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Development of a Conceptual Model for the Measurement of Overall Worker Effectiveness (OWE) In Discrete Manufacturing SMES

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Abstract *- The performance of a manufacturing organisation be it a small or large, depends on three key elements, viz. machines / equipment, raw materials, and human element and methods. Given that a fairly good maintenance strategy is in place and raw materials of desired specifications are available, the variation in organization's performance can be due to human elements and methods. It is for this reason, human element in any manufacturing setup can be termed as an organic element and other two as inorganic, in the sense that there will be fluctuations in the mind of human element which may cause a variation in the method followed. An important section of human element in a manufacturing setup is the labour force. For most manufacturing SMEs, the major asset is their labour force or Production-workers, since this section plays hands-on role in the conversion process of raw materials into useable end items. Thus, the desired improvement in the performance of manufacturing SMEs can be achieved through an improvement in the overall effectiveness of the labour force (production-workers) which in turn depends mainly on the three components, viz. performance (pace or speed at work), output quality and availability at work. In this paper, an attempt is made to present a simple conceptual model by the application of which the overall effectiveness of Production-workers can be measured and actions can be initiated to improve the same towards desired (world class or Six Sigma) output level.*

Index Terms **– Overall Worker Effectiveness, World Class Output Level, Conceptual Model, Effective Production-worker.**

I. INTRODUCTION

For today's manufacturing companies, staying competitive means continuously seeking ways in which they organize, manage, produce, and hire, train, and retain their personnel. People are the major component of any organization and their management is defined as the planned coordination of the activities of number of people for the achievement of some common, explicit purpose or goal through division of labour and function, and through a hierarchy of authority and responsibility [1]. The SMEs sector serves as a vital source of large-scale job generation and has tremendous potential to improve labour productivity [2]. In India, the SME sector employs about 30 million people [3] who contribute to the growth of the organization they serve as well to the nation's economy significantly. Their role in the transformation process of inputs to useable end products cannot be overlooked.

For most Indian manufacturing SMEs, Production-worker is one of the major assets as he / she has a hands-on role in converting a set of inputs to saleable products. Reference [4] argues that developing the potential of workers in an organization "is at the heart of high-performance manufacturing", be it a large or small organization. Thus, for an output at world class level, it has become imperative for SMEs to relook into the workers' aspects to enhance their productivity by way of improving their overall effectiveness at work.

A. Production-worker – A Key Element in the Conversion Process for Desired Output Level

Among many factors that affect the output level of a manufacturing process, it is the individuals who have a *hands-on* role in the shop floor activities. These individuals are production-workers. A production-worker is one (up through the foreman level) who is engaged in fabrication, processing, assembling, material handling and other related activities which are a part in the production of goods from raw materials [5]. A similar definition according to a report as in [6] states that 'Production-workers (also referred to as manual workers or blue collar workers) generally include those employees who are engaged in fabrication, assembly and related activities, material handling, warehousing and shipping, maintenance and repair, auxiliary production (such as power plants), and other services closely related to the above activities'.

This research study has defined a *Production-worker* as a direct labour who operates a machine tool, equipment, assembles component parts into an end item, or tests raw materials, component parts and end products. It is for this reason, a Production-worker's role in the conversion of raw material into finished goods with the desired specifications is vital. Thus, whenever implementation of strategies such as Six Sigma is contemplated for improving the output level in terms of quantity and quality, focus must be given to Production-workers and their current overall effectiveness must be evaluated by measuring their output level.

As a human being and for a set of other job related reasons, a Production-worker is affected by various factors. These factors may act as *barriers* or *boosters* for the overall effectiveness of a Production-worker in turning out the desired (Six Sigma) level output. For turning out an output at this level, the overall effectiveness of Production-worker

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needs to be at world class level. This is possible only when the factors affecting him are addressed in an appropriate manner. At this level of output, a Production-worker can be termed as an 'effective production-worker' (EPW).

B. The Theory of Overall Worker Effectiveness (OWE)

Total Productive Maintenance (TPM), an innovative concept from Japan is considered as the medical science of machines [7]. It is a strategy for maximizing the plant and equipment effectiveness by combining prevailing maintenance practices such as preventive maintenance and productive maintenance. The goal of the TPM program is to increase production, eliminate defects while, at the same time, increasing employees morale and job satisfaction. TPM brings maintenance into focus as a necessary and vitally important part of the business.

An important measure of TPM is 'overall equipment effectiveness (OEE)', and one of the targets of TPM is to obtain a minimum of 90% OEE [7]. It is considered to be the key performance indicator of equipment, an entire shop floor or a plant and is computed by multiplying the three efficiencies of the equipment, viz. availability, performance and quality [8].

In this research study, an attempt has been made to extend the concept of OEE to the Production-workers who possess a hands-on relation with the equipment. This concept can be termed as '***overall worker effectiveness*** (OWE)', which indicates the effectiveness of a Production-worker in turning out desired level output in terms of quantity and quality. This desired level can be equivalent to world class or Six Sigma at which level the OWE of a worker needs to be a minimum of 90% or more as with OEE. Production-worker being a human element cannot be expected to work the complete time, say, in a shift. With necessary time allowances for the Production-worker at work, the availability can be at 90% or more. However, the performance and quality efficiencies can be at or more than Six Sigma level each (99.99966%). Thus, when the three components are multiplied with the above threshold values, the OWE obtained will be 89.99938%. A Production-worker with this OWE value can be termed as an '*effective Production-worker*', who is capable of producing products that meet or exceed customer requirements, provided the equipment are maintained at the best level and materials meet desired specifications. However, it is hardly possible for a Production-worker to have this level OWE, since he is influenced by many factors while at work.

II. LITERATURE REVIEW

A careful and systematic effort was made to identify various factors influencing the performance, output quality and availability of Production-worker through literature survey and personal interactions with the industry and academic experts.

In today's competitive market, customers always tend towards products of higher quality and this high level quality output from any industry depends not only on technology or materials, but also on the human element, especially shop floor people. Hence, human element in today's manufacturing companies is one of the main elements for the success or failure of implementing any new change initiative. Because, the main reasons for the high percentage of systems failure are rarely purely technical in origin [9].

Reference [10] in an empirical study examines the relationship between *worker attitudes* and productivity in the US automobile industry by means of an extended model of production process. In a study of a large manufacturing system it is found that the workers need to be considered in any manufacturing system design and the extent of variation in workers' performance of production tasks is largely associated with workers' attitudes [11]. Another study as in [12] has shown that there is a correlation between *'job related attitudes*' and the *job performance* of middle level managers. Also, there exists a significantly larger correlation between 'job satisfaction' and job performance, the study reports.

It is also found that there was a positive relationship between workers' year of *schooling and productivity* [13]. Further, this study found that an impact of *training* was very much dependent on the training programs whether it was in accordance with the firms' needs. Among the important training programs were related to *technical* and computer skills.

One of the most important and highly variable elements of manufacturing companies is their workforce and optimizing its performance requires companies to establish methods of quantifying, diagnosing, and ultimately predicting the performance of their workforce, and this can be possible by way of improving the Overall Labour effectiveness [14]. The report focuses on the training, skills, workplace conditions and other factors to improve the overall effectiveness of the workforce.

Production-workers perceived increased levels of *skill required*, *responsibility*, *job knowledge*, and *workload* as significant in transitioning from conventional production work to automated production work [15].

Over the years, good remuneration has been found to be one of the policies organizations can adopt to increase their workers performance and thereby increase the organization's productivity. Lack of *motivation* in an organization may result in deficiencies in workers' job skill, knowledge, and other areas [16]. According to the authors, the future prospects of an employee depend on how well he / she is performing the tasks or job assigned. Also, workers place a great value on the rewards given to them by their employers. It is a well known fact that lack of rewards and motivation leads to workers dissatisfaction and they show their displeasure by poor performance.

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Volume 2, Issue 3, September 2012

Reference [17] throws light on devising a self-assessment scale for measuring the employees' perception while implementing a quality management system in Trinidad and Tobago SMEs. The study also revealed that not much research has been carried out on identifying standard constructs and measuring employees' perceptions towards quality improvement of SMEs.

Labour productivity is very much related to *skills* among workers that can be acquired through proper *training*. Workers who have attended training will be more efficient, productive and contribute to productivity growth. Some workers seek further training to enhance their existing skills or develop new one, with the expectation that this will lead to better jobs and a higher standard of living [18]. Training gives employees an opportunity to increase their productivity in the workforce, open new opportunities for career development, and potentially increase their earnings. Policy makers see training as contributing to the larger goal of improving the quality of workforce and competitiveness.

A positive relationship between human capital and productivity is also much influenced by workers' *wage rate*. A higher wage rate received by the workers will encourage them to work harder and contribute to higher productivity. Workers with *higher level of education* and attended formal training tend to receive higher wages and they are also more likely to contribute to career development, research and development and further human capital accumulation. Consequently, this contributes to higher productivity growth. Therefore, it is very important for firms to have more *educated workers* to gain this added stimulus effect.

A study [18] in the United States and Britain supports the positive relationship between *human capital* and the *firm's performance*. They found that *education* and *training* are more important determinant of productivity as compared to physical capital.

Firms with more educated workers are better able to sustain and control their present technology or adopt modern and new technology. They are more able to invest in human capital like training because knowledgeable workers learn and adapt faster and more innovative [19].

In another study [20] of a manufacturing company, it is found that the *health and safety* of Production-workers are affected by the *night shifts*. The authors have suggested an improvement to the 'work schedule', '*ergonomics design of the system and workplace surrounding*' for an improvement in the productivity, quality, and safety and health of the Production-workers.

The effect of three *environmental factors* – illumination, humidity and temperature around the workstation on the production rate (performance) of assembly workers has been examined by a study as in [21]. The study revealed that illumination and temperature were dominant factors influencing the production rate of assembly workers. Thus, it is evident that workplace conditions will have an influence on the effectiveness of the workers.

In support of the conclusions derived from the literature review, a preliminary study was conducted which included collecting the views of experts from industry and academics about what influences the overall effectiveness of production-worker in manufacturing SMEs to achieve a desired output level. With this personal interaction with the experts and the authors' experience, following fifteen factors have been identified as influencing the production-worker at work. The factors so identified have been classified or categorized as technical, personal, and external or environmental.

A. Technical

a. Established production system (system of machines, equipment, tools, etc. for production as well as quality control)
b. Job knowledge (specific and holistic)
c. Job skill
d. Training
e. Experience
f. Qualification

B. Personal

a. Attitude
b. Health
c. Motivation (financial/non-financial/job satisfaction)
d. Personal issues or problems
e. Behaviour

C. External or Environmental

a. Worker related policies
b. Company culture or Work life
c. Workplace conditions (ergonomics, noise, ventilation, neatness, etc.)
d. Working hours and shifts.

To determine the degree of influence of the fifteen factors identified on the effectiveness components (availability efficiency, performance efficiency, and quality efficiency) and hence on the overall effectiveness of the production-worker, a questionnaire survey of 246 production-workers from fifty ISO certified manufacturing SMEs in and around authors' locality was conducted. A total of fifteen items for six technical factors, thirty two items for five personal factors, and twelve items for the four external factors were framed in the questionnaire apart from six general items for the background information of the respondents. The items for the three main categories of the factors were so framed to reflect their influence on the effectiveness components. Based on the general information of the respondents, the production-workers were classified as 'qualified', 'qualified and experienced' and 'unqualified but experienced'. Fig. 1 below gives the summary of the influence of factors on OWE components of the three categories of production-workers:

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Volume 2, Issue 3, September 2012

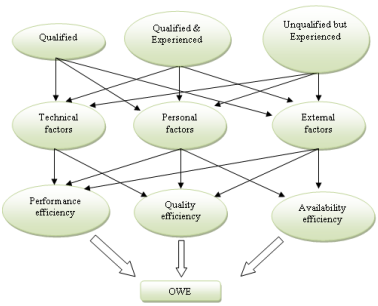

Fig. 1. OWE With Different Combinations of Worker-Factor-Effectiveness Components

III. DEVELOPMENT OF A CONCEPTUAL MODEL

An imperative for today's manufacturing SMEs to sustain and grow in the present competitive market is that their output must meet the customer requirements in terms of cost, quality and time. This depends on the effectiveness and efficiency of the conversion process of inputs to outputs, which in turn relies on the effectiveness of the workforce having hands-on role in the conversion process. Hence, it is the need of the hour for SMEs to look for measures that help their workforce to move towards world class (Six Sigma) level output. A conceptual model is developed which helps in knowing the current output level, points at the reasons (factors causing) for lower output level if any, and directs towards corrective measures from Production-worker-to-Production-worker in an iterative manner. If the reasons causing lower output level of a Production-worker are identified and addressed amicably, a Production-worker can be transformed into an effective-production-worker (EPW) to turn out world class (Six Sigma) level output.

The model is built based on the basic *transformation model* and the frameworks of implementing improvement initiatives in different organizations by many researchers. Reference [22] reports about the development of a conceptual framework for implementing statistical process control in any organization or an industrial setup. This framework also uses the concept of transformation model but does not take into account the Production-worker aspects. A framework for implementing Six Sigma in SMEs suggests a Six Sigma pilot project as the first stage when SMEs plan to implement this concept [23]. The framework emphasizes on education and certification (i.e., training) as important aspects of implementing initiatives such as Six Sigma in SMEs. Another framework for implementing Six Sigma in SMEs is developed based on MBNQA model [24]. Most TQM elements in this model are considered by Chang's framework as critical factors for applying Six Sigma concept in SMEs. A Lean Six Sigma framework has been developed by [25] from literature and the researcher's experience. The framework is aimed at improving specific government organizations. Another framework focusing the implementation of Six Sigma in large organization has been developed as found in [26]. This framework lacks in providing specific guidelines for implementing Six Sigma in SMEs. The concept of 'white belt' in training Six Sigma tools and techniques has been introduced by [27] for employees of small and medium enterprises that have limitations of sources to train their workforce. A study as in [28] reveals about developing a combined Total Productive Maintenance (TPM) and Six Sigma strategy for application into manufacturing SMEs to resolve critical-to-quality (CTQ) issues. A framework was developed by [29] for implementing TQM in small businesses and the author argues that small organizations need a clear and less complex framework for implementing concepts/approaches and to reap the real benefits.In all the above frameworks/models/strategies, the focus is on implementing the change initiatives holistically. However, there is a little or no focus on the aspects of Production-workers while implementing such initiatives.

The conceptual model developed in this research study focuses on Production-workers for their role in implementing any change initiative is significant for achieving a world class level output. This would help manufacturing SMEs to grow and sustain in the market resolving the issues related to Production-workers. The conceptual model is shown in Fig. 2 which is shown in Appendix.

The objective of the model is to help manufacturing SMEs to know the current output level of a Production-worker, identify the causes (factors) for low output level from a Production-worker and take remedial/corrective actions to make such workers to move towards world class output level.

A. *Assumptions in Developing the Conceptual Model*

The development of the model is based on the following assumptions:

1. Production-workers in batch type of manufacturing SMEs are considered.
2. In target group of SMEs, machines and/or equipment are fairly maintained, are in good condition, and the raw materials supplied are of desired quality.
3. Production-workers working in the regular shift (9am to 5pm) are considered.
4. A Production-worker who has completed a minimum of three years on the same job is an experienced worker.
5. Output level of a Production-worker is independent of age.
6. Factors that act as barriers affect all category workers and cause a variation in the 'overall worker effectiveness'.
7. Every Production-worker is capable of becoming an effective Production-worker to turn out world class (Six Sigma) level output.
8. Magnitude of influence of factors on Production-workers is independent of shifts.

B. *Elements of the Conceptual Model*

Number citations consecutively The conceptual model for transforming a Production-worker into an effective Production-worker for turning out world class level output is developed with the following main elements:

- Production-worker and the categories

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Volume 2, Issue 3, September 2012

- Output level
- Components of 'overall worker effectiveness' (OWE)
- Factors affecting the components of OWE
- Effective Production-worker

Production-worker and the Categories

The focus of this research study is basically on manufacturing SMEs producing a variety of goods catering the needs of domestic as well as international customers. A Production-worker in such enterprises will have hands-on role in converting raw materials into finished goods with the desired quality level. This research study has defined a production-worker as a person who operates a machine tool, equipment, assembles component parts into an end item, or tests raw materials, component parts and end products. He is considered equivalent to a direct labour. Following three categories of male Production-workers are considered for the study based on their qualification, skill or knowledge, and the experience they have on the current job:

Qualified: A person with necessary qualification for the job he is doing, who do not have a long practice on his present job.

Qualified and Experienced: A person with necessary qualification for the job he is doing and has gained necessary skills for his job through a long practice for a minimum period of three years.

Unqualified but Experienced: A person who has obtained necessary skills or knowledge of the job he is doing through a long practice but not possessing the required qualification.

Output Level

For making a Production-worker to move towards 'effective Production-worker', his current output level (overall worker effectiveness) needs to be measured. The output level can be measured in terms of the components of OWE, viz. availability efficiency, performance efficiency, and quality efficiency. These components can be evaluated in terms of actual time a Production-worker has worked in a shift, the pace at which he works (output rate), and the rejection rate at his end. To accomplish this task, specific formats have been developed which can be used by the supervisor in charge of the shift.

Components of 'Overall Worker Effectiveness' (OWE)

The term 'overall worker effectiveness' used in this research work is analogous to 'overall equipment effectiveness' (OEE), an important measure of 'total productive maintenance' (TPM). Thus, as with OEE, overall worker effectiveness is also made up of three components, with availability efficiency 90% or more which in practice is the commonly accepted world class level. However, performance efficiency and quality efficiency (the commonly accepted world class values as OEE components are 95% and 99.9% respectively) can be equivalent to Six Sigma efficiency value, that is, 99.99966%, at which level a Production-worker can be termed as an 'effective Production-worker'.

Availability Efficiency (A_{eff}): The actual time a Production-worker spends in work out of the total time in a shift. A Production-worker may not be available on work, sometimes, because of specific reasons, which causes a drop in his availability efficiency. The availability efficiency can be fixed to 90% or more as explained below:

1) The standard work time in a shift in manufacturing organizations is usually 8 hours or 480 minutes. This is taken equivalent to 100% of $A_{eff.}$
2) Production-worker as a human being should be provided with PF & D allowances. The total standard allowances (PF&D) provided for a production-worker are 9 to 15% of standard work time [30] in a shift.
3) This research work has fixed a reasonable total standard allowance of 10% of standard work time which equals 48 minutes. Thus, world class or Six Sigma level availability of a Production-worker during work is taken equivalent to 90% or more.

A production-worker who remains absent beyond these allowed limits will be treated as non-available during working hours, and the time of non-availability is noted down.

Performance Efficiency (P_{eff}): The rate of output of a Production-worker. That is, the number of component parts/products turned out by him to the total number stipulated to him. A variation in this value from the peak may occur because of specific factors affecting Production-worker.

Quality Efficiency (Q_{eff}): The number of good parts produced to the total number produced by the Production-worker. That is, the number of component parts/products produced by a Production-worker meets the specification limits set to the total number produced by him in a specified time period. Again, a variation in this efficiency value from the peak may occur because of specific reasons affecting the Production-worker.

Theoretical (standard) Q_{eff} is taken equivalent to Six Sigma value. That is, the output from a production-worker conforms to 99.99966% of specification limits. Thus, the quality of the output from a production-worker is expected to be $\geq$ 99.99966% for world class level. Q_{eff} in percentage is computed by multiplying the ratio of accepted output to the total output from a production-worker with 100. Output produced right the first time is considered as accepted output. Mathematically,

$$Qeff = \frac{\text{Accepted output produced right the first time during a specified time}}{\text{Total output produced in that time}} \times 100$$

It is possible that a Production-worker's performance efficiency may be very high but the number of rejections is more. This causes a drop in the value of OWE. Hence, it is important that the above efficiency values and the OWE values must be looked into 'together' and 'individually'.

Factors Affecting the Components of OWE

The literature review and the personal interaction with the selected industry people have made it a way to identify fifteen

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Volume 2, Issue 3, September 2012

factors that influence a Production-worker at work. These factors were grouped into three categories namely, Technical, Personal, and External or Environmental. The micro stage survey was conducted on 246 Production-workers of manufacturing SMEs to know the perceived influence of these factors on the Production-workers.

Technical factors are those which pertain to the job a Production-worker is doing such as his qualification, job knowledge, skill, etc. Personal factors are those such as attitude, health, personal problems, motivation, etc. which have a significant influence on the OWE. External factors are those such as workplace conditions, working hours and shifts, etc. These factors may act as both barriers and boosters for OWE. It is required that the barrier effects of the factors must be reduced and booster effects enhanced for an improvement in the OWE.

Effective Production-worker

An effective Production-worker is a Production-worker from any category who maintains an OWE at the desired level consistently and hence, he is capable of turning out world class (Six Sigma) output level. The barrier effects of the factors influencing him are reduced and the booster effects are enhanced. He can inspire other Production-workers to enhance their OWE and hence the output level.

IV. Conclusion

Since the major asset of most manufacturing SMEs where less automation prevails is their workforce, it is the need of the hour for SMEs to enhance the output level (number and quality) of the Production-workers. The model built in this research work helps manufacturing SMEs to identify key Production-workers whose OWE is below a specified level by measuring the OWE in terms of its efficiency components which in turn can be evaluated by the formats developed. The model points at the reasons (causes) for this low OWE which could be technical, personal, or external affecting the Production-worker. Once these causes for low OWE are addressed amicably, a Production-worker can move towards an improved OWE and his output level improves significantly.

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