CHAPTER-2

CHAPTER 2

LITERATURE REVIEW

2.1 EVOLUTION OF PERFORMANCE MEASURES IN INDUSTRIES

The basic ideas behind the need for performance measurement have remained the same over time; however, the systems for achieving a well-functioning performance measuring process have been under continuous change. At first, organizations often concentrated only on financial measures, which left operations unsuccessful. In later years especially after implementing the more holistic supply chain thinking, internal processes, customers, and innovations started to get more attention. Today, there are also different dimensions of the performance measurement, whereas in the 1980s, the focus was only on the "three Es," i.e., efficiency, effectiveness, and economy. During the last three decades, attention has shifted to quality and customer satisfaction (Klages, 1994). Performance Measurement (PM) provides vital information for advancing societal innovation: the process of developing, testing, and honing new and potentially transformative approaches to active social issues. With the right performance metrics, data, and analysis in hand, social innovators, non-profit organizations, government agencies, and businesses that present innovative, results-driven solutions to social inconveniences can make well-informed management decisions to drive continuous enhancement and long-term social impact. The researchers also considered the successes and failures contributing to each performance measurement system (PMS) and explored the factors influencing the performance measurement system (PMS). Several of the key factors included organization strategy, organization formation and environmental uncertainty that played an important role in the efficient and effective process of the organization. Taking into consideration, these factors when developing the performance measurement system is critical for the organization, and the significance of these factors is well documented in the literature. These elements are necessary in order to develop an effective performance measurement system and also to reflect the unique dynamics of the business environment.

An organization's performance is considered as a multidimensional umbrella that includes all aspects related to that organization's success and activities. It includes efficiency, effectiveness, quality, productivity, innovations, and profitability (Sink, 1985). Performance can be of any field. By measuring it, one can compare it with the latest benchmarked value in that particular field and accordingly improvement in the performance can be suggested. Effective Performance Measures are ***SMART*** which is **S**pecific, **M**easurable, **A**ccountable, **R**esults-oriented, and **T**ime-bound. Edson (1988) and Talley (1991) suggested that Performance Measurement System (PMS) is very necessary for continuous improvement. Bourne et al. (2000) suggest measurement systems should be reviewed and revised at a number of different levels. Evans (2004) highlights the maturity of the PMSs, better approaches to analyze performance results and sophisticated statistical techniques that correlate with a higher level of performance. In the construction field, performance measurement focuses on project performance in terms of time, cost, and quality (Ward et al., 1991). Dziekonski et al. (2018) examine the practice of performance measurement (PM) of the construction industry in Egypt. They recognized that the time of project delivery, clients' satisfaction, quality of work, and profitability are the key performance indicators (KPIs) while measuring the performance of the construction companies in Egypt. In today’s competitive markets, traditional finance-based measurements are most inappropriate and irrelevant and worst positively harmful. The study of Gomes, 2004; Tanden, 2004; Parida, 2006 have focuses on performance measurement other than financial measurements and have criticized the limitations of the traditional finance-based measurements. Chou et al. (2001); Simoes et al. (2010); Li et al. (2014); Talley et al. (2015) have highlighted the importance of evaluation of performance in ports and have discussed different tools, performance measures and indicators being used in this context. Keskin et al. (2019) have studied and analyzed the efficiency of airports and have compared the efficiency scores of privately and publicly operated airports in Turkey. They have used the analytical hieratical process (AHP) and data envelopment analysis (DEA) in their study and found that the airports operated by the private sector were more efficient than the airports operated by the public sector airports. Pathak et al. (2019) developed a framework for evaluating the performance of sustainable freight transportation systems. For developing this framework, they have integrated a Delphi study to search experts' opinions from academia as well as industry, Total interpretive structural modeling (TISM), and Fuzzy analytical hierarchy process (FAHP). Kabir et al. (2018) developed a Bayesian belief network (BNN) model to evaluate the performance of employees in the industrial and commercial organizations. According to Linna et al. (2010), performance measurement in welfare services highlights the need to develop more comprehensive measurement systems that include aspects of quality and long-term effectiveness. Srimai et al. (2010) have studied the evolutionary change of performance measurement and concluded that it took place in four significant aspects: from measurement to management, static to dynamic, operations to strategic and economic profit to stakeholder focus. The work of Elg M. et al. (2012) recommended methods for the improvement of performance in healthcare practices.

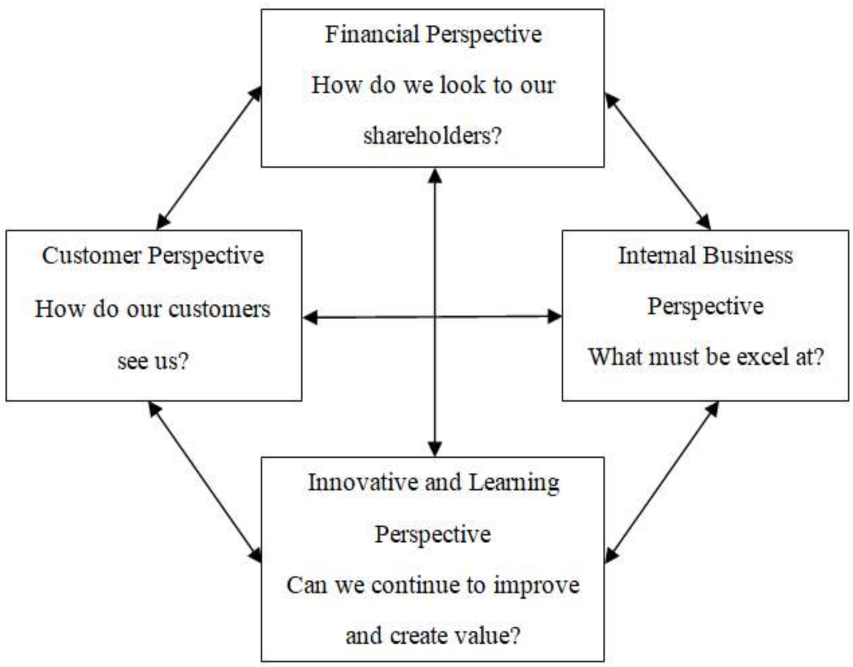
A couple of researchers have studied the evolution of performance measurement. The literature on performance evaluation also includes relevant studies dealing with efficiency, using the data envelopment analysis technique and attempting to identify relationships among multiple inputs and outputs (Langenus M & Dooms M, 2015). Examples of these studies include works by Al-Eraqi et al. (2010); Bergantino et al. (2013); Birgun and Akten (2005); Lin and Tseng (2007); Simoes and Marques (2010); Talley et al. (2015); Wu, Liang and Song (2010); and Wu, Yan and Liu (2010). Hernandez-Espallardo et al. (2011) and Carneiro et al. (2013) had carried out an empirical study in Portugal in 2012 and developed a framework based on five components and suggested a list of favorable conditions for good performance. Conditions are associated with resources of network classified in financial capital, social capital, human capital, management and organization, infrastructure and technological platform. A model based on performance analysis in the business network was proposed by Pekkola et al. (2013). It depends on the measurement of the maturity level of knowledge in three key areas, such as organization, human resources, and technology. Sainaghi et al. (2017) have studied the performance measurement in the hospitality and tourism industry and observed the following six characteristics namely,: (i) hefty capital investment, (ii) the complexity of service business, (iii) the customer being part of the service and production process, (iv) intangibility, (v) the importance of location or labor factors, and (vi) high vulnerability to the external environment, and their influence on the performance. Bititci et al. (2012) reviewed the literature on performance measurement and management and identified four visible phases of development in the techniques for measurement and management of performance. Development in the period extending from early 1900 to 1940 is considered as the stage of 'Productivity Management'. The second stage (from 1940-1980) was identified as 'Budgetary Control'. In the subsequent phase, between 1980 and 2000, strategic planning management practices and unpredictable surprises has been incorporated in the PM and is the period of 'Integrated Performance Measurement System.' The current development period starting from 2000 is termed as 'Integrated Performance Management.' Abhijeet et al. (2013) developed the concept of green PM by organizing a construct of 12 sets of components, namely knowledge management, top management commitment, green product and process design, employ training, employ empowerment, environment, suppliers and management, health and safety, production planning and control, cost, quality, customer environment performance requirements and customer responsiveness and company growth. Purbey et al. (2006) proposed a framework for measuring performance in healthcare processes. Their framework measures the performance from interrelated parameters such as efficiency, effectiveness, and flexibility. The study on PM of maintenance service in public health service was done by Hammerschmidt et al. (2012) with the following objectives: (i) to identify the best performers in a given service function (ii) to improve the abilities of poor performers. Melnyk et al. (2014) suggested that the Performance Evaluation System (PES) of any field should be made up of two components, i.e., performance measurement and performance management. Choong (2014) and Micheli and Mari (2014) have concluded that regardless of the continuous development in the performance measurement field, it suffers from solid underpinning theories and needs for identification of necessary and sufficient conditions that characterize the performance measurement systems. For measuring the performance in the health care sector, Gonzalez et al. (2017) have done empirical research which provided case study evidence on the Balanced Scorecard's adoption in health care. Lukman et al. (2018) has proposed a tool referred as S-Score for measuring the research performance of researchers, institutions and journals in the Indonesia. The S-Score results are ranging from S1 to S6. S1 has accredited as 85 or indexed in Scopus and S6 as (31-40) or low indexed journal. Tsarouhas (2018) has proposed the study for improving the operation of the croissant production line through OEE to find out the maintenance improvement potentials. The research is performed with the analysis of failure and repair data of the line. It helped the company to identify the problems related to the components of OEE. Anastasios et al. (2019) had studied about the factors which affect employee performance, and they found that job environment and management support have the strongest impact on job performance in the business sector. The drawback of this research was that it was not focused only on one business sector i.e., sample data is heterogeneous.

In the present scenario of business, everyone is measuring performance. A manager measures the performance of his subordinates. Congress, state legislatures, and the city councils are insisting that executive-branch agencies periodically report measures of the performance. Stakeholder organizations want performance measures so that they can hold the government accountable. From a practical standpoint, performance measurement (PM) is a process whereby the drivers and results of key activities surrounded by a broadcaster are measured using different types of information.

Performance measures can be used for several purposes. Moreover, different people have different purposes. Legislators have different purposes than journalists. Stakeholders have different purposes than public managers.

2.1.1 Purpose based Performance Measurement

The most important purpose of performance measurement (PM) is to convey reliable information to support decision-making. In the field of performance measurement, mainly the strategic purposes have been under focus. Usually, strategic performance measurement refers to the monitoring of companies' long-range plans and success. Though, quite often, companies have applied PM on lower levels of the organization, such as departments, units, teams, and even individuals. These measures often function close to the employees having behaviorist impacts as well. The manufacturers in Canada are still using financial performance measures, and that few had implemented modern approaches such as Balanced Scorecard (BSC) and Integrated Performance Measurement Systems (Gosselin, 2005). Volmohammadi et al. (2015) have applied Balanced Scorecard in the petrochemical company and presented a holistic approach to evaluating knowledge management practices on organizational performance. Biazzo et al. (2012) suggested that successful implementation of a performance measurement system (PMS) such as BSC in small and medium-sized enterprises (SMEs) requires the dedication of project leader who will ensure that the right metrics are adopted to the SME's peculiar business needs and operating environment. Chorfi et al. (2018) introduced a framework based on BSC and supply chain operations reference (SCOR) model for managing public healthcare supply chains. This model includes a set of key performance indicators (KPIs) to evaluate the supply chain quality by the satisfaction of internal and external stakeholders and by examining the quality of the service provided. Giovannoni and Maraghini (2013) have developed an integrated performance measurement system that reflected the organization's strategy in a comprehensive way. Bititci et al. (2004) found that the organizational culture, management styles, and performance measurement are related to each other and companies need an organizational culture that focuses on continuous improvement and strategic performance measurement. The history of performance measurement in the business sector can be traced back to its introduction in industrial production in the 19th century under the perception of the efficiency measurement. In the year 1992, Kaplan's and Norton's research on multidimensional performance measurement was published. They introduced The Balanced Scorecard (Figure 2.1), which not only includes financial measures but also measures on an operational level. The Balanced Scorecard is just a lone of the many performance measurement frameworks in the business world.



Source: Adopted from Kaplan and Norton (1992)

Figure 2.1 Balanced Scorecard Method

Traditionally, quality was also used as a measure for the measurement of performance. Initially, it was defined as the conformance to specification, but now it has been shifted towards customer satisfaction. According to Feigenbaum (1961), the true cost of quality is a function of failure cost, appraisal, and prevention. Many times, performance measurements are based on the following six criteria:

i. customer orientation;

ii. health, environment, and safety;

iii. working methods;

iv. process measures;

v. competence development;

vi. solving day to day problems

2.1.2 Components of Performance Measurement

Any system comprises of three components, such as man, material, and machine. By measuring the performance of all of these components, we can easily measure the performance of the system. In general, the metrics of individual human performance can be divided into five broad categories: perception, physical performance, operational skills, task performance, and cognitive performance (James et al., 2003). Performance in these broad categories can be affected or moderated by adverse conditions and by psychological factors such as the state of arousal (e.g., fear, fatigue), injury, and motivation. A common approach to assessing human performance is to measure a critical task-relevant aspect of performance, such as manual dexterity in small arms assembly or visual acuity in target identification.

2.1.2.1Measurement of Human Performance

The performance of a man working in the different field can be evaluated by using different metrics. The performance of an employee is measured through the metrics of punctuality, quality of work, observe personal habits, check their attitude, review personal presentation, carry out a client survey and carry out random checks.

Similarly, if in a toy factory, a worker might produce a hundred toys per day, but the majority of those toys are defective and unsellable, in this case, that worker's efficiency level is low, and work, time and material are being wasted. Seeing another aspect, suppose in a hospital, a doctor is doing a treatment of 20 patients, but 10 of them were found dead at the end of the day. Then, his (doctor's) efficiency is very poor, and hence performance is very low (James et al., 2003).

2.1.2.2 Measurement of Material Performance

The second component of any system is material. The measurement of the performance of the material is not a simple job. By seeing the different properties of materials, one can predict the performance of the material with previous experiences such as Density, Stiffness, Strength, Toughness, Hardness, Ductility, Impact Resistance, Thermal conductivity, Electrical conductivity, and Environmental resistance. The performance of material will vary under different situations, different conditions, and also in different places as well as a way of using it (James et al., 2003).

2.1.2.3Measurement of Machine Performance

The third component of the system is machine. The performance of various machines can be measured by different methods. For example, if one measures the performance of a computer, the computer performance metrics include availability, service time, bandwidth, relative efficiency, response time, channel capacity, latency, performance per watt, compression ratio, speed up, processing speed, and power consumption. Similarly, if one measures the performance of an engine, then he will consider the efficiency of the engine. Traditionally, equipment performance was expressed initially in terms of availability, reliability, and maintainability. Nakajima (1988) introduced the concept of Overall Equipment Effectiveness (OEE) as a performance metric of the product of the availability, performance, and quality of the equipment of the manufacturing industry. The exact definition of OEE differs between the applications and researchers.

2.2 PROGRESSIVE EVOLUTION OF OEE AND ITS IMPROVEMENT

The continuous improvement of performance metrics has led to the modification of the OEE tool to widen its fit to a much broader perspective in the manufacturing systems. Since, last two decades, researchers and practitioners have modified OEE in many ways to be practiced and followed in industries. With the advancement in research, definitions of OEE have been modified and formulations have been changed for its practical application. Some formulations like, Production Equipment Effectiveness (PEE) and Total Equipment Effectiveness Performance (TEEP) are still at the equipment level, while others Overall asset effectiveness (OAE), Overall production effectiveness (OPE), and Overall factory effectiveness (OFE) are extended to the factory level. Invancic (1998) modified OEE to incorporate the equipment and schedule losses and termed it as Total Equipment Effectiveness Performance (TEEP). TEEP describes the total performance of equipment when the equipment was productive and quantifies against the calendar time. TEEP is expressed as (Invancic, 1998)

$$TEEP = Availability \times Performance \times Quality \times Utilization \ldots\ldots \quad (2.1)$$

Where, first three factors reflect equipment losses and the fourth one consider schedule losses.

Raouf (1994) proposed a performance metric based on OEE named as Production Equipment Effectiveness (PEE) and suggested that in the components of OEE, there should be different weights while in the original OEE formulation, Nakajima had given equal weights to all the three components. Accordingly, Raouf (1994) expresses Production Equipment Effectiveness (PEE) as

$$PEE = A^{k}{}_{1} \times P^{k}{}_{2} \times Q^{k}{}_{3} \ldots\ldots \quad (2.2)$$

Where A= Availability, P=Performance, Q=Quality

k_i is the weights of the PEE elements (for i= 1 to 3), $0 < k_i \leq 1$ and $\sum k_i = 1$

At factory level, one can define different metrics of performance measurement such as Overall Factory Effectiveness (OFE), Overall Asset Effectiveness (OAE), and Overall Production Effectiveness (OPE). Among these three metrics, OFE is widespread and well recognized in the literature (Oechsner, 2003).

Badiger (2008) added a new factor called Usability in the existing method of OEE evaluation. This factor classified the unplanned downtime events into the equipment related downtime. The inclusion of the above factor leads a better categorization of equipment losses. In this categorization, the stop times are divided into two different groups such as planned and unplanned stop times. Hence, according to Badiger (2008),

$$Modified\ OEE = A \times U \times P \times Q \ldots\ldots (2.3)$$

Where, U =Usability

$$Usability = \frac{Running\ Time}{Operating\ Time}$$

Running time= [operating time – (operational stop time + induced stop time)]

Overall Asset Effectiveness (OAE) and Overall Production Effectiveness (OPE) metrics are rarely practiced. However, these metrics are implemented in industries under different formulations. They involve the practical approach to fit the specific requirement of the industries.

On the basis of OEE metrics, Huang et al. (2003) proposed a simulation analysis in studying the dynamic performance of a manufacturing system to define the Overall Throughput Effectiveness (OTE). Accordingly, OTE is given as (Huang et al., 2003)

$$OTE = \frac{\text{Good Product Output(units) from Factory } (Pg(F))}{\text{Theoretical Attainable Product Output(units) from Factory in Total Time } (Pth(F))}$$

Their experimental results show that the proposed approach is very effective to increase productivity. Also, the OTE can be used for benchmarking and comparison of the productivity of different factories. Braglia M. et al. (2009) proposed the model for calculating OEE of a manufacturing line and applied it to the automated line for the engine basement manufacturing line. It provides information to the practitioners to highlight where the critical inefficiencies take place. Gharfalkar et al. (2018) has proposed an indicator for measuring the resource efficiency and resource effectiveness for the manufacturing units. This indicator is named as Operational Resource Effectiveness (ORE_{ft}) which can be calculated by multiplying the efficiency or effectiveness of various elements of "resource use" with the efficiency or effectiveness of various elements of "waste generation." The main drawback of ORE_{ft} is its restricted use in manufacturing sectors only. Sari et al. (2019) have proposed methodologies for measuring Fuzzy Overall Equipment Effectiveness and line performance measurement using an artificial neural network (ANNs). These methodologies are used to improve the OEE and Overall line effectiveness (OLE) weaknesses based on intelligent systems and techniques such as Fuzzy Interference Systems (FIS) and ANNs. Table 2.1 presents evolution and modification of OEE with time and field of application.

Table 2.1 Chronological evolution of OEE

Metric	Applied for
OEE (Nakajima,1988)	First coined the concept and applied in manufacturing industries
PEE (Raouf,1994)	Uses the effects of the parameter on the elements of OEE and proposed weights for elements of OEE
TEEP (Ivancic,1998)	Considers the effect of maintenance and applied to the whole processing plant as a single entity
OFE (Scott et al., 1998)	Gives the effectiveness of the whole factory rather than a single equipment
OTE (Huang et al., 2003)	Uses to calculate the OEE of a manufacturing line
OAE (Muchiri et al., 2008)	To consider losses on the overall production process
Modified OEE (Badiger et al., 2008)	Added a new factor called Usability in the existing method of OEE evaluation
OWEE (Wudhikarn, 2010)	Gives a weighted approach as OEE does not prioritize the problematic equipment.

Different key performance indicators (KPIs) are used in mines to express the performance of heavy earth moving machinery, like dump truck. According to Osanloo (1995), Barabady (2007) and Dhillon (2008); availability and utilization are the key factors which directly affect the production in the mines. Hence, mining companies should be very careful for achieving and maintaining a high level of availability and utilization of the heavy earth moving equipment. The availability of equipment is directly related to its reliability. Commonly used KPIs for mining equipment are:

Reliability: Reliability describes the ability of a system or component to function under stated conditions for a specified period of time. A test will be reliable when it gives the same repeated result under the same conditions.

The most acceptable definition of availability is that

Availability of a machine is defined as the ability to perform a given task under given conditions for a given interval of times keeping in mind that all the required external resources are provided [ISO, 2006].

Ebeling, 1997 defined availability as the probability that a system or component is performing its required function at a given point in time or over a stated period of time when operated and maintained in a prescribed manner.

The percentage of time an equipment is available to perform its designed functions is a measure of its availability. Availability can be calculated as:

$$Availability = \frac{Available\ \ Time\,(AT)}{Total\ \ Time\,(TT)} = \frac{TT-(MNT+BDT)}{TT} \qquad \ldots\ldots\ldots (2.4)$$

Where, TT is total time, MNT is maintenance time and BDT is breakdown time of the dump trucks.

Availability classification: There are different classifications of availability given as below

I. Instantaneous (or point) availability
II. Mean availability
III. Operational availability
IV. Achieved availability
V. Inherent availability

I. ***Instantaneous Availability*:** This type of availability shows the probability of equipment working at a particular time, t.

II. ***Mean Availability*:** The mean availability is the proportion of time during a mission or time period that the system is available for use.

III. ***Operational Availability*:** It is properly explained by Mirabediny, 1998; Zoltan, 1999; Jeong & Phillips, 2001; Bhadury & Basu, 2003; Rai et al., 2011 and Mohammadi et al., 2013. It can be represented by the total number of hours "within a period" that machinery is fit for work.

IV. ***Achieved Availability*,** as seen by the maintenance department, (includes both corrective and preventive maintenance but does not include supply delays and administrative delays) is defined as:

$$A_a = MTBM/(MTBM + MAMT)$$

Where MTBM is mean time between corrective and preventive maintenance actions and MAMT is the mean active maintenance time.

V. ***Inherent availability***

It is associated with the in-built characteristic of the equipments and its parts. It is generally related to the design of the equipment due to which it ignores the downtimes while calculating it (Kumar, 1989; Sutton, 1992; Ebeling, 2000 and Bhadury & Basu, 2003).

Mathematically, $$A_i = MTTF/(MTTF+MTTR)$$

Where, A_i is inherent availability

MTTF is the mean time to failure and

MTTR is mean time to repair

Dhillon & Singh (1981) and Dhillon (2008) have explained that inherent availability is a factor of reliability parameter (how often a unit fails) and maintainability parameter (how fast the unit can be restored after failure).

A significant amount of research related to Reliability, Availability and Maintainability (RAM) of the mining equipment have already been carried out with the aim of improving the inherent availability.

Maintainability

It can be defined as the probability of performing a given maintenance task with a given period of time (Ebeling, 1997).

Maintainability generally depends on the design characteristic of the machine which set the procedures of maintenance.

It is often expressed as

$$M(t) = 1\text{-}\exp(-t/MTTR)$$

Where, MTTR is mean time to repair

Utilization

Utilization of equipment can be defined as the time which is utilized in the available hours. It can be expressed as (Lanke, 2014)

$$U = \frac{UT}{AT} = \frac{TT - (MNT + BDT + IT)}{TT - (MNT + BDT)} \quad \text{........ (2.5)}$$

TT is total time, MNT is maintenance time, BDT is breakdown time and IT is idle time.

While studying the environmental impact of dump trucks it was observed that the Overburden removal of a surface coal mine is energy-intensive process due to high consumption of energy (electricity and diesel). Release of greenhouse gases (GHGs) and particulate matters (PMs) from a number of sources are the main pollutant in surface mining activities that foster climate change and deteriorate ambient air quality (Ghose and Majee, 2000). Shovel – dump truck system provides higher degree of flexibility in operation, but the main disadvantage of this system is that it consumes high energy per unit volume (Darling, 2011). The fleet of dump trucks consumes approximately 70-80% of total diesel consumption in a surface coal mine operating with shovel-dump truck system for transporting large quantity of OB over long-haul network on unpaved roads. Da Silva et al. (2018) have reported that the rising diesel oil consumption is one of the most influential parameters of life cycle emission of mining processes. Mining sector consumes approximately 50 % of the diesel consumed by industrial sector in India. Zhang, Cai, Chen (2013) reported that transport cost in a surface mine with shovel-dump truck accounts for 1/3 or more of the total operating costs. Unit mining operations such as blasting, loading, transport, and unloading of material produce GHGs and PMs which are harmful to human health and the environment (Lal and Tripathy, 2012; Heal et al., 2012; Şengul et al., 2016). The mining industry had not paid adequate attention to assess the impacts of various classes of equipment systems of surface mining on the environment.

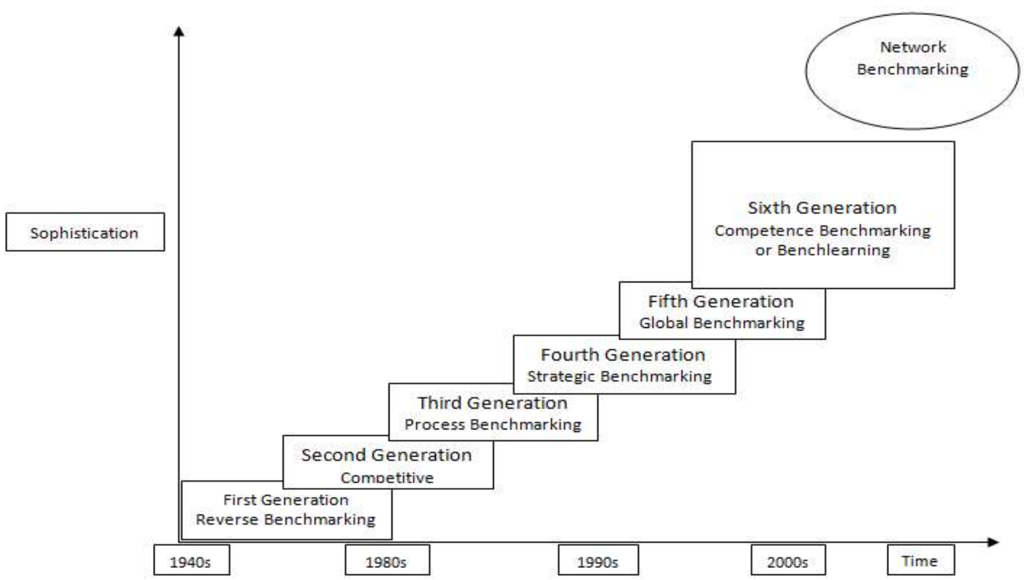
Emission of particulate matter is associated with various mining operations like excavations, construction of haul road and approach roads, drilling and blasting and transportation of minerals. Dust emissions are of great concern related to air quality surrounding mines. Air-blown particles from the stockpile of excavated material also raise the content of particulate matter in the air. Gaseous pollutants like sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) are emitted from the Heavy Earth Moving Machineries (HEMM) like dump trucks and excavators (Lamare and Singh, 2016).

Koptev et al. (2017) studied that expanding the open-pit dump truck usage areas and the need to transport more and more minerals results in producing more and more powerful open-pit dump trucks, and this all is about environmental problems and potential health risks for the personnel. Harmful gas concentrations in working areas became threatening enough to have the work in some areas completely halted, until the contents of harmful substances in the air, as well as visibility on the roads, get back to normal.

Dubov et al. (2020) have studied the use of alternative fuel for heavy-duty dump trucks as a way to reduce the anthropogenic impact on the environment. The data are presented on the available experience of using environmental friendly (alternative) fuels for heavy-duty dump trucks: electric energy, liquefied petroleum gas (LPG), compressed natural gas (CNG), liquefied natural gas (LNG). The studies conducted show that liquefied natural gas (LNG), for a number of objective reasons, seems to be the most promising alternative to diesel of all possible fuels in the segment of heavy-duty haulage vehicles. It is said that in Russia, in the Kemerovo region, for the first time, within the framework of one group of companies, an integrated project for the production of liquefied natural gas and its consumption by BelAZ heavy-duty dump trucks was successfully implemented. All these study shows that the environmental degradation by all these vehicles cannot be neglected while measuring the performance of these vehicles. Hence, this study includes environmental factor while measuring the performance of mining dump trucks.

2.3 FIXING BENCHMARK LEVEL OF PERFORMANCE

True benefit from measurement of performances can be achieved when the values are standardized i.e., benchmark values are fixed. Experts differ in the purpose and objective of benchmarking. Popular definitions of benchmarking give different insights. Vermeulen (2003) indicated that benchmarking is the process of identifying, understanding, and adapting best practices from within the company or other businesses to help in getting better performance. Being a relatively new management tool and technique, the benchmarking has been defined and understood in different ways. The widely used definition of benchmarking implemented by the Xerox Corporation and identified by Camp (1989) and McGaughey et al. (2005) is that benchmarking is the continuous process of measuring products, services, and practices against the companies those are accepted as industry leaders. Benchmarking cannot be performed once and ignored thereafter, in the faith that the task is finished. It must be a continuous process as industry practices constantly modify and industry leaders constantly get stronger (Chen, 2002). Also, benchmarking is viewed as a continuous process used to measure performance gaps, to establish where 'best practices' are and to initiate change capable of closing recognized gaps (Rohlfer, 2004). It adds an outer perspective to a total quality management system (TQM). Benchmarking ensures that the circle of continuous process improvement is turning in the direction of achieving higher standards of competitiveness. Numerous companies have adopted benchmarking as part of a Total Quality Management (TQM) approach (Wynn-Williams, 2005). Performance benchmarking inherits from Total Quality Management (TQM), a binding dedication to continuous improvement and monitoring. Moreover, the best practice does not remain constant; it changes over time as does an organization's own performance. Subsequently, the benchmarking needs revising to replicate internal changes and the changing competitive landscape (McGaughey et al., 2005). Benchmarking requires continuous learning to increase the full benefits of the benchmarking exercise (Codling, 1998). The more benchmarking is practiced, the more it can be useful to the next time. The decisive aim is the company in which benchmarking is just another facet of the culture, conducted with all at all levels. According to Dertouzos et al. (1989) and Hines (1998), the benchmarking seeks to build competitive capabilities in terms of technology, productivity, quality, and delivery to use against competitors. Benchmarking is a helpful tool for the empirical justification of enhanced operational and business performance outcomes in both domestic as well as global businesses (Voss et al., 1997; Luria and Wiarda, 1996; Lefebvre and Lefebvre, 1998). It is used to get better performance by considering the methods and practices essential to attain world-class performance levels. The most important objective of benchmarking is to understand those practices that will provide a competitive advantage; the target setting is secondary (Camp, 1995). Figure 2.2 shows the change of the focus of benchmarking with time.



Source: Watson (1993)

Figure 2.2 Growth of benchmarking as a quality improvement tool

2.3.1 Concept of Benchmarking

Targeting the best practices of the industry is considered as one of the tools of Total Quality Management (TQM). The use of this tool is extremely important because firms need to measure their functions against the best global practices. Benchmarking helps a company to compare its products, prices, policies, programs, or strategies to those of the best companies in the industry. It can be internal, comparing one department to another and external which would necessitate an organized benchmarking function. For an organization to maintain performance benchmarking, the function should be an organized and documented function completed on a perpetual basis. Thus, the aim of benchmarking is to build the most excellent in class target for the company, based on the information from both internal as well as external sources. The secret to benchmarking technique is "borrow – adopt – refine" the best attributes for continuous growth and development. According to Camp (1989), Learning by borrowing from the best and adapting their approaches to fit your own needs is the essence of benchmarking. The theme of the benchmarking concept is illustrated in Figure 2.3.

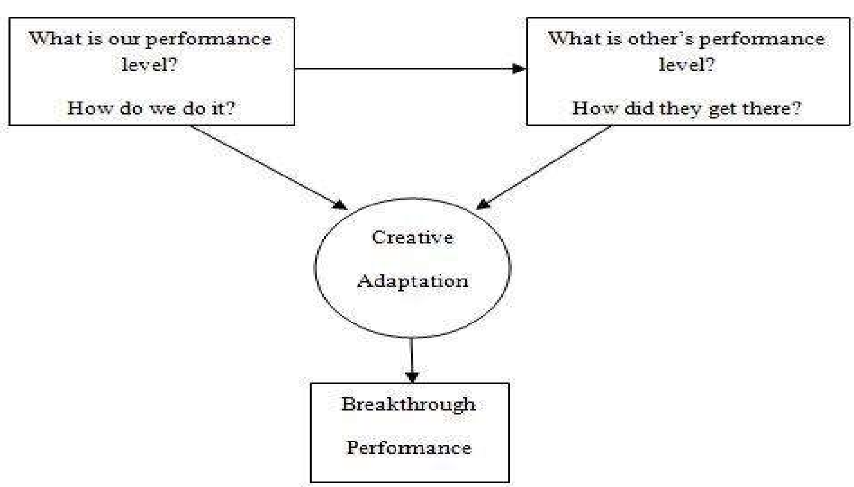


Figure 2.3 Concept of performance benchmarking

A benchmark is a point of reference against which things are measured for determining the status. In business, these points of reference can measure by questions about the product or service, e.g., how many, how much money, how much time by studying other industries and comparing the answers to these questions, we can compare our performance against others. As a result, an organization will be able to set new goals and adapt the best practices to their organization. This helps them to assure their customers with the best quality, cost, product, and services. Benchmarking has broad application in problem-solving, process improvement, innovation, re-engineering, strategy setting, planning, goal setting, and in other contexts also. Quite simply, benchmarking is an elementary business skill that supports quality excellence. Benchmarking can help in developing realistic goals, strategic targets, and facilities for achieving excellence in operation and maintenance (Almdal, 1994). Benchmarking is a well-planned and organized process with clear objectives and mechanisms to measure, compare and discover innovative ideas, assess if these suit or adopt practices and implement improvement. Benchmarking provides a proper exchange of information within an objective structure and timeline and focuses on learning (Meade, 1998). According to (Learning and Teaching Unit, 2012), comparisons may be made against individual benchmarking partners or groups, sets of accepted standards, or data from past performance. Benchmarking has also been widely used and commonly accepted business practice for many companies (Yaisn, 2002). It has also evolved into total quality management (TQM) and a powerful tool for performance analysis (Kirby, 2005). Finnigan (1996) names the key process steps in benchmarking as establishing the study plan, conducting the study, analysis of data, internalizing results and the closing gap with the competition, which includes integrating action and implementing plans and monitoring progress. Elnathan, Lin and Young (1996) had defined benchmarking as the process by which an organization targets key areas of improvement, studies the best practices of others, and implements processes and systems to improve its own performance. According to Edith Cowan University (2011), benchmarking is a continuous and systematic process of comparing products, services, processes and outcomes with other organizations or exemplars for the purpose of improving outcomes by identifying, adapting and implementing best practice approaches. Benchmarking is different to using quality assurance models, as quality assurance models normally focus on the least suitable standards and conformity and they are regularly imposed by management or external inspection requirements (Henderson-Smart, 2006). One of the most significant benefits of benchmarking is the discovery of innovative approaches and ideas. According to Meade, 1998; benchmarking highlights problem areas along with the potential for enhancement, providing inspiration to modify, and assists in setting targets and formulating policies and strategies. As a result of benchmarking, university leaders would know how their institution rates in definite areas in comparison with other ones, ascertain their competitive position relative to others, and also reveal the ways of enhancing their standard (McKinnon et al., 2000). Benchmarking can make sure that plans are being carried out and exhibit areas of merit to stakeholders (Wilson and Pitman, 2000). Elnathan, Lin, and Young (1996) define two dimensions for benchmarking classifications: information gathering methods and information sharing methods. Denrell (2005) points out the limitation of benchmarking execution, i.e., selection bias. Selection bias means "relying on samples that are not representative of the entire population." If companies consider only successful companies for comparison, they will not have a total picture of success through the implementation of remedial measures for failures.

2.3.2 Use of Benchmarking in Industries

Benchmarking is not a new tool; it is just a new name for the concept that existed prior in the public sector. Governmental entities were forced to execute a concept related to benchmarking in the 1970s, long before it was widely used in the private sector. Public companies had to benchmark themselves against similar organizations to show responsibility for the use of resources to the governmental authorities (Bowerman et al., 2001). The term relative performance evaluation is another name to what is known today as benchmarking (Dopuch and Gupta, 1997). Benchmarking technique is used not only in economics and business organization but also in information technology, insurance, financial management, facilities management, human resources, utilities and education (Alstete, 2008). Azhar and Omar (2008) added that benchmarking is mainly useful in industries where cost effectiveness is important, and competition is strong. Benchmarking has been mostly applied in finance and accounting functions, including planning and budgeting, financial analysis, billing, accounts receivable, accounting systems development, credit collections, and internal auditing. Companies can compare practices, functions, activities, products or performance against a benchmark (Azhar and Omar, 2008). Comparing amongst firms, Xerox is regarded as the pioneer in the USA to have used benchmarking as a business practice. Ahren and Parida (2009) have used benchmarking data for the railway infrastructure and noted that benchmarking is an efficient tool that can support the management towards continuous enhancement. Benchmarking has been widely used by various industries worldwide, both for domestic as well as global businesses.

2.3.3 Benchmarking Practices in Various Countries

In the early 1990s, 65% of the Fortune 1000 organizations used benchmarking as a management tool to gain competitive advantage (Foster, 1992). In France, benchmarking was so popular that 55 percent of the French 1000 companies used benchmarking frequently and 80 percent of them regarded it as a successful tool of change (Maire et al., 2005). Ball et al. (2000); Kim et al. (2008); Graham (2005); Jarrar and Zairi (2001), reported that benchmarking was embraced by firms cutting across different industries including education, manufacturing, healthcare sector, banking, financial services, construction, insurance and government along with other sectors as a competative tool. Research on performance measures has found that several companies rely on choosing the benchmarking performance measures that are linked with an organizational plan (Meybodi, 2009). The application of strategic tools by management to achieve competitiveness is forever aligned towards the organizational objectives and goals. According to Rigby (2001), more than 70 percent of company managers globally used the following four types of management tools: strategic planning, mission and vision statements, benchmarking and customer satisfaction measurement. Consultants, practitioner journals, statutory and professional bodies suggest benchmarking as an explicit requirement for betterment of several organizations. However, there are facts that in some situations, the costs may outweigh the profits. The exercise of benchmarking was not limited only to the western world. Japanese firms used benchmarking broadly as a planned tool to catch up with the world's best firm (Ohinata, 1994).

Benchmarking is completely consistent with 'kaizen' (Imai, 1986), constant performance improvement through process orientation and now adopted quite widely in the UK manufacturing sectors. One should keep in mind that benchmarking or analogous approaches were not an usual practice in all kinds of organizations. Thus, it is essential to separate out benchmarking from the myriad approaches to performance measurement (PM) and improvement which is really found in some form in the majority of UK organizations. As result of such a situation, some of the benchmarking practices, such as cost and quality control, sales maximization and market share (Salem, 2005), which have been adopted by companies in one country, may not be easily prescribed to companies operating in difffernt environment.

According to Brewer (2003) of the Cooperative Centre for Construction Innovation, benchmarking is more than measuring performance. Its purpose is to improve performance by comparing different organizations to identify relative strengths and weaknesses. By systematically comparing the processes used by different organizations, benchmarking helps each organization involved in a benchmarking study to identify ways of improving performance. However, benchmarking is often dependent on the individual or organization carrying out the process. This is because the benchmarking process tries to realize what is already done and to obtain objective evidence or information about the level of performance a company should be pursuing. The final goal is to develop an action plan to close the gap between the poor and strong performers. The benchmarking process has to be externally focused, measurement based, information intensive, objective and action gathering. A study of benchmarking literature indicates that the key steps of benchmarking process are not considerably different from one another. A thorough self-analysis of benchmarking is very essential to enhance the advantages of it for comparing with other organizations (Epper, 1999).

2.3.4 Different models of benchmarking

According to Elmuti and Kathawala (1997), the benchmarking process should present the basic framework for action, with flexibility for adjustment to meet individual needs. The model chosen by the organization should be clear and basic, emphasizing logical planning and organization and establishing a protocol of behavior and outcomes. The purpose of the benchmarking process models is to describe the steps that should be carried out while performing benchmarking. Although the core of different benchmarking approaches is similar, most of the authors have tailored their methodology or models based on their own experience and practices (Partovi, 1994). According to Bhutta and Huq (1999), the benchmarking process may consist of many steps that vary in numbers; some companies have used up to 33 steps while others have used only four. Except for the pioneering ten-step benchmarking process of Xerox (Camp, 1989), other popular benchmarking models are Spendolini's (1992) five-step process, IBM five phase/14-step process (Eyrich, 1991) and many more to mention. Boxwell (1994) has suggested an eight-step benchmarking process, which has been used by Nath and Mrinalini (1995) to benchmark R&D Organizations. Sole and Bist (1995) has modified the Spendolini’s five-step process by adding one more step and emphasized that benchmarking assumes continual improvement as the goal of all corporations using the process and hence ensured that their model is circular. This model was used to benchmark the technical-writing departments producing sets of manuals for a product that runs on a diversity of operating systems. Similarly, Anderson and Moen (1999) have recognized 60 different existing models developed and planned by different researchers, consultants and experts from academic field and presented a new model – the benchmarking wheel. Deros et al. (2006) have reviewed some of the benchmarking frameworks and have classified the same into the following– academic/research-based models, consultant/expert-based models and organization-based models.

2.3.5 Phases of Benchmarking

Benchmarking has been divided into four different phases for easy understanding and implementation. These phases are further sub-divided. It is a structured step by step process model. Benchmarking should encourage to modify the process according to the needs and requirements. The four steps of benchmarking are Planning, Analysis, Integration and Action as depicted in Figure 2.4 with their sub-steps.

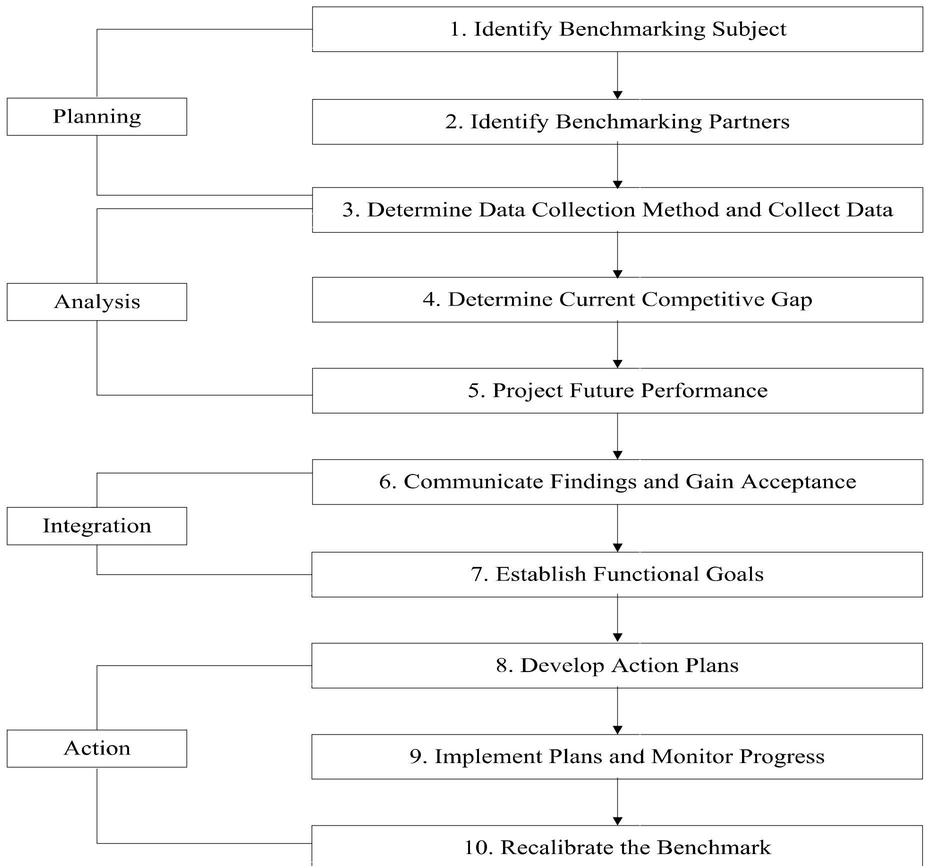


Figure 2.4 Phases of Benchmarking

Planning: Identify the product, service, or process to be benchmarked.

Analysis: Find out the gap between the firm's current performance and that of the benchmarked firms and explore the causes of significant gaps.

Integration: Establish goals and obtain the support of managers who must provide the resources for accomplishing the goals.

Action: Develop action plans and team assignment, implement the plans, monitor progress and recalibrate benchmark as improvements are made.

2.4 RESEARCH GAP AND MOTIVATION

After going through all the above literature, this research redefines the performance measure for dump trucks including the environmental impact aspect of dump truck operation. Both the internal and external losses occurring in the system and beyond the system are duly accounted in the modified performance measure and are useful for comparing, monitoring, and managing equipment and system performance. The proposed performance measure presents an approach that unites time performance, capacity performance, and environmental performance. This research also presents a methodology for categorizing performance level, thereby estimating a benchmark value that may be used for comparison against standard industry practices and devising apt corrective measures for performance improvement.