which was still much higher than earlier. It would hopefully take a stable upward trend now onward.

If compared to the labor productivity achieved in casting line in these 6 months with the set target (Fig. 6), it was found that after the adjustment had been made the production line had successfully registered increasing labor productivity towards the target. These significant improvements were occurred due to the implementation of the Kaizen decisions through small group workers participation, which was held on every week to troubleshoot the problem faced and brainstorming to find out the better solutions. On the other hand, the finishing line had undergone a stable performance. The labor productivity ratio had increased gradually except in August’01 for that the workers had to spend more time to finish the products produced from the new raw materials where a lot of bubbles and unfilled holes were found. Overall, although the labor productivity ratios in the finishing line from May'01 through October'01 were all under the targets but an upward trend was obvious. After the improvement in casting line, the finishing line performance was attained an increasing trend as shown in Fig. 6. It is already mentioned that both casting and finishing together make the whole production process.

**Plant productivity:** A typical measure of plant productivity reflects the utilization of machine capacity. If the ratio is high, it represents the machines in the company are well utilized. However, the ratio cannot exceed 1.00 although the main purpose is to get as high as possible.

Referred to the observation at the plant, only the injection casting guns were facing the unplanned downtime while the others were fully operated everyday throughout the months. The machines' total operating hours were obtained from the subtraction of the injection guns unplanned downtime from the total possible working hours. It was found that plant productivity ratios were unstable during the case study periods. The plant productivity had declined from June'01 to August'01 as shown in Fig. 7a.

Sometimes the casting line had to shut down or stop operations because of the gun problems. The main factor of the gun break down was due to the pump problem (Fig. 7b). During that time, the casting line workers were deployed to help the finishing line. Although the casting line did not produce any product during the shut down or stop-operation days but this did not stop the finishing line. This happened because of the application of "one-piece-flow" method. However it wasted the capacity of the machines and delayed the schedule of the casting line. The problem was analyzed and noticed to the management and recommended to buy an extra injection gun as a backup unit. The workers were asked to change the problem-gun within 2-3 hours to continue their work with the new one. The faulty gun then sent to the maintenance department for repair. After having the extra gun, the plant productivity had increased significantly (Fig. 7a).

**Product quality measures:** Quality encompasses every aspect of the organization and is actually an emotional experience for the customer. Customers want to feel good about their purchases, to feel that they have gotten the best value. They want to know their money has been well spent and they take pride in their association with a company with a high quality image. A product is considered good quality if it has been designed to successfully fill the customer needs and meet the specific requirements set by the customer. Here, a few measures have been shown.

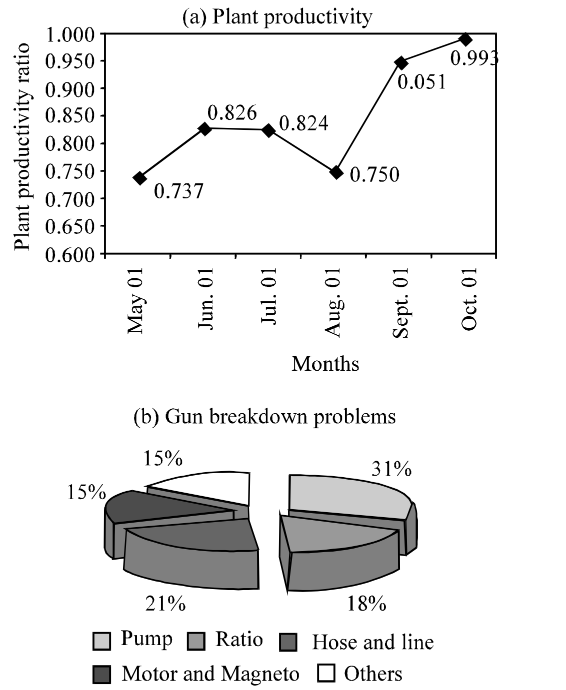


Fig. 7 a: Plant productivity trend, b: Gun breakdown problem

**Reject rate:** The reject rate can determine the quality of the product produced by a company. The higher the reject rate means the products produced are not in the good quality. As the reject rate increases, the loss of the company is also increases. This definitely affects the performance of the company at the competitors' world.

In case of our company, the target reject rate was set less than equal to 2.00%. However, it was usually higher than that except in Oct'01 (Fig. 8a). In August'01 the reject rate decreased to 2.03% (actually it referred to the products produced in the previous month, July'01). This was because the final voltage test couldn't be carried out at the same day of the production. It would be tested a few days or weeks later when the accumulated amount was significantly large.

The reasons for higher reject rate were the same as the other performance indicators where there were the material changes and gun problems occurred. The main cause for rejection was Partial Discharge (PD) failure due to the material problem, air bubbles and contaminant inside the mould during the casting (Fig. 8b). In October'01, the reject rate fallen down to 1.64%, which was better than the target value after the mixing ratio of the raw materials had been stabled. Through kaizen, the company was now trying to reduce the reject rate as low as possible to increase the product quality and fight with the competitors.

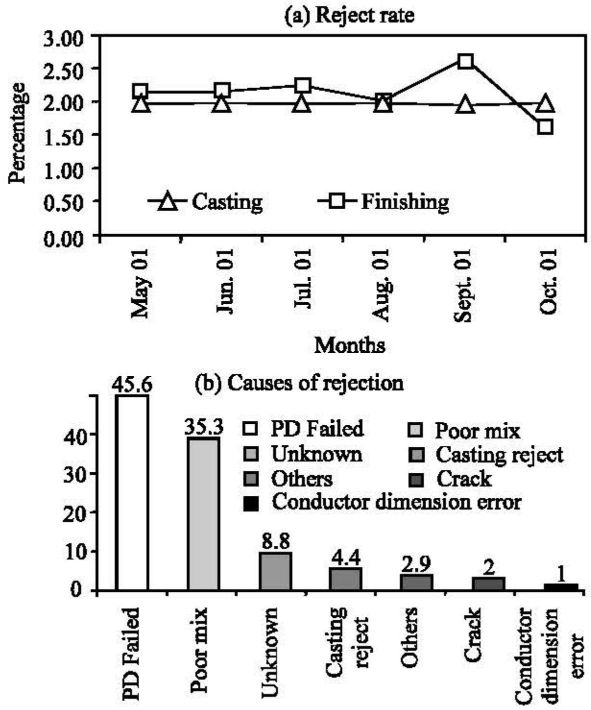


Fig. 8 a: Reject rate, b: Pareto chart on causes of rejection

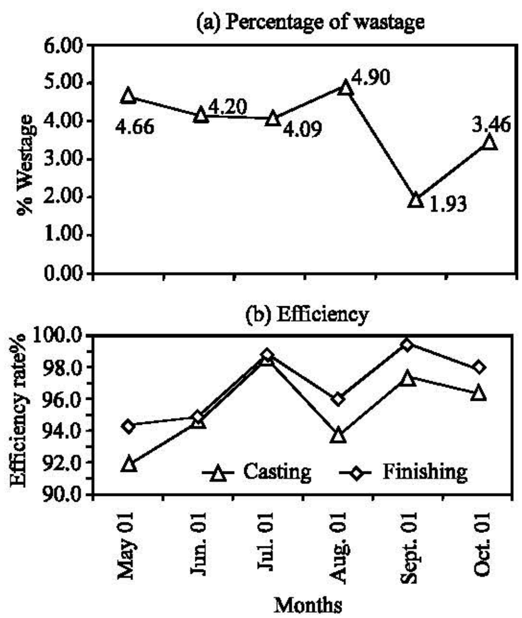


Fig. 9a: Percentage of wastage of raw material, b: Casting and finishing lines efficiencies

The finding of the reject rate would be more meaningful if the cost of the labor, material and other inputs were known to calculate the total loss of the rejected products. However, due to the policy of the company, the researchers were not allowed to obtain any monetary data from the plant.

**Wastage:** The wastage of raw material included the bad quality products, leakage of the injection guns and moulds. It also included the waste caused by the workers mistake like over poured or accidentally poured material and so forth.

From the Fig. 9a, the percentage of wastage was lower than 5.0%. For the reasons said earlier, the higher wastage, both in terms of percentage and number was occurred during the trial-and-error period when the products produced were thrown immediately after the casting process. The leakage of material from the new mould also caused waste of the raw material. However, the percentage then decreased in September'01 and again increased in October'01. It was found that the trend of the percentage of wastage was unstable in those days.

**Line efficiency:** Efficiency means how well the input resources are utilized. From the monthly trend graph shown in Fig. 9b, the average efficiency for the finishing line between May'01 and October'01 was higher than the casting line. The difference had occurred because the finishing line was performed according to the planned schedule. There was no machine breakdown that could affect the efficiency during that period.

The lowest efficiency in casting line was occurred when the guns break down problems. The efficiency had been increasing after the foretold solution applied. However, the efficiency decreased again in August'01 due to the new raw material in use. The ratio was then increased again in September'01 after the extra guns had been installed. In October'01, due to the new product introduction, the new mould and lack of skill have caused the efficiency fall down once again. The shortfall of production had the correlation between material productivity, percentage of wastage and efficiency. The material productivity was also low in that month while the percentage of wastage was high.

In the finishing line, the efficiency fluctuated during these 6 months because of the same reasons in the casting line. In other words, the problem occurred at the casting line affected the performance of the finishing line. The longer finishing time delayed the schedule of production and caused the lower efficiency in the finishing line (Fig. 10).

After the development of the Standard Operation Procedure (SOP) under the Kaizen activity, the efficiency was increasing. In order to maintain this appreciable performance, the workers should be encouraged to do the tasks more carefully and seriously at the first time to avoid any rework after the voltage test. They should try to apply the concept "do-the- right-things-first" instead of "do-the-things-right" later.

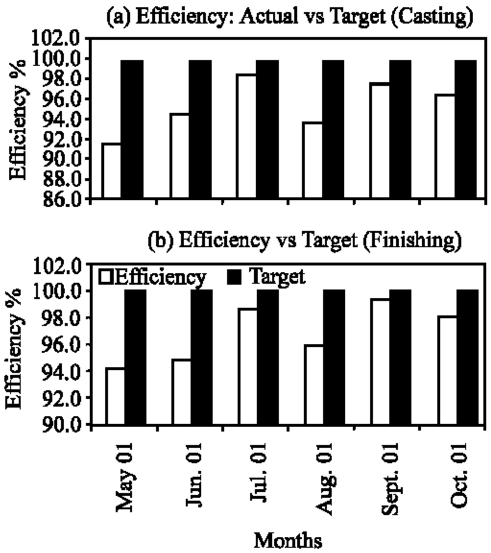


Fig. 10a: Casting line efficiency: Actual vs target, b: Finishing line efficiency: Actual vs target

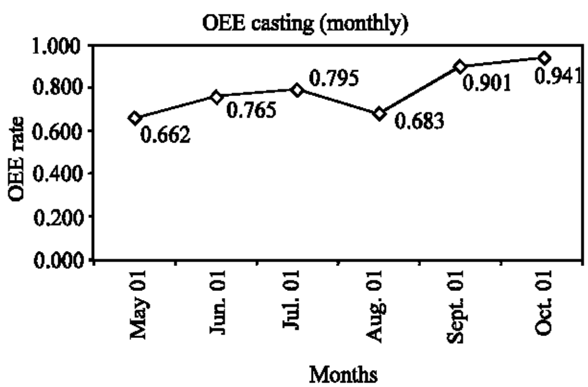


Fig. 11: OEE in the casting (monthly) line

**Equipment maintenance:** The role of maintenance in modern manufacturing is becoming ever more important, with companies adopting maintenance as a profit-generating business strategy. As the measurement activity provides the link between the actual output and the desired results, performance measurement systems are crucial to those who have a stake in maintenance, to ensure that they are not in conflict with the overall business needs.

**Overall Equipment Effectiveness (OEE):** Due to the complexity of data collection, the OEE measure was delimited to the casting process only (Fig. 11). In the monthly trend, the OEE was increasing gradually from May'01 except a lower value in August'01. However, the performance had rapidly improved again to a level of 0.941 in October'01. The implementation of Kaizen, JIT and SOP practices have driven the company performance to the peak of the target level. Therefore, this excellent performance should be maintained as a benchmark for increasing the manufacturing capability. The drop in August'01 was due to the lower availability where the gun broke down problems had increased the unplanned downtime.

The ideal condition for performance is greater than 0.95. It was found that for half of the six months the ideal state could achieve. However, the performance was not under full control due to shortage of the raw materials or conductors and problem of mould design. Quality measure in this OEE calculation was behind the ideal condition (Q>0.99). Although all the quality rates were greater than 0.97 where the average was 0.977, however the non-acceptance amount was still high compared to the ideal condition. Refers to the guideline set by Nakajima[28], if the OEE>0.84, the company could be considered as a world-class state.

**Control chart (X bar and R chart):** A control chart is a statistical tool that helps distinguish between natural and unnatural variation. The control chart is used to keep a continuing record of a particular quality characteristic. It is a picture of the state of a process over time. In short, the chart is used to improve the process quality, to determine the process capability, to help determine effective specifications, to determine when to leave the process alone and when to make adjustments and to investigate causes of unacceptable or marginal quality.

A number of control charts had been prepared to these factors and checked if there were any differences of the product characteristics before and after the introduction of the new system. The detailed of those charts are left aside from this write up. However, it is evident that the product variables (dimensions) were appreciably in stable state and closer to the centerlines. The Fig. 12 and 13 are self-explanatory, but depict that assignable causes were almost eliminated through the Kaizen process. The out of control point that had occurred was due to the mis-alignment and erroneous reading on the measurement scale while measuring the barrier middle diameter. Therefore, the control chart had to be revised.

As both X-bar and *R* control charts are interrelated, therefore the points removed from both X-bar and R charts, which were the 1st and the 6th points. After discarding the out-of-limited subgroups, both charts were found under control within the 2-sigma control limits. Based on both revised charts and the state of control condition defined by Summers[33], the 36 kV barriers produced exhibited a state of control because:

- Around 96% of the points were near the center value.
- There was about 9 points close to the center value.
- The points were appeared to float back and forth across the centerline.
- The points were balanced on the both sides of the centerline.
- There was no special patterns occurred.

The variation between the top diameters of the 36 kV barriers was higher than the middle diameters (Fig. 14). Its values distributed in the control charts were imbalanced

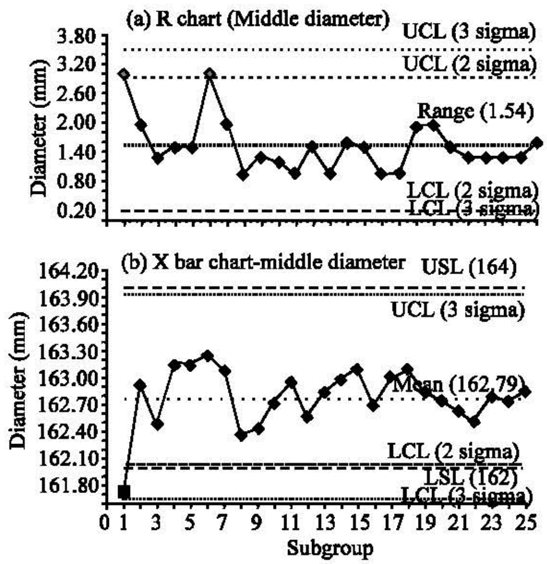


Fig. 12a: R chart for 36 kV barrier middle diameters, b: X-bar chart for its middle diameter

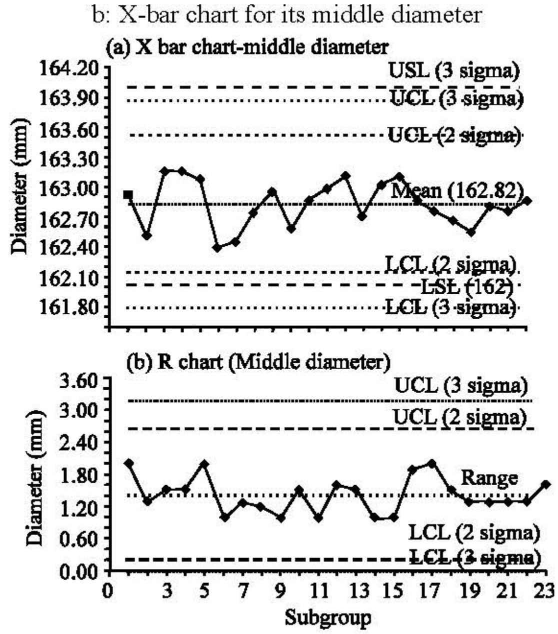


Fig. 13a: Revised X bar chart for 36 kV barrier middle diameter, b: Revised R chart

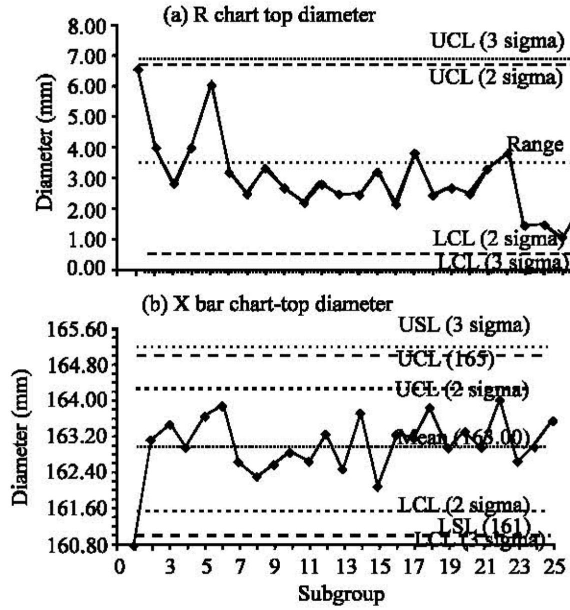


Fig. 14a: R chart for 36 kV barrier top diameter, b: X-bar chart for 36 kV barrier top diameter

on the both sides. Most of the values were under the centerline at the bottom side. This pattern is called run. Causes for the run occurred (R-chart) due to the change of workers skill, where they had tried to cast the barrier more carefully especially controlling the injection gun rate. On the other hand, the gradual improvement in the homogeneity of the process was established because of the changes in the incoming material, where no variation was occurred.

**Employee relations and training**

**Employee profile:** In the PU Plant, there were only 29 man workers. Nine of the workers were placed in the casting line while the other twenty were worked in the finishing line. The mean age among the casting line workers was 25.3 years (standard deviation, SD, 1.7 years) and among the finishing line workers 32.1 years (SD 7.6 years). Among the casting line workers, 25% had been gainfully employed for more than 5 years while 37.5% worked less than one year. On the other hand, 10 percent and 25% of the finishing line workers had worked for more than 10 years and 5 years respectively. Almost half of the workers in the finishing line were the expatriate having working experience of less than a year.

**Training:** Generally, a new inexperienced worker would automatically be placed at the finishing line once he joins this plant. After the conformation period, he would be transferred to the casting unit if he were found suitable by the supervisor. Otherwise he would continue in the finishing line. During the Kaizen implementation, the workers in the PU Plant were sent to the Kaizen course such as "5S practices" group-by-group. The seminar on the Standard Operating Practices (SOP) was organized by the human resources department to demonstrate and explain the standard procedures in the casting and finishing lines. Normally, the courses and booklets were distributed with the contents in bi-language version (Bahasa Malaysia and English). This helped the workers understand better as some of the workers were school dropped in their primary level.

However, there was no specific training on modern casting techniques allocated for the workers in the casting plant. The new worker was only exposed to on-the-job-training where one had to learn the casting technique from the experienced workers. However, some of the casting line workers were sent to the special course outside the company when the new equipment was brought or a new design was introduced to learn the correct way of use, open, assemble as well as maintenance.

**Absenteeism:** The absenteeism was defined when the worker did not come to the work without assigning any reason and giving a prior notice. According to the record taken from the human resources department, it was found that the absenteeism in the PU Plant was, however, very low. There were only two workers with each two days absent in the year of introduction of Kaizen, 2001. This low absenteeism was due to the strict rules stated in the "workers guideline" set by the company and accepted by the Electrical Industry workers' union. It was stated that if a worker absent from work without showing any valid reason or notice for more than two days continuously, he would be terminated from his work.

Nevertheless, the workers were satisfied with the paid annual leave given according to the length of service with the company. This was ensured through an interview with a number of workers as shown in Table 5.

In short, the low absenteeism in the PU Plant had marked a good performance in the production lines, as there was sufficient available man-hour.

**Employee turnover rate:** In the recent past, the company had employed 9 (nine) foreign workers from two south Asian countries for it were to cheaper labor payment to foreign workers and the high turnover rate of the local workers. However, the employee turnover rate had been reduced compared to the past years after the implementation of JIT Kaizen. The new implementations have changed the old work environment with the better plant layout design, work methods and participation. The JIT organization philosophy has eased the workload and thus also reduced the work stress. In 2001, only 3 workers resigned from this plant, one on health ground while the other two went to continue their studies in technical schools. The low turnover rate resulted from the increased satisfaction level among the local workers after the implementation of JIT Kaizen. The plant, by now was not with huge foreign workers as were in the recent past. This reflected a good performance in the human resource measures.

Table 5: Paid annual leave structure

| Less than 1 year | No annual leave |
|---|---|
| After 1 year | 14 days + |
| After 5 years | 20 days + |
| After 7 years | 21 days + |
| After 10 years | 24 days + |

Table 6: Workers' payment structure

| Promotion level | Basic Pay | Promotion Rate |
|---|---|---|
| Trainee | RM 950 | RM 95 |
| Grade IV | RM 850 | RM 85 |
| Grade III | RM 790 | RM 79 |
| Grade II | RM 680 | RM 68 |
| Grade I | RM 600 | RM 60 |

**Motivation drives:** Motivation is vital in any jobs if individuals have to render their best efforts to it. Assuming that employees have the necessary skills and are given ample opportunity for good performances, then effectiveness depends on their motivation. Getting people at the place of work is of secondary importance. What matters is getting them to pay efforts and work willingly while they are there. To adapt a new system, like JIT, it is of utmost important.

In the studied company, the motivation given to all the workers including the foreign workers was principally in terms of money reward rather than honor (Best Worker in The Month and etc). To show the appreciation of the workers' contributions, gold lockets were awarded to those workers who have served the company for long 15 years and 25 years. On the other hand, every worker was rewarded with two months' salary bonus at the end of every year. The 10% increase on the salary was given to every level of promotion. The workers' basic pay and promotion rate were depended on the level of promotion (Table 6).

The promotion case had been reviewed once every three years by both the company's human resources department and the Electrical Industry Workers Union in Malaysia. The aim of the review was to satisfy the workers in order to obtain quality work performance towards the productivity improvement.

**Recommendation:** The implementation of Kaizen and non-cost performance measurement in the company was still almost in the beginning stage. The full implementation would require 2-3 years. At this stage, the following recommendations can be made.

- From the observation, it is found that the testing schedule was not performed in the proper way. The test should be done everyday and both non-tested and the tested product should not be accumulated for a long period. It is better to test the products immediately after the completion of the finishing task. This type of testing schedule will enable the adjustment to be made immediately at the earlier stage of production if any problems are likely to occur such as mixing ratio of the (new) raw material or the mould misalignment.
- More performance measures should be periodically/regularly applied by the company such as the productivity measures, OEE measures, control charts and so on that will cover a comprehensive measure. By having the comprehensive indicators, the company can easily find out the weakness in the production or feel proud of its achievement. The adjustment can be made immediately to improve the low performance, while reward can be given as an appreciation of the good performance.
- All the measurements applied currently need to be reviewed by considering the "base value" and "weight" calculations as discussed earlier in order to get more logical and tangible information.
- Due to non-availability of the financial data, monetary performance calculation couldn't be covered in this study. However, it is advisable for the company to carry out themselves in areas such as Total Factor Productivity and overall efficiency, which are the powerful indicators for the company to have an overall view on their performance.
- Presently, the maintenance system which includes servicing and repairing of the machine when it breaks down, checking the safety features etc. are done by one technician and a trainee worker. It could be proposed that the workers in the casting line carry out the "first line" maintenance by cleaning and checking the machine everyday against the specified criteria. This could lead to one of the JIT as well as TQM system called "Total Preventive Maintenance (TPM)" which aims maximizing the overall effectiveness of equipment through the people those operate and maintain the equipment. Workers who work within the line should be made responsible to take care of the respective machine without relying upon the technicians for maintaining the machine.
- To enable the workers carry out some maintenance work including safety checks, repair, cleaning and servicing by them, they need to be provided with proper training before they can start doing the work. Therefore, the on-the-job-training alone is not sufficient in order to provide the correct techniques to carry out the work. More technical training should be carried out either in-house or out of the company. Besides, the technical training allocated for the technician should require a longer period because the participants need to learn in detail and be hands-on about machine safety, maintenance and changing tools.
- As is known, the six-sigma engineering is not a new initiative in the precision engineering industry; its popularity is getting increased at the turn of the 21st century. Defined as a business improvement strategy, six-sigma initiative can be used to improve profitability to drive out waste, reduce quality costs and improve the effectiveness and efficiency of all operations that meet or even exceed customers' needs and expectations. In statistical terms, six-sigma refers to 3.4 Defects Per Million Opportunities (DPMO), where sigma represents the variation about the average of any process. This is an approach that has much to offer in all areas of management. It is not an end in itself but can be used as one of the foundations of good practice.

However, due to the intermediate stage with JIT, Kaizen and growth in the studied company, it appears difficult to apply the six-sigma practices here compared to those electronic manufacturers. Thus, it is advisable that the company should begin with the three-sigma practices as to control the quality of the products produced. In three-sigma level, it means that only 66,807 defects per million opportunities would occur. In other words, the conforming rate of the products would be 99.73% while the reject rate is only 0.27%. There is a gap to achieve this value if compared to the target reject rate desired by the company which is 2.0%. From this, it is found that the target reject rate set is lower than the two-sigma level (4.5% of reject rate), but it is still rather higher compared to the standard of the competitive world. Therefore, the company should aim to lower down the reject rate slowly towards three-sigma level.

- Since the PU plant is now implementing Kaizen approach, some activities under Kaizen have been carried out, such as JIT, small group activities SOP and so forth. To reach the higher level in the competitive world, the PU plant should try to take a big step towards the practice of Total Quality Management (TQM), not only in the production line but throughout the company as well. The journey towards TQM can provide a quality product to customers, which in turn will increase productivity and lower the production cost. With a higher quality product and lower price, competitive position in the marketplace will be enhanced. This series of events will allow the company to achieve the objectives of profit and growth with greater ease. In addition, the work force will have job security, which will create a satisfactory place to work.

## CONCLUSION

Overall, the objectives of this case study have been achieved and fulfilled. This experience can be applied in other manufacturing companies. From this research several conclusions are made below:

- In a firm producing multiple products simultaneously, in order to get reasonable and accurate information, a number of performance calculations can be based on the "base value" and "weight consideration" concepts.
- Despite high labor or material productivity in one production line (sub-optimization) than others for the same final product or family of products, the overall productivity might drastically suffer from being the target level. In this case, the casting line labor productivity has shown the improvement trend, whereas for the finishing line the labor productivity was always under the target value.
- Research for further checking of the substitution ratios of raw materials may improve the product quality, material productivity and reduce the wastage of materials and environmental hazards. The new blend of raw materials after a few trials has increased the product quality and improved the material productivity gradually towards the target level.
- A minor investment in modern technology can bring a significant return in a manufacturing line or firm. In this case, although the plant productivity in the beginning of the studied period was poor, however, after the installation of spare guns, the plant productivity had then showed a significant improvement.
- The Statistical Process Control (SPC) tools such as Pareto chart or control charts can help to locate the causes of poor quality or extent of the reject rate. Here, the reject rates could be brought down as close to the target value, 2.0%. The causes of rejection had been investigated and followed by the troubleshooting with workers participation. However, the three-sigma initiative had been introduced as a recommended guideline to reduce the reject rate as low as possible or to improve the quality of the customer products.
- The percentage of wastage of the raw material was found relatively high compared to the target value. It was fluctuating over the time under the traditional method. The reduction of wastages of the raw material or other resources is susceptible to the modern methods. A proven modern method or technology can minimize this and bring stability.
- Complexity in manufacturing process can be eased by conducting work-studies. The efficiency of the finishing line was always better than the casting line. This happened because there was no serious equipment problem in the finishing line but the injection guns in the casting line was frequently causing the stoppage of production and delayed the production directly. Introduction of newer technology could help reduce that bottleneck.
- The OEE measures only applied to the casting line through its skilled operators. Its OEE value has shown a significant figure (average value, 0.79) where OEE has been increased gradually and reached to the target and now towards the world class standard (OEE > 0.84) set by Nakajima[28]. The operators should be trained and empowered to record the loss data and take adequate measures in all production lines.
- The variable control charts had been introduced to measure the dimensions that were very critical and essential. From the R chart and X-bar chart drawn, it was found that one dimension of the product was not under the state of control compared to another dimension, although the variations occurred in both dimensions. The causes for out-of-control measurement had been identified and determined. The control limits were then revised for those out-of-control measurements that could be discarded because of the assignable causes.
- Process capability calculation enabled us to show the process that was capable of being centered. The process of producing the top diameter of the barrier was performing centered where the mean value was equal to the target value. While for the middle diameter, the process was not capable enough.
- The workers work happily than before after the introduction of the new and people participatory system, Kaizen. The absenteeism and employee turnover rate were found reducing compared to the previous years.

- For successful implementation of a new system like JIT or Kaizen, organizational structural along with employees' ability enhancement through training is a vital issue. In this case study, it was observed that the workers were not exposed to adequate training courses especially for the workers involved in the casting line. They were not provided training (external) on modern casting methods but could only learn the casting technique from the experienced workers on-the-job.
- The reward and benefits given by the company have increased the motivation among the workers. They were willing to work harder to increase the productivity and improve quality of the process and products.

Overall, the performance of the company could be considered good and growth trend is obvious from the time of introduction of the new system. Under Kaizen approach, the PU Plant was indeed marked success towards productivity improvement. Over the time, upon company wide 'total' implementation of JIT, the performance measures will show a road to success.

There are definitely rooms for improvement. Therefore, a number of recommendations have been made based on the successes and limitations found in the company. For example, the scope of change of testing schedule, additional performance indicators, financial performance indicators, "first line" maintenance approach and sufficient technical training should be there. On the other hand, some of the further studies were also suggested in this write-up to drive the company towards a world class standard.

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