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Uncertainty Factors in Real Manufacturing Environment

M. A. Wazed, Shamsuddin Ahmed and Nukman Yusoff

Department of Engineering Design & Manufacture, Faculty of Engineering, University of Malaya (UM), 50603 Kuala Lumpur, Malaysia.

Abstract: The important part of managing uncertainty is identifying as many sources and factors of uncertainty as possible. The main purposes of this paper are to enhance the understanding of uncertainty – its sources, factors and effects on the system by documenting the current state of affairs. This paper is based on a comprehensive and up-to-date review of the existing literatures on manufacturing under uncertain conditions. The authors have identified the various sources and factors of uncertainty in manufacturing/production environment and adjusted the focus on the techniques and models used to tackle the storms. It is observed that that the combined effects/impacts of the uncertainty factors on the system parameters yet to be nattily studied.

Key words: Lead time, Safety stock, Demand, capacity constraints.

INTRODUCTION

The fundamental concern of manufacturing resources planning is to guarantee that the best promising quantity of the item is released at the best likely time, at the lowest costs within some given constraints of the system like availability of the resource(s) in need. Planning in a manufacturing environment is commonly carried out on the basis of material requirements planning (MRP) logic (Koh, S.C.L. and S.M. Saad, 2006; Vollmann, T.E.*et al.,* 1988) but the MRP logic has a major shortcoming to deal with uncertainty.

MRP, manufacturing resource planning (MRP II), enterprise resource planning (ERP) and ERP II are for controlling production-planning activities, have been widely implemented in contemporary manufacturing enterprises. They become the central systems in manufacturing environments within which production data such as demand, supply, product, inventory, accounting, costing, lead-time and routing are kept in an integrated manner. The same MRP logic is used in MRP II and ERP in their production-planning modules (Enns, S.T., 2001). thus their inability to cope and respond to uncertainty is still prevailing and the planned order release (POR) schedules are indifferent to those generated from an MRP system (Koh, S.C.L. and S.M. Saad, 2006; Koh, S.C.L. and S.M. Saad, 2003). Also, MRP logic does not take capacity constraints into account (Buxey, G., 1989; Krajewski, L.J. and L.P. Ritzman, 1993). As MRP planning systems do not afford a solution to these fundamental issues, planners have to adjust the planning frequently (Spitter, J.M. *et al.,* 2005).

Today's manufacturing enterprises must be responsive and able to tackle uncertainty quickly and robustly in order to sustain and enhance business competitiveness. In order to respond to uncertain demand, supply and production process, the role and performance of a production planning and control system within a manufacturing enterprise will challenge (Koh, S.C.L. and A. Gunasekaran, 2006).

In general, optimization problems include uncertainty in the problem strictures, which are usually defined by probability distributions. Uncertainty incurs losses of the dependability to the output of models and therefore constrains the applications of models, especially for multi-stage models where uncertainty may propagate and accumulate. Consequently, the primary issues of concern in this paper are: i) to enhance the understanding of uncertainty, ii) to identify the sources, factors and effects of uncertainty in manufacturing premises by documenting the current state of affairs, and iii) to instigate fruitful future research by identifying gaps between the relevant issues and available literature.

Uncertainty:

Uncertainty refers measuring the degree of differences between the models and the respective real systems' values or between the estimation of variables and their true values. The uncertainty can be caused by the errors associated with the model itself and the uncertainties of the model inputs. One of the challenges of multi-stage

Corresponding Author: M. A. Wazed, Department of Engineering Design & Manufacture, Faculty of Engineering, University of Malaya (UM), 50603 Kuala Lumpur, Malaysia. Telephone: +60-143-605425, Fax: +603-7967-5330
Email: awazed@gmail.com

manufacturing system is the propagation and accumulation of uncertainty, which influences the conformity of the outputs. Modern manufacturing enterprises are facing increasing pressure to respond to production dynamics caused by disruption of uncertainty (Koh, S.C.L. and S.M. Saad, 2003). This section reviews the perspectives and sources for uncertainties in manufacturing systems.

Perspectives and sources of uncertainty:

Uncertainty means different things to different people. For example the error-estimate for a measurement is referred to as uncertainty (Figliola, R.S. and D.E. Beasley, 1991). Yen and Tung, (1993). attributed uncertainty mainly to a lack of perfect understanding with regard to phenomena or processes. Ayyub and Gupta, (1994). characterized uncertainty as an inseparable companion of any measurement at the experimental level, and as the vagueness and incompleteness of understanding of complex real problems at the cognitive level. Zhao *et al*., (1995). defined uncertainty as the differences or errors between models and the reality. (Oberkampf *et al.,* 1999). described uncertainty as a potential deficiency in any phase or activity of a modeling process due to lack of knowledge. Delaurentis and Mavris, (2000). provided the definition of uncertainty as incompleteness in knowledge (either in information or context) which causes model-based predictions to differ from the reality in a manner described by some distribution functions. Zimmermann, (2001). defined stochastic uncertainty as the unknown of the future state of a system due to lack of information, and fuzziness uncertainty as the vagueness concerning the description of the semantic meaning of events, phenomena or statements themselves. Some researchers referred to uncertainty as a form of disturbance (Lindau and 1995. Saad, and 1998). Other definitions of uncertainty found in literature are recapitulated in Table 1.

Ho (1989). categorizes uncertainties into two groups: (i) environmental uncertainty, and (ii) system uncertainty. Environmental uncertainty includes uncertainties afar the production process, such as demand uncertainty and supply uncertainty. System uncertainty is allied to uncertainties within the production process, such as operation yield uncertainty, production lead time uncertainty, quality uncertainty, failure of production system and changes to product structure, to mention a few. Uncertainty can also be classified differently from the view point of its sources as below:

1. Natural uncertainty, also referred to as inherent uncertainty and physical randomness, which is due to the physical variability of a system (Yen, and Y. Tung, 1993; Ayyub, and Chao, 1997; Hazelrigg, G.A., 1996).
2. Model uncertainty due to simplifying assumptions in analytical and prediction models, simplified methods and idealizing representations of real performances (Yen, and Y. Tung, 1993; Delaurentis, 2000; Hazelrigg, G.A., 1996; Du, X. and W. Chen, 2000; Gu, X. *et al.,* 1998).
3. Measurement uncertainty resulting from the limitation of measurement methodologies and the capability of measurement systems (Yen, and Y. Tung, 1993; Delaurentis, 2000; Hazelrigg, G.A., 1996).
4. Operational and environment uncertainty (Yen, and Y. Tung, 1993; Delaurentis, 2000).
5. Statistical uncertainty due to incompleteness of statistical data and the use of sampled information to estimate the characteristics of these parameters (Ayyub, and Chao, 1997).
6. Subjective uncertainty related to expert-based parameter selection, human factors in calculation, fabrication and judgment (Ayyub, and Chao, 1997).

Table. 1: Definition of uncertainty

Definition	Reference
Uncertainty can be defined as any unpredictable event in manufacturing environments that disturbs operations and performance of an enterprise.	Koh and Saad (2002)
Uncertainty is defined as any unplanned events that occur during production, which disrupt orders execution.	Koh and Saad (2003b
Uncertainty is defined as any unpredictable event that disturbs the production process in a manufacturing system that is planned by MRP, MRP II or ERP system.	Koh and Saad (2003a
Uncertainty can be defined as any unpredictable event that disturbs the operation and production in a manufacturing system.	Koh (2004)
Uncertainty is the dissimilarity between the amount of information required to execute a task and the amount of in formation already infatuated.	Mula et al. (2006a)
Situation where the current state of knowledge is such that (1) the order or nature of things is unknown, (2) the consequences, extent, or magnitude of circumstances, conditions, or events is unpredictable, and (3) credible probabilities to possible outcomes cannot be assigned.	Business Dictionary (2008)
Degree to which available choices or the outcomes of possible alternatives are free from constraints. Situation where neither the probability distribution of a variable nor its mode of occurrence is known.	

The model uncertainty is further classified as i) input uncertainty as referred to as input parameter uncertainty, external uncertainty and precision uncertainty (Du, X. and W. Chen, 2000. Gu, X. *et al.,* 1998). ii) bias uncertainty which is induced in transforming the physical principles of scientific theory into analytical or raw models for engineering use and transforming the analytical or raw models into numerical simulation models (Gu, X. *et al.,* 1998). iii) model parameter uncertainty arising from the limited information in estimating the characteristics of model parameters (Ayyub, and Chao, 1997. Manners, W., 1990). iv) model structure uncertainty (Laskey, K.B., 1996), which is due to the assumption and simplification of the model structure.

Factors of uncertainty:

Uncertainty can be measured by the frequency of its occurrence, and analyzing the relative contribution and resulting effect on delivery performance can quantify whether the impact is minor or major. Koh and Saad (2003) identified eight uncertainties that are most likely to affect customer delivery performance. These are external late supply, internal late supply, planned set-up time exceeded, machine break-downs, labor unavailability, tooling unavailability, demand batch size enlargement and customer design changes. Their simulation output highlighted four uncertainties that have significant effects to PDL (parts delivered late) and FPDL (finished product delivered late). These are external late supply, machine break-downs, demand batch size enlargement and customer design changes.

The concept of 'yield factor' is used to embrace system uncertainties. A composed yield factor relates the quantities of required inputs to satisfy a demand of specified output when the system uncertainties cause losses of articles in different levels of the production process. Therefore, the composed yield factor is a function of the prominent production factors in the different stages of the process (Mula, J., *et al.,* 2006). The factors pertinent to uncertainty reported in different issues of publications are summarized in Table 2.

Table. 2: Factors for uncertainty

Factor (s) of uncertainty	Reference
System uncertainty	Sommer (1981), Miller et al. (1997), Hsu and Wang (2001), Reynoso et al.(2002)
Lead time uncertainty	Ould-Louly and Dolgui (2004), Mohebbi and Choobineh (2005), Koh and Gunasekaran (2006), Brennan and Gupta (1993), Dolgui and Ould-Louly (2002), Huang et al. (1982)
Environmental uncertainty, Supply uncertainty	Ho et al. (1995), Billington et al. (1983)
Operation yield uncertainty	Huang et al. (1985)
Interrelationship between levels	Kim and Hosni (1998)
Demand uncertainty	Bourland and Yano (1994), Ho et al. (1995), Ho and Carter (1996), Brennan and Gupta (1993), Escudero and Kamesam (1993), Vargas and Metters (1996), Miller et al. (1997), Kira et al. (1997), Mohebbi and Choobineh (2005), Grabot et al. (2005), Mula et al. (2006b), Koh and Gunasekaran (2006), Balakrishnan and Cheng (2007), Mula et al. (2007), Anosike and Zhang (2007), Arruda and do Val (2008), Ben-Daya and Noman (2008), Grubbstrom (1999), Agatz et al. (2008), Ahmed et al. (2003)
Probabilistic market demand and product sales price	Lan and Lan (2005), Mula et al. (2007), Leung et al. (2007)
Capacity	Mula et al. (2006b), Mula et al. (2007), Kim and Hosni (1998), Ahmed et al. (2003)
Resource breakdown/ uncertainty	Koh and Gunasekaran (2006), Balakrishnan and Cheng (2007), Arruda and do Val (2008), Xu and Li (2007)
Changing product mix situation	Anosike and Zhang (2007)
Labor hiring, labor lay-offs	Leung et al. (2007)
Quantity uncertainty	Koh et al. (2002), Guide and Srivastava (2000)
Cost parameters	Ahmed et al. (2003)
Quality	Heese and Swaminathan (2006)

Effects of and measures for uncertainty:

Uncertainty can be measured by the frequency of its occurrence, and analyzing the relative contribution and resulting effect on delivery performance. It can quantify whether the impact is minor or major. Many conceptual and mathematical models are proposed and used to manage competitive production/manufacturing under uncertainty. This section reviews the factors, their effects and models found in literatures.

Uncertainties in manufacturing have heterogeneous effects due to the interrelationships between resources and operations. The lead-time and demand uncertainties are individually and interactively significant determinants of system performance (Brennan, L. and S.M. Gupta, 1993). Lawrence and Sewell (1997) found that as processing time uncertainty increases, simple dispatch heuristics provide performance comparable or superior to that of algorithmically more sophisticated scheduling policies. Again increasing manufacturing flexibility leads to increased performance and to knob the uncertainty (Swamidass, P.M. and W.T. Newell, 1987).

A high level of lead time variability and demand variability has a strong effect both on the level of optimal safety lead times and optimal safety stocks (Molinder, A., 1997). In case of a high demand variability and low lead time variability, the lowest cost for all three structures was obtained by using safety stocks. In case with simultaneous high variability in demand and lead time, the lowest cost was obtained by using safety lead times. The poor supplier delivery performance, schedule/work-to-list not controlled, machine capacity shortages, finished product completed—not delivered, unacceptable product quality and engineering design changes during/after production have significant effect on late delivery.

The interactions between unacceptable/urgent changes to production schedule and poor delivery performance; and unacceptable product quality and engineering design changes during/after production yielded additional level of late delivery. The causes of uncertainty produce knock-on and compound effects on late delivery (Koh, S.C.L. and S.M. Saad, 2006). Compound effects are more difficult to control as compared to knock-on effects. Occurrence of uncertainty at a different time window does not change the characteristic and nature but may change the effects.

Various techniques are used to tackle the effect of uncertainty, e.g. overtime production, subcontracting, outsourcing, holding safety stock, and keeping safety lead-time. These techniques are adopted to minimize the effect of uncertainty on delivery to customer. The well known techniques are: buffering and dampening (Koh, S.C.L. and S.M. Saad, 2006; Koh, and A. Gunasekaran, 2006; Lindau, and Lumsden, 1995; Saad, S.M. and N.N. Gindy, 1998). Buffering technique is referred as a more physical arrangement, e.g. inventory buffer; whilst dampening technique is referred as a relatively intangible arrangement, e.g. safety lead-time (Koh, S.C.L. and A. Gunasekaran, 2006; Koh, S.C.L., *et al.,* 2000).

The safety stock and safety lead-time are the key robust techniques used by many researchers (Guide, V.D.R. and R. Srivastava, 2000). This justifies the research effort in applying safety stock or safety lead-time to manage uncertainty. But more system nervousness might be produced when using safety stock (Sridharan, V. and R.L. LaForge, 1989). This finding aligns with the conclusion from (Ho, *et al.,* 1995). (Buzacott and Shanthikumar (1994) found that the use of safety lead-time is preferred than safety stock when it is possible to make accurate forecasts of future required shipments over the lead-time. These findings limit the robustness of safety stock and safety lead-time with the constraint of the lead-time variation information (Koh, S.C.L. and A. Gunasekaran, 2006). Guide and Srivasta, (2000). and Koh, *et al.,* (2000). suggested the use of safety stock when faced with quantity uncertainty or safety lead time when faced with timing uncertainty, within MRP controlled batch-manufacturing environment using simulation modeling. Overtime and multi-skilling labor techniques are as well found to be used by practitioners, though they have conflicting role on delivery performances (Koh, S.C.L. and A. Gunasekaran, 2006). SMEs usually apply fire-fighting techniques to deal with uncertainty (Koh, *et al.,* 2000). This implies that they do not manage uncertainty systematically and hence do not prepare themselves for the future if the same uncertainty recurs (Koh, S.C.L. and S.M. Saad, 2006).

Vargas and Metters (1996) proposed a “dual-buffer” heuristic, the first for triggering production and the second for replenishing stock internally, which outperforms a single buffer heuristic in tackling demand uncertainty Ho, *et al.,* (1995). developed an uncertainty-dampening framework to reduce system nervousness caused by external supply uncertainty, external demand uncertainty and internal supply uncertainty. It was found that holding safety stock, safety capacity, safety lead-time and rescheduling are useful to buffer and dampen these uncertainties Ho and Carter (1996). simulate static dampening, automatic rescheduling and cost-based dampening techniques to tackle external demand uncertainty. They conclude that the system improvement is dependent on the appropriate use of the dampening techniques and the lot-sizing rules. Holding safety capacity and rescheduling were also found to be the common buffering and dampening techniques used by many practitioners (Koh, S.C.L. and A. Gunasekaran, 2006).

Newman *et al.,* (1993) proposed a dynamic equilibrium model to demonstrate the trade-offs and interrelationships between manufacturing flexibility innate in an enterprise’s processes and infrastructure, the uncertainties faced by the enterprise and the way in which the enterprise’s processes and infrastructures are buffered with inventory, lead-time and capacity. Trade-off between flexibility and uncertainty is required to achieve system agility (Prate and, 2000). Pagell and Krause (1999) suggested that there is no relationship between the measures of environmental uncertainty and operational flexibility and there is no relationship between an enterprise’s performance and its effort to align the level of operational flexibility with its external environment. It means that fitness of flexibility in managing uncertainty depends on specific types of uncertainty and an enterprise’s environment. Enns (2002) investigated the effects of forecast bias and demand uncertainty in a batch production environment using integrated MRP planning and execution test bed. The effects of uncertainty on delivery performance in an MRP-controlled batch manufacturing environment with multiproduct and multilevel depended demand is modeled using simulation (Koh, 2004). Also an MRP order release timing logic is developed and modeled with unique method called the tagging configuration, which is conceptualized from the parent and child in MRP systems (Koh, 2003). Knowledge-management approach is used by (Koh and Gunasekaran, 2006) for managing uncertainty in manufacturing enterprises that use MRP, MRP II or ERP for production planning. Manufacturing enterprises should use both tacit knowledge of uncertainties and buffering and dampening techniques, simultaneously with the explicit knowledge that is generated by the intelligent agent, for managing uncertainty (Koh and Gunasekaran, 2006).

How and to what extent uncertainty disturbs in planning and scheduling of production using MRP, MRP II or ERP is examined, and diagnosis the underlying causes for uncertainty through a questionnaire survey by Koh and Saad (2006). With the existing manufacturing system's structures and constraints as well as considering the system reconfiguration and restructure, an agent-based approach is presented by Anosike and Zhang (2007) to achieve optimized utilization of resources in changing demand distribution and product mix situation. The conceptual techniques are summarized in Table 3.

Table. 3: Conceptual techniques to tackle uncertainty

Technique	Reference
Buffering	Lindau and Lumsden (1995), Ho et al. (1995), Buzacott and Shanthikumar (1994), Frizelle et al. (1998), Saad and Gindy (1998), Guide and Srivastava (2000), Koh et al. (2000), Koh (2004), Koh and Saad (2006), Koh and Gunasekaran (2006)
Dampening	Lindau and Lumsden (1995), Ho et al. (1995), Ho and Carter (1996), Frizelle et al. (1998), Saad and Gindy (1998), Buzacott and Shanthikumar (1994), Guide and Srivastava (2000), Koh (2004), Koh et al. (2000), Koh and Gunasekaran (2006), Koh and Saad (2006)
Overtime labor Multi-skilling labor Fire-fighting techniques (SMEs usually apply)	Koh et al. (2000), Koh and Saad (2006)
Overtime production	Koh et al. (2000, 2002), Koh and Saad (2006), Koh and Gunasekaran (2006)
Subcontracting and outsourcing	Koh and Gunasekaran (2006), Koh et al. (2002)
Dual-buffer	Koh and Gunasekaran (2006), Vargas and Metters (1996)
Safety capacity and rescheduling	[Koh and Gunasekaran (2006), Ho et al. (1995)
Knowledge management approach	Koh and Gunasekaran (2006)
Questionnaire survey	Koh and Saad (2006)
Execution test bed	Enns (2002)
Simulation model	Koh (2004)
Agent based approach	Anosike and Zhang (2007)

In order to address uncertainties, several mathematical models have been proposed. Examples of these models include interval model, convex model, fuzzy sets and random models. Interval model, introduced in the early 1900s, can give rigorous bounds for a solution and applied to different fields (Lew, *et al.,* 1994; Penmetsa, and Grandhi, 2002). Convex model extended the interval model from one dimension to multi-dimension, and have been used in construction engineering, mechanical engineering, structural engineering, mechanics and other fields (Lindberg, H.E., 1992; Attoh-Okine, N.O., 2002). Fuzzy sets, introduced by Zadeh, (1965). were initially used in fields such as economics, social sciences to address the uncertainties induced by the imprecise and vague information. Afterwards they are extended to engineering areas (Wood, and Antonsson, 1989; Wood, *et al.,* 1992). Random model represents the uncertainty through probability mass function or probability density function, also has considerable applications in engineering (Deng, 1989; Pawlak, 1985).

Billington, *et al.,* (1983) and Chung and Krajewski (1984). commenced the mathematical programming (MP) approaches to cope with capacity constraints. Belvaux and Wolsey (2001). conferred assorted models for lot sizing under capacity constraints, where the lead times are implicit outputs of the optimization procedure. Under demand uncertainty, Bourland and Yano (1994). developed multi-objective optimization model that considers capacity slack, safety stock and overtime, which aims to minimize the expected cost per unit time of inventory, overtime and set-up costs (where applicable). Escudero and Kamesam (1993). originate a stochastic programming model for MRP with uncertainty in demand which is given as a random parameter. Molinder, (1997). proposes simulated annealing to find good safety stock and safety lead time under the stochastic demand and lead time.

A manufacturing resource planning algorithm which can handle limited production capacity is presented by (Harris, *et al.,* 2002: Ahmed, *et al.,* 2003). have addressed a multi-stage capacity expansion problem with uncertainties in demand and cost parameters, and economies of scale in expansion costs. Choi and Enns (2004). have considered the capacity-constrain with stochastic lot arrival and lot-sizing problem in the batch production environment. Ould-Louly and Dolgui (2004). have investigated a multi-period and multi-component supply planning problem for assembly systems with random lead time and fixed demand. Combinatorial manufacturing resource planning (CMRP) model with the concept of balancing the machine productivity and the human capability as well as step by step algorithm to reach the maximum profit solution under the deterministic market demand is constructed by Lan and Lan (2005).

Grabot, *et al,* (2005). suggested F-MRP (Fuzzy-MRP) model, to handle the uncertainty and imprecision of demand allowing to pass through all the MRP II steps (Material requirement planning, Load balancing, Scheduling). Mula, *et al.,* (2006). presents a new linear programming model for medium term production planning in a capacity constrained MRP, multi-product, multi-level and multi-period manufacturing environment. Mula, *et al.,* (2007). developed a fuzzy production planning model to generate production plans under uncertainty in parameters as important as market demand, capacity and costs data. Robust optimization model for a medium-term planning horizon is developed by Leung, *et al.,* (2007). to solve multi-site production planning problem with uncertain data. Ben-Daya and Noman, (2008). developed integrated inventory inspection models with and without replacement of nonconforming items discovered during inspection when the demand is stochastic. Arruda and do Val, (2008). have represented a discrete event model considering random time periods. The sources of randomness are: demand for the end products and the variability in the time length to complete each stage. Lusa, *et al.,* (2008). presents a multistage scenario stochastic optimization model that takes into consideration demand uncertainty when planned working time is considered as annualized hours (AH).

Conceptual models are widely used in design and manufacturing. However, no models can completely capture all the characteristics of the simulated physical system. It is asserted that the values of the physical variables which describe the behavior of the physical system in Heisenberg uncertainty principle are impossible to specify accurately and simultaneously. Heisenberg's Uncertainty Principle states that it is impossible to know both the exact position and the exact velocity of an object at the same time.

From the authors' observation, the broad classifications of the uncertainty models used to deal with uncertainty are: Conceptual models (like yield factor, safety stock, safety lead time etc), Artificial intelligent based models (like fuzzy set theory, fuzzy logic, multi-agent system etc), Simulation models (like heuristic method, network modeling, queuing theory etc.) and Analytical models (like mathematical programming, stochastic programming etc).

Conclusions:

Manufacturing planning and control entails the acquisition, utilization and allocation of limited resources to production activities so as to satisfy customer demand over a specified time horizon in the most efficient and effective way. Typical decisions include work force level, production lot sizes, assignment of overtime and sequencing of production runs. Manufacturing planning and control problems are inherently optimization problems, where the objective is to develop a plan to meet demand at a minimum cost or that fills the demand and maximizes profit. The consideration of uncertainty is vital to harvest the benefits and to maintain the competitive outputs.

Any planning problem starts with a specification of customer demand that is to be met by the production plan. In most contexts, future demand is at best only partially known, and often is not known at all. Consequently, one relies on a forecast for the future demand. To some extent, any forecast is inevitably inaccurate and one must decide how to react to this demand uncertainty. Demand is a key initiator for the uncertainty.

The identification of the relevant costs is also an important issue. For production planning, one typically needs to determine the variable production costs, including setup related costs, inventory holding costs, and any relevant resource acquisition costs. There might also be costs associated with imperfect customer service, such as when demand is backordered. There are limited production resources that cannot be stored from period to period. Choices must be made objectively as to which resources to include and how to model their capacity and behavior, and their costs. Also, there may be uncertainty associated with the production function, such as uncertain yields or lead times. The choice of planning horizon, appropriate cost parameters, the lead times, service level, safety stocks, input quality etc. under uncertainty are needed to be analyzed in holistic manner and to be incorporated with models for the production and resource-related decisions.

In this article, the authors identified the possible sources and factors of uncertainty in manufacturing enviroment. The effects and measures for uneertainties are discussed in reference of various models and studies. Managing uncertainty effectively and efficiently requires a balanced planning and control. One must understand which uncertainty is to tackle and how to tackle it in order to obtain the maximum improvement in to the system.

In summary, there are many factors of uncertainty in real production/ manufacturing environment and to tackle them professionally, various tools/ techniques/models are applied. But the combined effects/impacts of the uncertainty factors on the system parameters have yet been studied. So far no research has been conducted in developing any holistic model to study the uncertainty issues in multi-period, multiple products and multi-stage environment for manufacturing resources planning. The effects of incorporation of component commonality in the aforesaid models and on the system parameters remain in the fissure and hence needed research attention.

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