UTM UNIVERSITI TEKNOLOGI MALAYSIA
RESEARCH UNIVERSITY

International Journal
of
Innovative Computing

Journal Homepage: http://se.cs.utm.my/ijic

Case Studies in Implementing Dynamic Production Planning and Scheduling System in Make-To-Order High-Mix-Low-Volume Small and Medium-Scaled Industries for Production Efficiency

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***Abstract*— To manage a high-mix manufacturing environment efficiently is a big challenge for the small and medium-scaled industries (SMIs) because of the nature of its dynamic and ever changing production environment. This has added extra challenges for the SMIs to adopt the right and suitable computerized system for improvement. This paper reviews the implementation of computerized planning and scheduling system to the make-to-order (MTO) high-mix-low-volume (HMLV) SMIs to overcome their daily production challenges in managing the products, processes and resources. Investigation has been conducted in two local manufacturing companies to study the effectiveness of implementing the planning and scheduling system that has brought improvement to the MTO HMLV production environment. The research was conducted in mixed mode of qualitative and quantitative methods after the software being implemented for a year. The findings show the implementation of the system that can bring improvements overall. However, there are some other challenges not related to the software have been discovered such as human factors. The issues are listed in discussion section. The outcome of this research will accrue to manufacturers through an improved understanding of the operation and performance of implementing the system. The authors recommend further research works to be carried out to determine the other key success factors for MTO HMLV SMIs to implement computerize system to improve overall production efficiency.**

Keywords — Dynamic capacity planning and scheduling; make-to-order; high-mix industry.

I. INTRODUCTION

The nature of the manufacturing environment in an engineer-to-order company is very dynamic and ever changing [1]. The strategy and approach to handle the discrete or continuous or process manufacturing processes are different [2, 3]. Bertrand et. al indicated approaches to handle process industry shop, the mass assembly shop, low volume component manufacturing and the project shop are different too [4]. Therefore to implement manufacturing solution effectively for a highly dynamic production environment in order to improve production efficiently is a big challenge. Researches show that implementing an e-Manufacturing solution in high-mix SMIs effectively require to integrate the dynamic capacity planning and scheduling system into the business processes in order to streamline the entire production process workflows [1,5]. Enterprise Resources Planning (ERP) is not the best choice for make-to-order (MTO) high-mix-low-volume (HMLV) industry [6]; instead, Advanced Production Scheduling (APS) shall be considered to complement the ERP in production control to better manage the dynamic change production environment [7]. However APS may not be the best fit for all cases especially the industries that are doing MTO jobbing [8]. These are the concerns and challenges to be considered by the small and medium-scaled industries (SMIs) who are in discrete

manufacturing environment to adopt and implement computerized manufacturing solution.

This paper reviews the implementation of computerized planning and scheduling system to MTO HMLV industry to address these issues by looking into product, process and resources. Investigation has been conducted on two local manufacturing companies to study the applicability of the proposed approaches, and suitability to be implemented in the MTO HMLV and high-mix high volume (HMHV) production environment. The research has been conducted in mixed mode of qualitative and quantitative methods after the companies implemented the computerized manufacturing software solution for a year. The scope of software implementation covered defining the product portfolio with clear bill-of-materials (BOM) structure and its production process flow with dynamic resources allocation to create a seamless product value stream. The process covered the entire manufacturing processes from production order creation, production planning and scheduling and tasks tracking. Production reports were generated for monitoring and served as decision support tools for change management. In this research the level of agreement from the key management personnel on the improvement achieved has been studied and analyzed.

II. Research Methodology

A. Case study companies

The case studies were carried out on two local manufacturing companies **MfgCo1** and **MfgCo2**. Both of the companies are the typical make-to-order, high-mix precision companies that fabricate precision mechanical parts, tools, dies, core and cavity of molds and jigs and fixture. The background information of the companies is shown in Table 1.

TABLE I. Case study companies

Descriptions	MfgCo1	MfgCo2
Nature of business	Fabrication of precision mechanical parts for Electronics, Automation, Oil and Gas, Medical Devices industries	Fabrication of precision tools, dies, core and cavity of molds, jigs and fixtures for Plastic and Metal Stamping Industries
Company type & size	SMI, approx. 50 employees	SMI, approx. 70 employees
Characteristics	Make-to-order High-mix, low volume	Make-to-order, High-mix, low volume
Facilities	Approx. 50 machines,	Approx. 70 machines
Resources	CNC Milling, Turning, Grinding, QC tools like CMM, Roughness tester, high gauge	CNC, EDM, Wirecut, Milling, Lathe, Profile and Surface Grinding, CMM, Laser cut, and QC tools like CMM, high gauge

B. Manufacturing solution deployed

Both companies have adopted a same locally developed manufacturing management software solution that is capable of handling manufacturing order, production process planning, dynamic scheduling and live status tracking and stock control [13]. The software comes with the interactive graphical user interface that allows users to visualize the bill-of-materials (BOM) and product routing processes. The schedule board is interactive that allows the production planning and controller (PPC) to monitor, update and dynamically change the schedule if there is any ad-hoc issue. The job order card can be generated from the system with barcode to allow the production workers to update the job status using the production terminals. Job status is updated immediately after the data inputs and user can monitor all manufacturing orders and job status from the visual management dashboard. Various production reports can be generated from the software for management reporting, change control and decision making.

C. Measuring methodology

The MfgCo1 and MfgCo2 implemented the solution for a year with the on-going support and services from the solution provider. The evaluation and data analysis were based on the assessment on achievement on product, process, resources and overall operation for one year. Questionnaires were set for each category and measured on the agreement level of the improvement on each category. We use the simple scoring method for computation i.e. score 1 for "strongly disagree", score 2 for "disagree", score 3 for "neutral", score 4 for "agree" and score 5 for "strongly agree."

III. Results And Data Analysis

In general, the case studies companies did agree the implementation of dynamic planning and scheduling system to handle product, process and resources has successfully improved their production and processes efficiency. The result shown in Figure 1 is the percentage of the total score versus the total sum of that category:-

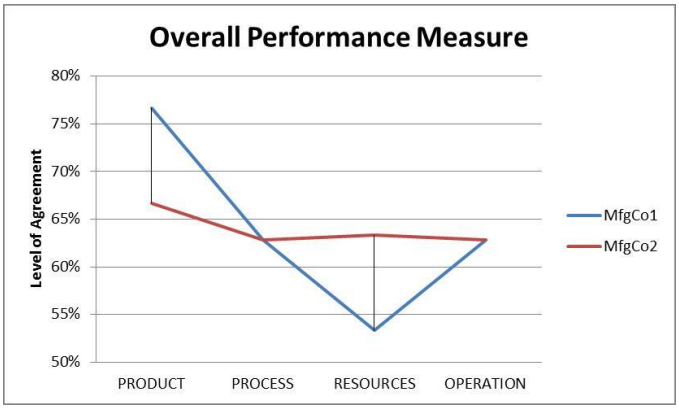

Fig. 1. Performance measure on MfgCo1 and MfgCo2

The details of the assessment for each category are indicated in the followings:-

A. Product improvement

MfgCo1 and MfgC02 agreed that the solution could help to manage the product documentation and its traceability as shown in Fig. 2. MfgCo1 felt the proper definition of product structure and BOM could allow the company to capture the product knowledge and reuse the product information easily.

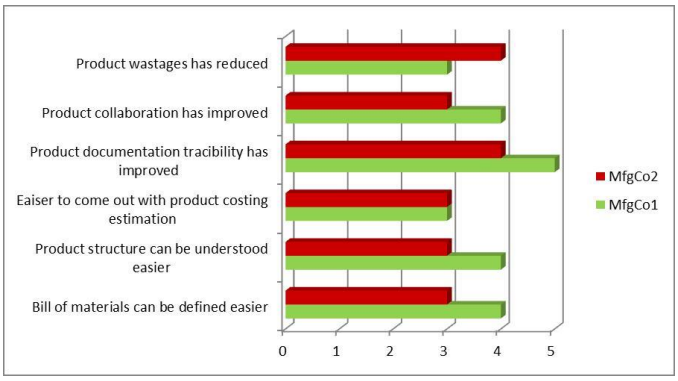

Fig. 2. Product improvement

B. Process improvement

MfgCo1 and MfgCo2 agreed that the implementation of the solution has an impact on the process improvement as shown in Fig. 3. The production operation, process flow and transparency have increased. The product value stream and routing process can be traced easily.

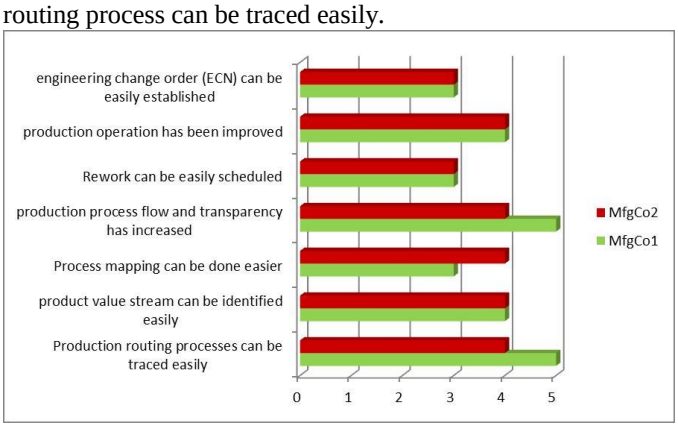

Fig. 3. Process improvement

C. Improvement in resource management

Company MfgCo2 agreed that the solution could improve resources management as shown in Fig. 4. However, MfgCo1 has tougher challenge in resources planning and scheduling and rate lower for the resources capacity determination. Reasons can refer to discussion section.

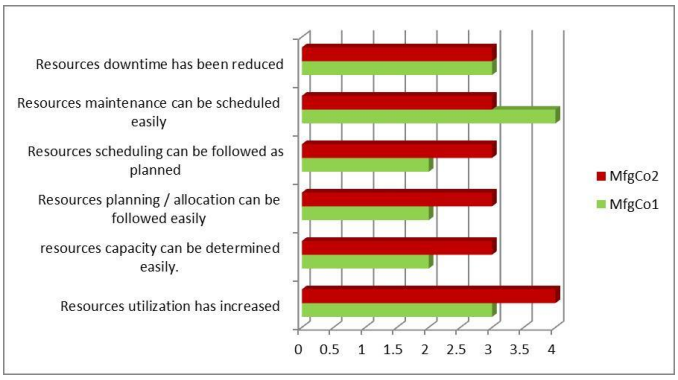

Fig. 4. Improvement in Resource Management

D. Operation improvement

MfgCo1 and MfgCo2 agreed that production management system implementation can help them to improve and manage their product and operation. They have improved their ability to promise and commit to their customers as the results shown in Fig. 5.

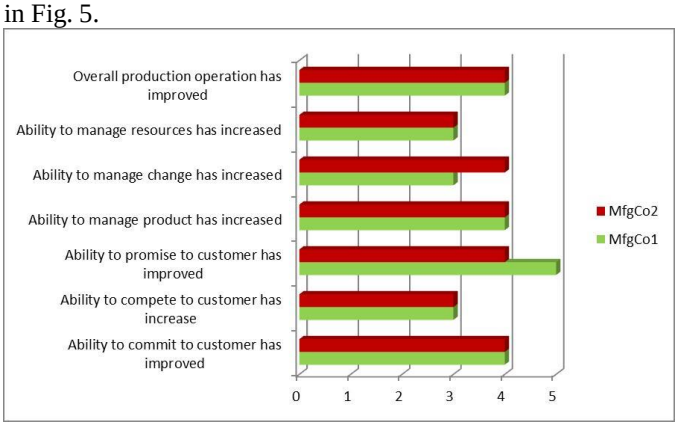

Fig. 5. Operation improvement

In general, the system is able to streamline the production processes and improve the inter-departmental communication. The live status reporting has improved the visibility of the work-in-progress and reduces the fire-fighting issues.

IV. Discussion

Despite the results showed improvements in overall production shop floor control, there are some challenges are yet to be addressed, and beyond the current software solutions capabilities. The production planning and order acceptance are a difficult management problem in MTO HMLV companies because the arrival of orders into the company is a stochastic process where the customers' enquiries cannot be predicted in advance. This challenge faced by the case study companies are aligned with discussion by other research works done by Wortmann [9], McKay [10], Hendry et.al. [11] and Kingsman [12].

Referring to the results gathered above, subsequent interview session with the MfgCo1 and MfgCo2 have discovered the followings challenges faced by the companies.

A. The production lead time is too short

Some enquiries sent in by customers required to be delivered within the same day. Typically it is a MTO case for the new parts that has not been done before. Production manager is required to determine the product routing process, working on what they think best and possibility some try-an-error procedures. Before the PPC enters the job into the software, the job may have been accomplished at the production floor and ready for delivery to the customer. In such scenario, scheduling using software has become unnecessary. That has added the challenge for the PPC to maintain the master production schedule. For recording purposes, PPC needs to enter the job into software for back-tracking. Otherwise those ad-hoc jobs are not shown in the production reports and affecting the computation on the actual resources (machine and man) utilization.

B. The departmental supervisor overwrites the schedule prepared by the planner

Department supervisors are making their own decision to work on the tasks which they think it is best to get done according to their priority. That has resulted the entire production scheduling prepared by the planner is out of order. The department supervisor being asked reveals that normally they can determine whether to change the cutting tools set before starting a new job. They would prefer not to change the tools set in order to shorten the setup time for next job on queue. Therefore they made the final decision to reprioritize the job in hand and informed the PPC after the changes are made.

C. None-estimated time for the CNC code preparation for multi-axis profile cutting

The MfgCo1 and MfgCo2 are both having high-end 3-axis CNC machines to handle the jobs that require complex profile cutting. The CNC programming is handled by the CAD/CAM department and the duration to complete the tasks is determined by the skills, knowledge and the CAD/CAM tools available at the R&D department. The PPC needs to decide whether to include the CNC programming as one of the tracking tasks in the overall production planning for a new manufacturing order received. That will affect the entire production lead time in completing the manufacturing order.

D. Method to handle the in-process QC inspection

Both MfgCo1 and MfgCo2 are required to implement the in-process QC inspection for the precision parts using coordinate measurement machine or gauges to ensure the fabricated parts are within the tolerance before they can proceed to the next process. The duration to conduct the in-process QC is varying from case to case therefore it is difficult for PPC to plan out the time accurately. Prolonging in completing the in-process QC may affect the time for entire scheduled-tasks in the production plan. It will make the entire production schedule vulnerable.

V. CONCLUSION

The outcome of this research will accrue to manufacturers through an improved understanding of the operation and performance of implementing the dynamic production capacity planning and scheduling system. Despite there are some production issues could not be addressed well using the system, the case study companies implemented the alternative approaches or work-around to handle those issues. Further research works can be carried out on the other MTO companies and investigate for the other unidentified issues and challenges in the MTO HMLV production environment. It can be concluded that ability to implement dynamic production capacity planning and scheduling is one of the key success factors for high-mix SMIs to achieve lean manufacturing to improve production efficiency.

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