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Review of Selected Models for Optimal Decision Making in Jobshops

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Abstract: Much research has been done on how to solve the problems of jobshop resulting in a wide variety of approaches, models and assumptions. This study highlighted the peculiarities of jobshops that had posed serious threat to a successful implementation of management decisions, most especially in the developing countries. It further selected four out of these decisions and carried out a comprehensive and concise review of the existing models and approaches on them, thereby exposing the strengths and weakness of these models in solving the problems of jobshops. The study concluded by given possible direction for future research so that current barriers in jobshops could be holistically addressed.

Key words: Jobshops, peculiarities, management decisions, review, holistic, Nigeria

INTRODUCTION

Jobshop, a system which deals with manufacturing variety of products using machines in a general network configuration, each of these products follows a different plan that specifies the sequence of machines it must visit and the operations performed by them. It often necessitates resetting or adjusting the equipment when one order is completed before the next can be processed. In this situation, management decisions become haphazard in order to suit the changes in demand pattern, machine configuration, personnel and material allocations.

From literature, it was observed that major strategic decisions that posed threat to the effective management of jobshops include; Demand Management, Manpower Planning, Tools and Equipment Planning, Material Requirement Planning, Due-Date Determination, Cost Estimation, Jobshop Scheduling and Shop Floor Control/Record Management. (Harding, 1975; Adam and Ebert, 1993; Kareem and Aderoba, 2003).

This study reviewed the research of researchers in solving the problems emanating from selected strategic decisions, specifically, Demand Management, Manpower Planning, Tools and Equipment Planning and Material Requirement Planning. The research aimed to assist current researchers to know the state of the art in order to prevent duplication of effort and as well guide the research focus on jobshops. The study is organised as follows: it briefly discussed the peculiarities associated with jobshops; it reviewed the existing models to solve the problems arising from Demand Management, Manpower Planning, Tools and Equipment Planning and Material Requirement Planning. The study is concluded with suggestions for future research and possible features that could be incorporated into the existing models.

PECULIARITIES OF JOBSHOPS

Peculiarities of jobshops, most especially in the developing countries are the inherent problems of jobshops resulted from its nature that need to be simplified or solved to have functional jobshops. Adam and Ebert (1993) considered jobshop as a situation where some research centers may be idle and at the same time, some will be severely over loaded or experience a large build-up of orders awaiting processing. The situation may also necessitate resetting or adjusting the equipment when one order is completed before the next could be processed.

Idris and Aderoba (2000) observed that setting up a new jobshop in developing countries has been hindered by inadequate capital to execute the project in one fell swoop. The commercial banks which would have been of assistance are usually unwilling to give credit to jobshops because their products are usually undefined and the cash flow is not readily predictable. This situation has forced the interested investors in jobshops to start with inadequate facilities with hope of expansion through the returns generated from the installed facilities/machinery which is hardly predictable, thereby makes management decisions unreliable and sometimes difficult to execute (Idris, 2002).

Akinnuli and Aderoba (2000) bring to limelight some extraneous factors in jobshops, particularly in developing countries that affect flow time prediction. These factors according to the researchers include shortage and erratic power supply, inability to secure needed raw materials in-time, inadequate finance for working capital, problems of labour and the problems arising from socio-economic and political situations of developing nations.

Peculiarities of jobshops also include lack of patronage at the gestation period and uncertain demand during growth. These result to under-utilisation of labour and possibility to lay off staff during this period. This brings about the problem of job securities which consequently discourage skilled and competent staff from seeking employment in jobshops.

Other peculiarities include the impossibility of jobshops to make use of data from previous production as each new job exhibits its own special characteristics and requirements, lack of systematic arrangement for cost estimation coupled with non-availability of modern computing facilities and standard time data, lack of appropriate job scheduling which result to backlog of jobs, vague knowledge of materials needed that are multiple in natures because of different request pattern of demand in jobshops and limited storage facility (Aderoba, 1997; Aderoba *et al*., 2003).

In addition, Akintunlaji (2003) lists some peculiarities associated with materials planning in jobshops, mostly in developing countries as; inability to stock materials because of variability of orders, unpredictability of demand and holding cost, difficulty to determine the most economical quantities of materials to order for at a given time, limited capacity in terms of manpower, machines, suppliers and limited operational capital to procure and stock needed materials. These peculiarities have created problems for effective and efficient decisions making in jobshops thus series of models were formulated to solve the problems. Some of these models are hereby discussed.

REVIEW OF MODELS ON SOME SELECTED STRATEGIC DECISIONS IN JOBSHOPS

Demand Management model: Demand Management according to Vollmann *et al.* (1997) is a process that includes forecasting which takes place before, during and after production planning. Common methods of forecasting include, Qualitative Techniques, Exponential Smoothing Technique, Time Series Analysis, Casual Relationships and Simulation.

Exponential Smoothing Technique was considered to be the best forecasting method that could be used in jobshop, (Wybark, 1973; Makridakis, 1982; Aderoba, 2000). Gardner (1985) presented a comprehensive study on exponential smoothing where its historical development was traced to the time of Second World War. The research critically commented on the merits of various models and discredited others based on his own research as well as the research of other researchers. In the conclusion, exponential smoothing technique was also rated as one of the best forecasting methods.

In using the exponential smoothing technique, only three pieces of data are needed. These are; the most recent forecast, the actual demand that occurred for that forecast period and a smoothing constant (α). This smoothing constant (ranges between 0 and 1) determines the level of smoothing and the speed of reaction to differences between forecasts and actual occurrences.

The value for this constant is subjective and is determined both by the nature of the product and the feelings of the managers as to what constitute a good response rate (Chase and Aquilano, 1985). These features fit the situation in jobshop where there is scanty record from the previous jobs as well as the need for manager to use his initiative to determine the nature of each job which hardly similar to others.

Not only that exponential smoothing technique is simple in formulation and application, it was also rated as the best that gives accurate and optimal results for jobshops (Kareem, 2004).

Idris (2008) modified this technique not only to forecast for the optimal demand hours for jobshop services in time t based on previous forecast and actual demand in time t-1 but also determines the optimal quantity of material needed in time t. The model is as shown in Eq. 1:

$$D^f_{jt} = D^f_{jt-1} + \alpha^*_{jt} (D^a_{jt-1} - D^f_{jt-1}) \quad (1)$$

Where:

- D^f_{jt} = Forecast hour of demand expected in activity centre j in period t
- D^f_{jt-1} = Previous forecast hour of demand in activity centre j in period t-1
- D^a_{jt-1} = Actual hour of demand in activity centre j in period t-1
- α_{jt} = Smoothing constant for activity centre j to be used in period t

If forecast is to be done where no previous forecast (D^f_{jt-1}) exist, a starting forecast could be made by using an average of actual demand of the preceding periods over the first n periods, where n could be:

$$n = \frac{2}{\alpha} - 1 \quad (2)$$

(Round n to the nearest integer) therefore:

$$D^{t}_{it-1} = \frac{\sum_{n=1}^{n} D^{a}_{in}}{n} \tag{3}$$

Where:

D^{a}_{jn} = Actual demand of activity j in period n

MANPOWER PLANNING MODELS

Recent research interest on the objective of manpower planning had gone beyond arranging for the necessary number of suitable people to be allocated to various jobs usually in hierarchical structure or just getting the right number of right people in the right jobs in the right place at the right time. But it has extended to a process that predict for both demand and supply of manpower and looking at policies to reconcile any difference between the two which is often refer to as closing the manpower gap.

Historically, origin of models of manpower systems could be traced to Seal (1945). However, simple models were reported by Edwards (1983) to have been used by manpower planners long before then. Mehlmann (1980) developed an optimal recruitment and transition strategies for manpower systems using dynamic programming recursion with the objective of minimising a quadratic penalty function which reflects the importance of correct manning of each grade under preferred recruitment and transition patterns.

The research of Zanakis and Maret (1981) was based on Markovian goal programming model with pre-emptive priorities and provided a more flexible and realistic tool for manpower planning problems.

Aderoba and Kareem (1997) developed a heuristic approach to determine crew size based on queuing model. Fapetu and Kareem (2003) developed a workload approach to crew size determination by introducing factor to account for the uncertainty in the performance of maintenance crew. Igboanugo and Eriobo (2004) also adopted a transition probability matrix approach to stochastic measurement of manpower stock and flow to forecast for manpower supply and demand. However, the model fails to put in place a strategy to reconcile any difference between the two (supply and demand) if it occurs.

Review of manpower planning models by Edwards (1983) showed that most of the existing research looked at the problem of Manpower Planning from the perspectives of supply and demand only, while few considered manpower costs along with various recruitment policies. Poornachandra Rao (1990) observed that no research had been reported with the objective of minimising manpower costs but later research of Ramirez-Beltran (1995) and Poornachandra Rao (1990) catered for this deficiency but however, assumed knowledge of a labour requirement and unrealistic assumptions about uncertainty of demand.

Poornachandra Rao (1990) made attempt to identify various costs associated with Manpower Planning system based on this, a Manpower Planning model with the objective of minimising the manpower system costs was formulated. The major limitation of the model is the consideration of manpower costs in isolation of various constraints and operating policies under which a manpower system operates. The model proposed an integrated model which will minimise the manpower costs in the presence of the system constraints and other operating policies.

Grinold (1976) examined the problem of producing a commodity with uncertain future demand with time lags in the production process and with the commodity itself being a vital input in the production process. Kurosu (1986)'s research which is of relevance to jobshops situation described the influence of demand uncertainties on waiting time, idle time and rate of losing customers. The study modeled demand as a queuing process and gone as far as prescribing timing and conditions for temporary increasing or decreasing process capacity to absorb fluctuations in demand but, however failed consider the manpower costs. Aderoba (2000) established a procedure for determining appropriate levels of full time labour and overtime engagement.

Unlike many other models for manpower planning, the study did not assume a particular distribution for demand but proceeded to forecast demand on a continuing basis for the production system using both judgmental decision in the initial forecast and exponential smoothing on emerging historical records.

The model however failed to consider the effects of other strategic decisions like availability of tools and equipment and promised due dates. Idris (2008) develops a model similar to Aderoba's model but with the following added features; facility that minimises the alternative cost which caters for the increase in manpower, facility that provides for internal transfer of manpower from centre (s) with excess labour-hour to centre (s) with shortage labour-hour during implementation period as a control measure and also facilitate easy integration with a model that will forecast for a realistic demand and with manpower scheduling. The model developed by Idris is as shown in Eq. 4:

Min C^{*m}_{jt}

$$W_{jt}M_{jt-1} + \Omega^{e}_{jt}\left(W^{e}_{jt}M^{e}_{jt}\right) + \Omega^{t}_{jt}\left(W^{t}_{jt}(D^{f}_{jt} - D^{f}_{jt-1})\right) + \Omega^{p}_{jt}\left(W^{p}_{jt}(D^{f}_{jt} - D^{f}_{jt-1})\right) \quad (4)$$

Where:

W_{ji} = Wages and salaries paid to each of the existing staff in activity centre j in period t

W^{e}_{ji} = Wages and salaries paid to each of the newly employed staff in activity centre j in period t

W^{i}_{jt} = Cost incurred for temporarily transferred manpower to activity centre j in period t

W^{pi}_{jt} = Wages and salaries paid to the part time staff engaged in activity centre j in period t

M_{jt-1} = Number of the existing staff in centre j in period t-1 that would be catered for in period t

M^{ejt} = Number of the newly employed staff in centre j in period t

D^{1}_{jt} = Forecast hour of demand expected in activity centre j in period t

D^{1}_{jt-1} = Forecast hour of demand in activity centre j in period t-1

Ω^{e}_{jt} = Factor to determine the fraction of new manpower to be recruited in activity centre j in period t

Ω^{t}_{jt} = Factor to determine the fraction of manpower-hour to be transferred to activity centre j in period t

Ω^{p}_{jt} = Factor to determine the fraction of manpower-hour to be engaged on part time basis in activity centre j in period t

S_{jt} = Total salary and wages paid to the manpower in activity centre j in period t

H_{jt} = Total working hour of manpower in activity centre j in period t

The model has the following relaxations and constraints:

- If $D^{f}_{jt} \geq D^{f}_{jt-1}$

then

$$\Omega^{e}_{jt} + \Omega^{t}_{jt} + \Omega^{p}_{jt} = 1 \quad (5)$$

Otherwise:

$$\Omega^{e}_{jt} = \Omega^{t}_{jt} = \Omega^{p}_{jt} = 0 \quad (6)$$

- Optimum value of C^{*m}_{jt} can be determined by varying the values of $\Omega^{e}_{jt}, \Omega^{t}_{jt}$ and Ω^{p}_{jt}
- Number of manpower (M_{jt}) to be engaged in activity centre j in period t is determined using Eq. 7:

$$M_{jt} \geq \frac{D^{f}_{jt-1} + \theta_{jt}(D^{f}_{jt} - D^{f}_{jt-1})}{H_{jt}} \quad (7)$$

M_{jt} must be rounded up to the nearest integer no

Where:

$$\theta_{jt} = 1, \text{ if } D^{f}_{jt} \geq D^{f}_{jt-1} \quad (8)$$

= 0, if otherwise

- The existing manpower should not be retrenched during the planning horizon i.e.

$$M_{jt-1} = M_{jt} - Ijt \text{ for all j, t} \quad (9)$$

Where:

- I_{jt} is the voluntary attrition by workers. That is, the growth of workers should be monotonically increasing during the planning period

$$W_{jt} = \frac{S_{jt}}{M_{jt}} \quad (10)$$

- Part-time labour can only be engaged if there is no excess labour hour that can be transferred from another centers, i.e., $\Omega^{p}_{jt} = 1$

$$\text{if } \Omega^{t}_{jt} = 0 \quad (11)$$

TOOLS AND EQUIPMENT PLANNING MODELS

Tools and equipment planning is commonly referred to as capacity planning in many literature. Its objective is to determine the number of tools/equipment that will adequately sustain the production process. Early research on tools/equipment planning like that of Shubin and Madeheim (1975) derived a formula which established numbers of tools/equipment required for any particular operation by dividing the capacity required for such operation by the available capacity, while Cornelius and Ranjit (1975) developed a model for capacity expansion in convex cost networks with uncertain demand. These two aforementioned models were developed based on the knowledge of the available capacity and the capacity required.

Psoinos (1975) used stochastic approach to give expected number of machines required, while Miller and Davis (1977) showed various deterministic and stochastic approaches to capacity planning. Richard *et al.* (1989) adopted queuing methods to determine the number of machine/equipment required for production activities, while Aderoba (1997) and Idris and Aderoba (2000) planned for acquisition of equipment by developing models for sequential investment in machineries. Idris (2008) developed a dynamic tools and equipment planning model specifically for jobshop, taking into consideration the fact that capacity needed in jobshops is stochastic, clouded with various socio-political interferences. The model forecasts for future capacity, provides an effective control measure, minimises the equipment costs with consideration of effects of other strategic decisions on tools and equipment. The model is mathematically as shown in Eq. 12:

Min C_{jt}^{*e} :

$$K_{jt-1}E_{jt-1} + \Pi_{jt}^{p}K_{jt}^{p}E_{jt}^{p} + \Pi_{jt}^{c}K_{jt}^{c}\left(D_{jt}^{f} - D_{jt-1}^{f}\right) + \Pi_{jt}^{o}K_{jt}^{o}\left(D_{jt}^{f} - D_{jt-1}^{f}\right) + \Pi_{jt}^{b}K_{jt}^{b}\left(D_{jt}^{f} - D_{jt-1}^{f}\right) \quad (12)$$

Where:

- E_{jt-1} = Number of available equipment in activity centre j in period t-1
- E_{jt}^{p} = Number of equipment in activity centre j to be acquired in period t
- K_{jt-1} = Cost of purchasing and maintaining the existing equipment in activity centre j in period t-1
- K_{jt}^{p} = Cost of purchasing and maintaining new equipment in activity centre j in period t
- K_{jt}^{c} = Cost of contracting out the activity to be performed by equipment i in period t h^{-1}
- K_{jt}^{o} = Cost of overtime engagement of equipment in activity centre j in period t h^{-1}
- K_{jt}^{b} = Cost of borrowing equipment needed in activity centre j in period t h^{-1}
- K_{nj}^{i} = Initial cost of purchasing equipment n
- D_{jt}^{f} = Forecast hour of demand expected in activity centre j in period t
- D_{jt-1}^{f} = Forecast hour of demand in activity centre j in period t-1
- Π_{jt}^{p} = Factor to determine the fraction of new equipment to be purchased in activity centre j in period t
- Π_{jt}^{c} = Factor to determine the fraction of equipment-hour of centre j in period t to be contracted out
- Π_{jt}^{o} = Factor to determine the fraction of equipment-hour of centre j in period t to be executed using overtime engagement
- Π_{jt}^{b} = Factor to determine the fraction of equipment of centre j in period t to be borrowed
- H_{jt} = Usage hours of equipment in activity centre j in period t
- I_{nj} = Installation cost of equipment n
- Y_{n} = Expected life span of equipment n (in hours)
- δ_{jt}^{e} = Machine maintenance factor

For the implementation of the model, the underlisted constraints and relaxations were considered

- If $D_{jt}^{f} \geq D_{jt-1}^{f}$ Then

$$\Pi_{jt}^{p} + \Pi_{jt}^{c} + \Pi_{jt}^{o} + \Pi_{jt}^{b} = 1 \quad (13)$$

Otherwise:

$$\Pi_{jt}^{p} = \Pi_{jt}^{c} = \Pi_{jt}^{o} = \Pi_{jt}^{b} = 0 \quad (14)$$

- Optimum value of C_{jt}^{*e} can be determined by varying the values of $\Pi_{jt}^{p}, \Pi_{jt}^{c}, \Pi_{jt}^{o}$ and Π_{jt}^{b}
- Number of equipment (E_{jt}) to be made available in activity centre j in period t is determine using Eq. 1:

$$E_{jt} \geq \frac{D_{jt-1}^{f} + \lambda_{jt}(D_{jt}^{f} - D_{jt-1}^{f})}{H_{jt}} \quad (15)$$

E_{jt} was rounded up to the nearest integer no

Where:

$$\lambda_{jt} = 1, \text{ if } D_{jt}^{f} \geq D_{jt-1}^{f} \quad (16)$$

$$= 0, \text{ if otherwise} \quad (17)$$

- $$K_{jt-1} = \delta_{jt}^{e} \sum_{n=1}^{E_{jt}} \left[\frac{K_{n}^{i} + I_{n}}{Y_{n}E_{jt-1}} \right] \quad (18)$$

and

- $$K_{jt}^{p} = \delta_{jt}^{e} \sum_{n=1}^{E_{jt}^{p}} \left[\frac{K_{n}^{i} + I_{n}}{Y_{n}E_{jt}^{p}} \right] \quad (19)$$

δ_{jt}^{e} = Machine maintenance factor

MATERIAL REQUIREMENT PLANNING MODELS

The objectives of Material Requirement Planning (MRP) include control of inventory levels, assign operating priorities for items and plan capacity to load the production system effectively. The importance of material requirement planning is emphasized by that material intake utilisation and re-ordering policy are crucial components for optimal sustenance of any production system.

Literature is very rich in models on material or inventory management, though most of these models were designed to minimise total cost of production by balancing cost of order, holding cost of inventory and shortage cost and were classified under deterministic models or probabilistic models. Among the existing models are ABC inventory models, economic order quantity model (Tersine, 1982; Taha, 1992), purchase inventory model (Sarma and Prasad, 1992), deterministic lot-size inventory model (Shah and Shah, 1992) and economic order quantity model under permissible delay in payment when supply is random (Trivedi and Shah, 1993). Most of these models generate confidence in the stock of meeting any anticipated demand by providing for no shortage. However, they failed to find application in jobshops because the models do not provide for situations like dynamic nature of material cost, vagaries production requirements, uncertainties in job demand and dates for execution of jobs as well as availability of materials in the resource market.

In most uncertainty models, attention had only been focused on demand, although in some few models such as Taha (1992), Gupta and Brennan (1995) and Ho *et al.* (1995) considerations were given to space limitation, supply uncertainty and process uncertainty, respectively.

Most of these models employed probability distributions such as normal and exponential distributions. However, Aderoba *et al* .(2003) model, one of the uncertainty models, provided for a more realistic approach to the problem of inventory management by incorporated standard forecasting techniques into economic order quantity model.

The research also facilitates the usage of actual demand data as they emerge during the planning horizon and allows periodic review process. As comprehensive as this model was, it failed to consider the importance of scheduled-due date.

The issue of scheduled-due date was; constraints on space and fund; multiple raw mat considered by Akintunlaji (2003) model. The model managed the material requirements by providing weekly reports of orders that must be released to work centres in order to meet the scheduled-due dates of jobs, however the model not only failed to optimise its objective but overlook stochastic nature of jobshop environment which necessitate a standard forecasting technique.

Considering the peculiarities of jobshops, material requirement model that will be significant must consider uncertainty of demand and supply erials and allows continue review as well as dynamic analysis to cater for uncertainty situations which fall into three categories; demand uncertainty, supply uncertainty and process uncertainty.

Idris (2008)'s model considered the nature of jobshop that needs to accommodate variety of products, thereby makes material requirement decisions become task of trade-off between cost of holding multiple inventory and the penalty cost in not meeting the due date, due to shortage of material. The model integrated variables; which controls inventory levels, assign operating priorities, plan capacity to load the production system adequately and meet the scheduled-due date of jobs and accounts for other jobshops operating characteristics. The model is shown in Eq. 20:

$$\text{Min} = C_{kt}^{*v}$$

$$\mu_{kt}^{e}\begin{pmatrix}(D_{kt-1}^{f}-D_{kt-1}^{a})P_{kt-1}+\\(D_{kt-1}^{f}-D_{kt-1}^{a}-D_{kt}^{f})P_{kt}\\+\left\{2(D_{kt-1}^{f}-D_{kt-1}^{a})-D_{kt}^{f}\right\}P_{kt}^{h}\end{pmatrix}+\mu_{kt}^{ee}\begin{pmatrix}(D_{kt-1}^{f}-D_{kt-1}^{a})P_{kt-1}+\\(D_{kt-1}^{f}-D_{kt-1}^{a})P_{kt}^{h}\end{pmatrix}+\mu_{kt}^{ne}(P_{kt}+P_{kt}^{s}+0.5P_{kt}^{h})D_{kt}^{f} \quad (20)$$

Where:

C_{kt}^{*v}	=	Optimal cost of inventorying material k in period t
P_{kt-1}	=	Unit price of material k at period t-1
P_{kt}	=	Unit price of material k at period t
P_{kt}^{h}	=	Holding cost of material k at period t
D_{kt-1}^{f}	=	Set up cost of material k at period t
P_{kt}^{s}	=	Forecast quantity of material k predicted to be used in period t -1
D_{kt-1}^{a}	=	Actual quantity of material k used in period t-1
D_{kt}^{f}	=	Forecast quantity of material k expected in period t
R_{kt}	=	Re-order point for quantity k in period t

For the implementation of the model, the following constraints and relaxations were observed:

If $D_{kt-1}^{f}-D_{kt-1}^{a}>0$ and
$D_{kt}^{f}>(D_{kt-1}^{f}-D_{kt-1}^{a})$ then

$$\mu_{kt}^{e}=1 \text{ and } \mu_{kt}^{ee}=\mu_{kt}^{ne}=0 \quad (21)$$

and
If $D_{kt-1}^{f}-D_{kt-1}^{a}>0$
and $D_{kt}^{f}<(D_{kt-1}^{f}-D_{kt-1}^{a})$ then

$$\mu_{kt}^{ee}=1 \text{ and } \mu_{kt}^{e}=\mu_{kt}^{ne}=0 \quad (22)$$

but
If $D_{kt-1}^{f}-D_{kt-1}^{a}\leq 0$ then

$$\mu_{kt}^{ne} = 1 \text{ and } \mu_{kt}^{e} = \mu_{kt}^{ee} = 0 \quad (23)$$

If $D_{kt-1}^{f} - D_{kt-1}^{a} > 0$ and $D_{kt}^{f} > (D_{kt-1}^{f} - D_{kt-1}^{a})$ then

$$R_{kt} = D_{kt}^{f} - (D_{kt-1}^{f} - D_{kt-1}^{a}) \quad 24$$

If $D_{kt-1}^{f} - D_{kt-1}^{a} > 0$ and $D_{kt}^{f} < (D_{kt-1}^{f} - D_{kt-1}^{a})$ then

$$R_{kt} = 0 \quad (25)$$

CONCLUSION

This study showd the peculiarities of jobshops, a typical environment for the manufacturing of low-volume/high-variety products. These peculiarities range from; non-uniformity loading in work centres, stochastic nature of demands, vague knowledge of materials, extraneous socio-economic and political influences among others which have made decisions making in jobshops to be extremely difficult.

Among the decisions that are salient in jobshops are; demand management, Manpower Planning, tools and Equipment Planning as well as material Requirement Planning. This study reviewed the existing models on these aforementioned salient strategic decisions. It critically commented on the merits of these models and discredited others based on their relevance to jobshop peculiarities. It further proposed pointers for future research and directions for new research to complement and enhance the effectiveness of the existing models.

RECOMMENDATIONS

Though, there have been a great deal of research effort focused on solving the problems of jobshop over decades, resulting in a wide variety of approaches and models as shown in this study. However, it was discovered that there is no comprehensive theoretical model which integrate the strategic decisions in jobshops in order to solve the problems holistically.

In view of the earlier, it is recommended that researchers should focus on hybrid methods to solve these problems as a single technique cannot solve them and as well a similar review research should be done on other strategic decisions, not covered by this study.

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