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Industrial Engineering

Measurement Systems

Reduction of Bullwhip

Highlights

Acid Battery Industries

Developments and Trends

Discovering Thoughts, Inventing Future

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BA in Mathematics (Licenciatura)
University of Barcelona

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Associate Professor and Research Department Division of Neuromuscular Medicine
Davee Department of Neurology and Clinical NeuroscienceNorthwestern University
Feinberg School of Medicine

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Assessing the Existing Performance Measures & Measurement Systems in Developing Countries: An Ethiopian Study

By Fasika Bete Georgise, Klaus-Dieter Thoben & Marcus Seifert
University of Bremen

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Keywords : performance measurement system; key performance indicators; developing country, industrial analysis.

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Strictly as per the compliance and regulations of :

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Fasika Bete Georgise [α σ ρ], Klaus-DieterThoben [σ] & Marcus Seifert [σ]

Abstract - The global integration and rapid applicability of supply chain concepts in manufacturing industries creates both opportunities and challenges for developing countries. The developing countries are becoming more open to adapting and accepting Western business practices. One of the important issues in this context is the use of the standard performance measurement systems. In the current literature, the capability to measure the performance of manufacturing industry operations can be seen as an important prerequisite for improvement. Companies have increased the capabilities of their performance measurement systems. The manufacturing industries in developed countries have been developed and implemented successfully multi-dimensional performance measures, and measurement systems for their business success. Whereas research results and data related to developing country's state of performance measures are very minimal. With the recent global integration and economic relevance of developing countries, we investigated the level of performance measurement systems in Ethiopian. The paper presents the existing practices in performance measures, and measurement systems based on case studies on twelve companies and questionnaire survey on thirty two companies'. A survey and case study results show that manufacturing industries still largely use financial and productivity performance measures. Despite the powerful advantages of performance measurement, it has not been widely implemented in the manufacturing industry in developing countries. The current performance measurement systems have faced different challenges what they did not encounter in developed nations companies. Especially, the existing infrastructures as enablers were much below the required standard. Further research and analysis could be done to adapt the performance measurement systems to the developing countries scenarios.

Keywords : performance measurement system; key performance indicators; developing country, industrial analysis.

I. Introduction

Currently, businesses in developing countries have been challenged from fierce competition. Developing nations have been started to realize their protectionism strategies at home land will not continue as best for their competitiveness. As a source of raw material for companies in developed countries, raw material preparation and semi-processed products are being produced in developing countries, sometimes thousands of miles away from the point of consumption – developed countries. During this period, the concept of supply chain management (SCM) has gained wide acceptance in the developed world. However, the benefits from supply chain (SC) concepts would be rather much better if the attempts included their developing country's counterpart. For improving the supply chain which both developed & developing countries as members, both developed and developing countries need to consider all supply chains members. There is a need for a consideration of improving supply chains from raw material sourcing process, which developing countries act as key players.

In order to gauge the effectiveness of supply chain management efforts, companies in developed countries utilize performance measurement systems. There have been many attempts to model, measure and improve the performance at the organizational and inter-organizational level in the developed countries (Chen and Paulraj, 2004; Sharma and Bhagwat, 2007; Kaplan and Norton, 1992; Keegan et al., 1989; Dixon et al., 1990; Globerson, 1985). The supply chain operations reference (SCOR) model is one of widely accepted quasi-industrial standard that proves to be extremely effective in supply chain modeling, performance measure and best practice. The SCOR model allows supply chain partners to ``speak a common language'' because it provides standard definitions for processes, process elements, and performance metrics. As the SCOR model offers standard definitions of performance measures for the supply chain processes, it is easier for managers and practitioners to identify relevant measures and use them. Companies in developed countries have implemented SCOR model as standard criteria for evaluating and improving their SC performance (Phelps, 2006; Galazzo, 2006; Magnusson, 2010).

In recent years, companies are cooperatively working to increase competitiveness, and gauging the performance of supply chains has become increasingly more important. In order for a supply chain to succeed,

Author α: International Graduate School for Dynamics in Logistics (IGS), University of Bremen.
Author σ : Bremer Institut für Produktion und Logistik GmbH - BIBA, Hochschulring 20, D-28359 Bremen, Germany.
Author ρ : School of Mechanical & Industrial Engineering, Hawassa University, Hawassa, Ethiopia.
E-mails :{geo, tho, sf}@biba.uni-bremen.de,
br mailto:sf%7d@biba.uni-bremen.de

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companies in both developed and developing countries should measure the performance of the whole supply chain and identify areas of improvement for increased competitiveness. When looking at the textile and apparel supply chain in figure 1, more of the upstream portion (closer to raw materials) is located in developing countries.

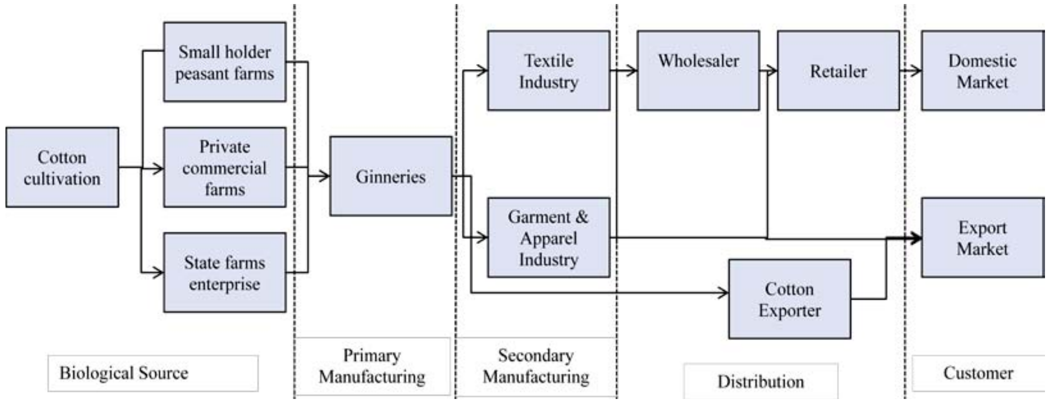

Figure 1 : Textile and garment supply chain

Efforts to improve supply chain performance by these upstream companies should be based on the expectations of their downstream supply chain members – apparel marketers and retailers. As an example, the Sri Lankan textile and garment industry is currently trying to improve productivity (Joint Apparel, 2007). Neely (1999) and Burgess, Ong and Shaw (2007) support the view that increasing competition necessitates an improved performance measurement system. Companies in developed countries are obtaining best advantages by implementing supply chain (SC) as strategies. Nevertheless, there is still a lack of significant literature on study of supply chain practices and performance measurement in developing countries (Austin, 1990; Saad et al., 2006; Georgise et al., 2011). Practitioners and managers has heard cliché ``what gets measured, get done!'' If the effectiveness and efficiency of an activity cannot be measured, it could not be properly controlled. For this effect, performance measurements are crucial to the manufacturing industries in developing countries also.In our research paper, we attempt to find if the key performance indicators and performance measurement systems used in Ethiopia are in line with relevant literature. To achieve this, we review the current literature on the performance measurements system and examined the key performance indicators and performance measurements systems are used in developing nations based on the experiences of the Ethiopian Manufacturing Industries. It also attempts to highlight the main enablers, barriers and challenges of performance measurement systems in Ethiopian context. We have used exploratory approach in order to gain deeper knowledge about what the problem really consists of, and further understand the phenomenon. The research question includes ``what``, ``how`` and ``why``.

- What are the problems of performance measurement systems in developing countries?
- How do Ethiopian manufacturing industries measure performance today? Are they inclined to use financial measures or non-financial ones?
- What type of performance measurement approaches used by Ethiopian manufacturers?
- What are the types of information and communication technologies enablers available in the practices?
- What are the main challenges and barriers faced for implementation of the new performance measurement approaches?

This paper seeks to answer the above research questions. The real practices in Ethiopian context were collected with help of survey questionnaire and semi-structured interview. More specifically, manufacturer asked to what extent they use various key performance indicators, whether they have a performance measurement system in place and if so, what type of system, and whether or not they had any information system to support PMS.

The remainder of the paper is divided into seven main sections. In the first, the relevant literature is reviewed on performance measurement systems. In the second, the main problems raised in the performance measurement systems in the developing countries are discussed from the literature. The research methodology is presented in section four. In the five, analyses the fieldwork data to assess the status of the performance measurements with respect to the Ethiopian manufacturing industry. The studies demonstrate how the Ethiopian manufacturing companies measures their performance; what are the available enablers to facilitate performance measurement systems; and identify the challenges and barriers for past performance measurement systems shortfalls have occurred. The last

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two sections summarize the key findings and draw some conclusions related to the performance measurement in the developing countries.

II. Performance Measurement Systems

In recent published papers and literature, it became apparent that the terms, frameworks, models and systems, were often used interchangeably with performance measurement. For the purpose of this paper, we consider performance measurement system to be useful ways of thinking about modeling, evaluating and improving supply chain. Lee and Bilington (1992) suggested SC performance measurement systems (PMSs) are necessary for firms to successful implement SCM. According to Neely et al. (2002) "A Performance Measurement System is the set of metrics used to quantify the efficiency and effectiveness of past actions" and "it enables informed decisions to be made and actions to be taken because it quantifies the efficiency and effectiveness of past actions through the acquisition, gathering, sorting, analysis and interpretation of appropriate data". PMSs are considered as a tool to gain competitive advantages and continuously react and adapt to external changes (Cocca, 2010).

Love and Holt (2000) and Mbugua et al. (1999) make a distinction between performance indicators, performance measures and performance measurement. As Mbugua et al. (1999) state, performance indicators determine the required measurable evidence to prove that a planned effort has achieved the expected result. Based on their definition, indicators are called measures when they can be measured without ambiguity and with some degree of precision. In other words, performance measures report clearly about the relationships between program activities, outputs and outcomes associated with them (Thomas, 2006). He also claims performance indicators are less precise than measures, as they usually provide only a proxy indication of the performance of a program or system. Thomas (2006) further continues: "whereas measures might be likened to numbers on a gauge, performance indicators might be compared to alarm bells". However, when it is not possible to find a precise performance measure, it is better to refer to performance indicators. However, performance measures and targets are key elements of performance measurement.

Research on performance measurement systems (PMS) have mostly been focused on a single company. However in the last few years focus has shifted to incorporate a supply chain perspective, with several PMS proposed (Holmberg, 2000; Van Hoek 1998; Lapide, 2000; and Chan and Qi, 2003). An important step to transforms the individual business units into a fully operational integrated supply chain member is to design and implement supply chain performance measures and performance measurement systems. From such design each business enterprise will be take a responsibility not only for its own business performance but also for the overall performance of the supply chain (Gunasekaran, Patel, Tirtiroglu, 2001). Hence there is now an increasing focus on supply chain measures and the overall performance. The organizational dependency and supply chain relationship are growing increasingly complex from linear to multi-echelon, outward-facing network. With increasing integration of global supply chain and involvement of developing countries, the manufacturing companies have faced more challenges and barriers to model, measure, and improve their supply chain. Most companies lack the tools that can quickly shift through and present data coming from supply chain partners and systems. We can observe four important questions ''How to model?'', ''what to measure?'', ''what type of enablers required?'' and ''how to improve it?'' to be tackled in order to have successful PMS. Therefore, an effective supply chain performance measurement process should be able to directly address performance areas that create sustainable profitability and financial strength. In order to accomplish this requirement, the SCOR Model, which has been developed by more than thousand member organizations and partners and which is broadly disseminated both among scientists and practitioners, is mainly used to facilitate the current challenges of supply chain modeling, evaluating and improving.

In operational supply chain, a bigger challenge is to collect, sort and analyze the data generated by each processes. The challenge for many companies lies in determining what information is necessary to drive improvements and efficiencies at each process in the supply chain, and designing an information management environment to turn the raw data into meaningful metrics and key performance indicators (KPI). Key performance indicators are measurements that directly relate to key business requirements. Information from supply chain management (SCM) processes must be collected, measured, analyzed and continuously monitored. This requires integration of data coming out of ERP (Enterprise Resource Planning), SCM and all other systems supporting these business processes. Supply chain integration software enables companies to work in partnership with other links both in upstream and downstream supply chains.

III. Problems of Performance Measurement Systems in Developing Countries

Recent years, manufacturing businesses are becoming more integrated in global businesses has forced companies re-examine their supply chain processes in order to remain in their competitive

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position. Companies in developed and developing countries have realized the importance of integrating their supply chains in their improvement activities. These improvement goal set by both developed and developing countries to supply chain improvements can only realized if a sound system is established and agreed upon to measure the performance. Performance measurement systems will afford the crucial adjustment reason for effecting improvements in supply chain (Gunasekaran, 2004). Hence, most economies are moving towards organizational improvement to compete favourably in the current dynamic environment by focusing on key elements of modern management (Ohemeng, 2009; Waal 2007; Karuhanga, 2010). Lack of literature, lack of professional expertise, different cultural context, and low level of infrastructure are the main challenges for performance measurement systems in developing countries.

a) Lack of research & literature

One of relevant challenge to the concepts of performance measurement is the limited availability of literature and research on the application of these concepts in the context of developing nations. Company in developed countries has given more attention on supply chain performance with their competitors. They have less emphasis to their counterpart companies in the developing countries. Although literature on the global literature on the global supply chain integration is growing, the issue of problem in developing countries has received little attention. Much of the discussion has concentrated on global supply chain which includes developed and emerging countries supply chains and less emphasis for supply chains that developing countries participating especially Africa. Much as there is limited research on performance measurement in developing countries with 95 percent of empirical research focused on "institutional theory" in the developed world compared to only 5 percent in the developing country in the past 2 decades (Elzinga et al., 2009; Waal, 2007).

b) Low level of integration

With a variable involvement of almost all functions of an organization, and those of the other members of a supply chain, the design of a supply chain performance measurement system will require extensive involvement among supply chain members (Lee & Billington, 1992; Beamon, 1999). The key performance indicators (KPI) will need to be established carefully, considering strengths and limitations of all members, the cultural contexts and other environmental factors. Due to the complexities involved in measuring supply chain performance, very few companies actually succeed in performance measurement system of their supply chains as a whole in developed countries (Gunasekaran, Patel, & Tirtiroglu, 2001; Hudson, Lean, & Smart, 2001). The performance measurement systems, however, must be designed at both the supply chain and companies basis (Lambert and Pohlen, 1999).

c) Lack of professional expertise

The overall lack of skills and expertise often makes it not viable for developing countries to develop complex system such as performance measurement systems. The major challenge is to identify, evaluate and select the key performance indicators, which are appropriate to assess performance. Even if the existing performance measurement frameworks are highly helpful, their adoption and implementation in the developing nation's scenarios are often constrained by different business operation environment. However, they can be used as guidance how the appropriate measures can be identified, introduced and ultimately used to manage the business. As the issues of global integration and collaboration include developing countries are becoming one of the point of research agenda, the supply chain members and strategies vary from one country to another, and the KPI are bound to reflect from differences (Karuhanga, 2010).

d) Low level of infrastructure

The other important challenge is the existing information and communication technologies, infrastructure, enablers and supply chain integration software. Lack of basic information technologies infrastructure creates tremendous barriers for smooth information flow. While the benefits of having supply chain integration software are tremendous, the costs associated with purchasing, operating and maintenance such a system can be prohibitive. In association with low enablers facilities, the performance measures data collection, analysis and decision becomes difficult one (Andersen et al., 2006).

e) Cultural Context

The new innovative performance measurement systems are created in the context of developed countries. When this new PMS are applied directly in the cultural context of developing, the systems are faced different types of challenges that did not happen in the developed nations. The PMS may not be designed to include all aspects of cultural that influence individual and organizational behaviour in the less developed countries. Because of these potential difficulties, the implementation of PMS in diverse environments is beginning to receive attention from researches (Karuhanga, 2010; Wall, 2007; Bititici, 1997). Rejc Buhovac & Slapnicar (2007) in their studies about performance measurement in Eastern Europe, they point out PMS should be designed for the context in which the company operates, implying that system arising from a developed country must be adapted in a developing country. The other most comprehensive research in PMS in developing countries is done by

Holmes, Pineres & Kiel (2006). They have argued that implementation of the PMS in developing countries is difficult due to lack of resources, politicization of public administration and corruption.

In a recent article, Neely (2005) concludes that the performance measurement system domain is a relatively mature field of academic study. Although various research articles discuss the popularity of the performance measurement systems in the USA and Europe, and the growing interest in Asia (Neely & Najjar 2006), Africa is not even mentioned. This is confirmed by the lack of scientific literature on performance management in the African context. However, there are some developments on the researches by practitioners and academicians in developing countries that have shown interest in supply chain and performance measurement systems (Abdelsalam, 2009; Deloitte, 2009; Irfan, 2008; Magder, 2005). Some of the studies like Sinkovic (2011) and Wall (2007) have researched the applicability modern performance measurement systems in the developing countries context and proposed a research agenda (Sinkovic, 2011; Waal, 2007). Other's research results have discussed the state and challenges of supply chain and performance measurement system (Naude, 2011; Msimangira et al., 2009; Khalifa et al., 2008; Msimangira, 2003).

In certain developing countries, such as India, performance improvement efforts are being concentrated on improving productivity (Bheda, 2002; Bheda, 2003). However, instead of simply improving productivity, companies should understand the basis of performance measurement in their supply chain and improve their operations to meet the terms of performance of their suppliers and customers. This idea is illustrated by the Triple P-model (Figure 2). Here one can see that performance is constructed of profitability and productivity, and includes attributes of quality, delivery, speed, flexibility, and price recovery (Tangen, 2005).

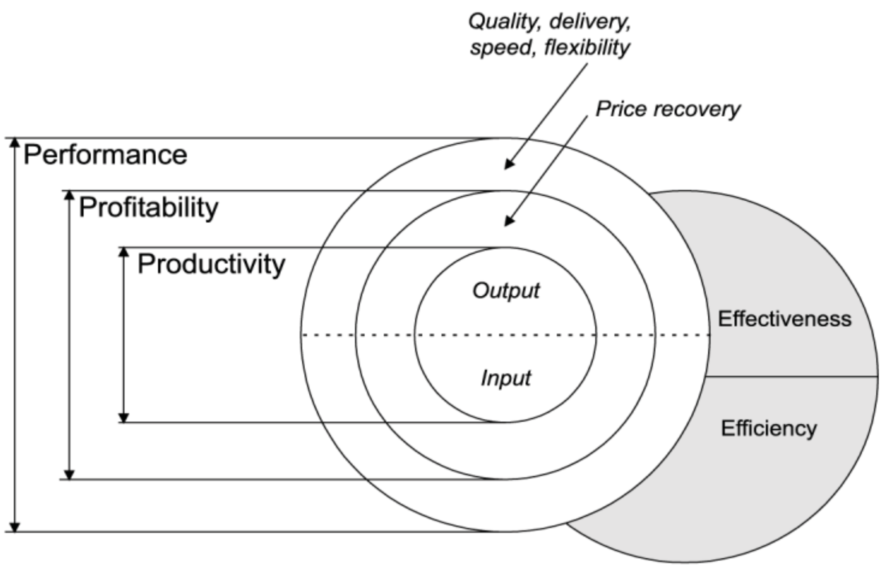

Figure 2 : Triple P-model (Tangen 2005)

However, Waal (2007) cites a number of studies, which show that of recent, there is an increasing interest in performance measurement in most organizations in some Africa countries such as Burkina Faso, Egypt, South Africa, Kenya, Ghana, Uganda, Ethiopia (Waal and Augustin, 2005; Abdel Aziz et al., 2005; Motswiane, 2004; Malinga, 2004; Tessema, 2005; Ohemeng, 2009; Kagaari et al., 2010). Despite such efforts, the consensus is that performance measurement has not made tremendous contribution to organisational efficiency and effectiveness in Africa (Ohemeng, 2009). Despite the increasing interest in performance management the failure rate of 56 percent (Waal and Counet, 2009) in the implementation process is still relatively high. Developing countries should therefore concentrate more on introducing and copying such tools and system from western world which are not always the best suited to their local environments. There is no question that is theory adopting management practice which have proven-to be effective is a better alternative for an organization than investing limited and scare resources in efforts which do not amount to much more than `reinvesting the wheel´. And also the poor management practice, bureaucratic inefficiencies and low productivity levels in many organizations of developing countries create considerable pressure for managers to adapt speedy, ready-to implement strategies. Hence, we can observe the need for companies in developing countries such as Ethiopia to adapt frameworks suitable to their needs and context taking into account, national issue, infrastructure and organizational culture. From the literature analysis, we derive the following conclusions:

Implementation a PMS in developing countries faces challenges due to the environmental factors and contexts which did not encountered into developed countries scenarios.

- Lack of expertise and practical research in the area of performance measurement systems in context of developing countries.
- Lack of infrastructure and resources constraints creates a different challenge for the existing PMS implementation.
- Lack of experience in the selection, evaluation of KPI and PMS.

IV. Research Methodology

The research methodology is based on empirical data collected through a survey with help of a questionnaire and unstructured interview questions. The objective of this survey is to examine the status performance measurement systems, performance measures, information and communication technologies, and barriers and challenges for modern performance measurement systems. The objective of the study is to make more familiar through a survey, and information is collected at one point in time. The methodology was based on a survey through a questionnaire and personal interviews. Final version of the questionnaire was sent to the 200 Ethiopian companies. 32 filled responses have been received, which gives a response rate of 17%.

a) Research Design

Both qualitative and quantitative methodology is essentially motivated by the need to gain an insight into the level of implementation and the challenges of successful the performance measurement in the Ethiopian manufacturing industry. The methods to collect data include literature review, semi-structured interview and questionnaire survey. A random sample 200 Ethiopian manufacturing was selected for the survey from the population of 1737 medium- and large-sized Ethiopian manufacturing companies. This contains name of the Organization, their location, main products, type of industry, and their postal addresses. Selection criterion was based on ownership structures: private & public sectors, producers for local and export markets, industry's sizes and industry groups. A random sample of 200 companies was drawn from the list of large and medium manufacturing industries. The manufacturing industry in developing countries is composed of many different sectors. In Ethiopian perspective, major manufacturing sectors are food, textile and garment, leather and leather products, beverages, chemicals, construction material and forest industries (Ethiopian Statistical authority, 2002). We have selected also 12 companies, which have volunteered for the close industrial case studies from the 200 manufacturing industries.

Figure 3 shows general research methodology for the paper. The industrial analysis and fieldwork were carried out in two stages. The first stage of the fieldwork was based on an exploratory questionnaire survey and was divided into two main parts. The first part was focused on issues related to the situations of performance measurement and type of performance measures used in Ethiopia. The second part focused on the barriers, challenges and enables for implementation of concept of performance measurement, which includes performance frameworks, performance measures/metrics and issues of application and adaptability of the SCOR model.

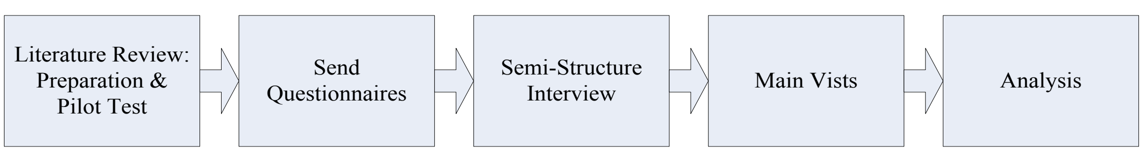

Figure 3 : Research Methodology Overview

The second stage was carried through semi-structured interviews with senior managers of Ethiopian manufacturing industries. The main objectives of the second stage were to ascertain the issues pertaining to practices of performance measurement and measures in the Ethiopian manufacturing industry and to investigate the main challenges and barriers associated with its implementation. A total of 12 top managers responsible for production operations and supply chain were interviewed. The interviewees were drawn from companies selected for questionnaire survey, which mainly respond to the survey questionnaires and three companies which did not respond to the survey questionnaires but prefer to participate in interview activities. The duration of the interviews varied from 90 to 120 minutes. The composition of samples for both the interviews and the questionnaires were selected from Ethiopian medium and large manufacturing industries. In both cases, the respondents were decided by top managers in command of operations and supply chain.

b) Survey Questionnaires and interview questions development

The survey questionnaires and interview questions was developed from critical review of the literature on performance measurement system, supply chain, SCOR model (SCC, 2010; Gosselin, 2005; & Hasan, 2008). The results of literature review were used for developing better questionnaires. This paper assessment is the part of the large empirical results. The questionnaire has been developed on a four-point Likert scale. Scale various issues of Supply Chain modeling, measurement and improvement have been incorporated relevant to Ethiopian context. The questionnaire contained 3 sections. Section 'A' contains two questions related to performance measures and measurement issues. Section 'B' contained questions related to status of information and communications technologies for information exchange and data collection such as the use of Enterprise Resource planning systems (ERP) system and Electronic data interchange (EDI) technique for data exchange. The third section 'C' contains question dealt with the main challenges and barriers for performance measures and performance measurement systems. The questionnaires was first pretested using two researchers from research institutes and two university instructors and then pretested using 10 industrial practitioners from five industrial organization from research population. Based on the feedback, revisions were required. Major adjustments were done on the number of questions per sections and scale used in the questionnaires. Furthermore, the reconstructions and minor re-wordings to questions were required to remove ambiguities and slight changes to the layout of the questionnaires to improve readability. Annexure was given in the end of the questionnaire, which contained key for the responses and explained in brief the terminology used in the questionnaire to avoid unknown bias.

On the other hand, the protocol of semi-structured interview questions was divided also into three sections. The first section was designed to collect information on the background and size of the respondent's organization. Section B: solicited information regarding the importance placed on different performance measures by Ethiopian manufacturing companies by asking them to indicate to what extent, they used performance measures. In the last section, Section C: participants were asked questions about their enables used such as organizations' information and communications technologies system and barriers and challenges existing for smooth implementation of these technologies. In particular, the respondents were requested to respond the type of a specialized software or system to support their PMS. We tried to interview persons rather high up in the company hierarchies that were involved in the strategic decision-making process, so that they could provide us with in-depth answers regarding how the company deals with performance measurement, and we were given the possibility to interview people who worked directly with matters related to performance measurement daily.

V. Results and Analysis

a) Survey Results

i. Response Rate

Two questionnaires mailed to the director of manufacturing were returned as a result of having incorrect addresses. A total of 42 responses was received, 36 of which were usable, giving a response rate of 16%. The sample population was fairly evenly distributed between that who was a producer for export market firms (30%) and those who were a producer for local market firms (70%). The respondents' participation as an exporter or local markets the firms provided an opportunity to examine whether world-class performance measurement systems are only prevalent in organizations. Non-response bias can result from a low response rate and/or missing responses affecting the conclusions about the variables being examined in the study.

ii. Respondent Organization Profiles

The respondents were spread over a range of industry groupings with the majority being, beverages, chemicals and food industries 22%, 19% and 19% respectively. The next largest industry was leather and leather products & building materials industries with 11.3% each, closely followed by metal and metal products industry (9%). On the other hand, p industries (3%), textile and apparel (3%) were in the tail end. Figure 6 shows, the detail respondent composition and their respective percentage share. The size of the companies varied greatly, from less than 50 to 2000 employees, with annual revenue varying just as much, between 5,000 and 50 billion US dollars.

iii. Performance Measurement Approach

One of the aims of this research was to determine what approaches to performance measurement are used by Ethiopian manufacturers. Table 1 show that twenty-five percent of the respondents use Balanced Scorecard method of measuring performance, with 21.9% of these also employing an activity based costing approach. 9.4% of the respondents use an integrated performance measurement system; 6.2% used ISO 9000 based performance measurement system. These other approaches were specified as being only 3.1% was economic value analysis. The other, 34.4% did not state what approach they used.

Based on the answers, it is possible to observe that the most common answer was that the company did not use any performance measurement system. The most commonly used approaches are the Balanced Scorecard in original versions and Activity Based Costing. The third most common used approach is the Integrated Performance Management System. No one company is responded about the SCOR model application in the survey.

iv. *Performance Measures*

When listing the performance measures to be rated on frequency of use were composed of fifteen performance measures. Respondents were asked to state the frequency of use of each measure using a likert scale from one to four, one being never and four being always used. The mean results from this section were then tabulated. The performance measures to rate were categories into three: financial, production, sales and customer satisfaction. The mean results from this section were then tabulated. Table 1 takes a preliminary look at the extent to which organizations used the fifteen selected performance measures. They are dominated by production measures and followed by financial measures.

Table 1 : Types of performance measures used in Practice

Rank	Performance Measure	Mean	Standard Deviation
1	Cost of goods sold	3.67	0.75
2	Gross profit margin	3.47	0.76
3	Number of units produced	3.37	0.91
4	Amount of finished goods inventory	3.33	0.98
5	Total sales revenue	3.27	1.06
6	Amount of material inventory	3.27	0.96
7	Rate of incidence of production defects	3.10	0.87
8	Number of customer orders completed	3.10	0.98
9	Order accuracy / fill-rate	2.80	0.98
10	In-stock rates / stock-outs	2.75	1.06
11	Number of worker injuries	2.67	0.94
12	Compliance	2.60	1.02
13	Damages	2.46	1.05
14	Backlog in the delivery schedule	2.41	1.16
15	On-time delivery	2.37	0.91

v. *Organization's Information and communication technologies*

The third part of the questionnaire's survey was designed to gather information about the companies' information and communication technologies (ICT) system. In particular, whether they use a specialized software or system such as an enterprise resource planning (ERP) system, methods of information exchange and/or specialized software or systems, it was also to determine how well their information & communication technologies system support different performance measurement. It was determined that 100 % of the respondents' do not have a specialized system. It was determined that 92% of the respondents' either do not, in fact, have an ERP system and uses for intended purposes. The supporting software/systems were, for the most part, of an in-house nature. E-mail is widely used information exchange tools extensively in foreign purchases. Table 2 shows the level of ICT implementation.

Table 2 : Level of information & communication technology implementation

Type of information and communication technologies	Level of Information communication technology implementation			
	Poor	Fair	Good	Excellent
Advanced planning and scheduling software	26%/8	26%/8	26%/8	23%/7
Automated material handling system (hardware)	16%/5	148%/5	23%/7	13%/4
Bar coding/automatic identification system	15%/4	46%/12	27%/7	12%/3
Electronic mail system	10%/3	65%/20	13%/4	13%/4
Electronic data interchange (EDI) capability	31%/10	34%/11	22%/7	13%/4
Enterprise Resource Planning systems (ERP) system	46%/13	46%/13	0%/0	7%/2
E-procurement system	83%/15	11%/2	6%/1	0%/0

vi. *Main challenge & barriers for new performance measurement approach*

Some of challenges & barriers highlighted by the research include:

- The excising model specificity to the developed countries operating environment;
- Quality of skilled and cost effective workforce;
- Lack of ICT infrastructure;
- Difficulty to implement the models & handle for practical operations;
- Non systematic approach to measuring customer requirements; and

- Management practices and organizational working culture. Table 3 shows the different challenges and barriers with their respective mean value and standard deviation.

Table 3 : Challenges & barriers of performance measurement system implementation

Rank	Challenges & barriers for performance measurement and supply chain	Mean	Standard Deviation
1	The excising model specificity to the developed countries operating environment	2.97	0.76
2	Quality of skilled and cost effective workforce	2.94	0.84
3	Lack of ICT infrastructure	2.93	0.78
4	Difficulty to implement the models & handle for practical operations	2.79	0.89
5	Non systematic approach to measuring customer requirements	2.78	0.74
6	Management practices and organizational working culture	2.77	0.91
7	Difficult to establish relationships based on shared risks & rewards	2.68	0.86
8	Lack of employee loyalty/motivation/empowerment	2.57	0.88
9	Lack of physical infrastructure	2.45	0.91
10	A lack of willingness to share needed information	2.45	0.91

b) Interview Results

i. Interviewed Companies

In-depth interview has been conducted in twelve manufacturing industries in Ethiopia. The organizations were systematically sampled from the initial list of survey respondents and volunteers who send feedback for the e-mail requests. The twelve organizations in this case study were selected because of their experience in export market and integration with global supply chains. The data collection was conducted via semi-structured interviews along with the industrial visit with top managers in the their respective organizations.

ii. Findings from the case studies

Based on the interview it was possible to analyze the current situation regrding to performance measurement systems and performance metrics used in manufacturing industries. The current stae within the defined areas are summarized in the following table 4. Table 4 shows the summary of the current state of performance measures, and measurement implemnetation.

Table 4 : Summary of the current state of performance measurement

Area	Current State
Performance measurement systems/approach/model	- Most performance measurement systems have adopted and copied by government initiatives, no initial investigation to adopt and copy about the approriateness at the company level, there were frequent changes after few challenges, to the new one, - The performance measurement efforts are limited to measuring production operations on the working floor, - The result of measurement are mostly used for control purpose and not actively used for improvement,
Key Performance Indicators (KPI)	- The key performance indicators are maily focusing on cost, finanace and efficiency of the production operations, and do not provide a comprehensive overview of all important areas of the company especially KPI related to customer services, - In most companies key performance indicators focus on productivity and cost, - Generally, most companies key performance indicators have not yet defined company wide perspectives and in relation with supplier and customers,
Enabling Technologies	- The performance measures data are to a large extent manually gathered, - E-mail and telephone are fequent used tools for information exchange within company and outside, - All companies did not have enterprise resorce planning (ERP) software. However, some companies have started some activities to develop local software that can be applicable in different departments,
Challenges & Barriers	- Lack of updated sales information from fragmanted customes like developed countries such as point of sales & operation information,

	- Wrong perception about performance measurement by employees that makes the companies to focus on financial measures, - No serious evaluation for adopting the different performance measurement models, no follow up and evaluation to find the reason for failure from practices and challenges for implementation.

VI. Discussion

This paper presents a survey that is part of a wider study aiming adapting a performance measurement system for developing countries scenario. The purpose of this study was to collect some empirical evidence on the level of performance measurement experience in manufacturing industries. The usable sample size in the research was small. The low response rate does not support statistical analysis nor can make any generalization of the findings, certain observations be made. The findings of this study with regard to performance measures used regularly by the Ethiopian manufacturing respondents contrast quite markedly in some aspects to those found by Gosselin and Hasan (Gosselin, 2005 & Hasan, 2008). Gosselin (2005) found that the ten most frequently used measures were dominated by financial measures. Whereas Hasan (2008) studies found that production measures are most regularly used by New Zealand manufacturers. However, Ethiopian manufacturing study got the mixture of uses both financial and production measures.

The reviewed literature has suggested that firms should put more emphasis on non-financial measures in comparison to financial measures in their performance measurement system. In addition, recently there has been a shift in the new development of performance measures to include supply chain performance measures too. However, the findings from the interviews and questionnaires show the level of performance measures not only focus on financial measures but also restricted to the organizational boundaries. Even the performance measures used inside the companies were the focus in departmental performance measures. We can observe from figure 4 the summary of the existing performance measures and industrial practices in three levels: strategic, tactical and operational performance measures. The existing performance measures still lack the recent influential measures in current businesses such as time, customer satisfaction, flexibility and reliability measures.

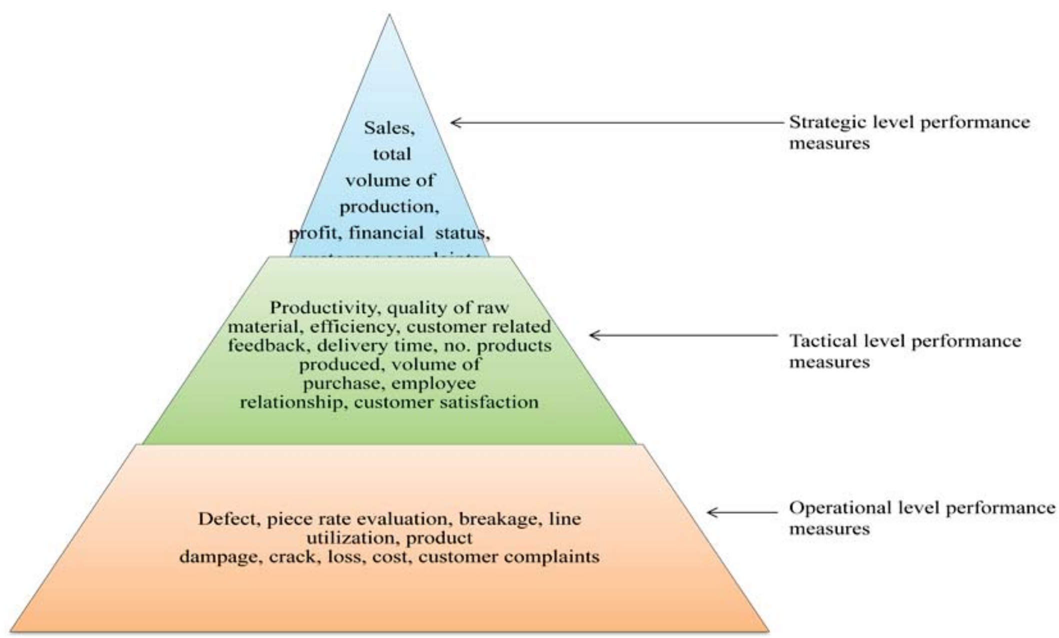

Figure 4 : Performance measures in three levels

The study also sought to find out what performance measurement approaches were commonly adopted by Ethiopian manufacturers. Over thirty percent of the manufacturing industries have not implemented any performance measurement systems. Next twenty-five and around twenty-two percent use contemporary systems, that is, the balanced scorecard and activity based costing. No clear trends were evident in the results though, as to whether these modern PM approaches used non-financial measures to a greater extent than financial. The Balanced Scorecard literature implies that if this system is implemented correctly, non-financial measures should be foremost. Results from this study showed little or no difference between approaches. Interestingly, no organization that completed the survey was planning on adopting a new performance approach in the foreseeable future. However, from case studies companies, only two out of twelve manufacturing industries have tried the balanced scorecard implementation. Eighty-four percent of the respondents were not implemented any performance measurement system. Table 5 shows the summary of the performance measurement system and performance measures characteristics found in the research.

Table 5 : Performance measurement characteristics

	Key Characteristics
PMS/Performance Measure	There are some PMSs have initiatives by the government to adopt the modern performance measurement system. However, they have started without careful selection and after some trial for implementation; they have stopped & just jumped to another new one. Example government initiation to implement like Integrated Performance Measurement Systems after some trial they have jumped to Balanced Scorecard.
	Less attention has given for time and customer satisfaction.
	Recently productivity and financial have gained more attention.
	Employees are fear of performance evaluation & feel insecure.
	Only functional based measures leads reinforced functional silos fostering arms-length transactions among departments.
	Manual data collection.
	Mangers think that it was additional challenge and work burden to implement the performance evaluation & keep records.
	People are not open to discuss each other and feedback directly about performance.

The other outcomes of the research were gathered data on the organization's information and communication technologies level. Most of the companies have practiced the manual type of data collection for the performance measures data. The PMS data collection was not supported by information and communication technologies; however, financial measures were collected with better accuracy ones. Financial data collection was well supported while operational performance data collection was poorly supported. These results indicate a deficiency in current information systems. Most of the communications within the companies were done through paper works. Some companies have started to use computer and internet facilities to supported information sharing inside the organization boundaries. The uses of the internet supported company-wide activities were rare. Most companies use the internet for international purchases and communication with foreign suppliers. Table 6 lists the major enable for communications and data collection.

Table 6 : Type of enablers for communication and information collection

Communication	Key characteristics
Enabling technologies	E-mail used mostly in communicating with foreign suppliers.
	Mail, fax, mobile & fixed phone for local connection widely used communication techniques.
	Face to Face (F2F) communication for local purchases.
	No Electronic Data exchange (EDI), No Internet based B2B tools
	No planning & scheduling software such as MRP I & II used however some companies planning Enterprise Resource Planning (ERP)
	Some local made functional based software used such as Inventory (Warehouse) Management, Budget & Finance management software,

VII. Conclusion

The manufacturing industry in developing countries performs supply chain functions in the upstream supply chain as the source of raw material, which has low barriers to entry, such as textile & garment, leather and leather products industries, food industries and other's basic commodities. However, recent advancements in manufacturing technologies and dynamic market competitiveness strategies, it is supply chains (SC) rather than companies that compete.

This new trend of competitiveness will be and has already affected developing countries at large. For the intended purpose of integration and collaboration, companies in the developing countries need to upgrade their manufacturing performance with the help of new manufacturing technologies such as supply chain and performance measurement systems. The manufacturing industry in the developing companies is less likely to have formal performance measurement system, and they are concerned, basically, with survival. The industries are fewer sophisticated companies, with little automation and few design/development capabilities.

It appears that Ethiopian manufacturers are not only aware of, but some industries have started to implement the modern performance measurement system. Furthermore, the respondents indicated that the financial measures are being used more frequently than the non financial measures. However, it is also important to note that irrespective of the type of performance measurement system approach adopted, the majority of the respondents' information systems are not giving good support to their performance measurement activities. It appears that the respondent's information systems are still very much attuned to the historical dominance of the financials. No companies have tried to implement the system such as an ERP; however, there was some initiation to build house-made local software for integration different functions of the department. World class performance measurement techniques are being used, and there are indications that financial as well as non-financial measures are being used.

There is an increasing awareness about the need to integrate and collaborate with world-class players and enhance performance through the use of supply chain concepts and performance measurement systems. Ethiopian manufacturing industries are increasingly attempting to improve the coordination and integration with their suppliers both within and outside the national boundaries, especially those who have already engaged in export activities with foreign companies. However, most measurement activities are influenced by improving the tangible factors which are easy to measure such as cost and productivity. Similarly, there is reluctance to adopt and adapt already tested and proved models for performance measures and improvement purpose. There is also a less an awareness and tendency to believe that key performance measures such as quality, delivery and lead time can be improved by selecting the suppliers and customers who possess significant technical experience and expertise. The existing performance measures should be tailored to include time, quality and other supply chain performance measures.

Although implementation of the performance measurement system has been highly recommended in literature for better integration and benefits from supply chain concepts, the majorities of organizations are not using this performance measurement innovative and is still lying on the traditional financial measures. The results show clearly that there is a need to better understand how an organization in the developing countries can adapt and implement performance measurement systems and how they can manage their supply chain to improve their competitiveness with better integration with their counterpart companies in developed countries.

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An Approach to Reduce Waste in Lead Acid Battery Industries

By Md. Jasim Uddin, Pritom Kumar Mondal, Md. Atiqur Rahman & Md. Hasibur Rahman Lemon
Khulna University of Engineering and Technolog, Bangladesh

Abstract - The following paper aims to inform the readers about various hazardous wastes like solid waste, liquid waste and air pollutant generated in lead acid battery industries, harmful effects of those wastes and necessary treatment needed to neutralize those hazardous wastes. Efficient methods of neutralizing those hazardous wastes to reduce the harmful effects on both human and nature are shown here. Considering ISO 14001:2004 some treatment plants like effluent treatment plant (ETP), air treatment plant (ATP), and Fume Neutralizer Plant are essential for neutralizing those hazardous wastes. The performance of those treatment plants are evaluated by checking out important parameters like PH, total dissolved solids (TDS), biological oxygen demand (BOD), chemical oxygen demand (COD), chlorides and other heavy metals. Here the limits of those parameters of effluent both before treatment and after treatment are shown and finally some recommendations about waste management are given in the conclusion section.

Keywords : lead acid battery, effluent treatment plant, biological oxygen demand, waste management.

GJRE-G Classification : FOR Code: 660401

AN APPROACH TO REDUCE WASTE IN LEAD ACID BATTERY INDUSTRIES

Strictly as per the compliance and regulations of :

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Keywords : lead acid battery, effluent treatment plant, biological oxygen demand, waste management.

I. Introduction

Battery industry represents an important and growing sector where the uses of toxic and hazardous materials are quite frequent. By visiting some renowned lead acid battery industries like Abdullah Battery Company Pvt. Ltd, Electro-battery industry and 'RAHIMAFROOZ' battery industry we have come to know that the substitutions of toxic and hazardous materials by non-toxic and non-hazardous materials are not totally developed yet. Lead is one of the vital ingredients of the lead acid batteries.

Global lead consumption was exceeded 10 million tons in 2011 and approximately 80% of the lead produced is used in manufacturing lead acid batteries [1] [2].

There is immense growth in the demand for the lead batteries. Lead poisoning is the most serious environmental health threat to children and one of the most significant contributions to occupational disease. Lead causes symptoms ranging from the loss of neurological function to death depending upon the extent and duration of exposure both children and adults can suffer from an illness including effects on central nerve system, kidneys , gastrointestinal tract and blood forming system. Lead also affects the reproductive system in both men and women [3]. The annual cost of lead poisoning in children in the U.S. alone is estimated to exceed $43.4 billion, worldwide estimates are not available, but would greatly exceed this figure, as exposures are known to be significantly higher in developing countries [4]. The average blood lead level among children residing near battery plants in developing countries is 13 times the average level observed for children in the United States and the average workers blood lead level in battery manufacturing plant in developing countries is over 4 times the level considered to be elevated by the U.S. CDC for the purpose of surveillance.

In production of lead acid battery huge amount of sulfuric acid (H2SO4) is used. It lowers the PH value of water when mixed up with water which raises the acidic property of water [5] [6]. If lead acid batteries are disposed of in a solid waste landfill or illegally dumped the lead and sulfuric acid can seep into the soil and sulfuric acid contaminated ground water, potentially affecting the quality of our drinking water supply.

Government has taken steps to ensure the proper management of this hazardous waste and safety of both human and environment because of so many disaster and environmental impacts in the last few years. Battery waste water is characterized by its PH, BOD, TDS, COD, Sulphate, Chlorine and heavy metals like Arsenic, Lead [7]. The levels of pollutants in lead acid battery wastewater also vary depending upon the process adopted in battery manufacturing. Liquid wastes are neutralized by proper ETP system, the pollutants of the air are removed by ATP and solid wastes are reused in production process by recycling [8]. The purpose of this waste management is not only to keep the environment sound but also to make the production process economical.

II. Methodology

After visiting some renowned battery industry then their existing waste management system was studied by discussing with concern personal. From battery waste management literature and consulting with industry waste concern person and discussing with some chemist some proposed ETP, ATP, fume neutralizer plant and recycling plant was developed.

Author α σ : Undergraduate student, Department of Industrial Engineering & Management (IEM), Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh.
E-mails : jasim.ipe@gmail.com, pritom.ipe08@gmail.com
Author ρ ω : Undergraduate student, Department of Civil Engineering (CE), Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh. E-mails : atique_ce2k8@yahoo.com lemon_rlnd@yahoo.com

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Here methodology includes the treatment of liquid waste, air pollutant and solid waste. The treatments are possible by the proper functioning of ETP, ATP, Fume Neutralizer Plant and recycling plant. The performance of those treatment plant were judged by differentiating the values of different parameters like PH, BOD, TDS, COD, TSS, Chloride and Sulphate before treatment and after treatment. The samples were collected at inlet and outlet of the effluent treatment plant units and analyzed as per Standard Methods for the Examination of Wastewater. The samples were analyzed for various parameters like p^H, BOD, COD, TSS, and TDS.

a) Effluent Treatment Plant

ETP has designed to provide chemical processes and these processes are needed to balance the PH level of waste water. Separation of oil from wastewater to purify it is also another purpose of ETP. Lead acid batteries are obtained through the chemical processes by using Lead, PbO, sulfuric acid and other chemical substances. The unwanted residue obtained at the time of preparation of acid forming, jar forming and other processes which contribute to major amount of COD, TDS, TSS and leady effluent and other heavy metals. Here the designed ETP consists of all component units such as oil separation tank, neutralizing tank, Alum dozing tank, NaOH dozing tank, one step purifier, Sedimentation tank, pure water tank, PH and TDS test units etc. A Schematic block diagram of the treatment plant is shown in the Fig.1.

At first effluent is taken to the oil separation tank where oily substances are separated from the waste water which can also be called heavy water. Then it is taken to the heavy water tank through a pipeline. Then heavy water is taken to the neutralizing tank where Alum and NaOH are dozed from alum dozing tank and NaOH dozing tank respectively to balance the PH level. Then PH is used to test the PH level of the water in the neutralizing tank. The activities in the neutralizing tank will be repeated until the PH level reaches to the acceptable limit. When the PH level is okay then TDS test will be conducted. If the result of the TDS is not satisfactory then that water will be experienced a chemical process called Ion Exchange where colloidal particles will become sediment. Then the water will be filtered. Now again TDS test will be conducted. If this time result is okay then the water will be sent to the one step purifier. If the value of TDS is inacceptable limit in the very first time it will be then directly sent to the one step purifier without conducting the process of Ion Exchange. In one step purifier light particles are separated from the water. Then it will be sent to the sedimentation tank for the final separation of the sludge. Then it will be sent to the pure water tank and this water can be reused in production process or it can be allowed to go the environment.

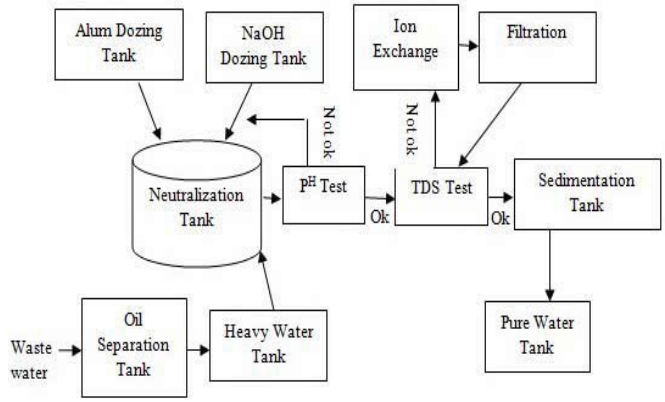

Figure 1 : Schematic block diagram of ETP

We have made estimation about the size and capacity of different units of our designed ETP. The estimation is made by considering that the monthly production is 50000 batteries. The size and capacity can be varied with the frequency of the production.

Table 1 : Size and capacity of different units of ETP

SN.	Unit	Sizes	Capacity (Approximate)
1	Oil Separation Tank	2.5m*2.0m*3.0m=15.0m^3	15000 liter
2	Heavy Water Tank	2.0m*1.8m*2.8m=10.08m^3	10000 liter
3	Neutralizing Tank	1.5m(Diameter)*3m(Height)=5.3m^3	5000 liter
4	Alum Dozing Tank	1.5m*1.0m*2.5m=3.75m^3	3700 liter
5	NaOH Dozing Tank	1.5m*1.0m*2.5m=3.75m^3	3700 liter
6	Rotary Vacuum Filter	Cloth having 10 μ, vacuum create at 500 to 600 mmHg	5 RPM, 75Kg/hr Sludge removal
7	Sedimentation Tank	2.3m*2.2m*2.5m=12.65m^3	12500 liter
8	Pure Water Tank	2.0m*1.5m*2.5m=7.5m^3	7400 liter
9	Sludge drying bed	2.0m*1.75m*2.0m=7.0m^3	7000 kg

b) Air Treatment Plant

There are many air emission technologies like Electrostatic Precipitators, Fabric Filters or Bughouse and Wet Scrubbers. These technologies are commonly installed to reduce the concentration of substances in process off-gas before stack emission. In the case of lead acid battery industries the Bughouse technology is the best suited and economical dust collection process. Bughouse technology has 90% efficiency to separate air pollutant like acid mist, leady fumes and particulate matters. In the case of lead acid battery lead is the most devastating air pollutant.

Our designed ATP is based on Bughouse technology. It consists of rotary unit, separation house, U-shaped condenser chamber, one cone chamber, two cone chamber, bughouse and chimney. The schematic block diagram of our designed ATP is shown in Fig.2.

At first exhaust gas is sucked by a rotary unit and then the gas is forced to strike with the wall of the house where heavy particles like lead will be fallen down. Then the gas will pass the condenser chamber. The condenser chamber consists of four U-shaped condensers where the gas will be condensed to remove the particles. Then the gas will be moved towards the one cone chamber. In one cone chamber, the gas will be circulated and moved downward rapidly and at the bottom, it will face an obstacle. Then the gas will move upward and heavy will be separated because of upward movement. Now the gas will move towards to the two cone chamber and will be divided into two groups for more perfect separation of heavy air pollutant. Then the gas will be sucked by the bughouse for the final separation of the dust from the gas and after this pollutant will be removed. Then the gas will be allowed to go to the atmosphere. This process is very much economical because here huge amount of lead will be recovered in different stages of the process.

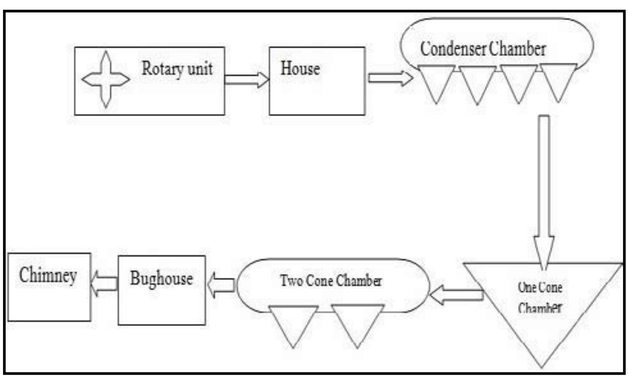

Figure 2 : Schematic block diagram of ETP

c) Fume Neutralizer Plant

Fume neutralizer plant is designed for the treatment of fume to neutralize acidic gasses. In ATP heavy particles like Lead, particulate matter etc. is separated from the fume. In lead acid battery industries huge amount of sulfuric acid (H_2SO_4) is used in electrolysis process. Because of the electrolysis process some acidic gasses like SO_2, SO_3 etc. are generated which increase the acidic property of the air. The increasing acidic property of the air is very much harmful for the environment. So it is very much essential to neutralize the acidic property of the air.

Our designed fume neutralizer tank consists of blower, neutralizing tank, NaOH dozing tank and exhaust chimney. The schematic block diagram of the designed fume neutralizer tank is shown in Fig.3.Fume is sucked by a blower and then forced to go to the neutralizing tank where NaOH is dozed. In neutralizing tank a chemical reaction is taken place between NaOH and acidic gasses. By the chemical reaction the acidic property of the fume will be neutralized. Then the fume will leave the plant and go to the environment through the exhaust chimney.

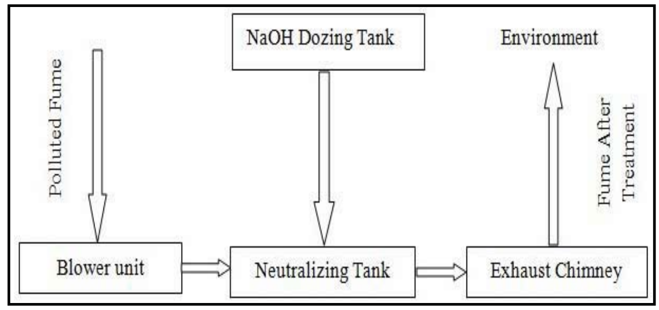

Figure 3 : Block Diagram of Fume Neutralizer Plant

d) Hazardous and Solid waste management

Solid waste, also known as dry refuse and is practically in dry state. Disposal of refuse is depending upon frequency of generation and production of products. Plastic scrape, leady paste, lead oxide paste and glass mats are treated as hazardous waste. Leady paste generated from ETP and dry lead from ATP which are sent for recycling of lead and it has not any direct ill effect to worker. Lead oxide paste from processing reused itself in process. The discarded plastic scrapes are mostly sent it for recycling. Recycling is the recovery of material from waste created in manufacturing and consumption, for reuse in the production of new items [9]. Recycling is very much essential because with the help of recycling we will be able not only to remove reusable materials from the waste which will reduce the environmental pollution due to solid waste but also to utilize recoverable materials as a production input which will help to conserve both nonrenewable resources and energy. Our proposed overall recycling system is divided in to two segments. In-plant recycling and recycling or secondary material industry are these two segments.

In the case of In-plant recycling strategy it is possible at several stages of production to recycle certain materials within the same manufacturing facility. When in-plant recycling is not feasible, it may be possible to recover certain materials from waste by secondary material or recycling industry. Overall view of the total recycling system is shown in Fig.4.

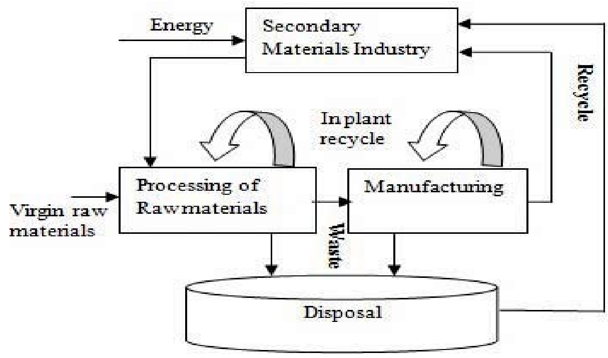

Figure 4 : Overall view of the total recycling system

Here we can see that solid wastes are disposed in the time of processing of raw materials and manufacturing. In-plant recycling is only feasible in the case of processing of raw material and production of final process. If in-plant recycling is not possible then secondary material industry is needed. Then the disposal from different areas like raw material processing area, manufacturing area are collected and sent to the secondary material industry for recycling. Waste can be directly sent to the secondary material processing industry from the manufacturing area. After recycling of the solid waste in secondary recycling industry, we can get our production input. Then these production input will be sent to the raw material processing zone and after processing which will be used in production of the final goods.

III. Result & Discussion

The analysis of wastewater is usually being carried out for pH, COD, BOD, TDS, TSS, Chlorides, Sulphates. The results of treatment for major pollutants in treated and untreated water with respect to each treatment operations are discussed below. The effluent parameters were continuously checked in few lead acid battery industries to know the range of the values of those parameters for obtaining better quality effluent that has to reach the effluent standard limits as prescribed by MPCB. Considering the range of the values of different parameters, the designed ETP will be able to keep the parameters in the standard limit. Daily checking is needed for pH, TDS, TSS, lead for the safety and unit process requirement point of view. Effluent samples were collected from several lead acid battery industries. In laboratory these samples were used to conduct some chemical operations which are specified in the above designed ETP to ensure that whether the ETP is working soundly or not. The average pH ranges for influent waste was 2 to 3 which showed the acidic nature and after the designed treatment it was neutralized. In wastewater, dissolved solids consists mostly of inorganic salts such as, chlorides, sulphates, lead, arsenic etc., and a small amount of organic matter and dissolved gases. The industrial wastewater contains large amount of chlorides, which can cause significant disruption in the ecological balance. Many techniques have been adopted in order to reduce the amount of chlorides in wastewater like demineralization, reverse osmosis, coagulation, precipitation, electro dialysis and so on. In this study, the variations in pH due to acidic waste which generated from jar formation and acid dilution plant had highly acidic in nature. The value of total dissolved solids (TDS) in the wastewater was very high and after lime treatment TDS was standardized. By analyzing the value of TDS in few industries, it was noticed that it ranges from 2800 to 3100 mg/l which had been reduced to 2100 to 2200 mg/l. Wastewater contains considerably high COD due to presence of some organic and inorganic materials. Before treatment, COD had a value ranges from 900 to 1000 mg/l which had also been reduced to acceptable limits 250 to 300 mg/l after designed treatment. Graph shows variation in daily influent and effluent wastewater. Daily fluctuation presented in graph those are given below in Figure no. 5.,6,7,8. Fig.5 shows variation in p^H value against days the variations ranges 2 to 3 and 7 to 8. Before treatment P^H had a low value that means the wastewater was acidic and after treatment it had been seen that P^H value had increased and the acidic property had also been neutralized.

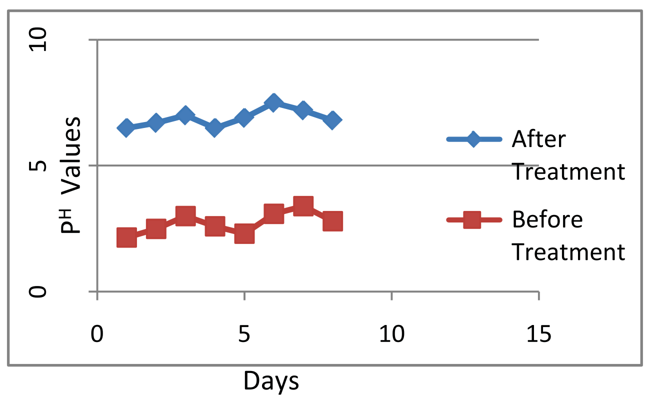

Figure 5 : Variation in pH value against days

Fig.6 shows variation in TDS values against days, the variations in influent TDS due to presence of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular in suspended form. Here it is seen that the value of TDS before treatment was 2800 to 3100 mg\l and after treatment it had been reduced to 2100 to 2200 mg\l.

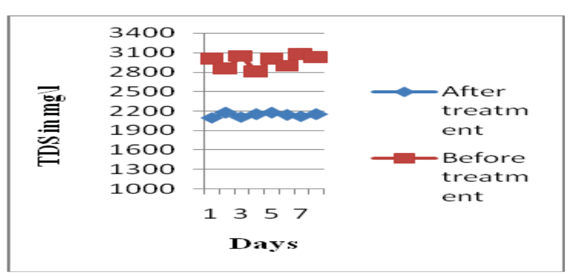

Figure 6 : Variation in TDS values against days

Fig.7 shows variation in COD values against days, the variations in influent COD due to presence of chlorides, sulphates, heavy metals and other chemicals. Before treatment COD was 900 to1000 mg\l and after treatment it had become 250 to 300 mg\l.

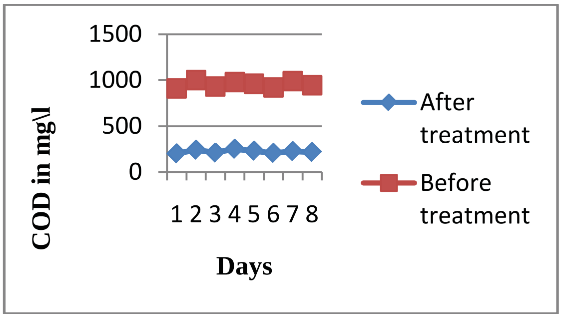

Figure 7 : Variation in COD values against days

Fig. 8 Shows variation in BOD values against days. Before Treatment BOD was 350 to 450 mg\l and after treatment it had been reduced to 50 to 100 mg\l.

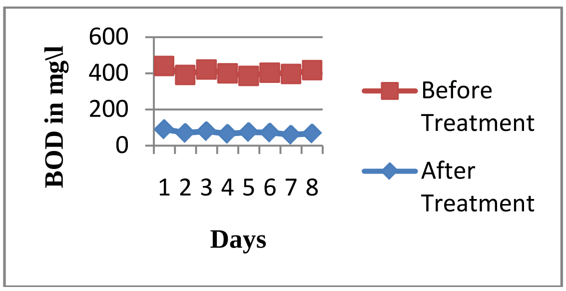

Figure 8 : Variation in BOD values against days

In lead acid battery production, huge amount of lead is needed and a portion of that lead is wasted and mixed with the fume. So it causes air pollution and presence of lead in air is very harmful especially for children. So, an ATP has been designed which has 90% efficiency to reduce the amount of lead in fume. Electrolysis process is needed to be conducted to produce battery. Which causes the generation of acidic gasses and that is very much harmful not only for human but also for environment. Those acidic gasses can be neutralized in fume neutralizer plant by chemically reacting with NaOH. Solid wastes or hazardous wastes are very much frequent in production processes and have a great impact on the atmosphere. Solid waste can be reused by recycling. Plastic scrape, leady paste, lead oxide paste and glass materials are the most common solid waste produced in lead acid battery industry. All these solid wastes can be recycled either by in-plant recycling or by secondary material industry.

IV. Conclusions

The study indicates that all major pollutants including heavy metals will be drastically reduced in the wastewater during the treatment process. The pH, BOD, COD, TSS and TDS of raw influents are generally recorded to pH 2.5, BOD 370 mg/L, COD 950 mg/L, TDS 3100mg/L and TSS 275 mg/L, while the mean values of the same parameters in the treated effluent estimated will be 7.6, 74.6 mg/L, 182 mg/L, 90 mg/L and 1945 mg/L. Generally the ratio of COD and BOD in the raw effluent is found 2.60, which will be significantly reduced to 2.3.The treated effluent results showing that all the inorganic matters will be removed significantly. If all the treatment units run successfully then waste disposal system will be appropriate. It will then not only help to keep the environment green but also help the industry economically by reducing waste and recycling it to make raw materials.

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Reduction of Bullwhip Effect in Auto Assembly Industry

By A.S.M. Tanvir Hasan, Muhammed Ridwanul Hoque, Nujhat Kawsari & Tomal Das
University of Engineering & Technology

Abstract - The main focal point of this study is to categories the reasons of Bullwhip Effect by fishbone diagram and tries to reduce bullwhip phenomenon. Three steps are followed here to resolve bullwhip effect. First, identify the causes. Fishbone diagram helps to classify the core reasons of it. The second part is to analyze the causes and discuss the effect of these causes and try to recommend some probable solutions. The third and last part is to observe the practical situation of bullwhip effect. Here, a case study is to be studied and apply the following solution of this supply chain system and observe how these solutions resolve the bullwhip phenomenon.

Keywords : *supply chain, bullwhip effect, fishbone diagram.*

GJRE-G Classification : *FOR Code: 910205*

REDUCTION OF BULLWHIP EFFECT IN AUTO ASSEMBLY INDUSTRY

Strictly as per the compliance and regulations of :

Reduction of Bullwhip Effect in Auto Assembly Industry

A.S.M. Tanvir Hasan [α], Muhammed Ridwanul Hoque [σ], Nujhat Kawsari [ρ] & Tomal Das [ω]

Abstract - The main focal point of this study is to categories the reasons of Bullwhip Effect by fishbone diagram and tries to reduce bullwhip phenomenon. Three steps are followed here to resolve bullwhip effect. First, identify the causes. Fishbone diagram helps to classify the core reasons of it. The second part is to analyze the causes and discuss the effect of these causes and try to recommend some probable solutions. The third and last part is to observe the practical situation of bullwhip effect. Here, a case study is to be studied and apply the following solution of this supply chain system and observe how these solutions resolve the bullwhip phenomenon.

Keywords : supply chain, bullwhip effect, fishbone diagram.

I. Introduction

A Supply Chain (SC) includes all the participants and processes involved in the satisfaction of customer demand: transportation, storages, retailers, wholesalers, distributors and factories. A large number of participants, a variety of relations and processes, dynamics, the uncertainty and stochastic in material and information flow, and numerous managerial positions prove that Supply Chains should be considered as a complex system in which coordination is one of the key elements of management.

An important observation in supply chain management was made by Forrester (1961), who illustrated the effect of the variance amplification, called the bullwhip effect, in a series of case studies. The bullwhip effect is a tendency for small changes in end-consumer demand to be amplified as one move further up the supply chain. Common practical effects of this variance amplification were described in cases of companies Procter & Gamble and Hewlett-Packard, and are presented to students worldwide through the business game “Beer Game” developed on MIT (Sterman, 1989).

Logistics executives at Procter & Gamble (P&G) examined the order patterns for one of their best-selling products, Pampers. Its sales at retail stores were fluctuating, but the variability was certainly not excessive. However, as they examined the distributors' orders, the executives were surprised by the degree of variability. When they looked at P&G's orders of Materials to their suppliers, such as 3M, they discovered that the swings were even greater. At first glance, the variability did not make sense. While the consumers, in this case, the babies, consumed diapers at a steady rate, the demand order variability in the supply chain were amplified as they moved up the supply chain. P&G called this phenomenon the "bullwhip" effect.

When Hewlett-Packard (HP) executives examined the sales of one of its printers at a major reseller, they found that there were, as expected, some fluctuations over time. However, when they examined the orders from the reseller, they observed much bigger swings. Also, to their surprise, they discovered that the orders from the printer division to the company's integrated circuit division had even greater fluctuations.

II. Supply Chain

Supply chain refers to the chain of supply of goods from manufacturer to the customer. It consists of two individual and complete words namely- supply & chain. Supply stands for providing or to furnish something of need. According to the dictionary a chain means a series of connected units of metal which are used to make a link. Generally it refers to something that helps to create a link between two or more things. Hence the meaning of supply chain may be expressed by the phrase-An interlinked process of system to provide the customers with the required goods or service.

It is clear that supply chain includes every single point that complete the chain of supply such as supplier, manufacturer, distributor, retailer, customer etc. The supply chain of a company is called successful when the flow of material from one point to another is possible at an optimum cost as well as the final product is at customers' hand at the right time.

This may seem to be contradictory at some extent. Providing service to the customer requires a good level of inventory and a shorter lead time. On the other hand if the inventory gets higher, the cost increases. The combination of these two is necessary to make a supply chain a success. For example Rahim Afrooz sells generators. Even if all know that transportation needs a certain lead time customers are not willing to wait that long. They want the service just in time. This is why the company has to maintain a minimum level of inventory depending upon their demand forecast. They are to choose what kind of

Author α σ ρ ω : Undergraduate student, Department of Industrial Engineering & Management (IEM), Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh.
E-mails : neeltoha@gmail.com, ridwan.hoque.ipe08@gmail.com, nujhat_sadmani@yahoo.com, tomal_das@live.com

transportation is to be taken for the process. Air is such a medium that takes a little time at a relatively high price. On the contrary water-ship is not costly but takes more time to deliver product.

A very poor result can happen to a certain supply chain if it is attacked by the bullwhip effect. There are some reasons behind this vital effect. Whatever the causes are, they are not unsolvable. Proper coordination is a must to solve the problems. Only a successful supply chain can lead a business towards prosperity.

III. The Bullwhip Effect

In Supply Chain, Bullwhip is an important term. Actually it is a phenomenon. The Bullwhip Effect is one of the main reasons for the inefficiencies of Supply Chain. Mainly this phenomenon is created for lacking of coordination and passing necessary information. Bullwhip Effect causes the fluctuation of demand variable and this effect the overall Supply Chain very much. Customer, Retailer, Wholesaler and Manufacturer are much related to the affect of Bullwhip effect. But increasing and decreasing demand is highly responsible for bullwhip effect. But some causes can be identified.

1. Over reaction of the backlog orders.
2. Communication gap between the partners.
3. Lead time and delay times between order processing, demand, and receipt of products.
4. Order batching: technique for decreasing ordering costs due to price discounts for bulk ordering, shipping cost decrease by ordering full-truck loads, etc.
5. Limited order size.
6. Error in demand forecasting.

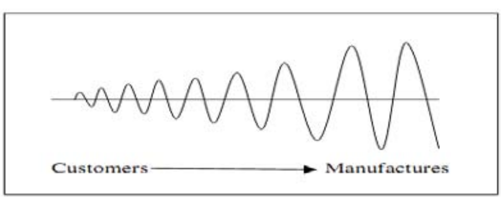

Figure 1 : Bullwhip Effect

For any company it is very necessary to manage the supply chain. The whole profit depends on it. So the symptom should be known. They are:

1. Huge inventory
2. Error or poor forecasting
3. Capacities(excessive or insufficient)
4. Unavailable products
5. Information gap

IV. Causes of the Bullwhip Effect

Normally several causes are responsible for Bullwhip Effect in supply chain [2]. They are:

1. Demand forecast updating
2. Order batching
3. Price fluctuation
4. Rationing and shortage gaming

Fishbone diagram help us to detect these causes.

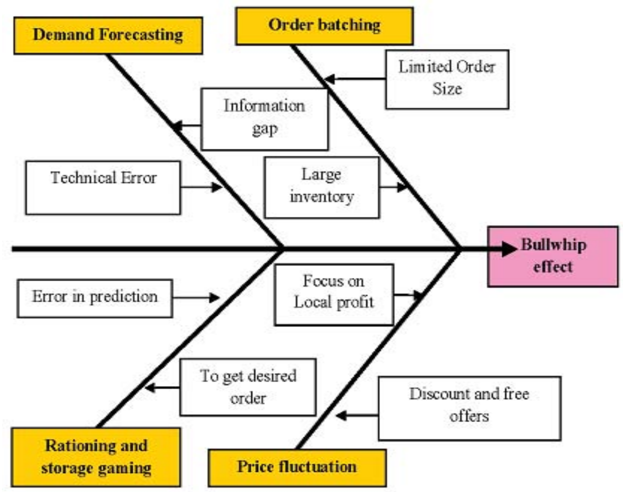

Figure 2 : Fishbone Diagram

a) Demand Forecast Updating

Demand forecast generally are based on the orders of the previous echelon. But it is not based on the actual customer demand. Actually this is future plan of the demand that is to be forecasted by the manager [1]. But forecast error is a common thing, so information gap is created between the partners. So it is very tough to match the real situation and the forecasted result. That creates the bullwhip in the chain.

For example, if a manager uses, say, exponential smoothing (future forecast is always updated as demand increases) the order sent to the supplier reflects the amount needed to replenish the stocks to meet the requirements for future demands and safety stocks which might be considered necessary [2].

b) Order Batching

"Cost is to be minimized", that is the main them of any company. So to reduce the fixed cost and setup cost, order batching is performed. Normally company wants to order in batches, so that the transportation cost will be minimized. To make more benefit influences a company for order batching. But Bullwhip effect is created when the forecast and order are not matched. For Example, Consider a periodic review stationary demand system with full backlogging at a retailer. The retailer would thus use an order up to level to monitor its inventory. This implies that he would order an amount equal to the preview cycle's demand in every review cycle [3].

Order batching can be defined in sentence, which is "When the cost (fixed) is not zero, the ordering is uneconomical, but order batching is occurred."

c) Price Fluctuation

Price fluctuation is another major cause of creating this bullwhip phenomenon. Normally more than 80% dealings between manufactures and distributors of an industry follow an arrangement that is known as "forward by" arrangement. That is happen but the attractive price offer by the manufacturer. Forward buying is one of the main causes of price fluctuation. Different types of offers like discounts, quantity discounts, free offers rebates and coupons are normally given by the manufacturers and distributors. These causes enhance the price fluctuation very much.[1]

d) Rationing & Shortage Gaming

Rationing and shortage gaming is another common reason for bullwhip effect. Most of the demands are placed on the basis of forecasting or sometimes on prediction. Sometimes demands are many but the supply are not enough. In this case, the products are ordered more than its demand, so that the number of delivered products generally is the percentage of the number of products actually needed [4].

For example, a retailer actually needs 75 units, but he orders 100 units in the hope of getting 75 units. The main output of this rationing scheme is to make a situation that the demand is raising but actually that is totally artificial [5]. A retailer ordering based on what it expect to sell gets less and as a result loses sales, whereas a retailer that influences its order is rewarded.

e) Competitor

Competition is another backbone for creating bullwhip effect in supply chain. Every super market is competitor to the others. So they offer many services to their customers. Sometimes they offer discounts on many products or group of products. That is why bullwhip effect is enhanced.

f) Inventory

Inventory is also a responsible basis of bullwhip effect. For example, many companies make large stock of mango in its season. But their motive is to sell these mangos in offseason. That is why demand of the mango is increased and last of all; bullwhip effect is created in the whole supply chain.

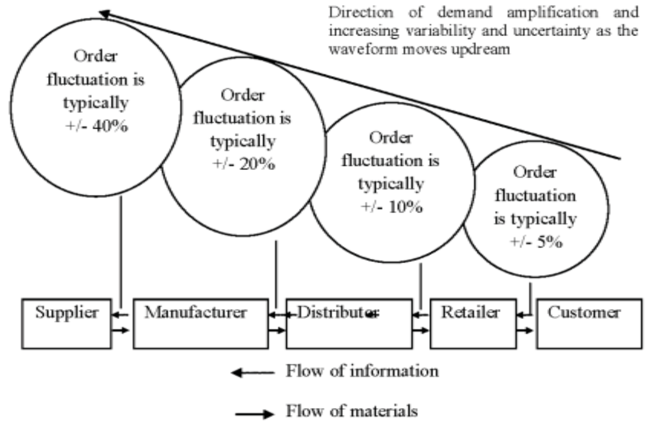

Figure 3 : Typical Upward order fluctuation

V. Real Scenario Of Bullwhip Effect (Case Study-Swaraj Mazda Limited)

Swaraj Mazda limited (SML) is a light commercial vehicle (LCV) manufacturing Company situated in Punjab. The information has taken the form of supply chain in SML as shown in (Figure 4). This inbound supply chain starts with 1st tier suppliers consisting of foreign suppliers and local suppliers. Since SML imports a variety of engine components: Information is collected from the customer directly. Internet can be used for that purpose. Customer will give the order on website to the dealer on which the company will have the direct right to access.

Company production	40 vehicles a day
Models offered	10 models with 79 variants
Manufacturing sequence	Based upon demand (flexible manufacturing)
Number of zonal office	10
Number of Dealers	130
Demand variation	Customer demand is assumed to be normally distribute.
Backordering	Backordering is allowed but returns to the factory are not allowed.
Transport lead time	2-3 days (depending upon the location of zonal office/dealers.

Table 1 : Information of SML

In complete-knocked-down condition (CKD), therefore they constitute 1st tier suppliers. These components in raw material form or sub-assemblies reach the factory stores for assembly. After manufacturing/assembly the finished vehicles reach the factory stockyard for dispatches to zonal offices then zonal offices send the vehicles to the dealers. Customers place the orders and get the delivery from the dealers only and not from the zonal offices or the company directly. The whole supply chain involves the flow of goods, cash and information and some time reverse logistics also in the form of returned defected and damaged vehicles.

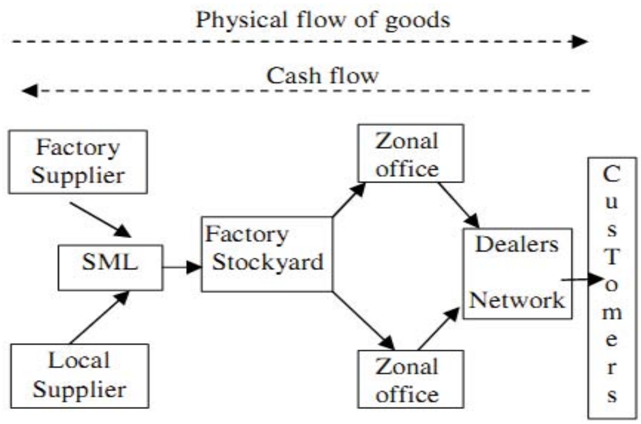

Figure 4 : Supply chain model of SML

VI. Quantifying the Bullwhip Effect in SML

As shown in Figure 1, the outbound supply chain in SML extends from the factory to the zonal offices and from zonal offices to the dealers and then ultimate customers. Dealers collect orders from the customers and send to the zonal offices (ZO). ZOs after consolidating the orders send them to the factory for replenishment. Since, ZOs do not have any access to the customers' demand data. Therefore the demand of ZOs for LCVs is forecasted on the basis of the demand of dealers generated from the customers. The variability in orders placed by the dealers is bound to be significantly higher than the variability in customers' demand. The ZOs are forced to carry more inventories of finished vehicles than the dealers in order to meet the same service level as the retailer. This demand variability or bullwhip effect is more serious in large ZOs in south and Madhya Pradesh. This results in ineffective transportation, more carrying cost, more ordering cost and more manpower. Similarly company has to keep an extra inventory of raw materials, sub-optimal space

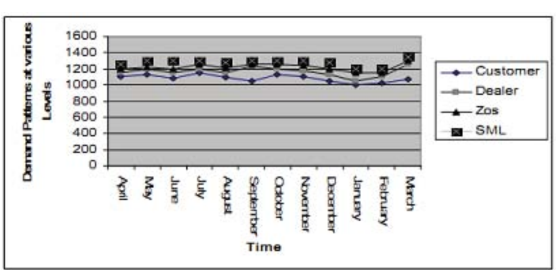

Figure 5 : Demand pattern of different stages

Since the cost per vehicle runs in lacs of rupees, therefore, this phenomenon is bound to create a serious resource crunch in the company. Table 2 shows demand orders at various levels. Each time when the demand flows up in the supply chain, additional orders take place. During the year 2005-06, the cumulative figure from customer demand to the SML demand to suppliers comes to a staggering figure of 2185 finished vehicles. These vehicles remain hidden at SML factory-stock-yard (FSY), 10 zonal offices and 130 dealer points. If we quantify this figure into rupee value (An average of Rs 5 lacs), the total Bullwhip cost amounts to Rs 109.25 cr.

1	2	3	4	5	6
2005-06	Customers	Dealers	ZOs	SML	Dev.(2-5)
April	1100	1150	1200	1250	150
May	1130	1200	1225	1300	170
June	1080	1150	1200	1300	120
July	1150	1200	1250	1300	150
August	1090	1150	1210	1280	190
September	1050	1230	1250	1300	150
October	1130	1200	1250	1300	170
November	1100	1175	1240	1300	200
December	1050	1125	1200	1280	230
January	1000	1050	1150	1200	200
February	1020	1100	1150	1200	180
March	1075	1280	1300	1350	275
Total	12975	13980	14625	15360	2185
% increase	100	107.75	112.72	118.38	16.64

Table 2 : Orders of different stages

The total customer orders were 12975 during the year, but dealers demand stood at 13980 with an increase of 7.75%. Similarly zonal offices also inflated their demand to 14625, an increase of 12.71%. Finally SML's orders to supplies were 15360 with 18.38% increase. As a whole the total demand inflation by SML over the customer demand was 16.84% Figure 4 shows the graphical view of it. The line inflates each time when the demand travels up in supply chain.

VII. Coordination on Performance in SML

SML experienced complete lack of coordination, since each stage in the supply chain wanted to optimize its local objectives without considering the impact on the complete supply chain. It hurt the performance of the entire supply chain and ultimately the total supply chain profits were less than what could be achieved through coordination. SML receives demand information even during periods of time in which the dealer does not order. Therefore SML is suffering from 'Extended Bullwhip Effect'. The following bullwhip ill effects were seen.

Performance Mreasure	Impact of Bullwhip Effect
Supply chain delevery reliability	
Delevery Performance	Decreased
Fill Rates	Decreased
Order fulfillment	Decreased
Supply chain Responsiveness	
Order fulfillment lead time	Increased
Supply chain flexiability	
Supply chain Response time	Increased
Product flexiability	Decreased
Supply chain costs, and	
Cost of goods sold	Increased
Total supply chain costs	Increased
Management costs	Increased
Value-added Productivity	Decreased
Returns Processing Costs	Increased
Supply chain asset management efficiency	
Cash-to-cash Cycle Time	Increased
Inventoy Days of Supply	Increased

Table 3 : Impact of Bullwhip

VIII. Reduction of Bullwhip Effect

We can try to give many ways to solve the bullwhip effect. Here SML can be a nice way to solve that example that we have mentioned previously. SML witnessed following main obstacles to coordination in the supply chain [6]:

1. Lack of information
2. Forecasting based on orders and not on customer demand and
3. Push based production system

The following damage control measures have been adopted:

a) *Share the Information*

SML and its supply chain partners are in progress to use CPFR (collaborative planning, forecasting and replenishment) for information sharing and coordination. Now internet is the main way to place order. At the time for forwarding the demand to the zonal offices, the dealers also take help from internet. Here 54.63 days and 437 man hours are saved. (2185/40)= 54.63 days and 54.63x8= 437 man hours)

b) *Push pull system*

Push-pull production system can be very effective. The material is being pushed through assembly, but the whole vehicle is pulled through actual orders. Mainly this is monitored by forecasting. The pull-through replenishes what is being sold from the stockyard. The production and distribution depend on the demand. For this reason they are highly related with the customer demand than forecast demand. The main strategy in SML is to avoid obstacle of large fixed and working capital in finished vehicles. SML tries to fill the order after receiving order from zonal office. Now SML has stopped inflating the demand from zonal offices.

c) *Demand generation module*

Here the zonal office places their order with the factory by internet. Demand is submitted separately fro each model. First adjustment is needed the order fulfilled in the past one week. Usually a distributed order is produced, which is a consolidation of all the orders received during the past one week. This order generated ultimately determines the dispatch from the factory and the sales in the coming week. Depending on the backorders, customers, the required buffer stock, and the available stock, the order communicates with the factory.

Order from Zonal office = Dealer/Customer order + Backorders + Required buffer Stock - Available Stock

d) *Allocation Module*

In this module, allocation of vehicles to the dealer is made according with the. After the day's production run, allocation is done. For each model, the stock has to perfect for meeting the demand fully. Available stocks are delivered for the lacking of actual stocks. Demand and supply for each model is measured independently. And shortfall in the supply of one model is not made up by extra supply in any other model. The allocated stocks are supplied to their destination.

e) *Inventory Placement*

The company maintains 10 zonal offices throughout the country; the main purpose is to reduce delivery times to its customers. A higher than expected demand from one zone /region can be offset by a lower than expected demand from another. 'Forward placement approach' is followed by the company, which means locating stock closer to customers at a zonal office and dealer's stockyard (Figure 4). Forward placement has an advantage of faster delivery times in the order fulfillment process; consequently service to the customer is quicker [6].

f) *Distribution Module*

Factory Stockyard (FSY): In the company, FSY is located itself and wholly owned by SML. All the vehicles are directly dispatched to the FSY and this is happened after assembly. The advantage comes from "inventory pooling", which helps to make reduction in inventory and safety stock. That is happened for the merging of variable demands from the zonal offices.

Zonal offices (ZO): ZOs are company owned and operated. The importance of cycle time and control over order accuracy drove this decision to invest in facilities at zonal offices.

Dealers: The Company deals with a vast network having 130 dealers. A dealer team associated with the zonal offices helps the supervisors in carrying out survey and making true forecasts of the vehicles they also act as a link between the dealers and the zonal offices. The customers place their orders with dealers, which are notified to the zonal offices. And further the zonal offices after compiling these orders send to the company for replenishments [6].

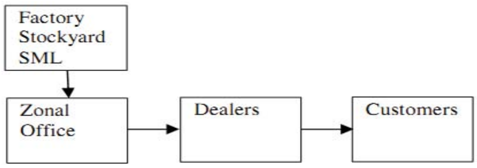

Figure 5 : Distribution Module

g) Hub & Spoke approach of information sharing

Hub and spoke approach are also followed by the SML. Each spoke acts as a connection to a member of the supply chain. All the members of supply chain pass the information to a central hub representing zonal offices and each member has access to all information provided by the other members. By sharing this information, all supply chain partners can see the changes occurring anywhere in the supply chain and respond to those changes instantly. This information sharing has been made possible with the use of electronic data interchange (EDI) and Internet. This has resulted into following benefits to SML:

1. Quick information
2. Reduction of paperwork
3. Improved billing
4. Customer service improvement
5. Competitive advantage
6. Error free demand forecasting
7. Minimize the cycle time in receiving projected and actual demand information
8. Establish the monitoring of actual demand for product to as near a real time basis as possible.
9. Understand product demand patterns at each stage of the supply chain.
10. Minimize or eliminate information queues that create information flow delays.
11. Eliminate inventory replenishment methods that launch demand lumps into the supply chain.
12. Identify, and preferably, eliminate the cause of customer order reductions or cancellations.

Finally, the generous return policies that manufacturers offer retailers aggravate gaming. Without a penalty, retailers will continue to exaggerate their needs and cancel orders. Not surprisingly, some computer manufacturers are beginning to enforce more stringent cancellation policies.

IX. Conclusion

In this paper, we have tried to focus how 'Bullwhip Effect" is created in Supply Chain. With the help of an example we tried present the overall situation of Bullwhip effect in Supply Chain. We also try to resolve the bullwhip effect by several methods. Here we can see that, the lead time of an order can amplify the variability.

If we use cross docking and the actual use of information technology then the lead time can be decreased. Here Vendor managed Inventory, Point of Sales and CPFR ca be some other supports in this situation.

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Assembly Line Balancing: A Review of Developments and Trends in Approach to Industrial Application

By Naveen Kumar & Dalgobind Mahto
Green Hills Engineering College

Abstract - Assembly line balancing is to know how tasks are to be assigned to workstations, so that the predetermined goal is achieved. Minimization of the number of workstations and maximization of the production rate are the most common goals. This paper presents the reviews of different works in the area of assembly line balancing and tries to find out latest developments and trends available in industries in order to minimize the total equipment cost and number of workstations.

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GJRE-G Classification : *FOR Code: 091599*

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Strictly as per the compliance and regulations of :

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Naveen Kumar [α] & Dalgobind Mahto [σ]

Abstract - Assembly line balancing is to know how tasks are to be assigned to workstations, so that the predetermined goal is achieved. Minimization of the number of workstations and maximization of the production rate are the most common goals. This paper presents the reviews of different works in the area of assembly line balancing and tries to find out latest developments and trends available in industries in order to minimize the total equipment cost and number of workstations.

Keywords : assembly line balancing, workstations, production and equipment cost.

I. Introduction

Line Balancing means balancing the production line, or any assembly line. The main objective of line balancing is to distribute the task evenly over the work station so that idle time of man of machine can be minimized. Lime balancing aims at grouping the facilities or workers in an efficient pattern in order to obtain an optimum or most efficient balance of the capacities and flows of the production or assembly processes.

Assembly Line Balancing (ALB) is the term commonly used to refer to the decision process of assigning tasks to workstations in a serial production system. The task consists of elemental operations required to convert raw material in to finished goods. Line Balancing is a classic Operations Research optimization technique which has significant industrial importance in lean system. The concept of mass production essentially involves the Line Balancing in assembly of identical or interchangeable parts or components into the final product in various stages at different workstations. With the improvement in knowledge, the refinement in the application of line balancing procedure is also a must. Task allocation of each worker was achieved by assembly line balancing to increase an assembly efficiency and productivity.

Author α : M.Tech student, Green Hills Engineering College, Solan, India. E-mail : nkj1986@gmail.com
Author σ : Professor, Green Hills Engineering College, Solan, India.

a) Definitions of Related Terms

i. *Line Balancing*

Line Balancing is leveling the workload across all processes in a cell or value stream to remove bottlenecks and excess capacity. A constraint slows the process down and results if waiting for downstream operations and excess capacity results in waiting and absorption of fixed cost.

ii. *Single-Model Assembly Line*

In early times assembly lines were used in high level production of a single product. But now the products will attract customers without any difference and allows the profitable utilization of Assembly Lines. An advanced technology of production which enables the automated setup of operations and it is negotiated time and money. Once the product is assembled in the same line and it won't variant the setup or significant setup and it's time that is used, this assembly system is called as Single Model Line.

iii. *Mixed Model Assembly Line*

In this model the setup time between the models would be decreased sufficiently and enough to be ignored. So this internal mixed model determines the assembled on the same line. And the type of assembly line in which workers work in different models of a product in the same assembly line is called Mixed Assembly Line.

iv. *Multi Model Assembly Line*

In this model the uniformity of the assembled products and the production system is not that much sufficient to accept the enabling of the product and the production levels. To reduce the time and money this assembly is arranged in batches, and this allows the short term lot-sizing issues which made in groups of the models to batches and the result will be on the assembly levels.

The model of different assembly lines and levels of activities are presented below in Fig. 1, Fig. 2 and Fig. 3

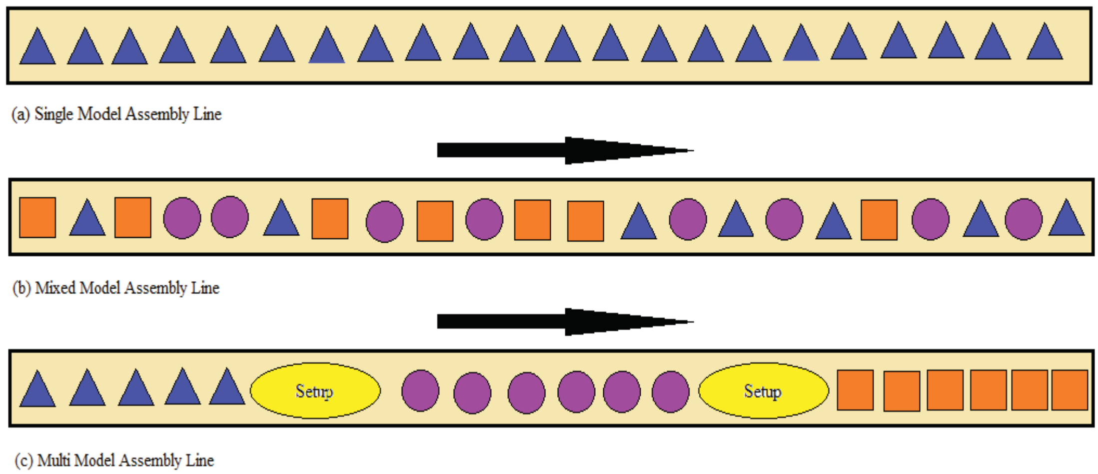

Figure 1 : Assembly lines for single and multiple products

Number of models	Single Model	Mixed Model	Multi Model
Line control	Paced	Unpaced asynchronous	Unpaced synchronous
Frequency	First-time installation		Reconfiguration
Level of automation	Manual Lines		Automated Lines
Line of business	Automobile Production		Further example

Figure 2 : Investigated kinds of Assembly Line Balancing [ALB]

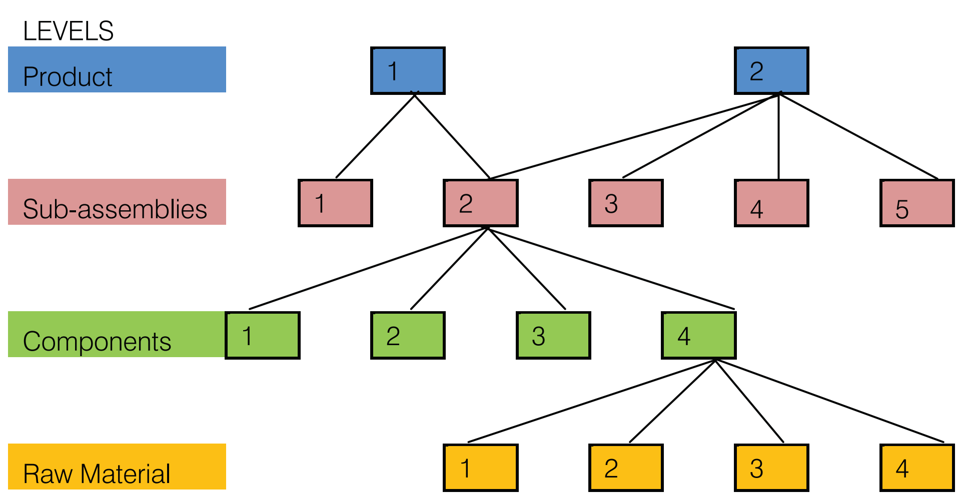

Figure 3 : Production levels in a typical manufacturing environment

v. *Non Value Added Costs*

a. *Cost from Overproduction*

Production costs money. There is no need to produce such products which cannot be sold. This is the most deceptive waste in today's time and resources utilization is to be maximized. Overproduction includes making more than what is required and making products earlier than required.

b. *Excess Inventory Cost*

Higher inventory cost is not beneficial for any company in today's variable demand business climate. Costs which are associated with the inventory are space, obsolescence, damage, opportunity cost, lagged defect detection and handling. In the case of obsolete inventory, all costs invested in the production of a part are wasted. Excessive inventory should be eliminated.

c. *Processing Cost*

Efforts that add no value to the desired product from a customer's point of view are considered as non-value added processing. Non value added operations should be eliminated. Vague picture of customer requirements, communication flaws, inappropriate material or machine selection for the production are the reasons behind this type of waste.

d. *Defective Products*

Companies give much emphasis on defects reduction. However defects still remain the major contributors towards the non-value added cost. Cost associated with this is quality and inspection expenditure, service to the customer, warranty cost and loss of customer fidelity.

e. *Transportation Cost*

Cost associated with material movement is a significant factor in the non-value added cost function. In a well designed system work and storage areas should be near to its point of use. This consumes huge capital investment in terms of equipment required for material movement, storage devices, and systems for material tracking. Transportation does not add value towards the final product.

f. *Motion*

Any motion that does not add value to the product or service comes under non-value added cost. Motion consumes time and energy and includes man or machine movement. Time spent by the operators looking for a tool, extra product handling and heavy conveyor usage are the typical example of the motion waste.

g. *Waiting*

If line is not properly balanced and inappropriate material flow selection are the reasons behind waiting time. The time spent on waiting for raw material, the job from the preceding work station, machine down-time, and the operator engaged in other operations and schedules are the major contributors in the waiting time.

b) *Terms In Line Balancing Technique*

In assembly line balancing system, there is various term normally used.

i. *Cycle Time*

Cycle time is the Maximum amount of time allowed at each station. This can be found by dividing required units to production time available per day.

$$Cycle\ time = \frac{Production\ \ Time\ per\ day}{Unit\ required\ \ per\ day} \qquad \text{(eq.1)}$$

ii. *Lead Time*

Summation of production times along the assembly line.

$$Lead\ time = \sum Production\ Time\ along\ the\ assembly\ time \qquad \text{(eq.2)}$$

iii. *Bottleneck*

Delay in transmission that slow down the production rate. This can be overcome by balancing the line.

iv. *Precedence*

It can be represented by nodes or graph. In assembly line the products have to obey this rule. The product can't be move to the next station if it doesn't complete at the previous station. The products flow from one station to the other station. A typical precedence diagram is mentioned in Fig.4 below to represent the activities.

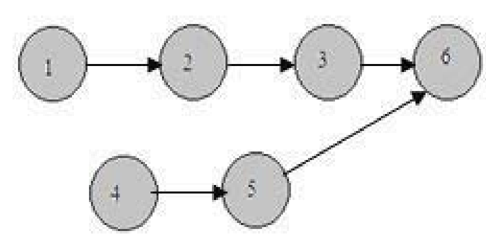

Figure 4 : Example of Precedence Diagram

v. *Idle Time*

Idle time is the time specified as period when system is not in use but is fully functional at desired parameters.

vi. *Productivity*

Define as ratio of output over input. Productivity is depends on several factors such as workers skills, jobs method and machine used.

$$Productivity = \frac{Output}{Labour * Production\ \ time\ per\ day\,(hour)} \qquad \text{(eq.3)}$$

vii. *Smoothness Index*

This is the index to indicate the relative smoothness of a given assembly line balance. A smoothness indeed is zero indicates perfect balance.

$$SI = \sqrt{\sum_{i=1}^{k} (STmax - STi)^2} \qquad \text{(eq.4)}$$

Where,

STmax - maximum station time (in most cases cycle time),

STi - station time of station i.

viii. *Balance Delay*

This is the ratio of total station time to the product of cycle time and the number of workstations.

$$BD = \left[\left\{ (K) * (CT) - \left(\sum_{I=1}^{K} STi \right) \right\} / \{(K) * (CT)\} * 100\% \right] \qquad \text{(eq.5)}$$

II. Aims And Objectives Of The Work

The aim of this is to minimizing workloads and workers on the assembly line while meeting a required output.

The aims and objectives of the present study are as follows:-

- To reduce production cost and improve productivity
- To determine number of feasible workstation.
- To identify the location of bottleneck and eliminate them.
- To determine machinery and equipment according to assembly mechanism.
- To equally distribute the workloads among workmen to the assembly line.
- To optimize the production functions through construction of mix form of automation assembly and manual assembly.
- To minimize the total amount of idle time and equivalently minimizing the number of operators to do a given amount of work at a given assembly line speed.

III. Literature Review

Lean and agile manufacturing is a very vast field and Line Balancing in industries is also very important. Many times in conferences this is main topic of discussion and many students and scholars also publish their work on this topic. Amen (2000) **[1]** presented work on an exact method for cost-oriented assembly line balancing. Characterization of the cost-oriented assembly line balancing problem had been shown by without loading the stations maximally the cost-oriented optimum. According to him criterion two-stations-rule had to be used. An exact backtracking method was introduced for generating optimal solutions in which the enumeration process was limited by modified and new bounding rules. Results of an experimental investigation showed that the new method finds optimal solutions for small and medium-sized problem instances in acceptable time.

A survey on heuristic methods for cost-oriented assembly line balancing was presented by Amen (2000) **[2]**. In this work main focus was on cost-oriented assembly line balancing. This problem mainly occurs in the final assembly of automotives, consumer durables or personal computers, where production is still very labor-intensive, and where the wage rates depend on the requirements and qualifications to fulfill the work. In this work a short problem description was presented along with classification of existent and new heuristic methods for solving this problem. A new priority rule called best change of idle cost was proposed. This priority rule differs from the existent priority rules because it was the only one which considers that production cost were the result of both, production time and cost rates.

A work on new heuristic method for mixed model assembly line balancing problem was published by Jin and Wu (2002) **[3]**. A goal chasing method was presented which is a popular algorithm in JIT system for the mixed model assembly line balancing problem. In this work, definition of good parts and good remaining sequence were provided and analyze their relationship with the optimal solutions objective function value. A new heuristic algorithm was also develop called 'variance algorithm' the numerical experiments showed that the new algorithm can yield better solution with little more computation overhead.

Fleszar and Hindi (2003) **[4]** presented a work on enumerative heuristic and reduction methods for the assembly line balancing problem. They presented a new heuristic algorithm and new reduction techniques for the type 1 assembly line balancing problem. The new heuristic was based on the Hoffmann heuristic and builds solutions from both sides of the precedence network to choose the best. The reduction techniques aimed at augmenting precedence, conjoining tasks and increasing operation times. A test was carried out on a well-known benchmark set of problem instances; testify to the efficacy of the combined algorithm, in terms of both solution quality and optimality verification, as well as to its computational efficiency.

A work on assembly line balancing in a mixed-model sequencing environment with synchronous transfers was presented by Karabati and Sayin (2003) **[5]**. An assembly line balancing problem was considered in a mixed-model line which was operated under a cyclic sequencing approach. Study of the problem was done in an assembly line environment with synchronous transfer of parts between the stations. They formulated the assembly line balancing problem with the objective of minimizing total cycle time by incorporating the cyclic sequencing information. They showed that the solution of a mathematical model that combines multiple models into a single one by adding up operation times constitutes a lower bound for this formulation. An alternative formulation was proposed that suggested minimizing the maximum sub cycle time.

A work was presented by Simaria and Vilarinho (2004) [6] on genetic algorithm based approach to the mixed-model assembly line balancing problem of type II. According to them mixed-model assembly lines allow for the simultaneous assembly of a set of similar models of a product. A mathematical programming model was presented in this work and an iterative genetic algorithm based procedure for the mixed-model assembly line balancing problem with parallel workstations, in which the goal was to maximize the production rate of the line for a predetermined number of operators.

A fuzzy logic approach to assembly line balancing work was presented by Fonseca et al. (2005) [7]. This work deals with the use of fuzzy set theory as a viable alternative method for modeling and solving the stochastic assembly line balancing problem. Variability and uncertainty in the assembly line balancing problem had traditionally been modeled through the use of statistical distributions. Fuzzy set theory allowed for the consideration of the ambiguity involved in assigning processing and cycle times and the uncertainty contained within such time variables. COMSOAL and Ran-ked Positional Weighting Technique were modified to solve the balancing problem with a fuzzy representation of the time variables. The work showed that the new fuzzy methods capabilities of producing solutions similar to, and in some cases better than, those reached by the traditional methods.

Gokcen (2005) [8] presented a work on shortest route formulation of simple U-type assembly line balancing problem. A shortest route formulation of simple U-type assembly line balancing (SULB) problem was presented. This model was based on the shortest route model developed in for the traditional single model assembly line balancing problem. Agpak and Gokcen (2005) [9] presented their work on assembly line balancing: Two resource constrained cases. A new approach on traditional assembly line balancing problem was presented. The proposed approach was to establish balance of the assembly line with minimum number of station and resources and for this purpose, 0–1 integer-programming models were developed.

A work was presented by Bukchin and Rabinowitch (2006) [10] on branch and bound based solution approach for the mixed-model assembly line-balancing problem for minimizing stations and task duplication costs. A common assumption in the literature on mixed model assembly line balancing is that a task that is common to multiple models must be assigned to a single station. In this work a common task to be assigned to different stations for different models. The sum of costs of the stations and the task duplication was to be minimized. An optimal solution procedure based on a backtracking branch and bound algorithm was developed and evaluates its performance via a large set of experiments. For solving large-scale problems branch and bound based heuristic was developed.

Levitin et al. (2006) [11] works on genetic algorithm for robotic assembly line balancing. Flexibility and automation in assembly lines can be achieved by the use of robots. The robotic assembly line balancing (RALB) problem was defined for robotic assembly line, where different robots may be assigned to the assembly tasks, and each robot needs different assembly times to perform a given task, because of its capabilities and specialization. The solution to the RALB problem includes an attempt for optimal assignment of robots to line stations and a balanced distribution of work between different stations. It aims at maximizing the production rate of the line. Gokcen and Agpak (2006) [12] presented their work on goal programming approach to simple U-line balancing problem. A goal programming model for the simple U-line balancing (ULB) problem was developed. The proposed model which was the multi criteria decision making approach to the U-line version provides increased flexibility to the decision maker since several conflicting goals can be simultaneously considered.

A work on heuristic solution for fuzzy mixed-model line balancing problem was presented by Hop (2006) [13]. This work addresses the mixed-model line balancing problem with fuzzy processing time. A fuzzy binary linear programming model was formulated for the problem. This fuzzy model was then transformed to a mixed zero one program. Due to the complexity nature in handling fuzzy computation, new approximated fuzzy arithmetic operation was presented. A fuzzy heuristic was developed to solve this problem based on the aggregating fuzzy numbers and combined precedence constraints. The general idea of our approach was to arrange the jobs in a sequence by a varying-section exchange procedure. Then jobs were allocated into workstations based on these aggregated fuzzy times with the considerations of technological constraint and cycle time limit. Promising results were obtained by experiments.

Gamberini et al. (2006) [14] presented their work on a new multi-objective heuristic algorithm for solving the stochastic assembly line re-balancing problem. In this work a new heuristic for solving the assembly line rebalancing problem was presented. The method was based on the integration of a multi-attribute decision making procedure, named technique for order preference by similarity to ideal solution (TOPSIS), and the well known Kottas and Lau heuristic approach. The proposed methodology was focused on rebalancing an existing line, when some changes in the input parameters (i.e. product characteristics and cycle time) occur. Hence, the algorithm deals with the assembly line balancing problem by considering the minimization of two performance criteria: (i) the unit labor and expected unit incompletion costs, & (ii) tasks reassignment.

A work was presented by Song (2006) **[15]** on recursive operator allocation approach for assembly line-balancing optimization problem with the consideration of operator efficiency. An optimization model was used for assembly line balancing problem in order to improve the line balance of a production line under a human centric and dynamic apparel assembly process. An approach was proposed to balance production line through optimal operator allocation with the consideration of operator efficiency. Two recursive algorithms were developed to generate all feasible solutions for operator allocation. Three objectives i.e. the lowest standard deviation of operation efficiency, the highest production line efficiency and the least total operation efficiency waste were rearranged to find out the optimal solution of operator allocation. The performance comparison demonstrated that the proposed optimization method outperforms the industry practice.

Dolgui et al. (2006) **[16]** works on special case of transfer lines balancing by graph approach. In their work for paced production they considered a balancing problem lines with workstations in series and blocks of parallel operations at the workstations. Operations of each workstation were partitioned into blocks. All operations of the same block were performed simultaneously by one spindle head. All blocks of the same workstation were also executed simultaneously. The operation time of the workstation was the maximal value among operation times of its blocks. The line cycle time was the maximal workstation time. A method for solving the problem was based on its transformation to a constrained shortest path problem.

A survey on problems and methods in generalized assembly line balancing was presented by Becker and Scholl (2006) **[17]**. Assembly lines are traditional and still attractive means of mass and large scale series production. Since the early times of Henry Ford several developments took place which changed assembly lines from strictly paced and straight single-model lines to more flexible systems including, among others, lines with parallel work stations or tasks, customer oriented mixed model and multi-model lines, U-shaped lines as well as un paced lines with intermediate buffers. Assembly line balancing research had traditionally focused on the simple assembly line balancing problem which had some restricting assumptions. Recently, a lot of research work had been done in order to describe and solve more realistic generalized problems.

Kim et al. (2006) **[18]** presented his work on endo symbiotic evolutionary algorithm for the integration of balancing and sequencing in mixed-model U-lines. A new evolutionary approach in mixed model U-shaped lines was proposed to deal with both balancing and sequencing problems. The use of U-shaped lines was an important element in Just-In-Time production. For an efficient operation of the lines, it is important to have a proper line balancing and model sequencing. A new genetic approach was proposed to solve the two problems of line balancing and model sequencing called endosymbiotic evolutionary algorithm.

Peeters and Degraeve (2006) **[19]** works on linear programming based lower bound for the simple assembly line balancing problem. The simple assembly line balancing problem was a classical integer programming problem in operations research. A set of tasks, each one being an indivisible amount of work requiring a number of time units, must be assigned to workstations without exceeding the cycle time. They presented a new lower bound, namely the LP relaxation of an integer programming formulation based on Dantzig–Wolfe decomposition. A column generation algorithm was proposed to solve the formulation and a branch-and-bound algorithm also proposed to exactly solve the pricing problem.

A work on optimal piecewise-linear program for the U-line balancing problem with stochastic task times was published by Urban and Chiang (2006) **[20]**. The utilization of U-shaped layouts in place of the traditional straight-line configuration has become increasingly popular. This work examines the U-line balancing problem with stochastic task times. A chance-constrained, piecewise linear, integer program was formulated to find the optimal solution. Various approaches were used to identify a tight lower bound. Computational results showed that the proposed method was able to solve practical sized problems.

Hirotani et al. (2006) **[21]** works on analysis and design of self-balancing production line. In a self-balancing production line each worker was assigned work dynamically. In this work, they examine other less restrictive conditions that can achieve the same self-balancing effect, and furthermore, characteristics of this line were analyzed by deriving the imbalance condition and analyzing the influence of initial position. In addition, a method for designing a self-balancing line based on our results was proposed.

A work was presented by Dimitriadis (2006) **[22]** on assembly line balancing and group working: A heuristic procedure for workers groups operating on the same product and workstation. In this work they examined an assembly line balancing problem that differs from the conventional one in the sense that there were multi-manned workstations, where workers groups simultaneously perform different assembly works on the same product and workstation. The proposed approach here results in shorter physical line length and production space utilization improvement, because the same number of workers can be allocated to fewer workstations. A heuristic assembly line balancing procedure was thus developed and illustrated. Finally, experimental results of a real-life automobile assembly plant case and well known problems from the literature indicate the effectiveness and applicability of the proposed approach in practice.

Lapierre et al. (2006) **[23]** presented his work on balancing assembly lines with tabu search. Balancing assembly lines is a crucial task for manufacturing companies in order to improve productivity and minimize production costs. Despite some progress in exact methods to solve large scale problems, software's implementing simple heuristics are still the most commonly used tools in industry. Here a new tabu search algorithm was presented and discussed. Its performance was then evaluated on Type I assembly line balancing problem. They discuss the flexibility of the meta-heuristic and its ability to solve real industrial cases.

For productivity improvement Gokcen et al. (2006) **[24]** published a work on balancing of parallel assembly lines. Productivity improvement in assembly lines is very important because it increases capacity and reduces cost. If the capacity of the line is insufficient, one possible way to increase the capacity is to construct parallel lines. In this study, new procedures and a mathematical model on the single model assembly line balancing problem with parallel lines were proposed.

Amen (2006) **[25]** works on cost-oriented assembly line balancing in which model formulations, solution difficulty, upper and lower bounds was also considered. Cost oriented assembly line balancing was discussed in this work. First focus was on special objective function and a formal problem statement. Then they concentrate on general model formulations that can be solved by standard optimization tools and introduce several improvements to existent models. These models were designed for either general branch-and-bound techniques with LP-relaxation or general implicit enumeration techniques. Further they discuss the solution difficulty of the problem and showed that the maximally-loaded station rule had to be replaced by the two-station rule.

Azar et al. (2006) **[26]** presented their work on load balancing of temporary tasks in the l_p norm. In this on-line load balancing problem has been considered on *m* identical machines. Jobs arrive at arbitrary times, where each job had a weight and duration. A job had to be assigned upon its arrival to exactly one of the machines. The duration of each job was known only on completion. Once a job has been assigned to a machine it cannot be reassigned to another machine. Focus was to minimize the maximum over time of the sum (over all machines) of the squares of the loads, instead of the traditional maximum load.

A state-of-the-art exact and heuristic solution procedure for simple assembly line balancing was presented by Scholl and Becker (2006) **[27]**. Whenever a line has to be configured or redesigned the assembly line balancing problem arises there and had to be solved. It can be distributing of the total workload for manufacturing. In this work, they an up-to-date and comprehensive survey of simple assembly line balancing problem research with a special emphasis on recent outstanding and guiding contributions to the field had been given.

A balancing method and genetic algorithm for disassembly line balancing was developed by McGovern and Gupta (2007) **[28]**. Disassembly active-ties take place in various recovery operations i.e. in re-manufacturing, recycling and disposal. Returned pro-ducts need to be automatically. It is therefore important that the disassembly line be designed and balanced for maximum works efficiently. In this work the problem was mathematically defined and proven NP-complete. Also, a new formula for quantifying the level of balancing was proposed. A first-ever set of a priori instances to be used in the evaluation of any disassembly line balancing solution technique was then developed and a genetic algorithm was presented for obtaining optimal solutions for disassembly line balancing problems.

Agpak and Gokcen (2007) **[29]** discussed a chance constrained approach to stochastic line balancing problem. In this work, chance constrained 0–1 integer programming models for the stochastic traditional and U-type line balancing (ULB) problem were developed. These models were solved for several test problems that are well known in the literature and the computational results were given. Also, a goal programming approach was presented in order to increase the system reliability, which was arising from the stochastic case. A classification of assembly line balancing problems was presented by Boy sen and Flie dner (2007) **[30]**. Assembly lines are special flow-line production systems which are of great importance in the industrial production and assembly lines even gained importance in low volume production of customized products. A classification scheme of assembly line balancing was provided for the ease communication between re-searchers and practitioners.

Ant algorithms were also developed by Bautista and Pereira (2007) **[31]** for a time and space constrained assembly line balancing problem. This work mainly focused on the application of a procedure based on ant colonies to solve an assembly line balancing problem. Time and Space constrained Assembly Line Balancing Problem was also presented and a basic

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model of one of its variants. An ant algorithm was presented that offered good results with simple balancing problems. Finally, the validity of the proposed algorithms was tested by means of a computational experience with reference instances.

A station-oriented enumerative algorithm for two-sided assembly line balancing was developed by Xia-o-feng et al. (2008) **[32]**. A station-oriented enumerative algorithm for two-sided assembly lines balancing was proposed in this work. Firstly the time transfer function was defined and combined with the precedence relation to compute the earliest and the latest start time of tasks. With the direction and cycle time constraints, a station-oriented procedure based on the start time was designed to assign tasks, starting from the left station to the right station of the position. The proposed algorithm was integrated with the Hoffmann heuristic to develop a system for solving two-sided assembly lines balancing problems. The test was per-formed on the well known benchmark set of problem instances. Experimental results demonstrate that the proposed procedure is efficient.

Boysen and Fliedner (2008) **[33]** presented a versatile algorithm for assembly line balancing. In this work discusses a two stage graph-algorithm, which was designed to solve line balancing problems including practice relevant constraints, such as parallel work stations and tasks, cost synergies, processing alter-natives, zoning restrictions, stochastic processing times or U-shaped assembly lines. A work on Assembly Line Balancing in Clothing Company was developed by Eryuruk et al. (2008) **[34]**. In this two heuristic assembly line balancing techniques known as the Ranked Positional Weight Technique developed by Helgeson and Birnie, and the Probabilistic Line Balancing Technique developed by El-Sayed and Boucher, were applied to solve the problem of multi-model assembly line balancing in a clothing company for two models.

Boysen et al. (2008) **[35]** in their work on assembly line balancing tried to make understand that which model to use when. This work structures the vast field of assembly line balancing according to characteristic practical settings and highlights relevant model extensions which were required to reflect real-world problems and open research challenges were identified. Balancing and scheduling tasks in assembly was done by Andres et al. (2008) **[36]** lines with sequence-dependent setup times. According to them the classical Simple Assembly Line Balancing Problem (SALBP) has been widely enriched over the past few years with many realistic approaches and much effort has been made to reduce the distance between the academic theory and the industrial reality. The problem presented in this work adds sequence-dependent setup time considerations to the classical SALBP and when-ever a task is assigned next to another at the same workstation, a setup time must be added to compute the global workstation time. After formulating a mathematical model for this innovative problem and showing the high combinatorial nature of the problem, eight different heuristic rules and a GRASP algorithm were designed and tested for solving the problem in reasonable computational time.

Miralles et al. (2008) **[37]** works on Branch and bound procedures for solving the Assembly Line Worker Assignment and Balancing Problem: Application to Sheltered Work centers for Disabled. In this work a new problem called Assembly Line Worker Assignment and Balancing Problem (ALWABP) was introduced. The problem consists of providing a simultaneous solution to a double assignment: (1) tasks to stations; and (2) available workers to stations. After defining the mathematical model for this problem, a basic Branch and Bound approach with three possible search strategies and different parameters was presented. They also proposed the use of a Branch and Bound-based heuristic for large problems and analyzed the behavior of both exact and heuristic methods through experimental studies.

Simple and U-type assembly line balancing problems with a learning effect was presented by Toksari et al. (2008) **[38]**. In this reported work, they introduced learning effect into assembly line balancing problems. In many realistic settings, the produced worker(s) or machine(s) develops continuously by repeated the same or similar activities. Therefore, the production time of product shortens if it is processed later. They showed that polynomial solutions can be obtained for both simple assembly line balancing problem and U-type line balancing problem with learning effect. A dynamic programming based heuristic for the assembly line balancing problem was presented by Bautista and Pereira (2009) **[39]**. The simple assembly line balancing problem was the simplification of a real problem associated to the assignment of the elementary tasks required for assembly of a product in an assembly line. The present work proposes a new procedure to solve the problem named Bounded Dynamic Programming. This use of the term Bounded was associated not only with the use of bounds to reduce the state space but also to the reduction of such space based on heuristics.

Choi (2009) **[40]** presented a work on goal programming mixed-model line balancing for processing time and physical workload. They present a new mathematical model of line balancing for processing time and physical workload at the same time. According to them line balancing was the problem to assign tasks to stations while satisfying some managerial viewpoints. Comparing the pay offs between the two overloads, test results showed that well balanced job allocation was able to be obtained through the proposed model. And they conclude that the model may be very useful for the operation managers to make decisions on their job scheduling efforts.

A mathematical model and a genetic algorithm for two-sided assembly line balancing were presented by Kim (2009) [41]. A two-sided assembly line is a type of production line where tasks are performed in parallel at both sides of the line. The line is often found in producing large products such as trucks and buses. In this they presented a mathematical model and a genetic algorithm (GA) for two-sided assembly line balancing. The mathematical model can be used as a foundation for further practical development in the design of two-sided assembly lines.

An ant colony optimization algorithm for balancing two-sided assembly lines was presented by Simaria and Vilarinho (2009) [42]. Two-sided assembly lines are a special type of assembly lines in which workers perform assembly tasks in both sides of the line. The highlighted approach of this work is to address the two-sided mixed-model assembly line balancing problem. First, a mathematical programming model, then, an ant colony optimization algorithm

An efficient approach was presented by Gao (2009) [43] for type II robotic assembly line balancing problems. This study presented a type II robotic assembly line balancing problem, in which the assembly tasks had assigned to workstations, and each workstation needs to select one of the available robots to process the assigned tasks with the objective of minimum cycle time. An innovative genetic algorithm (GA) hybridized with local search was proposed for the problem. Sabuncuoglu et al. (2009) [44] presented an ant colony optimization for the single model U-type assembly line balancing problem. An assembly line is a production line in which units move continuously through a sequence of stations.

Ege et al. (2009) [45] works on Assembly line balancing with station paralleling. In their study they assume an arbitrary number of parallel workstations can be assigned to each stage. Every task requires a specified tooling/equipment, and this tooling/equipment should be available in all parallel workstations of the stage to which the task was assigned. Their objective was to find an assignment of tasks to stages so as to minimize sum of station opening and tooling/equipment costs. They propose two branch and bound algorithms: one for optimal solutions and one for near optimal solutions. Becker and Scholl (2009) [46] worked on balancing assembly lines with variable parallel workplaces: Problem definition and effective solution procedure. Assembly line balancing problems (ALBP) arise whenever an assembly line is configured, redesigned or adjusted. In this work an extension of the basic ALBP to the case of flexible parallel workplaces products were considered. The problem was defined and modeled as an integer linear program. As a solution approach a branch and bound procedure was proposed which also can be applied as a heuristic.

Balancing of mixed-model two-sided assembly lines was presented by Ozcan and Toklu (2009) [47]. A new mathematical model and a simulated annealing algorithm for the mixed model two-sided assembly line balancing problem had been presented. The proposed mathematical model minimizes the number of mated-stations as the primary objective and minimizes the number of stations as a secondary objective for a given cycle time. In the proposed simulated annealing algorithm, two performance criteria considered were maximizing the weighted line efficiency and minimizing the weighted smoothness index.

A binary fuzzy goal programming approach was presented by Kara et al. (2009) [48] for single model straight and U-shaped assembly line balancing. Assembly line balancing generally requires a set of acceptable solutions to the several conflicting objectives. In this study, a binary fuzzy goal programming approach was applied to assembly line balancing. Models for balancing straight and U-shaped assembly lines with fuzzy goals were proposed. An illustrative example was presented to demonstrate the validity of the proposed models and to compare the performance of straight and U-shaped line configurations.

A comparison of exact and heuristic methods for a transfer line balancing problem was presented by Guschinskaya and Dolgui (2009) [49]. Transfer line balancing problems (TLBP) deal with the optimization of serial machining lines. At every machine, the operations were performed by blocks. The operations within each block were executed simultaneously by the same multi-spindle head. In the lines considered here, the spindle heads of each machine are activated sequentially. The objective of TLBP was to group the operations into blocks and to assign the blocks to machines in order to minimize the total amount of the required equipment.

Che et al. (2009) [50] have explained on cooperator selection and industry assignment in supply chain network with line balancing technology.

Integrating assembly planning and line balancing using precedence diagram was presented by Abdul-Hassan (2009) [51]. According to them, assembly planning and assembly line balancing are considered as two independent tasks. Assembly planning represents a fundamental step in the operation of a manufacturing system that involves product assembly while line balancing represents one of the biggest technical problems in designing and operating a manual assembly line. A methodology called COMSOAL-PLB (Computer Method of Sequencing Operations for Assembly Lines of Assembly Planning and Line Balancing) was developed to incorporate making decisions on process planning and production planning for assembly product.

Ozcan and Toklu (2009) [52] works on Multiple-criteria decision-making in two-sided assembly line balancing: A goal programming and a fuzzy goal programming model. They presented a mathematical model, a pre-emptive goal programming model for precise goals and a fuzzy goal programming model for imprecise goals for two-sided assembly line balancing. The mathematical model minimizes the number of mated–stations as the primary objective and it minimizes the number of stations as a secondary objective for a given cycle time. A work on MIP approach for balancing transfer line with complex industrial constraints was presented by Essafi et al. (2010) [53]. According to them at least one CNC machine is to be installed at each workstation. The objective was to assign a given set of operations required for the machining of the part to a sequence of workstations while minimizing the total number of machines used. This problem was subject to precedence, exclusion and inclusion constraints.

Toksari et al. (2010) [54] works on assembly line balancing problem with deterioration tasks and learning effect. In this simultaneous effects of learning and linear deterioration were introduced into assembly line balancing problem. In many realistic settings, although the actual task time of a task is modeled as an increasing function of its starting time due to deterioration effects the produced worker develops continuously by repeated the same or similar activities. The objective of problem was to minimize the station number and a mixed nonlinear integer programming model was developed. A research work on assembly line balancing to minimize balancing loss and system loss was published by Roy and Khan (2010) [55]. Assembly Line production is one of the widely used basic principles in production system. The main aim was to redefine the objective of the Assembly Line Balancing Problem and sequentially handle Balancing Loss and System Loss.

Fan et al. (2010) [56] published their work on balancing and simulating of assembly line with overlapped and stopped operation on the subject modeling and simulation of assembly line with overlapped and stopped operation, builds mathematical model for the assembly line both under certainty and uncertainty environment.

Essafi et al. (2010) [57] worked on balancing lines in CNC machines based on heuristic method of line balancing. The optimization of production systems is an important stage for manufacturers to minimize costs and remain competitive. However, in the current economic context, with market volatility and fluctuation in demand, industrials manufacturers need more flexible production systems. Thus, new types of lines were created; i.e. flexible and reconfigurable transfer lines. The flexibility or the recon figurability of a line is obtained through the use of special machines, a developed control system for the line, a specific architecture, etc. The use of Computer Numerical Control (CNC) machines is a common way to add more flexibility or reconfigurability to a machining line. Such machines are highly automated and use computer programs to define the different tools to use for a specific part. Therefore they correspond to standard and interchangeable units in which a new program can be loaded to change the production.

Ozcan (2010) [58] published their finding on balancing stochastic two-sided assembly lines: A chance-constrained, piecewise-linear, mixed integer program and a simulated annealing algorithm. In this type of a production line, both left-side and right-side of the line are used in parallel. The problem of balancing twosided assembly lines with stochastic task times was considered in this work. A chance-constrained, piece wise linear, mixed integer program was proposed to model and solve the problem. A work on multi objective constructive heuristics for the 1/3 variant of the time and space assembly line balancing problem: ACO and random greedy search was reported by China et al. (2010) [59]. Two new multi objective proposals based on ant colony optimization and random greedy search algorithms was presented to solve a classical industrial problem: time and space assembly line balancing. Some variants of these algorithms had been compared in order to find out the impact of different design configurations and the use of heuristic information.

Yeh and Kao (2010) [60] reported on a new bidirectional heuristic for the assembly line balancing problem. According to them, Assembly line balancing problem (ALBP) is one of the well-known NP-hard layout planning problems for mass production systems. Similarly, a work on simultaneous balancing and scheduling of flexible mixed model assembly lines with sequence-dependent setup times was published by Ozturk et al. (2010) [61]. They have considered simultaneous balancing and scheduling of flexible mixed model assembly lines with sequence-dependent setup times. They have proposed alternate Mixed Integer Programming and Constraint Programming formulations.

Likewise, in the field of application of genetic algorithm the important works have been performed by Taha (2011) [62] Akpinar and Bayhan (2011) [63] and Chica et al. (2011) [64].

Ozbakir and Tapkan (2011) [65] published their work on bee colony intelligence in zone constrained two-sided assembly line balancing problem. In this study two-sided assembly line balancing problem with zoning constraint was solved by bees algorithm so as to minimize the number of stations for a given cycle time. Likewise, a work on bi-criteria assembly line balancing by considering flexible operation times was presented by Hamta et al. (2011) [66].

Kilincci (2011) [67] worked on firing sequences backward algorithm for simple assembly line balancing problem of type 1 and published their work on the same. The objective of simple assembly line balancing problem type-1 (SALBP-1) was to minimize the number of workstations on an assembly line for a given cycle time. A new heuristic algorithm was presented to solve the problem. The presented algorithm makes an order of firing sequence of transitions from Petri net model. Task was assigned to a workstation using this order and backward procedure.

A work was published by Chica et al. (2011) [68] which shows their work on different kinds of preferences in a multi-objective ant algorithm for time and space assembly line balancing on different Nissan scenarios. The main focus of this was to study influence of incorporating user preferences based on Nissan automotive domain knowledge to guide the multi-objective search process with two different aims. First, to reduce the number of equally preferred assembly line configurations and second, to only provide the plant managers with configurations of their contextual interest in the objective space based on real-world economical variables.

Otto and Scholl (2011) [69] worked on discrete optimization incorporating ergonomic risks into assembly line balancing. In manufacturing, control of ergonomic risks at manual workplaces is a necessity commanded by legislation, care for health of workers and economic considerations. In this work it has been shown that even though most ergonomic risk estimation methods involve nonlinear functions, they can be integrated into assembly line balancing techniques at low additional computational cost. Their computational experiments indicate that re-balancing often leads to a substantial mitigation of ergonomic risks. Line balancing analysis of tuner product manufacturing was published by Sihombing et al. (2011) [70]. In the tuner production line, number of operator, production tools/equipment, and production process are three significant factors related to productivity through using of line balancing method. This study performed the line balancing method through simulation model in order to reduce the line unbalancing causes and relocate the workforce associated to idle time, eliminating the bottleneck, and at the same time maintaining/ improving the productivity.

Yag mahan (2011) [71] presented mixed-model assembly line balancing using a multiobjective ant colony optimization approach. This work deals with the mixed-model assembly line balancing problem and objective for this problem was to minimize the number of stations for a given cycle time. To solve this problem a multi-objective ant colony optimization algorithm was proposed. To prove the efficiency of the proposed algorithm, a number of test problems were solved. The results showed that the MOACO algorithm is an efficient and effective algorithm which gives better results than other methods compared.

Multi-objective optimization of a stochastic assembly line balancing: A hybrid simulated annealing algorithm was published by Cakir et al. (2011) [72]. This work deals with multi-objective optimization of a single-model stochastic assembly line balancing problem with parallel stations. The objectives were as follows: (1) minimization of the smoothness index and (2) minimization of the design cost. Ozbakira et al. (2011) [73] works on Multiple-colony ant algorithm for parallel assembly line balancing problem. Assembly lines are designed as flow oriented production systems which perform operations on standardized products in a serial manner. In this work, a novel multiple colony and algo rithm was developed for balancing by objective parallel assembly lines. The proposed approach was extensively tested on the benchmark problems and performance of the approach is compared with existing algorithms.

Blum and Miralles (2011) [74] works on solving the assembly line worker assignment and balancing problem via beam search. In this work they deal with a specific assembly line balancing problem that was known as the assembly line worker assignment and balancing problem (ALWABP). This problem arises in settings where tasks must be assigned to workers, and workers to work stations. In this work an algorithm based on beam search was introduced for solving the ALWABP with the objective of minimizing the cycle time when given a fixed number of work stations, respectively, workers.

Hou and Kang (2011) [75] presented their work on online and semi-online hierarchical scheduling for load balancing on uniform machines. In their work they consider online and semi-online hierarchical scheduling for load balancing on m parallel uniform machines with two hierarchies. The procedures for the time and space constrained assembly line balancing problem was presented by Bautista and Pereira (2011) [76]. The Time and Space constrained Assembly Line Balancing Problem (TSALBP) is a variant of the classical Simple Assembly Line Balancing Problem that additionally accounts for the space requirements of machinery and assembled parts. The present work proposed an adaptation of the Bounded Dynamic Programming (BDP) method to solve the TSALBP variant with fixed cycle time and area availability.

Weida and Tianyuan (2011) [77] work on strategic robust mixed model assembly line balancing based on scenario planning. Assembly line balancing involves assigning a series of task elements to uniform sequential stations with certain restrictions. Decision makers found that a task assignment which is optimal with respect to a deterministic or stochastic/fuzzy model gain poor performance in reality. In real environments, assembly line balancing robustness was a more appropriate decision selection guide. A robust model based on α worst case scenario was developed to compensate for the drawbacks of traditional robust criteria.

A genetic algorithm based approach for simultaneously balancing and sequencing of mixed-model U-lines with parallel workstations and zoning constraints was presented by Hamzadayi and Yildiz (2012) **[78]**. A Priority-Based Genetic Algorithm based method was presented for the simultaneously tackling of the mixed-model U-shape assembly line line balancing/model sequencing problems with parallel workstations and zoning constraints and allows the decision maker to control the process to create parallel workstations and to work in different scenarios. In this, simulated annealing based fitness evaluation approach was developed to be able to make fitness function calculations easily and effectively.

Cheshmehgaz (2012) **[79]** worked on accumulated risk of body postures in assembly line balancing problem and modeling through a multi-criteria fuzzy-genetic algorithm. A novel model of assembly line balancing problem was presented that incorporates assembly worker postures into the balancing. Also a new criterion of posture diversity was defined and contributes to enhance the model. The proposed model suggests configurations of assembly lines via the balancing and the assigned workers gets the opportunities of changing their body postures, regularly.

Mahto and Kumar (2012) **[80]** works on an empirical investigation of assembly line balancing techniques and optimized implementation approach for efficiency improvements. The concept of mass production essentially involved the assembly of identical or interchangeable parts of components into the final product at different stages and workstations. The relative advantages and disadvantages of mass or flow production were a matter of concern for any mass production industry. How to design an assembly line starting from the work breakdown structure to the final grouping of tasks at work stations had been discussed in this work using two commonly used procedures namely the Kilbridge-Wester Heuristic approach and the Helgeson-Birnie Approach. Line Balancing was a classic, well-researched Operations Research optimization problem of significant industrial importance. The core objectives of this work was to optimize crew size, system utilization, the probability of jobs being completed within a certain time frame and system design costs. These objectives were addressed simultaneously, and the results obtained were compared with those of single-objective approaches.

A work on assembly line balancing in garment industry was presented by Chen et al. (2012) **[81]**. A grouping genetic algorithm (GGA) was developed for ALBP of sewing lines with different labor skill levels. GGA can allocate workload among machines as evenly as possible for different labor skill levels, so the mean absolute deviations can be minimized. Real data from garment factories and experimental design were used to evaluate GGA's performance.

Rabbani et al. (2012) **[82]** works on mixed model U-line balancing type-1 problem. In this a new approach to balance a mixed model U-shaped production system independent was developed for any product sequences. This approach was based on minimization of crossover workstations. In balancing mixed model assembly lines in U-shaped line layouts was more complicated than that of straight lines.

A model was developed in which minimizing the number of crossover workstations and maximizing the line efficiency were considered at same time.

Mixed-model assembly line balancing in the make-to-order and stochastic environment using multi-objective evolutionary algorithms was stated by Manavizadeh et al. (2012) **[83]**. A multi-objective genetic algorithm (MOGA) was present to solve a mixed-model assembly line problem (MMALBP), considering cycle time (CT) and the number of stations simultaneously. In this work, a mixed-model assembly line had been put forth in a make-to-order (MTO) environment according to the stochastic environment of production systems. Also a MOGA approach was presented to solve the corresponding balancing problem and the decision maker was provided with the subsequent answers to pick one based on the specific situation.

Modeling and solving constrained two-sided assembly line balancing problem via bee algorithms was presented by Tapkana et al. (2012) **[84]**. A fully constrained two-sided assembly line balancing problem was addressed in this research work. A mathematical programming model was presented in order to describe the problem formally. Due to the problem complexity, two different swarm intelligence based search algorithms are implemented to solve large-sized instances. Bees algorithm and artificial bee colony algorithm had been applied to the fully constrained two-sided assembly line balancing problem so as to minimize the number of workstations and to obtain a balanced line.

Chutima and Chimklai (2012) **[85]** works on multi-objective two-sided mixed-model assembly line balancing using particle swarm optimisation with negative knowledge. Particle swarm optimisation (PSO) is an evolutionary metaheuristic inspired by the swarming behavior observed in flocks of birds. A PSO algorithm was presented with negative knowledge (PSONK) to solve multi-objective two-sided mixed-model assembly line balancing problems. Instead of modelling the positions of particles in an absolute manner as in traditional PSO, PSONK employed the knowledge of the relative positions of different particles in generating new solutions.

Multi objective memetic algorithms for time and space assembly line balancing were presented by Chica et al. (2012) **[86]**. Three proposals of multi-objective memetic algorithms were presented to solve a more realistic extension of a classical industrial problem: time and space assembly line balancing. These three proposals were, respectively, based on evolutionary computation, ant colony optimization, and greedy randomized search procedure. An efficient branch and bound algorithm for assembly line balancing problem with parallel multi-manned workstations was presented by Kellegoz and Toklu (2012) [87]. Assembly lines with parallel multi-manned workstations and one of their balancing problems were addressed, and a branch and bound algorithm was proposed. The algorithm was composed of a branching scheme, some efficient dominance and feasibility criteria based on a problem-specific knowledge. A heuristic-based guidance for enumeration process was included as an efficient component of the algorithm as well. Battaia and Dolgui (2012) [88] works on reduction approaches for a generalized line balancing problem. The objective of the work was to minimize the cost of the line being designed. This work presented effective pre-processing methods which can reduce the size of the initial problem in order to shorten the solution time required. Rule-based modeling and constraint programming based solution of the assembly line balancing problem was discussed by Topaloglu et al. (2012) [89]. The assembly line balancing problem employs traditional precedence graphs to model precedence relations among assembly tasks. This work proposed to model assembly constraints through the well known If-then rules, and to solve the rule-based model through constraint programming (CP), as CP naturally models logical assertions. It has been also shown that how to map a rule-based model to a CP or an integer programming (IP) model. The result of experiments showed that CP was more effective and efficient than IP.

Simultaneous solving of balancing and sequencing problems with station-dependent assembly times for mixed-model assembly lines was presented by Mosadegha et al. (2012) [90]. In this work Mixed-Model Assembly Line (MMAL) was considered and studied for balancing and sequencing problems as well as solved. A new Mixed-Integer Linear Programming (MILP) model was developed to provide the exact solution of the problem with station-dependent assembly times. Yoosefelahi et al. (2012) [91] published a work on type II robotic assembly line balancing problem: An evolution strategies algorithm for a multi-objective model. The aim of the study was to minimize the cycle time, robot setup costs, robot costs and a procedure was also proposed to solve the problem. In addition, a new mixed-integer linear programming model was developed.

A hybrid PSO algorithm for a multi-objective assembly line balancing problem with flexible operation times, sequence-dependent setup times and learning effect was published by Hamta et al. (2013) [92]. In this a multi-objective (MO) optimization of a single-model assembly line balancing problem (ALBP) considered where the operation times of tasks were unknown variables and the only known information was the lower and upper bounds for operation time of each task. Three objectives were simultaneously considered as follows: (1) minimizing the cycle time, (2) minimizing the total equipment cost, and (3) minimizing the smoothness index. A new solution method was proposed which is based on the combination of particle swarm optimization (PSO) algorithm with variable neighborhood search (VNS) to solve the problem.

A Simulated Annealing algorithm for a mixed model assembly U-line balancing type-I problem considering human efficiency and Just-In-Time approach was presented by Manavizadeh et al. (2013) [93]. This work deals with balancing a mixed-model U-line in a Just-In-Time (JIT) production system. The research tries to reduce the number of stations via balancing the workload and maximizing the weighted efficiency. In this study two types of operators were assumed: permanent and temporary. Both types can work in regular and overtime periods. Based on their skill levels, workers were classified into four types. The sign at each work station indicated types of workers allowed to work at that station. An alert system using the hybrid kanban systems was also considered. A Simulated Annealing algorithm was applied in the following three stages for solving this problem. First, the balancing problem was solved by determining number of stations; secondly workers were assigned to the workstations in which they were qualified to work and finally an alert system based on the kanban system was designed to balance the work in the process inventory.

A simulated annealing algorithm for multi-manned assembly line balancing problem was presented by A bdolreza et al. (2013) [94]. In this work a simulated annealing heuristic was proposed for solving assembly line balancing problems with multi-manned workstations. The line efficiency, line length and the smoothness index were considered as the performance criteria. A work on an iterative genetic algorithm for the assembly line worker assignment and balancing problem of type-II was published by Mutlu et al. (2013) [95]. In this study, they considered the assembly line worker assignment and balancing problem of type-II (ALWABP-2). ALWABP-2 arises when task times differ depending on operator skills and concerns with the assignment of tasks and operators to stations in order to minimize the cycle time. An iterative genetic algorithm (IGA) was developed to solve this problem.

Tuncel and Topaloglu (2013) [96] works on assembly line balancing with positional constraints, task assignment restrictions and station paralleling: A case in an electronics company. A real-life Assembly Line Balancing Problem was discussed in this for an electronics manufacturing company. The main characteristics of the problem were as follows: (i) a set

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of operations are related to the front part of the workpiece and others are related to the back part of the workpiece, which in turn makes all tasks dependent on the position of the workpiece, (ii) some of the tasks must be executed on the same station and no other tasks should be assigned to this station due to technological restrictions, (iii) parallel stations are allowed to increase the line efficiency at the required production rate and to overcome the problem of assigning tasks with operation times that exceed the cycle time. Initially, the problem was formulated as a 0–1 integer programming model and solved using CPLEX solver. Then, the effect of alternative work schedules such as multiple shifts and overtime on the expected labor cost of the line was analyzed.

A work on hybridizing ant colony optimization via genetic algorithm for mixed-model assembly line balancing problem with sequence dependent setup times between tasks was presented by Sener et al. (2013) **[97]**. This work presented a new hybrid algorithm, which executes ant colony optimization in combination with genetic algorithm (ACO-GA), for type I mixed-model assembly line balancing problem (MMALBP-I) with some particular features of real world problems such as parallel workstations, zoning constraints and sequence dependent setup times between tasks.

A work on stability measure for a generalized assembly line balancing problem was published by Gurevsky et al. (2013) **[98]**. A generalized formulation for assembly line balancing problem (GALBP) was considered, where several workplaces were associated with each workstation. The objective of this work was to assign all given tasks to workstations and workplaces while minimizing the line cost estimated as a weighted sum of the number of workstations and workplaces. The goal of this article was to propose a stability measure for feasible and optimal solutions of this problem with regard to possible variations of the processing time of certain tasks. A heuristic procedure providing a compromised between the objective function and the suggested stability measure was developed and evaluated on benchmark data sets.

A work on two-sided assembly lines balancing with assignment restrictions was presented by Purnomo et al. (2013) **[99]**. Two-sided assembly line is a set of sequential workstations where task operations can be performed in two sides of the line. In this work a mathematical model was proposed for two-sided assembly line type II. The aim of the model was minimizing the cycle time for a given number of mated-workstations and balancing the workstation simultaneously.

Mozdgira et al. (2013) **[100]** published their work using the Taguchi method to optimize the differential evolution algorithm parameters for minimizing the workload smoothness index in simple assembly line balancing. An assembly line is a flow-oriented production system in which the productive units performing the operations, referred to as stations, are aligned in a serial manner. In this work the SALBP is further classified into SALBP-1, SALBP-2, SALBP-E and finally SALBP-F. In this work, a differential evolution algorithm was developed to minimize workload smoothness index in SALBP-2. Also, the algorithm parameters were optimized using the Taguchi method.

IV. Summary of Literature Survey

The summery research done by experts in the area of line balancing have been presented in Table 1 in the ascending order of year and classification are given in Fig.5. Ironically, there are ample works and have been performed by researchers on SALB, GALB and MALB, before 2000 among them the noted works were carried out by Falkenauer, Delchamber, Anderson, Ferris, Tsujimura, Kim and Rekiek et al.etc.

Table 1 : Summary of the developments in line balancing based on literature survey

Reference No.	Author Name (Year)	Investigated Problem Type
1,2	Amen (2000), (2000)	Cost-oriented assembly line balancing
3	Jin and Wu (2002)	Mixed model assembly line balancing
4	Fleszar and Hindi (2003)	Heuristic and reduction methods for the ALB
5	Karabati and Sayin (2003)	ALB in mixed-model sequencing environment
6	Simaria and Vilarinho (2004)	MMALB balancing problem of type II
7	Fonseca et al. (2005)	Fuzzy logic approach to assembly line balancing
8	Gokcen (2005)	Simple U-type assembly line balancing
9	Agpak and Gokcen (2005)	Assembly line balancing
10	Bukchin and Rabinowitch (2006)	MMALB problem for minimizing stations
11	Levitin et al. (2006)	Robotic assembly line balancing
12	Gokcen and Agpak (2006)	Simple U-line balancing problem
13	Hop (2006)	Fuzzy mixed-model line balancing
14	Gamberini et al. (2006)	Assembly line re-balancing

15	Song (2006)	Assembly line-balancing
16	Dolgui et al. (2006)	Transfer lines balancing
17	Becker and Scholl (2006)	Assembly line balancing
18	Kim et al. (2006)	Mixed-model U-lines
19	Peeters and Degraeve (2006)	Simple assembly line balancing
20	Urban and Chiang (2006)	U-line balancing problem
21	Hirotani et al. (2006)	Self-balancing production line
22	Dimitriadis (2006)	Assembly line balancing
23	Lapierre et al. (2006)	Balancing assembly lines with tabu
24	Gokcen et al. (2006)	Balancing of parallel assembly lines
25	Amen (2006)	Cost-oriented assembly line balancing
26	Azar et al. (2006)	Load balancing of temporary tasks
27	Scholl and Becker (2006)	Simple assembly line balancing
28	McGovern and Gupta (2007)	Disassembly line balancing
29	Agpak and Gokcen (2007)	Stochastic line balancing
30	Boysen and Fliedner (2007)	Assembly line balancing problem
31	Bautista and Pereira (2007)	Time and space constrained assembly line balancing
32	Xia-o-feng et al. (2008)	Two-sided assembly line balancing
33	Boysen and Fliedner (2008)	Assembly line balancing
34	Eryuruk et al. (2008)	Assembly line balancing
35	Boysen et al. (2008)	Assembly line balancing
36	Andres et al. (2008)	Balancing and scheduling tasks in assembly
37	Miralles et al. (2008)	Assembly line worker assignment and balancing
38	Toksari et al. (2008)	Simple and U-type assembly line balancing
39	Bautista and Pereira (2009)	Assembly line balancing problem
40	Choi (2009)	Mixed-model line balancing
41	Kim (2009)	Two-sided assembly line balancing
42	Simaria and Vilarinho (2009)	Balancing two-sided assembly lines
43	Gao (2009)	Type II robotic assembly line balancing
44	Sabuncuoglu et al. (2009)	Single model U-type assembly line balancing
45	Ege et al. (2009)	Assembly line balancing with station paralleling
46	Becker and Scholl (2009)	Assembly lines with variable parallel workplaces
47	Ozcan and Toklu (2009)	Mixed-model two-sided assembly lines
48	Kara et al. (2009)	Single model straight and U-shaped assembly line balancing
49	Guschinskaya and Dolgui (2009)	Transfer line balancing
50	Che et al. (2009)	Supply chain network with line balancing technology
51	Abdulhasan (2009)	Assembly planning and line balancing
52	Ozcan and Toklu (2009)	Multiple-criteria decision-making in two-sided assembly line balancing
53	Essafi et al. (2010)	Transfer line with complex industrial constraints
54	Toksari et al. (2010)	Assembly line balancing problem
55	Roy and Khan (2010)	Assembly line balancing
56	Fan et al. (2010)	Balancing and simulating of assembly line
57	Essafi et al. (2010)	Balancing lines with CNC machines
58	Ozcan (2010)	Balancing stochastic two-sided assembly lines
59, 64,68, 86	Chica et al. (2010), (2011), (2011), (2012)	Time and space assembly line balancing problem
60	Yeh and Kao (2010)	Assembly line balancing

61	Ozturk et al. (2010)	Balancing and scheduling of flexible mixed model assembly lines
62	Taha (2011)	Two-sided assembly line balancing
63	Akpinar and Bayhan (2011)	Mixed model assembly line balancing problem with parallel workstations
65	Ozbakir and Tapkan (2011)	Two-sided assembly line balancing
66	Hamta et al. (2011)	Bi-criteria assembly line balancing
67	Kilincci (2011)	Simple assembly line balancing problem of type I
69	Otto and Scholl (2011)	Assembly line balancing
70	Sihombing et al. (2011)	Line balancing analysis
71	Yagmahan (2011)	Mixed-model assembly line balancing
72	Cakir et al. (2011)	Stochastic assembly line balancing
73	Ozbakira et al. (2011)	Multiple-colony ant algorithm for parallel assembly line balancing problem
74	Blum and Miralles (2011)	Assembly line worker assignment and balancing problem
75	Hou and Kang (2011)	Scheduling for load balancing on uniform machines
76	Bautista and Pereira (2011)	Time and space constrained assembly line balancing
77	Weida and Tianyuan (2011)	Mixed model assembly line balancing based on scenario planning
78	Hamzadayi and Yildiz (2012)	Balancing and sequencing of mixed-model U-lines with parallel workstations
79	Cheshmehgaz (2012)	Body postures in assembly line balancing
80	Mahto and Kumar (2012)	Assembly line balancing techniques
81	Chen et al. (2012)	Assembly line balancing
82	Rabbani et al. (2012)	Mixed model U-line balancing type-I
83	Manavizadeh et al. (2012)	Mixed-model assembly line balancing
84	Tapkana et al. (2012)	Two-sided assembly line balancing
85	Chutima and Chimklai (2012)	Two-sided mixed-model assembly line balancing
87	Kellegoz and Toklu (2012)	Assembly line balancing problems with parallel multi-manned workstations
88	Battaia and Dolgui (2012)	Generalized line balancing
89	Topaloglu et al. (2012)	Assembly line balancing
90	Mosadegha et al. (2012)	Assembly times for mixed-model assembly lines
91	Yoosefelahi et al. (2012)	Robotic assembly line balancing type II
92	Hamta et al. (2013)	Multi-objective assembly line balancing
93	Manavizadeh et al. (2013)	Mixed model assembly U-line balancing type-I
94	Abdolreza et al. (2013)	Multi-manned assembly line balancing
95	Mutlu et al. (2013)	Assembly line worker assignment and balancing problem of type-II
96	Tuncel and Topaloglu (2013)	Assembly line balancing with positional constraints
97	Sener et al. (2013)	Mixed-model assembly line balancing
98	Gurevsky et al. (2013)	Assembly line balancing problem
99	Purnomo et al. (2013)	Two-sided assembly lines balancing
100	Mozdgira et al. (2013)	Simple assembly line balancing

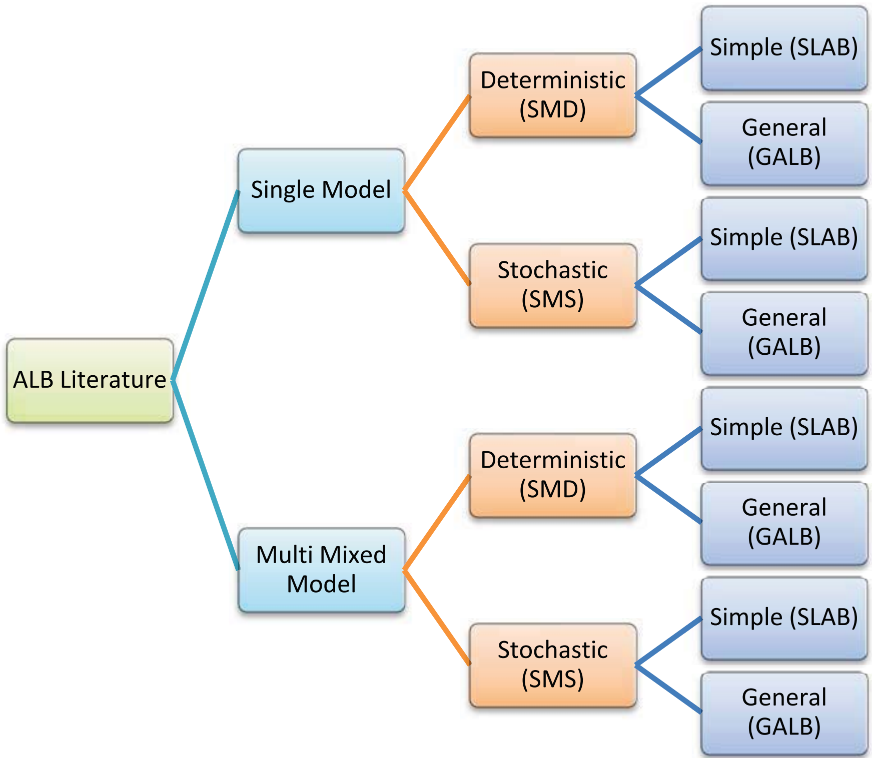

Figure 5 : Classification of assembly line balancing literature

V. Discussion

From the review of literatures it is found that Assembly line balancing can be used almost all types of industries. From the literature survey following points are needs to be discusse:-

- Experiments in line balancing show that optimal solutions for small and medium-sized problem are possible in acceptable time.
- A new improvement in priority rule is discussed which shows that production cost is the result of both production time and cost rates.
- Numerical experiments on a newly developed heuristic algorithm i.e. variance algorithm shows better solution with more calculations ahead.
- New cost reduction techniques are developed which focus precedence, conjoining tasks and increasing operation times; combined algorithms are tested for both solution quality and optimality verification, as well as to its computational efficiency.
- Different mathematical models that combines multiple models into a single one by adding up operation times and that suggested minimizing the maximum sub cycle time.
- A mathematical programming model presents an iterative genetic algorithm based on the mixed-model assembly line balancing problem with parallel workstations which maximize the production rate of the line for a predetermined number of operators.
- Backtracking branch-and-bound algorithm is developed and evaluates its performance via a large set of experiments and large-scale problems.
- For maximizing the production rate of the line robot assembly line balancing problems are solved for optimal assignment of robots to line stations and a balanced distribution of work between different stations.
- Three terms i.e. the lowest standard deviation of operation efficiency, the highest production line efficiency and the least total operation efficiency waste are studied to find out the optimal solution of operator allocation.
- A new genetic approach called endo symbiotic evolutionary algorithm is developed for solving the problems of line balancing and model sequencing.
- Experiment on a new heuristic assembly line balancing in real-life automobile assembly plant case results in shorter physical line length and production space utilization improvement, because the same number of workers can be allocated to fewer workstations.
- A new Tabu search algorithm is evaluated on Type-I assembly line balancing problem which shows the flexibility of the metaheuristic and its ability to solve real industrial cases.

- Experimental results of algorithm integrated with the Hoffmann heuristic shows the proposed procedure are more efficient.
- An ant colony optimization algorithm is proposed to solve the assembly problem in which two ants work simultaneously one at each side of the line to build a balancing solution which verifies the precedence, zoning, capacity, side and synchronism constraints of the assembly process.
- The single-model U-type assembly line balancing problem are solved by ant colony algorithms and showed very competitive performance.
- The generic algorithm mathematical model based on the assembly line balancing technology is adopted and results of real cases show that quickly and effectively than normal mathematical model.
- A simulation prototype system is developed for effective and correct assembly line balancing problem.
- Two-sided assembly lines with stochastic task times are considered for task time variation due to two-sided assembly lines with stochastic task times.
- New genetic algorithm is proposed to find the optimum solutions within a limited number of iterations.
- A bi-criteria nonlinear integer programming model is developed for minimizing the cycle time and minimizing the machine total costs.
- Simulation tools such as Fact- Model, to modeling the production line and the works estimated are used to reduce the line unbalancing causes and relocate the workforce associated to idle time, eliminating the bottleneck and improving the productivity.
- Parallel assembly lines provide some opportunities in improving increasing system flexibility, reducing failure sensitivity, improving system balance and productivity when the capacity of production system is insufficient.
- Bounded Dynamic Programming is adopted to solve the Time and Space constrained Assembly Line Balancing Problem variant with fixed cycle time and area availability.
- Priority-Based Genetic Algorithm is used for tackling of the mixed-model U-shape assembly line balancing/model sequencing problems with parallel workstations.
- New criterion of posture diversity is defined which assigned workers encounter the opportunities of changing their body postures regularly.
- Bees algorithm and artificial bee colony algorithm is applied to the fully constrained two-sided assembly line balancing problem so as to minimize the number of workstations and to obtain a balanced line.
- Genetic algorithm and iterative first-fit rule are used to solve the problem and experiments shows finding the best position over many workstations and the genetic algorithm provided more flexible task assignment.

VI. Conclusion

From the study of assembly line balancing it is found that assembly lines are flow-line production systems, where a series of workstations, on which interchangeable parts are added to a product. The product is moved from one workstation to other through the line, and is complete when it leaves the last workstation. Ultimately, we have to work for assigning the workstations so that predetermined goal is achieved. This can be done by minimization of the number of workstations and maximization of the production rate as studied in the literature survey.

It has been also observed that equipment costs, cycle time, the correlation between task times and equipment costs and the flexibility ratio needs a great attention.

- A heuristic procedure for solving larger size of problems can be designed.
- Paralleling of workstations and tasks may be studied to improve the line efficiency.
- To select a single equipment to perform each task from a specified equipment set.
- Bee and ant colony algorithm to be adopted for finding number of workstations.

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	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
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References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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