A comprehensive bibliography on effectiveness measurement of manufacturing systems

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ABSTRACT

Globalization has put fierce competition for manufacturing managers in terms of flexibility, smaller lead times, competitive costs, etc. To attain these capabilities, manufacturing managers are taking heedless decisions for investing in advanced manufacturing technologies, without measuring their actual effectiveness for their organisations. There is a need to measure the effectiveness of manufacturing systems to make better future policies and investment planning. This paper provides a comprehensive bibliography on the techniques and their rationale in the effectiveness measurement of advanced manufacturing systems. The paper cites 265 articles from a variety of published sources. The list contains published research mainly from 1990 to 2012 and a selected published work prior to 1990.

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1. Introduction

Measuring effectiveness of a manufacturing system is becoming an increasing concern for both academics and practitioners (Neely, et al., 2000; Neely A. D., 1998). Effectiveness of manufacturing system is defined as the production of desired output to meet customer requirements (Greshwin, Manufacturing Systems Engineering, 1994). Effectiveness is the ratio of actual output to the reference output. The starting point for making the measurement is to understand the difference between the efficient manufacturing system established by Western manufacturing companies and effective manufacturing systems introduced by Japanese car manufacturers (See Table 1) (Garside, 1999).

Observing the success of Japanese manufacturers, all manufacturing companies want to make their system effective by adopting new technologies like TQM, JIT, Lean Manufacturing, Automation in Manufacturing etc. These technologies although improves productivity substantially, yet due to their high input cost and complex implementation process, managers feel hesitant to adopt them. Moreover managers are afraid seeing the risk factor of investing huge amount of money without knowing the actual impact on output in their manufacturing environment.
Table 1
Comparison of efficient and effective manufacturing Systems

<table>
<thead>
<tr>
<th>Efficient</th>
<th>Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Plant</td>
<td>Flexible Automation</td>
</tr>
<tr>
<td>Functional Layout</td>
<td>Cells layout for material flow</td>
</tr>
<tr>
<td>Slow Changeovers</td>
<td>Rapid Changeovers</td>
</tr>
<tr>
<td>Batch size is large with long runs</td>
<td>Cost effective batch size</td>
</tr>
<tr>
<td>Maximizes machine utilization</td>
<td>Manufacture as per the need</td>
</tr>
<tr>
<td>Planned inventory buffers</td>
<td>Minimized inventory level</td>
</tr>
<tr>
<td>Long lead times</td>
<td>Shrunken lead time</td>
</tr>
<tr>
<td>Make to forecast</td>
<td>Make to order</td>
</tr>
<tr>
<td>Operations are difficult to handle</td>
<td>Manageable production</td>
</tr>
<tr>
<td>Overheads are high</td>
<td>Low overheads</td>
</tr>
<tr>
<td>High Production cost</td>
<td>Low Production cost</td>
</tr>
<tr>
<td>Customer concentrated</td>
<td>Reactive product readiness</td>
</tr>
<tr>
<td>Poor ownership of quality</td>
<td>Good ownership of quality</td>
</tr>
<tr>
<td>Poor schedule observance</td>
<td>Good schedule observance</td>
</tr>
</tbody>
</table>

The reasons for this is the inadequate effectiveness measurement models, which rationalise the decision making process and gives confidence to the managers by helping them to know what to invest, how to invest and where to invest. The famous quote in management is that “one which can’t measure cannot manage”. The process of deciding which measures of effectiveness for manufacturing system to adopt is a valuable one, not least because it pushes managers to be very specific about their priorities and the relationship among them, thereby identifying, and offering an opportunity to resolve, any hidden differences of opinion. The limitations of traditional measuring systems based on financial terms have been widely reported in the literature. The Measurement model should be simple, cognitive and objective. It should provide continuous improvement to the system. Widespread interest in this topic, however, is relatively recent. European Foundation for Quality Management's Business Excellence Model (see Fig. 1.) is an effectiveness measurement model. This consists of two distinct subsets of factors, broadly classified as enablers and results. In this, enablers are the levers that management can pull to deliver future results. One of the weaknesses of this, the terms used in this framework are so wide, that a number of models can be derived under each factor.

Fig. 1. European Foundation for Quality Management's Business Excellence Model

Wisner and Fawcett (1991) proposed a nine point process for measurement model design (see Fig. 2.) and emphasized that measurement model should be continuously updated seeing the current competition environment. At the end of the 1980s, world markets underwent a lot of change, including the implementation of new manufacturing technologies, and new production management philosophies. These changes have shown up the limitations of traditional performance measurement systems, as well as the need for new systems to be developed.

From the literature survey, it is evident that researchers have started using non-financial methods along with financial methods which are better suited for rating the performance of the manufacturing process on the basis of company’s competitive priorities, such as the achievement of the levels of quality.
agreed with the customer, the reliability of delivery, and/or flexibility. Various researchers have tried to model the measurement of effectiveness of a manufacturing system by identifying various critical factors and prioritizing them by using various decision making techniques (Yang, Chuang, & Huang, 2009; Jain et al., 2011; Ghalayini et al., 1997; Leong et al., 1990). The common limitation among these models is that, either they do not have considered the interrelationships among critical factors at all or at the most in hierarchal way. Even researchers have tried to find the overall effectiveness index by simply multiplying the weights of the factors with the company’s performance for that particular factor, by doing this, they straightway, rule out any interrelationships among the factors, which is rather unusual. So, there is a need to develop an effectiveness model that considers the interrelationship among the factor at the inner and outer level, with the provision of feedback and gives overall effectiveness index. This effectiveness model should follow the ‘9’ point process described in Fig. 2. The model will help managers benchmark the manufacturing system’s effectiveness with their peers and can continuously improve their system to become the best in the market. This will further helps managers analyse the importance of one factor and effect of that particular factor over the system’s overall effectiveness and accordingly managers can prioritize their policies and investments to get the maximum competitive advantage.

Fig. 2. ‘9’ Point Process for Effectiveness Measurement Model

2. Manufacturing effectiveness-the need for change

Effective manufacturing system is the foundation for achieving competitive advantage and business excellence. Globalization has put managers under fierce competition to look for new technologies, which enable their manufacturing systems to produce high quality parts at the minimum cost. Garside (1999) identified the critical factors for an effective manufacturing system:

- Recognises cost effective production methods
- Develops manufacturing cells according to the business need
- Creates team environment for self-directed work groups
- Provides methods for investment appraisal
- Plans for man power requirement
• Provides expansion, machine, process, routing and volume flexibility
• Provides methods to determine actual cost for manufacturing
• Introduces methods to control material and tooling
• Recognises the competition objectives and embed them into operational processes
• Establish quality control at each step of manufacturing
• Evaluates the customer satisfaction
• Integrates process design with the product introduction process
• Improves product reliability by re-designing the manufacturing process and assembly
• Assist the supplier base according to the competition objective
• Provides the provisions for feedback and continuous improvement

To attain these capabilities, manufacturing systems should be redesign to meet customer quality, delivery commitments and manage resources. In the past, organisations had only two general production alternatives available: line, or continuous flow, organised around products; and job-shop flow, organised around products; and job shop flow, organised around equipment groupings like milling machines and lathes. The disadvantage of the job-shop alternative is high work-in-process (WIP) inventories. The disadvantage of continuous process is difficulty of changing over from one product to another. These requirements have brought a new category of advanced manufacturing systems, in which the systems aspect of the manufacturing processes and the integration functions are the essential features. Many new acronyms used to describe the new aspects reflect this system aspect: JIT (just-in-time), CIM (computer-integrated-manufacturing), and FMS (flexible manufacturing system). This development has resulted in a quantum leap from a functional workshop to a flow-based, cellular manufacturing.

2.1 What are AMS?

A high technology development in computing and microelectronics, designed to enhance manufacturing capabilities. Advanced manufacturing technologies are used in all areas of manufacturing, including design, control, fabrication, and assembly. This family of technologies includes robotics, computer-aided design (CAD), computer-aided engineering (CAE), MRP II, automated materials handling systems, electronic data interchange (EDI), computer-integrated manufacturing (CIM) systems, flexible manufacturing systems, and group technology. The system, which is formed from these technologies, is known as advanced manufacturing system. Error! Reference source not found.An AMS typically involves (Parthasarathy & Sethi, 1990):

• A computer aided design system for developing and storing designs;
• A Computer aided manufacturing system that translates design information for manufacturing products; and controls material flow, tooling and testing;
• An automated storage and retrieval system for delivery/pick up of parts between machines and storage; and
• A supervisory computer that integrates all

An AMS integrates the information system, the manufacturing system, and the internal distribution system of the firm. AMS eliminates the need to buy different equipment for variety of products by providing its two distinctive characteristics: flexibility & integration. It offers manufacturing cells with capability of processing variety of parts. In this way, it helps to reduce man & machine, yet maintaining production levels. AMS offers many benefits: lower work-in-process, higher product quality, increase responsiveness to changing demands, and increased productivity. Though these benefits are very lucrative, there have not been many successful AMS.

2.2. Effectiveness of AMS

AMS provides greater choice of design variations that complicates the design process. Traditional manufacturing technologies predominantly enhance process efficiency and workers’ physical capabilities through rigid and mechanized design (Hirschhorn, 1984) whereas AMS works on
improving overall effectiveness of a manufacturing system (Choobineh, 1986; Kaplan, Must CIM be Justified by Faith Alone, 1986). Advantages are many but still, 50 to 75% adoption of AMS fail (Abdel-Kader & Dugdale, 2001). The failure of effective AMS has been associated with variety of problems:

- **Implementation problems**: Zammuto & O'Connor (1992) list the various problems arising from a lack of understanding of AMS and how these problems affect the implementation of such a system. Typical problems include implementation of AMS in a manner that does not support flexibility and management who are not willing to change their style and culture. A large number of authors have targeted this problem and have tried to provide the better solutions. The major contributions are: Attaran, 1989; Badiru, 1990; Baldwin, et al., 2002; Baldwin, et al., 1995; Beatty, 1990; Boyer, 1994; Boyer, et al., 1996; Burcher, et al., 1999; Chen, et al., 1994; Chen, et al., 1996; Co, et al., 1998; Costa, et al., 2009; Dangayach, et al., 2005; Dangayach, et al., 2003; Dangayach, et al., 2004; David, et al., 1996; Dean, et al., 1990; Dimnik, et al., 1993; Efstatathides, et al., 1999; Frohlich, 1998; Fulton, et al., 2010; Ghanal, et al., 2002; Kunnathar, 2000; Machuca, et al., 2004; McDermott, et al., 1999; Mital, 1999; Naik, et al., 1992; Percival, 2004; Rahman, 2008; Raj, et al., 2007; Raj, et al., 2008; Raj, et al., 2010; Ramamurthy, 1995; Roth, et al., 1991; Saberi, et al., 2010; Sambasivarao, et al., 1994; Sañchez, 1996; Schroder, et al., 1999; Shani, et al., 1992; Singh, et al., 2007; Small, et al., 1997; Sohal, et al., 2001; Sohal, 1996; Thomas, et al., 2007; Udo, et al., 1996; Voss, 1988; Yusuff, et al., 2004; Zairi, 1998; Zhao, et al., 1997.

- **Evaluation/Justification Problems**: Traditional financial methods are not adequate as AMS offers intangible benefits along with tangible. If these intangible benefits are not quantified during the appraisal of the technology, then they will appear as unexplained variances. This will force managers to refuse the investments in AMS that could be beneficial to the firm (Small & Chen, Investment Justification of Advanced manufacturing Technology: An Empirical Analysis, 1995). The main hurdle in adopting AMS is the non-availability of proper justification methods. Researchers have put forward a number of justification methods based upon objective and subjective benefits by using different decision making techniques and also highlighted the need for subjective justification methods. The representative ones are: Abdel-Kader, et al., 2001; Agarwal, 1997; Boyer, et al., 1997; Canada, et al., 1989; Canada, et al., 1990; Chan, et al., 2001; Choobineh, 1986; Datta, et al., 1992; Hynek, et al., 2007; Kaplan, 1986; Karsak, et al., 2001; Kumar, et al., 1996; Marri, et al., 2006; Meredith, et al., 1990; Meredith, et al., 1986; Naik, et al., 1992; Ordoobadi, et al., 2001; Primrose, 1991; Sambasivarao, et al., 1997; Slagmulder, et al., 1992; Small, 2006; Stainer, et al., 1996; Zammuto, et al., 1992.

- **Selection Problems**: Selecting a suitable AMS is an important issue on operations managers when making capital investment decisions to improve their manufacturing performance (Chuu, 2009). Furthermore, the rapid growth of the AMS industry is now creating problem in new directions. Prospective firms now face the situation of having to make a decision among several AMS, all of which are capable of performing a specific task. The development and use of appropriate assessment approaches are crucial to ensuring that the analysis of each AMT project considers all benefits and costs (Small & Chen, Investment Justification of Advanced manufacturing Technology: An Empirical Analysis, 1995). The representing work of researchers in the field of AMS selection is as: Agrawal, et al., 1991; Bangle, et al., 2004; Bozdağ, et al., 2003; Braglia, et al., 2010; Chu, et al., 2003; Chuu, 2009; Karsak, et al., 2002; Kumar, et al., 2010; Luong, 1998; Rao, et al., 2006; Sambasivarao, et al., 1995; Sarkis, 1997; Yurdakul, 2004.

From the literature survey of major publications from 1990 to 2012 on AMS Effectiveness, it is clear that AMS implementation is the most important factor for effectiveness as most of the publications are directed to this factor and the second important factor for effectiveness comes out to be justification. This should be agreeable because if we successfully initiate, plan &
execute, our projects will illustrate greater results. Fig. 3 presents the %age contribution of critical factors in AMS effectiveness measurement.

Fig. 3. %age contribution of major factors in AMS effectiveness measurement

The main drawback in cultivating all the benefits of AMS is the non-availability of proper and acceptable methods for the effectiveness of AMS (Chan et al., 2001). It will be in great interest to the manufacturing managers to have models on the effectiveness of AMS that address the issues of implementation, justification and selection while quantifying the intangible factors and giving an overall single numerical index. This work is now possible with the advancements in Multi attribute Decision Making (MADM) techniques and Fuzzy Logic. The major MADM techniques and the corresponding name of the developers are listed in Table 2.

Table 2
Historical Development of MADM Techniques

<table>
<thead>
<tr>
<th>S.No.</th>
<th>MADM Technique</th>
<th>Developer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Utility</td>
<td>(Bernoulli, 1738)</td>
</tr>
<tr>
<td>2.</td>
<td>Theory of games and economic behaviours</td>
<td>(Neumann &amp; Morgenstern, 1947)</td>
</tr>
<tr>
<td>3.</td>
<td>Choquet integral</td>
<td>(Choquet, 1953)</td>
</tr>
<tr>
<td>4.</td>
<td>Fuzzy Set</td>
<td>(Zadeh, 1965)</td>
</tr>
<tr>
<td>5.</td>
<td>ELECTRE methods</td>
<td>(Roy, 1968)</td>
</tr>
<tr>
<td>6.</td>
<td>DM in fuzzy environment</td>
<td>(Bellman &amp; Zadeh, 1970)</td>
</tr>
<tr>
<td>7.</td>
<td>ELECTRE I</td>
<td>(Roy, 1971)</td>
</tr>
<tr>
<td>8.</td>
<td>AHP I</td>
<td>(Saaty, 1972)</td>
</tr>
<tr>
<td>9.</td>
<td>MADM</td>
<td>(Keeney &amp; Raiffa, 1976)</td>
</tr>
<tr>
<td>10.</td>
<td>ELECTRE II</td>
<td>(Roy, 1976)</td>
</tr>
<tr>
<td>11.</td>
<td>Fuzzy integral evaluation</td>
<td>(Sugeno, 1974)</td>
</tr>
<tr>
<td>12.</td>
<td>ELECTRE III, IV</td>
<td>(Roy, 1978)</td>
</tr>
<tr>
<td>13.</td>
<td>TOPSIS</td>
<td>(Hwang &amp; Yoon, 1981)</td>
</tr>
<tr>
<td>14.</td>
<td>GREY</td>
<td>(Deng, 1982)</td>
</tr>
<tr>
<td>15.</td>
<td>Rough Sets</td>
<td>(Pawlak, 1982)</td>
</tr>
<tr>
<td>17.</td>
<td>FMADM</td>
<td>(Sakawa, 1984)</td>
</tr>
<tr>
<td>18.</td>
<td>Dynamic weights AHP</td>
<td>(Saaty, 1992)</td>
</tr>
<tr>
<td>19.</td>
<td>Rough Set MADM</td>
<td>(Pawlak &amp; Slowinski, 1994)</td>
</tr>
<tr>
<td>20.</td>
<td>TOPSIS for MODM</td>
<td>(Hwang, et al., 1996)</td>
</tr>
<tr>
<td>22.</td>
<td>Non independent ANP</td>
<td>(Saaty, 1996)</td>
</tr>
<tr>
<td>23.</td>
<td>Dynamic weights with habitual domain</td>
<td>(Tzeng, et al., 1997)</td>
</tr>
<tr>
<td>24.</td>
<td>Fuzzy measures and habitual domain</td>
<td>(Chen &amp; Tzeng, 1999)</td>
</tr>
<tr>
<td>25.</td>
<td>VIKOR</td>
<td>(Opricovic, 1998)</td>
</tr>
</tbody>
</table>

Some of the MADM techniques that will be helpful in measuring effectiveness of the AMS are discussed below briefly.
Analytical Network Process: ANP is a general form of AHP. AHP was first proposed by Saaty (1980a & 1980b). ANP simultaneously takes into account both feedback and dependence. There are multiple applications of ANP in many areas. Some representative ones are: product mix planning in semiconductor fabricator (Chung, et al., 2005); modeling the metrics of lean, agile and agile supply chain (Agrawal, et al., 2006); manufacturing system evaluation in wafer industry (Yang, et al., 2009); purchasing decisions (Ustun & Demirtas, 2009); supplier selection (Lang, et al., 2009); prioritizing success factors in manufacturing enterprises (Karpak & Topcu, 2010); customer relationship management (Oztaysi, et al., 2011).

Total Interpretive Structural Modeling (TISM): Total Interpretative Structural Modeling (TISM) approach is an extension of the well-established ISM approach (Nasim, 2011). ISM approach metamorphoses nebulous models of systems into unambiguous, manifest models, useful for many purposes (Sage, 1977). Warfield (1973, 1994, 1999) developed the philosophical basis and conceptualize the analytical details of the ISM process. Saxena et al. (2006) applied it in conjunction with other modeling methodologies in the context of energy conservation policy. There are multiple other applications of ISM in many areas; some representative ones are: knowledge management (Singh et al., 2003), supply chain management (Agarwal et al., 2007), flexible manufacturing systems (Raj et al., 2008), decision support systems (Hansen et al., 1979), waste management (Sharma and Sushil, 1995), vendor selection (Mandal and Deshmukh, 1994), knowledge management (Singh et al., 2003), product design (Lin et al., 2006), supply chain management (Agarwal et al., 2007), decision making (Lee, 2008), value chain management (Mohammed et al., 2008) and so on.

Graph Theoretic and Matrix Approach (GTMA): Graph theoretic and matrix model consists of digraph representation, matrix representation and permanent representation. It is a powerful technique to calculate a single numerical index for evaluation of critical factors pertaining to a problem of any field. Grover, Agrawal and Khan (2004, 2006) applied it for TQM evaluation of an industry and to find the role of human factors in TQM. There are multiple other applications of GTMA in many areas; some representative ones are: robot selection (Agrawal et al., 1991), failure cause analysis (Gandhi & Agrawal, 1996), development of maintainability index for mechanical systems (Wani & Gandhi, 1999), machinability evaluation of work materials (Rao & Gandhi, 2002), capability envelop of a machining process (Huang & Yip-Hoi, 2003), performance evaluation of TQM in Indian industries (Kulkarni, 2005), selection, identification and comparison of industrial robots (Rao & Padmanabhan, 2006), to optimize single-product flow-line configurations of RMS (Dou et al., 2009) and so on.

Techniques for Order Preference by Similarity to Ideal Solution (TOPSIS): TOPSIS method was proposed by Hwang & Yoon in 1981. This method is used to determine the best alternative based on the compromise solution. The compromise solution can be termed as the solution with the smallest Euclidean distance from the positive ideal solution and the farthest distance from the negative ideal solution. The positive ideal solution is regarded as the solution when all the attributes reach its maximum value and the negative ideal solution is termed as the solution when all its attributes reach the minimum level. So, TOPSIS method not only gives the solution closest to the optimal, but farthest from the inferior.

Grey Relational Analysis (GRA): During decision making process, the decision makers try to gather as much information as possible through surveys, investigations, sampling, etc., so as to reach the aspired decision, but obtaining all the information remains impossibility; therefore decisions are usually made in grey process, i.e. without complete information. This is where GRA, finds application in solving multi attribute decision making problems. GRA has been successfully applied in solving a variety of MADM problems. Deng (1989) proposed Grey Relational Analysis in the Grey Theory. GRA is a kind of impact evaluation model that can measure the degree of similarity or difference between two sequences based on their relation, which is called the Grey relational grade. If the alternative has the highest grey relational grade between the reference sequence and itself, then the alternative will be the
best choice. GRA has been further developed and widely applied in many areas; some representative ones are: Introduction to Grey Systems (Liu & Lin, 1998); Grey System Theory and Applications (Liu et al., 1999); Comparative Studies of using GRA in MADM Problems (Wu, 2002); Incidence Decision Making Models (Dang et al., 2004); GRA with Interval Numbers (Zhang et al., 2005); facility layout selection (Kuo et al., 2008); Supplier Selection (Wu, 2009); GRA with Intuitionistic Fuzzy Numbers (Wei, 2010); Energy Performance of Office Buildings (Lee & Lin, 2011); Personnel Selection (Zhang & Liu, 2011); Novel Models by using Visual Angle of Similarity (Liu et al., 2011); Novel Model Based on Grey Number Sequence (Liu & Xie, 2011).

Fuzzy Multi Attribute Decision Making (FMADM): Decision Makers (DMs) preferred to give their judgements in linguistic form like ‘low’, ‘average’, ‘high’ etc (Prabhu & Vizayakumar, 1996). There are attributes about which crisp performance scores cannot be assigned like ‘quality’, ‘corrosion resistance’, ‘looks’ etc. The classical MADM methods seem to be incapable of quantifying these judgements into crisp score. MADM methods remain silent about how to tackle this problem. If these attributes with linguistic terms are not quantified, they appear as unexplained variance in the decision making problem. Most of the real-world MADM problems are of mix type, containing crisp, fuzzy and/or linguistic performance attributes. It will be better to convert these linguistic values into fuzzy numbers for evaluation of technologies by using fuzzy multiple attribute decision methods (Chan, et al., 2001). To solve this problem fuzzy set theory to decision making problems was introduced by Bellman and Zadeh in 1970. Yager and Basson (1975) proposed fuzzy sets for decision making. But, the classical work to associate fuzzy set theory to MADM methods was done by Bass and Kwakernaak in 1977. Seeing the importance of the problem, number of researchers have proposed and reviewed several fuzzy MADM methods (Chen & Hwang, 1992; Triantaphyllou & Lin, 1996; Figueira et al., 2004). Some researchers have also applied FMADM methods in the field of advanced manufacturing technology like Perego and Rangone (1998) reviewed the use of FMADM for the selection of AMT; Abdel-Kader and Dugdale (2001) proposed a FMADM model for the evaluation of AMT, this model used the combination of AHP and fuzzy set theory to aggregate the financial and non-financial terms; Chhu (2009) applied fuzzy multiple group decision making with multiple fuzzy information for selection of advanced manufacturing technology, the model enables the decision makers to incorporate and aggregate fuzzy information. The models developed seem to be too complex and moreover, the different linguistic scales are ignored. A thorough review of the existing FMADM methods, clearly indicate that these methods are very complex and require too much cumbersome calculations. This problem becomes much more prevalent when alternatives and attributes are more than 10 (Rao, 2007). That drawback certainly limits their applicability to real-world problems. Chen and Hwang (1992) proposed an approach to solve MADM problems in a fuzzy environment. The approach is of two steps. In the first step, fuzzy data is converted into crisp scores. Then, as the next step, this data in the form of decision matrix is used to rank the alternatives by using MADM methods. In the following section, this method has been explained. This method logically converts linguistic terms into their corresponding fuzzy numbers through any of the eight conversion scales. These conversion scales are the extension of the work of Wenstop (1976), Bass and Kwakernaak (1977), Efstathiou and Rajkovic (1979), Bonissone (1982), Efstathiou and Tong (1982), Kerre (1982), and Chen (1988). These techniques can be applied to measure the effectiveness of manufacturing system even if the effectiveness factors have subjective nature. The nature of research on effectiveness or performance measurement of manufacturing systems is difficult to comprehend within the confines of any specific discipline, the relevant materials are scattered throughout numerous scholarly journals in various disciplines. Even with new search engines, the task of finding all the relevant articles is difficult and time consuming. Two excellent reviews of the literature can be found in Neely (2000, 2005). Raafat (2002) provided a comprehensive listing of articles on the justification of advanced manufacturing technologies. This paper brings together the wide-ranging work from a number of different disciplines and diverse with the published articles from 1990 to 2001 and provides a comprehensive bibliography on the subject. But it only targets the problem of justification, here in this paper authors have provided the comprehensive bibliography that covers every aspect of AMS effectiveness measurement and possible MADM techniques that can be
used for measurement. The paper cites 265 articles from a variety of published sources mainly from 1990 to 2012 and a few additional published work prior to 1990. Every effort has been made to include the relevant paper. As paper title provides the sufficient information about the contents so no additional information has been provided as in Raafat (2002)’s.

3. Concluding remarks

The nature of research on effectiveness or performance measurement of manufacturing systems is difficult to comprehend within the confines of any specific discipline, the relevant materials are scattered throughout numerous scholarly journals in various disciplines. Even with new search engines, the task of finding all the relevant articles is difficult and time consuming. Two excellent reviews of the literature can be found in Neely (2000, 2005). Raafat (2002) provided a comprehensive listing of articles on the justification of advanced manufacturing technologies. This paper brings together the wide-ranging work from a number of different disciplines and diverse with the published articles from 1990 to 2001 and provides a comprehensive bibliography on the subject. However, it only targets the problem of justification, here in this paper authors have provided the comprehensive bibliography that covers every aspect of AMS effectiveness measurement and possible MADM techniques that can be used for measurement. The paper cites 265 articles from a variety of published sources mainly from 1990 to 2012 and a few additional published work prior to 1990. Every effort has been made to include the relevant paper. As paper title provides the sufficient information about the contents so no additional information has been provided as in Raafat (2002)’s. This paper will not only help the researchers in providing the bibliography of the matter concerned but also help them to understand the problem of manufacturing effectiveness measurement in a better way with possible solutions with the deployment of MADM approaches.

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References


