Journal of Optimization in Industrial Engineering 22 (2017) 1-13
DOI: 10.22094/joie.2017.274

Development of Productivity Measurement and Analysis Framework for Manufacturing Companies

Yitagesu Yilma Goshu[a,*], Daniel Kitaw[b], Amare Matebu[c]

[a]*PhD candidate, Addis Ababa Science and Technology University, Addis Ababa, Ethiopia*
[b]*Professor, Addis Ababa Institute of Technology, Addis Ababa University, Ethiopia*
[c]*Assistant Professor, Bahir Dar University, Bahir Dar, Ethiopia*
Received 13 October 2016; Revised 24 November 2016; Accepted 28 January 2017

Abstract

The purpose of this research is to present an alternative approach for measuring productivity in manufacturing companies. To achieve the research objective, an in-depth investigation into the existing productivity measurement and analysis practices of the case of manufacturing company has been carried out through both qualitative and quantitative approaches. The investigation result has shown that there are serious problems in measuring and analyzing productivity at company level. Following the existing practices of analysis result, a new productivity measurement and analysis framework has been developed. The developed productivity measurement and analysis framework is found to be simple to understand, detects problem easily and realistically, compatible with modern management systems and tools, and potentially adaptable to similar manufacturing companies.

Keywords: Productivity measurement, Productivity analysis, Manufacturing company, Manpower.

1. Introduction

Productivity is a key concept, which has been long practiced as a means of companies' resource utilization assessment. To date, at least three field areas have dominated the field of productivity, namely economics, industrial engineering, and administration (Grunberg, 2004; Susan, 2007). These fields of studies have complicated a search for any exact definition of the concept of productivity. Regardless of the type of production, economic or political system, the simple definition of productivity, which is the ratio of output to input, remains the same. The intent of measuring productivity is to come up with a quantified measurement value. The ultimate goal of productivity measurement is, indeed, productivity improvement, which involves a combination of increased effectiveness and a better use of available resources.

To this end, though the complexity is there, companies' self-initiation for improvement is, therefore, a crucial element for coping with the highly competitive and alarming global focused threat. This can be ensured through better performance of the actions run to meet the objectives of the companies and productivity of the company's resources including: input materials, labor, energy, machineries and available space, among others. This, in turn, demands the effective, efficient, and integrated use of the production factors so that controlling of the production system aligning with the goal of the firm will be possible. Nonetheless, to control the production system, measuring and analyzing of the system is a pre-requisite. The use of appropriate performance and productivity measures and analytical techniques should be the quest of the industries so that the real and representative of the actual system performance will be measured. Otherwise, an ultimate wrong decision will be practiced.

Therefore, this research focuses on the productivity measurement and analysis of production systems. The research has been conducted while taking an Ethiopian leather footwear manufacturing case company. As a response to traditional and weak productivity measurement practices observed in the case manufacturing company, appropriate and practical productivity measurement framework that can detect waste and inefficient resource utilization has been developed.

Therefore, in this study, the existing measurement problem in the company has been investigated and a solution has been proposed.

2. Research Methodology

The objective of this research is to address issues in measuring and analyzing productivity of production system at company level. For this to come about, an appropriate way has been adequately devised, so that it can ensure its outcome as per the desired objective. Productivity

* Corresponding author Email address: Yitagesub@yahoo.com

measurement and analysis literature were considered to define the concepts and identify gaps in measurement and analysis of manufacturing companies' productivity. Following this, investigation of the existing practices using a case manufacturing company was carried out.

The case manufacturing company is a private owned company and was selected on the basis of its representativeness for Ethiopian medium and large manufacturing companies. The case company has a relatively plentiful data required for this research purpose. Ease of accessibility for frequent data collection is attributed to the company with respect to the researcher. The company is also trying to implement different modern management tools and systems including bench marking and quality management systems.

The required data for this research purpose were collected through various appropriate methods. Both qualitative and quantitative data, which were essential to investigate the current productivity measurement and analysis system of the case company, were gathered. The empirical data were collected through observation, interview, and review of documents and records.

Data collected through direct observation were carried out on the company through frequent and whole sites visits, starting from raw material and spare parts storages to finished products warehouses and sales shops for nearly three months. The interview was also carried out onsite, with the company's functional managers, division heads, experts and individual workers covering 20 % of the company workers, to investigate the current productivity management system of the company. Performing document and records review was the fundamental task in this research process. Therefore, the company's annual performance reports including production and technique annual performance, finance and accounting annual performance, human resource development and general service annual performance, and marketing and sales annual performance were collected for different years. Company profile documents and anniversary bulletins and others, such as the company's brushers, were among the company's documents reviewed. With these documents and records, it had been possible to see the existing productivity measurement and analysis system of the firm for about 20 years.

The next decision in the framework of this research was to investigate the existing productivity measurement and analysis of the company. Having analyzed the existing productivity measurement and analysis system, its shortfall was identified based on some defined criteria; for that matter, fan improved productivity measurement and analysis framework was proposed.

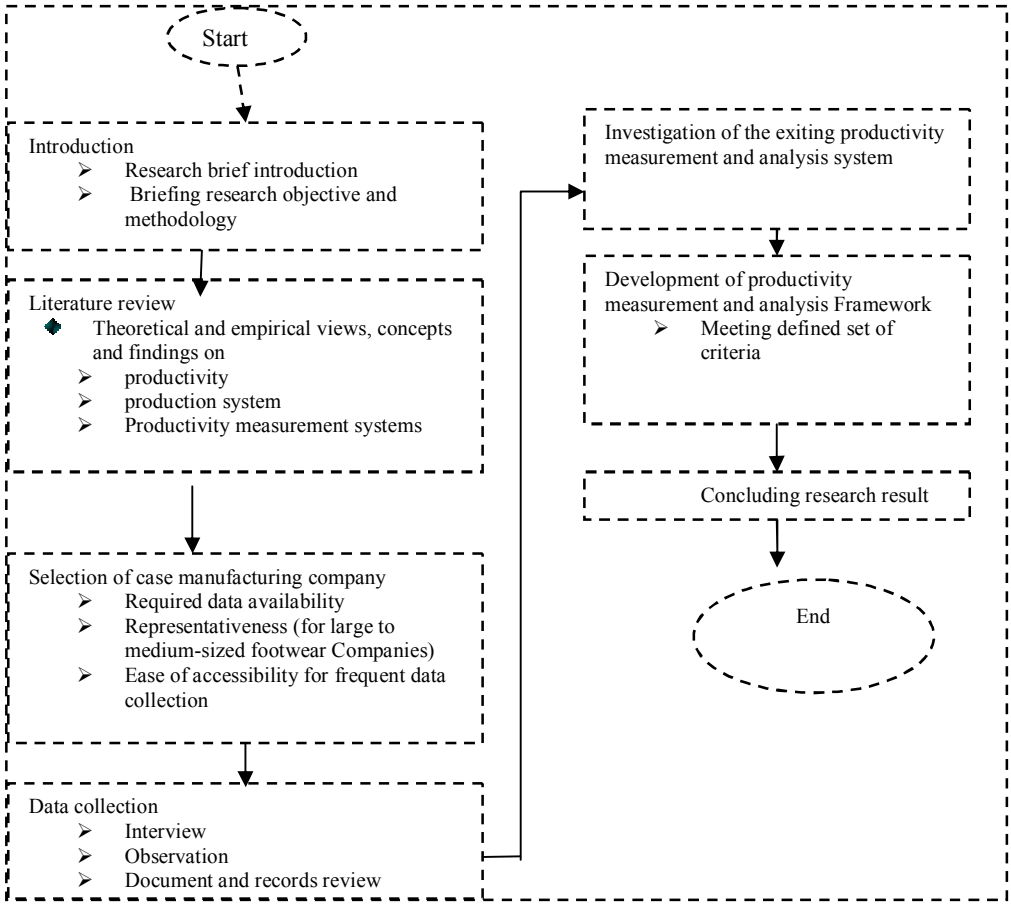

Fig. 1. Research Framework

3. Literature Review

3.1. Productivity and Productivity Management in Manufacturing System

A manufacturing system is a set of machines, transportation elements, computers, storage buffers and other items used together for producing goods (Gershwin, 2005). People are also part of the system. It is a process that receives various inputs and transforms it to the desired outputs; it can explain the simple model of a manufacturing system (see Fig 2). On the other hand, the least contentious definition of productivity is that there is a quantitative relationship between output and input (Harold Siow, 2014). The concept of productivity is so vital that it is generally agreed that productivity represents one of the major areas reflecting the term performance, especially for an organization or a production unit (Phusavat & Photaranon, 2006; Helo, 2005; Hoehn, 2003; Sumanth D. , 1985). It is, therefore, understood that managing productivity is a way to assure the performance of a company as it is the major component for the achievement of the competitiveness of an organization.

The definition of productivity is simple and complex at the same time, and this is because it is both a technical and managerial concept (Thomas G. , 2004). Productivity is defined and analyzed in various ways, and there is lack of consensus on a specific definition. Various professionals from different fields of study, including economists, accountants, behavioral scientists, engineers, managers, etc., define the term in relation to their own perspectives (Mohanty & Rastogi, 1986), but even within the same discipline, there are multiple definitions. (Tangen, 2005) forwarded the definition of the frequently used terms 'Efficiency', 'effectiveness', 'productivity', 'profitability' and performance in relative ways (Fig 3).

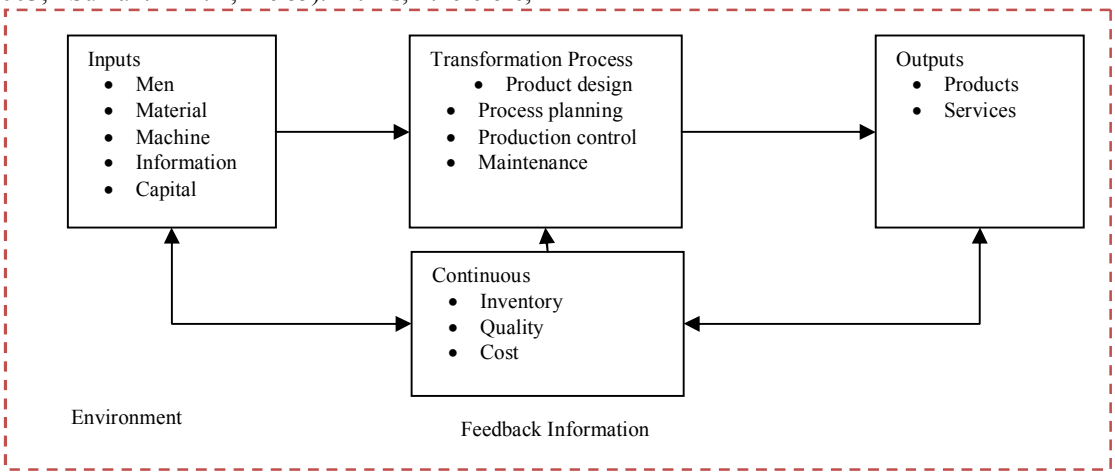

Fig. 2. Schematic production system (Kumar & Suresh, 2008)

Tangen argues that there is no single accepted view about the terms, 'efficiency' and 'effectiveness' in literature, and they are frequently confused with one another (Tangen, 2005). The definition of the terms were proposed by several authors including (Jan van Ree, 2002; Kurosawa, 1991; Neely, Gregory, & Platts, 1995; Sink & Tuttle, 1989; Sumanth D. , 1994). According to (Sink & Tuttle, Planning and measurement of in your organisation of the future, 1989), the terms 'effectiveness' and 'efficiency' are defined in simple words as 'doing the right thing' and 'doing things right', respectively. The relationship with the rest of the terms has also been proposed by (Tangen, 2005) in the triple P-model, (Fig 3). The term productivity is straightforward. Operationally, it is the relation between output quantity (i.e., correctly produced products which fulfils their specifications) and input quantity (i.e., all type of the resources that are consumed in the transformation process). It is in the central part of the Triple P-model. Profitability is also seen as a relation between output and input, but it is a monetary relationship in which it includes price factors (i.e., price recovery) on top of productivity span.

3.2. Productivity measurement types and methods

The central part in managing productivity is productivity measurement. Commonly speaking, productivity measurement is the quantification of both output and input resources of a productive system. The goal of productivity measurement is improvement of productivity, which involves a combination
of increased effectiveness and a better use of available resources. According to (Kendrick, Productivity Trends in United States for NBER, 1961), productivity type has been classified in economic terms as: 1. Partial Productivity, that is, ratio of gross or net output to a single factor input. Partial productivity is further divided by the type of input as: labor productivity, capital productivity, material productivity, and energy productivity; 2. Total Factor Productivity, that is, ratio of gross or net output to total labour and capital input expressed in monetary equivalents. 3. Total Productivity, which is, ratio of gross or

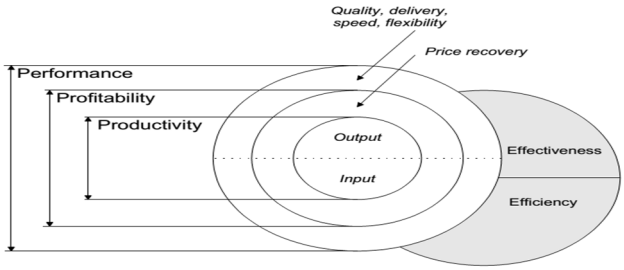

Fig. 3. The relationship between Performance, profitability and productivity, the Triple-P Model (Tangen, 2005)

net output to total inputs including labour, capital, material, energy and others, all expressed in monetary equivalents. The famous Multifactor Productivity Measurement Model (MFPMM) that comprises nine components developed by America Centre of Quality and Productivity (Fig 4) is suggested to be a comprehensive and analytical model to measure changes in productivity (Wazed & Ahmed, 2008). It uses the techniques to break the total variation into price and productivity effects

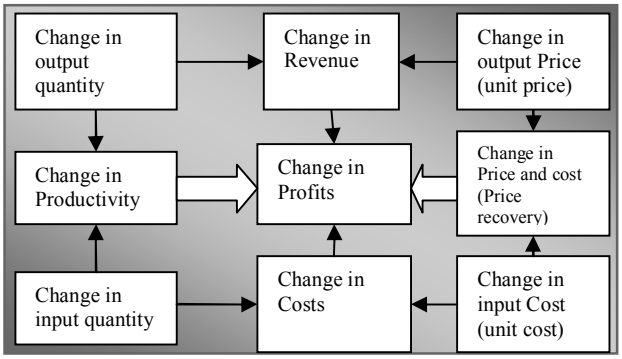

Fig. 4. Nine basic components for the MFPMM

Productivity measurement models can be classified in many ways. (Singh, Motwani, & Kumar, 2000) classified them as index measurement models, linear programming-based productivity models, and econometric productivity models. (Sink & Tuttle, Planning and Measurement in Your Organization of the Future, 1989) classified them as: partial-factor, total-factor and surrogate measures, which are used by public or private organizations (Wazed & Ahmed, 2008). A review of literature conducted by (Muthiah & Huang, 2006) on manufacturing systems productivity measurement and improvement also proposed that the models can be classified on the basis of operation research, control theory, and system analysis. They identified 15 operational research studies, 2 control theories, and 7 system analysis-based models. Having these different and various types of models creates confusion to select and use the appropriate technique so that practitioners or managers cannot use enthusiastically in their improvement decision processes in a simple and realistic manner.

The intent of measuring productivity is to come up with a quantified monitoring index. Empirically, however, both measurements of outputs and inputs involve aggregation problem, and this problem alone has situated productivity measurement in the sphere of complexity (Oyeranti, 2000). For example, the question of how to aggregate different products that do not have constant quality or characteristics constitutes the veil to be removed from output measurement. In the same notion, the problem of how to aggregate the different types of inputs into a well-defined composite unit remains a critical one on the side of input measurement (Grunberg, 2004). To solve output and input aggregation problem, particularly when heterogeneous inputs and outputs are combined, some authors have suggested that inputs should be added up to money values. The same thing should be done for output (Oyeranti, 2000).

4. Investigation of the Current Productivity Measurement and Analysis of the Case Firm

4.1. Profile of the case Company

The case manufacturing company is one of Ethiopia's biggest company, and it is among Africa's most experienced manufacturers of leather footwear. It is believed to be the leading Shoe Factory in the country with two main business production lines. The main business line is Production of variety of shoes including military boots, civilian work boots, regular shoes including children's and ladies shoes, all in genuine leather and supplied to both local and international markets. The second one is production of glue for various purposes, such as sole glue, vulcanizing glue, and lasting glue, and supplied to local market only. The case company has also the capacity of producing 536,000 pairs of various shoes and 200,000 kg of multi-purpose glue in 8 daily working hours' basis. The main processes are cutting, stitching, lasting, bottoming, and finishing.

4.2. The Case company regarding the Current productivity measurement and analysis system and its shortfall

The case manufacturing company has been measuring and analyzing the productivity of the firm for long. The company's productivity is measured only partially as revealed in the 50-year golden anniversary bulletin (Table-1). Measurement is done for the purpose of the factory production growth status evaluation. Together with productivity, sales volume is used for the company's overall performance evaluation (Table - 1). Productivity in the company is expressed as the ratio of the number of total number of pairs of shoes produced annually to the total number of employees of the firm.

$$\text{Productivity} = \frac{\text{Total number of annually produced pairs of shoes}}{\text{Total number of employees}}$$

This index is similar to Mills's index (Sumanth D. , 1985) developed for measuring productivity at industry level and given as:

$$\text{Mills Productivity Index} = \text{Output}/(\text{Number of wage earners})$$

This productivity measurement model, however, has got limitations, in that it cannot represent the company's productivity; it is not complete and inclusive and does not pinpoint problematic areas and opportunities for improvement as discussed in detail in the subsequent sections.

i. Mills's index approach was developed for Industry level of productivity measurement and analysis

Primarily, Mills developed this particular index approach for measuring productivity index at industry level such as manufacturing industry, services, federal government agencies, local government and city, transportation and distribution, retail trade, defense, construction industry, energy industry, and office and administration industries (Sumanth, 1985).

The measured productivity index may be used as to be indicative of productivity at industry level where considering other input factors, such as material, capital, and energy, is complex.

ii. The productivity Measurement system lacks completeness

By completeness, we mean the thoroughness with which outputs or results delivered and all inputs, or resources consumed, are measured and included in the productivity ratio (Wazed & Ahmed, 2008). In this regard, the existing productivity measurement system is not complete. The company's major outputs are different types of models of pairs of shoes and glues. The inputs are materials, labor, energy, machinery, equipment, and other utilities and facilities.

Table 1
Manpower, total product output, sales volume, and productivity of the case company (Source: 50 years the company's anniversary bulletin, company annual performances and own computations)

S/N	Fiscal year	Manpower (Number), X	Product output (piece in '000), Y	Sales amount (piece '000)	Productivity y/x
1	1980/1981	523	673	660	1.3
2	1981/1982	578	714	665	1.2
3	1982/1983	559	729	739	1.3
4	1983/1984	606	730	662	1.2
5	1984/1985	624	745	668	1.2
6	1985/1986	647	716	695	1.1
7	1986/1987	681	763	882	1.1
8	1987/1988	716	892	877	1.2
9	1988/1989	718	906	949	1.3
10	1989/1990	729	919	918	1.3
11	1990/1991	757	749	740	1.0
12	1991/1992	764	449	410	0.6
13	1992/1993	745	500	501	0.7
14	1993/1994	721	427	436	0.6
15	1994/1995	726	475	452	0.7
16	1995/1996	703	456	461	0.6
17	1996/1997	677	375	369	0.6
18	1997/1998	647	493	520	0.8
20	2007/08	512	628	-	1.2
21	2008/09	434	519	-	1.1

Nevertheless, considering the company's productivity measurement, only the number of pairs of shoes produced annually as an output and the total workforce the company employed is taken into account (Table 1). The glue production is neglected from the productivity analysis. The glue production is, however, one of the major product categories of the company. The glue production consists of Polyurethane synthetic plastic glue, sole Glue, last glue, and vulcanizing glue. The glue production contributes to an average of 45917 kg and 1,141,600 birr of glue as input to produce the company shoe products. Additionally, it contributes 1,144,000, 105,000, and 78,000 Ethiopian Birr to the local sales' amount of the organization as observed in the three consecutive budget years (Table 2), namely 2007/08, 2008/09, and 2009/10. Yet, this considerable product output of the company was not considered in the current productivity measurement and analysis system.

In a similar fashion, in the existing productivity measurement of the company, it has been observed that there is incompleteness in considering all factors of production of the company. These include the raw materials, machineries, energy and other utilities used in producing the final product of the firm. These input factors have key impact on the productivity of the organization.

Table 2
Domestic and export Sales for three consecutive fiscal years (Source: Annual financial performance report of the case company)

S/N	Types of product	2007/08			2008/09			2009/10		
		Piece (‘000)	Unit price	Value (‘000)	Piece (‘000)	Unit price	Value (‘000)	Piece (‘000)	Unit price	Value (‘000)
1	Military Local market	187	120.14	22445	301	136.35	41023	168	143.2254	24113
2	Military Export market	105	93.9	9859	28	95.14	2664	45	206.4432	9375
3	Working	142	90.52	12848	134	105.96	14234	131	110.5775	14529
4	Civil	171	104.54	17904	42	112.89	4700	44	102.8216	4526
5	Ladies	9	74.66	674	16	98.51	1618	13	93.19764	1218
6	Children	5	54.76	260	1.4	72.58	98	5	69.59123	349
	Total	619		63990	523		64337	407		54110
7	Glue	31	36.73	1144	3	38.1	105	2	41.80064	78
	Grand Total			65134			64442			54188

Ignoring these factors while measuring productivity of the firm will, in fact, result in erroneous effect and misdirect the company’s improvement effort. This impact was substantiated in 2007/08 and 2008/09. According to the existing productivity measurement and analysis of the company, the productivity of the firm was 1.2 and 1.1 pairs of shoes per employ in 2007/08 and 2008/09, respectively (Table 1). This result indicates that the productivity of the firm in 2007/08 fiscal year is better than that of 2008/09. The management of the company, hence, is expected to try to identify the success factors of the higher productivity year in the case of 2008/09 and adopt them to good use in the subsequent years.

iii. The productivity measurement and analysis system lack comparability

The existing productivity measurement system has got comparability problem. The company needs to identify its productivity growth by defining a base year, and based on that the index will be developed to determine whether it is growing or lagging in productivity with time. The existing productivity measurement and analysis system, however, measures productivity only as the rate of pairs of shoes produced per unit of labor utilized in the given period of time.

Secondly, the company is measuring its productivity without considering its product mix. Besides the glue production, the company is producing different types of shoes products. Each product has got its own labor requirement depending upon the process they demand for production. Moreover, the products’ proportion is variable from year to year. In 2007/08, for instance, direct labor hour’s cost per unit for the local market such as military shoe, gents, working, military export shoe, lady shoes and children shoes were 9.36, 6.73, 7.1, 7.21, 12.15, and 8.95 Ethiopian Birr, respectively (Fig 5). Correspondingly, the selling unit price of the products is highly variable (Fig 6). This indicates that the resource requirement and value of the products are variable to one another. On the other hand, the percentage product composition of the firm varies from year to year (Fig 7). As a result, equal number of either of the different products will not have equal resource requirement or value. This is analogous to considering having an equal number of BMW as an expensive automobile and a Baby Fiat car as an economy model (though it seems overstated), as if

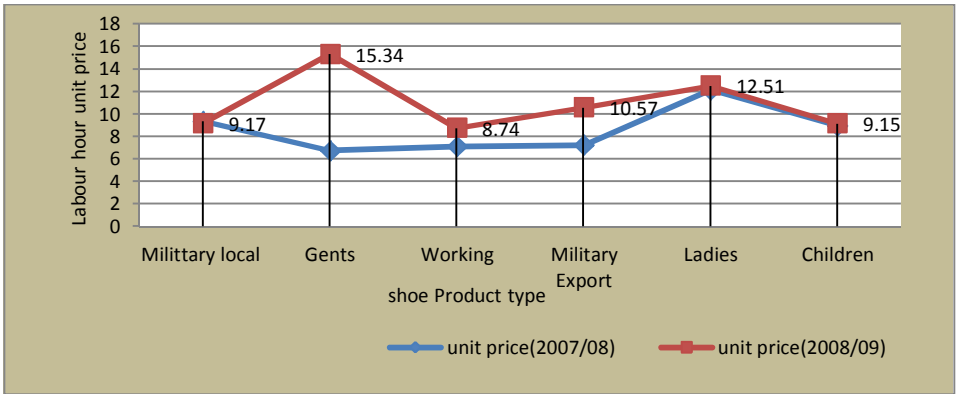

Fig. 5. Direct labour hour unit price requirement for each shoe product types (source: Annual financial performance report of the case company and own computation)

they had equal values and usability for the company performance or productivity evaluation measurement system. Moreover, the percentage in the number of Military Shoes produced for local market was 59.63 % in 2007/08. This percentage was lowered to 35.4 % in 2008/09. 24.23 % difference out of the total number of pairs of shoes the company could produce in the succeeding period was replaced by other products which have got different

resource requirement and value. Hence, calculating and comparing the companies productivity towards the number of the products only will result in erroneous conclusion.

iv. The productivity Measurement system is not inclusive

By inclusiveness, we mean a system covering all activities of a firm (Wazed & Ahmed, 2008). Hence, another limitation of the current productivity measurement system is that it is not inclusive. The number of pairs of shoes leaving the production floor and stored in the company's finished product stores or sales warehouses is considered as an output for measuring productivity. This, however, does not include at least the activities, role, and responsibility of marketing and sales workers of the firm. One cannot be sure that whether the company is selling its products or not with regard to this productivity measurement result. Moreover, the sales workers of the company, being summed as labour input, are evaluated for their productiveness for what they are not working. Their role is to sell the product and facilitate the sales of the company, but the number of pairs of shoes used as an output for productivity measurement is considered before it is sold.

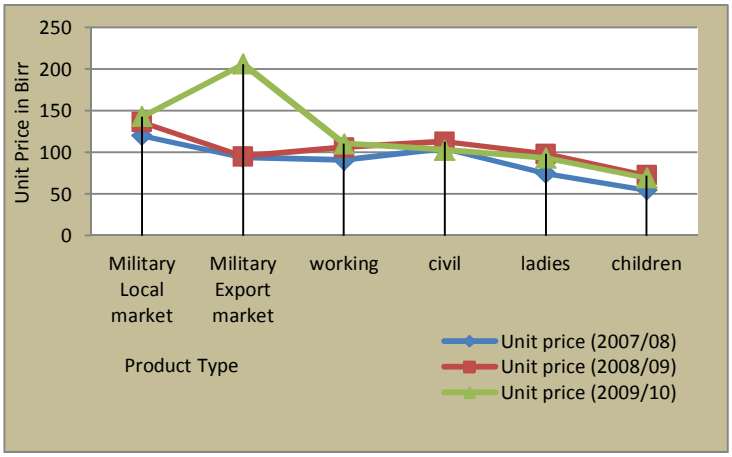

Fig. 6. Unit price of shoe products (source: Annual financial performance report of the case Company and own computation)

v. Limitation on identifying and detecting problematic areas and improvement opportunities

The productivity measurement is weak in identifying or prioritizing problematic areas where improvement actions are going to be taken. This can be demonstrated by the material inputs' shortage created and the substantial loss of production interruption observed in the 2008/09 fiscal year. Due to rubber shortage, the company could not produce 77, 177 pairs of shoes within 44 and half days. This accounts for 14.5 % from the total number of pairs of shoes produced in the year. In a similar manner, due to power outage, the company could not produce 108 hours and 13 minutes from the total regular working days (241.5 days) of the company, and this accounts for 31,293 pairs of shoes' loss of production. The fiscal year, however, had a productivity of 1.2 (that is, 1200 pair of shoes per a worker per a year) with the current productivity measurement and analysis method, and it is assumed to have better performance when compared to that of many of the production years of the company (Table 1). These major problems could not be detected with the current productivity measurement analysis.

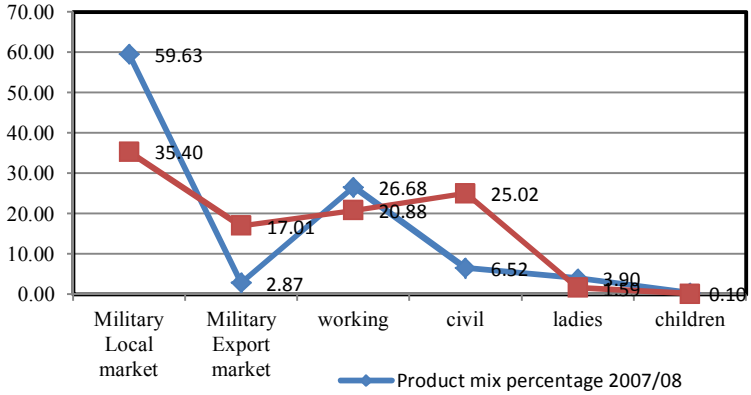

Fig. 7. Shoes product types composition percentage (source: Annual financial performance report of the case Company and own computation)

5. Development of Productivity Measurement and Analysis Methodology

Due to the high level and variety of productivity applications, the use and selection of appropriate measurement techniques and interpretation of the productivity analysis makes difficult. As a result, the concept of productivity measurement and analysis become vague for managers to use appropriately in their company. Whatever productivity measurement approach pursued, such as frontier or non-frontier, parametric or non-parametric, dual or primal to use, understanding the concept of productivity and its measurement at the desired level becomes a crucial element. Productivity measurement and analysis can be done at individual level, working group, process or subsystem level, firm level, industry level, sectoral level, national or international economy levels (OECD, 2001; Sumanth D. , 1985; Thomas & Baron, 1994).

Afterwards, once the level of analysis is determined, defining the output and input types and characteristics of the production function or system under quest becomes, however, an important step before measurement and analysis techniques are dealt with. Because the characteristics of the inputs and outputs are so diverse for different types of production system and the concept of production is applicable to different production types, such as manufacturing or service, small or big, careful considerations for selection of productivity measurement technique, analysis and result interpretation need to be searched for. First and foremost, the outputs are usually expressed in different forms to the inputs. Outputs are often measured in physical words (Groover, 2001) such as units (e.g., number of bottles produced, tones of sugar, megawatts of electricity, etc.) or values, such as Ethiopian birr. However the inputs are usually physically different and include measures of people (numbers, skills, hours worked or costs) or materials (tonnages and costs). Secondly, the ratio by itself tells us little about performance. A ratio of 0.8 is not as such important, unless it is compared with previous time periods, or a benchmark, or the potential productivity of the operation unit which is considered to be target. Third, many different ratios can be used (both financial and nonfinancial, that can be used) to create productivity ratios.

Another problem associated with productivity measurement and analysis, though mainly manifested in productivity analysis at macro and micro levels (the impact is reduced at nano-level) is that the productivity change obtained from the residual from production function is not only affected by input factors, but also it can be affected by economy of scale, technical capability, and quality of production factors of a production system (Thomas & Baron, 1994). This is why the productivity concept and its practical and proper application in companies remain vague.

Accordingly, in this research, the authors suggest that prior to carrying out productivity measurement and analysis activities, development of framework that defines how the productivity measurement and analysis is to be pursued and defining the level at which productivity analysis and measurement is going to be carried out would be important issues to take into account.

As noted so far, it is evident that the application of productivity concept ranges from individual or working groups of a company to international economy level. In addition, many professionals and practitioners, including economists, administrators, managers, politicians and industrial engineers, utilize the concept for their areas of work and study. Considering and dealing with all levels of productivity measurement and analysis is out of the scope of this research. Consequently, the scope of this research is restricted to deal with productivity measurement and analysis at company level; a precise, simple and realistic methodology for company level productivity measurement and analysis is developed and discussed in detail.

Hence, a productivity measurement and analysis framework (Figure- 8) has been developed. The framework guides and defines how the measurement and analysis process can be pursued at company level which will be worth considering. This, in fact, will reduce prejudice in implementation of productivity measurement and analysis system and will make measurement continuous and consistent. The methodology comprises the following components:

1. Definition of productivity measurement and analysis level
2. Definitions and Identification of the objectives and goals at the specified performance measurement level
3. Identification and determination of input and output parameters at the defined level
4. Productivity measurement model design and development
5. Weight assignment and Development of productivity index for the defined level
6. Result analysis and interpretation
7. Implementation and Model maintenance

As commonly known, a business main objective is to make profit (Thomas & Baron, 1994). Though some argue that definition of a business in terms of profit making is narrow. At the same time, goals and standards are necessary. Otherwise, there is no logical basis for choosing what to measure, what decisions to make, or what actions to take. Goals can be management directives or can be set in response to customer needs or complaints. For each critical activity or process selected for measurement, it is necessary to link the performance or productivity measurement with the goal of the firm. Consequently, business firms mobilize resources and capitals and adopt a conversion process to get the desired output by which the profit target is realized. Increased profitability is obtained through increased productivity or price recovery, among others (see Fig 4).

On the other hand, to maintain and obtain the required growth level of productivity in the company, the concept

and application of productivity management should be given emphasis. Consequently, the success of a productivity management process depends upon high degree of involvement and participation by all levels of management and employees. Because the role of management in productivity decline is a major factor (Sumanth D. , 1985), the need and commitment of managers towards productivity measurement and analysis have to be established.

- Assignment of dedicated productivity function or champions,
- creation of awareness on the importance of productivity,
- And establishment, implementation and maintenance of productivity programs

are among the roles of management for effective productivity measurement and analysis initiatives in a company.

As a result, the productivity measurement and analysis result will be a shared language; employees, managers, and other stakeholders or parties will collaborate towards the measurement, growth, and improvement of the productivity of the company.

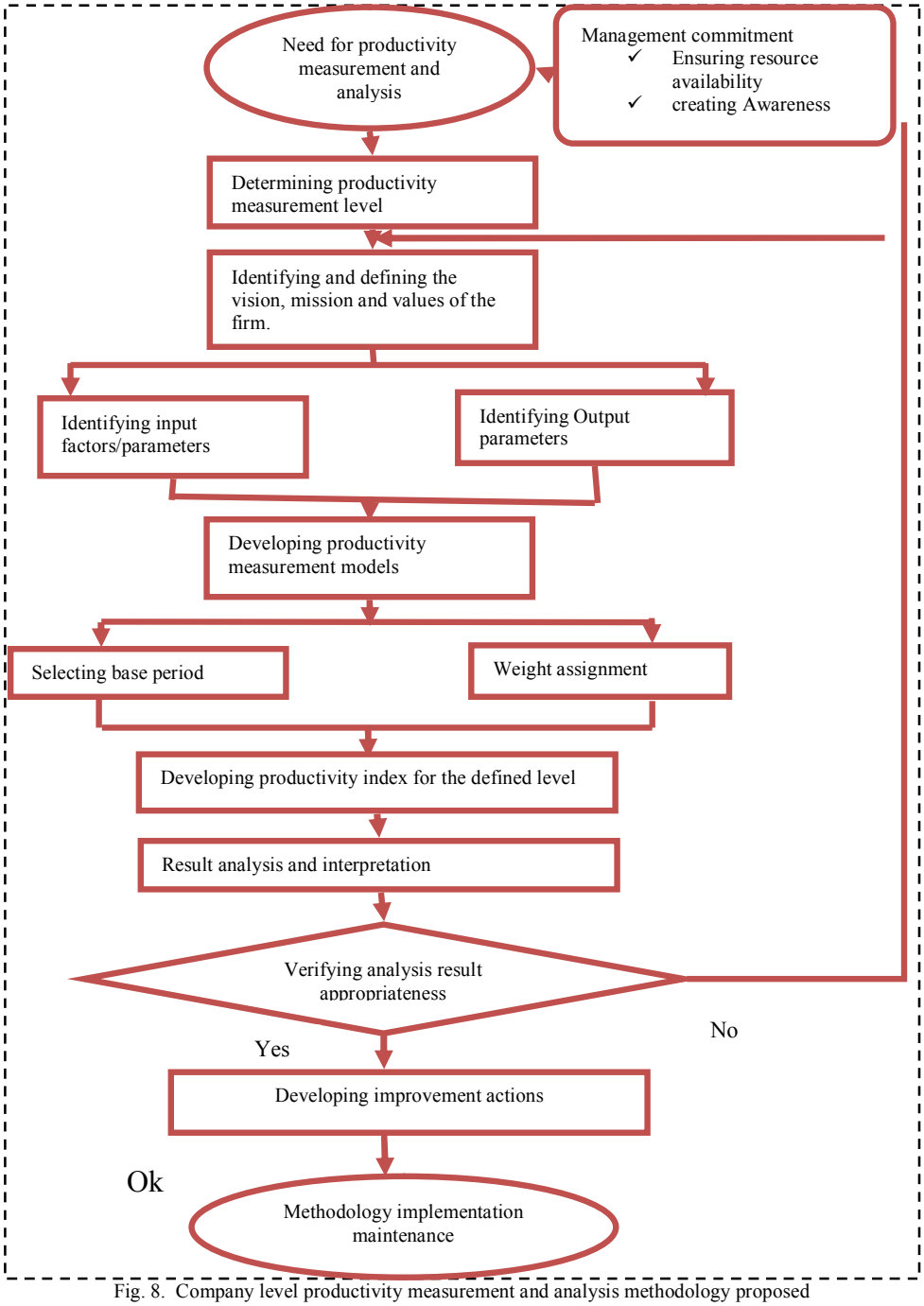

Fig. 8. Company level productivity measurement and analysis methodology proposed

5.1. Defining productivity measurement and analysis level

Productivity measurement and analysis of a company has traditionally been determined by employing productivity models such as Kendrick-Creamer (Kendrick & Creamer, Measuring Company ProductiVity: Handbook with Case Studies, 1965), Craig-Harris (Craig & Harris, 1973), and David J. Sumanth (Sumanth, 1985) in which productivity index is developed for either total productivity, total factor productivity or partial productivity. Following this approach, these productivity measurements are used by companies for monitoring and development of the daily operations and long-term strategic considerations.

The productivity index is measured usually based on values only or physical counts of the outputs and input factor or factors considered (Grunberg, 2004). This, however, has got limitation, in that identification of problems at the specified point in the firm is difficult. If materials as input factors, for example, are identified poorly productive, since the productivity of materials for a product is affected by different parties and points in the firm including activities, such as supplier selection, proper storage, proper handling, appropriate sourcing with the right quality and price, correct processing and proper checking, testing and verifications, taking improvement actions demand further investigation works. This lowers management enthusiasm to measure productivity meant for improvement. The use of total productivity measurement or partial productivity has only got inadequacy. It would be better to investigate the total productivity and partial productivity measurements used separately at this point.

Usually, the total productivity at company level is measured by taking the ratio of the total output in physical, invoiced sold goods, or monetary terms to monetary value of total or aggregate input factors. Its potential drawbacks could be explained hereunder.

- The interaction between each input and output separately is not shown using total factor productivity measurement only.
- Since the values of the input factors (capital, material, labour, energy, and other factors) are aggregated altogether, prioritizing improvement action (at what point, that is, function, working group or process, and on what factor or factors to take primarily) is difficult.
- It is too broad and difficult to be used as a tool for improving specific and potential areas. As a result, managers become reluctant towards the productivity measurement index and analysis result.

Similarly, at the company level, the application of a single factor productivity measurement only cannot satisfy the objective of productivity. One of the serious dangers of relying exclusively on partial productivity measures or on a single input factor lies in overemphasizing one input factor to the extent that the effect of the other inputs is underestimated or even ignored, leading to erroneous judgments and costly mistakes (Sumanth D. , 1985). Therefore, the use of partial productivity measures, such as labor productivity or capital productivity, may misrepresent the level of integrated productivity and misdirect the improvement efforts (Thomas & Baron, 1994; Liang & Liaw, 2006; Sumanth D. , 1985). It would be very important to investigate the overall and specific improvement potential areas to obtain the benefit of productivity analysis. At the same time, measurement of productivity and analysis at a company level can be approached systematically to make more realistic, complete, and simple evaluation that can detect problems and growth of the company and can go with modern management tools and systems whose companies nowadays implement improved performance and competitiveness.

Hence, measuring and analyzing productivity by employing system approach is deemed important. First, this calls for defining the productivity measurement unit or level in the company. The potential productivity measurement units in a typical production firm could be individuals, working groups, processes, functions and the organization as a whole (Sumanth D. , 1985; Thomas & Baron, 1994). Since labour productivity at individual level is usually estimated from the whole output, physical or value added on average base, considering individuals as a productivity measurement unit in a firm could either be costly or biased result. Rather, this issue could be addressed for further investigation and productivity improvement action by employing different productivity improvement tools including: motivational methods based on industrial psychologists and performance appraisals for salary structure/workload analysis extended by human resource specialists, and piece-rate/standard times determined by industrial engineers (Wazed & Ahmed, 2008). Use of process level as productivity measurement unit will, therefore, be a very important level for productivity measurement within a firm because:

- It manages to identify the problematic area to take improvement measurement action with little confusion, time, and cost
- It also makes the productivity measurement and analysis system:
  - be simple and easily acceptable by managers
  - easily integrated with the modern management system tools and philosophies
  - able to compare the effectiveness of the management system tools with that of the productivity measurement and analysis result
  - enable productivity level comparison among processes in the firm
- makes branches, functional and processes benchmarking possible

However, the use of process level productivity management cannot tell us the overall organization productivity level and identify its growth. Additional productivity measurement unit should be employed to have the entire productivity picture of the company to

know both the productivity level and growth of the firm. This urges us to measure the productivity of the firm as a unit. Therefore, measurement and analysis of a company's productivity will essentially be carried out at both process and company levels.

5.2. Definition and identification of the company's mission and values

All activities in a firm are carried out to meet its goal or objectives. The activities are organized into processes where each collectively contributes to the fulfillment of the company's strategic goal. The synergic effect of the multi-process efforts of the company ultimately valued the growth of the firm. Accordingly, each productivity measurement and analysis level effort should be related to the company's missions and values and be implemented for the achievement and validation of these targets. By doing so, it would be possible to increase the power of the calculated productivity index to detect potential improvement areas and facilitate the growth and competitiveness of the company.

5.3. Identification and determination of input and output parameters

As discussed in the literature review part of the research, the simple definition of productivity is the ratio of output to input. The nature and characteristic of the inputs and outputs used for productivity analysis of different production system is, however, different. Now, it is time to discuss issues pertaining to outputs and inputs in relation to productivity measurement at process level. It can be viewed from the following perspectives that:

- a manufacturing company is composed of definable and interrelated processes which are value added;
- a process has got its input and output and productivity is the ratio of output to input;
- Lower level outputs can be established from the final or organizational output (Thomas & Baron, 1994).

5.4. Productivity measurement model selection or design

Once having defined the level at which productivity measurement and analysis should be carried out, the selection of appropriate productivity measurement model will become the subsequent task. The productivity measurement and analysis techniques should define the criteria for fulfillment. Hence, depending on the objective or goal of the productivity measurement and analysis for the predefined level, setting appropriate productivity measurement and analysis criteria will ease the bias on what type of productivity measurement technique or model to select or design. Consequently, productivity measurement analysis should commonly fulfill the following criteria or objectives (Thomas & Baron, 1994; OECD, 2001):

- Represent the Company productivity.
- Identify or prioritize the problematic areas and determine the solutions for improving productivity in such areas resulting in identification of potential improvements
- Ensure its completeness; Completeness refers to the thoroughness with which outputs or result delivered and all inputs, or resources consumed, are measured and included in the productivity ratio.
    - Should be inclusive, including all activities of the company
    - Cost-effectiveness
    - Reduced degree of measurement error and productivity result in misinterpretations
    - Ability to decide how to reallocate resources
    - determining how well previously established goals have been met

5.5. Weight assignment and development of productivity index

Apparently, all activities, processes, and functions of an organization are designed to exist in the firm to meet the organization goals and objectives. Those processes which have no connection directly or indirectly to the goals and objectives of the firm need to be eliminated and should not be allowed to exist in the firm. Similarly, only the desired input factors should be assembled and those production factors which have no relation are not ideally collected within the firm. Hence, all processes and input factors of the firm are assumed to be essential for the fulfillment of its targets. However, not all processes have equal significance for the firm. The relative significance of each factor and processes varies from one another with respect to their value and the goal of the organization (Sumanth D. , 1985). As a result, prioritizing and weighting system is important.

Accordingly, the index which will be developed for the processes of the firm and their factors of transformation will have a different weighted value for the calculation of the processes and the firm's total productivity. To this end, depending on the processes and input factors of significance level, the following weighting criteria (Sahay, 2005; Sumanth D. , 1985) are worthy of use:

1. unit labor costs;
2. unit value added;
3. unit value;
4. degree of alignment with company objectives;
5. contribution analysis by improvement of individual factors;
6. needs and scope for improvement;
7. characteristics and degree of variability of factors from year to year.

These weighing criteria are used for assigning weighting value at the different stages of the productivity index calculation. Once experts and management of the firm discuss the significance of the processes and its input factors and output with regard to the achievement of the

company's goals and objectives directly or as cascaded from it, they will then rate and give values based on one or more of the weighing criteria enumerated here above.
Once the weight assignment is defined, there remains working for long period, and probably some changes along with little alignment with regard to the weight assignment might be required.
Following weight assignment, base period will be selected. Base period is a reference period with which the productivity of the current period is compared for its growth or decline. It can be any normal period in which the production was not much different from the average. A period in which a company laid off workers because of unprecedented shortages of raw materials, for example, cannot be considered as a base period. Thus, the base period can be defined by (Sahay, 2005; Sumanth D. , 1985):

1. Selecting an average period in which any unprecedented problems are not observed;
2. The best value of factors in past three years;
3. The value of factors in the immediate past year;
4. The average value of the factor in previous three years;
5. The moving average value of the factor in previous three years;
6. The productivity of the current year to be compared with a fictional value of productivity (best) calculated by considering the best value of factors in the last three years.

The base period for the weights is changed periodically to take changing economic conditions into account with the sub periods under study (Sumanth D. , 1985).

5.6. Result analysis and interpretation

The numbers and ratios or indexes resulting from a productivity measurement model give way to nothing more than a set of warning signs. Hence, based on results of the productivity measurement obtained in the preceding steps, analysis of the organization productivity performance will be carried out. The analysis covers the overall assessment of the company's productivity level and growth including identifications of the significance and severity of the current period performance. Comparison and evaluation of the result will yield identification and definition of the major productivity problems of the firm that could be prioritized and management will give attention for corrective action. Appropriate analytical tools, including histograms, Pareto chart, and bar graphs, could be beneficial, especially for proper presentation of the analysis result. Therefore, management can easily visualize the productivity problems and prompt to take productivity improvement actions as the required level.

5.7. Result verification and methodology maintenance

The appropriateness of the methodology needs to be verified against the goal and objective of the firm. This should be a continuous activity. Of course, once the productivity measurement and analysis methodology has been established in the firm, it will be maintained for longer time with little adjustment as required. Productivity programs will be one functional aspect of the firm through which company's objectives and goals are ensured to meet. The productivity measurement methodology will assure the accountability of processes owners, and consistent implementation of the system will assure the continuous improvement of the company's productivity. This, in turn, results in better growth and competitiveness of the firm.

6. Conclusion

Companies should measure their actions and results to control, because without controlling, taking improvement action is usually impossible. When they perform the measurements, they can understand and control their resources in a better way. This helps them to make a better, realistic and fact-based decision for improvement, thereby assuring a better competitive position. Productivity is one of the important company performance measurement constructs that enables the company to identify the degree of how much they use their resources to produce or get more products or services.
However, as observed in the case manufacturing company, there are serious problems in measuring and analyzing productivity at company level in Ethiopia. The measurement models (Table-1) put in place lacks completeness, inclusiveness, company objective alignment, comparability, ability to detect problematic and/or improvement opportunity areas, and the ability to reduce degree of measurement error and misinterpretation of productivity result. This research, hence, focuses on the productivity measurement and analysis and with the objective defining and devising a methodology (Figure-8) that enables production companies to measure and analyze their productivity to increase global competitiveness at the firm level. Accordingly, methodology which enables to measure and analyze productivity at company level has been developed. The methodology integrates the mission, objectives, and values of the company. It also bridges the shortcomings of the case company's productivity measurement and analysis system currently put in place. The measurement framework proposed is simple to understand, detects problem easily and realistically, and can be adaptable to similar manufacturing firms.

References

Craig, C. E. & Harris, C. R. (1973). Total Productivity Measurement at the Firm Level. Sloan Management Review, 14(3), pp. 13-29.

Gershwin, S. B. (2005). MIT. [Online] Available at: http://web.mit.edu/manuf-sys/www/[Accessed 3 June 2016].

Groover, M. P. (2001). Automation, Production Systems, and Computer Integrated Manufacturing. Asia: Pearson Education.

Grunberg, T. (2004). Performance Improvement towards a Method for Finding and Prioritizing Potential Performance Improvement Areas in Manufacturing Operations. *International Journal of Productivity and Performance Management*, 53(1), pp. 52-71.

Harold Siow, S. T. (2014). Qualitative productivity analysis: does a non-financial measurement model exist?. *International Journal of Productivity and Performance Management*, 63(2), pp. 250 - 256.

Helo, P. (2005). Managing agility and productivity in the electronics industry. *Industrial Management & Data Systems*, 104(7), pp. 567-577.

Hoehn, W. (2003). Managing organizational performance: linking the balanced scored to a process improvement technique. Bangkok, Proceeding of the 4th Annual International Symposium in Industrial Engineering on the Performance-based Management, Kasetsart University, pp. 1-12.

Jan van Ree, H. (2002). Added value of office accommodation to organisational performance. Work study, 51(7), pp. 357-363.

Kendrick, J. W. (1961). Productivity Trends in United States for NBER. New York: Princeton University Press, Princeton.

Kendrick, J. W. & Creamer, D. (1965). Measuring Company ProductiVity: Handbook with Case Studies. New York: National Industrial Conference Board.

Kumar, A. s. & Suresh, N. (2008). Production and Operations Management. 2nd ed. New Delhi : New Age International (P) Ltd..

Kurosawa, K. (1991). Productivity measurement and management at the company level: the Japanese experience, Advances in industrial engineering,. s.l.:Elsevier science publisher.

Liang, H. C. & Liaw, S.-Y. (2006). Professional practice measuring performance via production management: a pattern analysis. *International Journal of Productivity and Performance Management*, 55(1), pp. 79-89.

Mohanty, R. P. & Rastogi, S. C. (1986). An Action Research Approach to Productivity Measurement by. *International Journal of Operations & Production Management*, 6(2), pp. 47 - 61.

Muthiah, K. M. & Huang, S. H, (2006). A review of literature on manufacturing systems productivity measurement and improvement. *International Journal of Industrial and Systems Engineering*, 1(4).

Neely, A., Gregory, M. & Platts, K. (1995). Performance measurement system design. *International Journal of Operations & Production Management*, 15(4), pp. 80-116.

OECD, (2001). Measurement of Aggregate and Industry-Level Productivity Growth. Paris, France: Centre français d'exploitation du droit de copie (CFC).

Oyeranti, A, (2000). CiteSeerx. [Online] Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.511.9388&rep=rep1&type=pdf[Accessed 21 August 2009].

Phusavat, K. & Photaranon, W. (2006). Productivity/performance measurement. *Industrial Management & Data Systems*, 106(9), pp. 1272-1287.

Sahay, B. (2005). Multi-factor productivity measurement model for service organization. *International Journal of Productivity and Performance Management*, 54(1), pp. 7-22.

Singh, H., Motwani, J. & Kumar, A. (2000). A review and analysis of the state-of-the-art research on productivity measurement. *Industrial Management & Data Systems*, 105(5), pp. 234-241.

Sink, D. & Tuttle, T. (1989). Planning and measurement of in your organisation of the future. Norcross, USA: *Industrial Engineering and Management* Press.

Sink, D. & Tuttle, T. (1989). Planning and Measurement in Your Organization of the Future. Norcross, GA: IE Press.

Sumanth, D. (1985). Productivity Engineering and Management. New York, NY.: McGraw-Hill.

Sumanth, D. (1994). Productivity engineering and management,. s.l.:McGraw-Hill.

Susan, H. W. E, (2007). Outsourcing, Offshoring, and Productivity Measurement in U.S. Manufacturing. International Labour Review, 146(1-2), pp. 61-80.

Tangen, S. (2005). Demystifying Performance and Productivity. Tangen, S. (2005) *International Journal of Productivity and Performance Management*, 54(1).

Thomas, B. E. & Baron, J. P. (1994). USACERL Interim Report. [Online] Available at: http://www.cecer.army.mil/kws/tho_lit.htm[Accessed 10 June 2010].

Thomas, G. (2004). Performance Improvement towards a Method for Finding and Prioritizing Potential Performance Improvement Areas in Manufacturing Operations. *International Journal of Productivity and Performance Management*, 53(1), pp. 52-71.

Wazed, M. & Ahmed, S. (2008). Multifactor Productivity Measurements Model (MFPMM) as Effectual Performance Measures in Manufacturing. Australian Journal of Basic and Applied Sciences, 2(4), pp. 987-996.

This article can be cited: Yilma Goshua, Y., Kitawb, D. & Matebuc, A. (2017). Development of Productivity Measurement and Analysis Framework for Manufacturing Companies. *Journal of Optimization in Industrial Engineering.*10 (22), 1-13.

URL: http://qjie.ir/article_274.html

DOI: 10.22094/joie.2017.274