A FRAMEWORK FOR IMPLEMENTING QUICK RESPONSE MANUFACTURING SYSTEM IN THE JOB SHOP ENVIRONMENT

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ABSTRACT : *As time moved on and marketplace never stopped demanding for better quality, low cost and fast delivery, the resource constraint companies like Small and Medium Enterprises (SMEs) are always struggling to meet the expectations. This is especially distressed for those manufacturing companies that supply high-variety or custom-engineered products. The concept of Quick Response Manufacturing (QRM) was introduced by Professor Rajan Suri in the late 1980s with a strong focus on a companywide strategy to reduce lead-times. It has been highly recommended and implemented in many high-mix and low-volume companies. Despite this, limited research has been done in Malaysia especially in the SMEs that are supplying low-volume, high-mix and custom-engineered products. Although many success stories have been shared, the concept has yet to be spearheaded in the Malaysian industry. The objective of this paper is to develop a suitable QRM system for SMEs. This conceptual framework is also served as a guideline to implement QRM in the challenging environment. The framework is developed through case studies conducted in a SME in Malaysia with the integration of MRP system into the QRM to maximize the potential improvement.*

KEYWORDS: Quick Response Manufacturing (QRM), Small and Medium Enterprises (SMEs), Job Shop Environment, Malaysia

1.0 INTRODUCTION

Time moved on and yet no one can deny that manufacturing is the backbone of modern industrialized state till to date [1]. Enterprises especially SMEs today are struggling to keep up their competitiveness in the market. The contributions of SMEs to Malaysia's economies are critical. As shown in **Table 1**, SMEs in the manufacturing sector was the second largest, with more than 37,000 establishments representing 95.4% after the SMEs in the service sector [2]. SMEs face increasing pressure due to globalization and the demands from their customers. Therefore, it's crucial for them to increase their productivity in order to survive and prosper in the marketplace. This can only happen by adopting the right practices related to the manufacturing strategy of the company. There are many techniques and tools offered to SMEs to improve their performance, such as Toyota Production System (TPS), Lean tools, Agile Manufacturing (AM), Mass Customization (MC), Holonic Manufacturing Systems (HMS) and Quick Response Manufacturing (QRM).

In this paper, the QRM system was selected based on the manufacturing paradigms comparison studies [3,4]. Although many success stories have been shared from the western counterparts, QRM has yet to take off in Malaysia like TPS or Lean Tools. The reason for this laggard response might be due to the lack of understanding of its underlying concepts which cause many are still uncertain of tangible and intangible benefits they may achieve. To kick off QRM in the SMEs with high-mix, low-volume type of production is the challenge. This paper presents a conceptual framework developed to institute a suitable QRM system for SMEs. It is hoped that this framework would provide an important insights and guidance to the manufacturing SMEs to implement QRM. The rest of this paper is organized as follows. In section 2 illustrates the background of this research and reviews related literatures. In section 3 describes the QRM framework and finally, conclusions and future works are presented in section 4.

2.0 BACKGROUND OF THE RESEARCH

In any industrialized country, the SMEs are generally the largest in the manufacturing sector. To survive and prosper in the globalized market, SMEs have never stopped seeking the right strategy and practices to keep up their productivity and competitiveness. One of the speedy ways for the improvement of manufacturing system is the adoption of paradigms defined by recognized manufacturing strategies and concepts. In this section, we present a comprehensive review of literature relevant to this research and justification for the selection of approach best suited for our case study.

The case study focuses on high-mix, low-volume and custom-engineered type of production in a metal fabrication manufacturer (**Figure 1**) dealing with make-to-order (MTO) business. The major challenge facing the high-mix, low-volume and custom-engineered organization is that it has an erratic manufacturing system as compared to the typical mass production. One of erratic causal factors can be identified as schedule [5]. It's also acknowledged that the most common characteristic of many SMEs have within the MTO sector is job shop production. The Manufacturing Management literature has shared many paradigms with the aim of helping the companies to address the challenge of maintaining competitive in the globalised world [6]. The summary from the literature reviews presented in **Table 2** [3] and **Table 3** [4] showed that QRM is the most suitable for a manufacturer's position along with these three characteristics ie. high-mix, low volume and custom-engineerd.

Starting in the late 1980's, quick response techniques are needed more than ever for the SMEs to compete in today's global economy. Quick Response Manufacturing (QRM) is an emerging shop floor management technique best suited for high product mix and variable demand environments. Most of these types of companies have not managed to adopt QRM in a way that fully exploit their enterprise resources and support the business strategy. Over the last decade, a quick response manufacturing paradigm has been underlined as an alternative to, and possibly an improvement on, leanness. Suri [7] introduced QRM as a distinctive paradigm of reacting to dynamically changing markets where customers are demanding more differentiated products in lower volumes and within less production lead time.

The case studies focused on several points that are: methods to commence and execute QRM across the enterprise, application of QRM tools and practices, its major or unpredictable obstacles as well as ways to resolve them. Preliminary studies in the selected SME were carried out and coupled with literature reviews to construct a conceptual framework. The framework includes determining the gaps, identifying key areas for lead time improvement, defining improvement actions, suggestions on the usage of QRM tools as well as the steps to implement QRM. The framework was evaluated and revised by the company in order to increase its applicability.

The research is one of the first empirical studies which present the model as a new perspective to improve productivity performance of a company located in Malaysia. Malaysia have years of efforts to emphasize the importance of productivity, while there has been lack of participation to adopt the renowned ideas such as QRM to leverage the global competitiveness of the companies. Hence, the outcome of the research will spark the interests and beneficial to the manufacturing industries locally and perhaps within the Asean countries.

3.0 QUICK RESPONSE MANUFACTURING FRAMEWORK

Deros et al. [8] suggested that a framework is a set of simplified theoretical principles and practical guidelines which is easy to understand, efficient and can be implemented. A strong conceptual framework captures something real and does this in a way that is easy to remember and apply [9]. It is believed that a sound framework can assist and provide a guide in the implementation process [10]. Therefore, the QRM implementation framework was developed by conducting case studies in a SME in Malaysia is shown in **Figure 2** which consists of two parts that are described below.

The first part is to understand the current state and determine the gaps that to be addressed in the transformation plan, where it acts as a guide for improvement to be carried out. The second part is the integrated Material Requirements Planning (MRP) system to be developed as a supporting role in the deployment of a lead-time reduction strategy.

3.1 A QRM Enterprise Transformation Plan

QRM concepts must be firstly be understood before implementation. The first phrase of the framework structure is underpinned by four Strategies and Tools which are:

- Lead time as a management strategy
- Organizational structure
- System dynamics
- Enterprisewide application

Suri [7] stated that an effective strategy needs to be supported by a precise methodology and appropriate tools. Therefore, the QRM strategies that are supported by some means and techniques or activities have been defined in the transformation plan as shown in the framework (**Figure 2)**.

3.1.1 Lead Time as a Management Strategy

QRM suggests that an enterprisewide focus on reducing lead times will result in improvements in both quality and cost. Eliminating the non-value added time can lead to large cost savings while improving product quality and customer responsiveness. Hence, on a management level, QRM promotes a mindset change from cost-based to time-based thinking, making short lead times the yardstick for organizational success [11].

- ***Manufacturing Critical-path Time (MCT)***

QRM's strong focus on lead time reduction requires a comprehensive definition of lead time. To accomplish this, QRM introduces Manufacturing Critical-path Time (MCT). It is based on the standard critical path method; defined as the typical amount of calendar time from when a customer creates an order, until the first piece of that order is delivered to the customer [12].

3.1.2 Organizational Structure

Though QRM requires four fundamental structural changes to transform a company organized around cost-based management strategies to a time-based focus [12], not all are applicable based on the actual company conditions. Hence, only the shortlisted practices with some customization are presented.

- **Top-down Control to Team Ownership**

The work organization in QRM structure is based on team ownership. Provided with a job and a completion deadline, teams can decide independently on how to complete the job. To ensure quick response to high-variety demand, workers need to go through cross training [12].

- **Efficiency/Utilization Goals to Lead Time Reduction**

To support this new structure, companies must replace cost-based goals of efficiency and utilization with the overarching goal of lead time reduction [11].

3.1.3 System Dynamics

In QRM, the product-focused operation has to be complemented by a thorough understanding of system dynamics in order to make better decisions. Based on principles of system dynamics, QRM identifies high utilization of machines as one of the major obstacles to lead time reduction.

Table 1: Number of Establishments by Sector

Sector	Micro	Small	Medium	Total SMEs	Total SMEs	Large Firms	Total Establishments
	Number of Establishments				% Share	Number	Number
Manufacturing	21,619	13,934	2,308	37,861	5.9	1,808	39,669
Services	462,420	106,061	12,504	580,985	90.1	10,898	591,883
Agriculture	3,775	1,941	992	6,708	1.0	2,121	8,829
Construction	8,587	6,725	3,971	19,283	3.0	2,857	22,140
Mining & Quarrying	57	126	116	299	0.05	119	418
Total SMEs	496,458	128,787	19,891	645,136	100.0	17,803	662,939

Source: Economic / SMEs Census 2011 by Department of Statistics, Malaysia

- **Create Spare Capacity**

Many cost-based organizations aim for machines and labor to be utilized at close to 100% of capacity. QRM criticizes this approach as counterproductive to lead time reduction based on queuing theory, which shows that high utilization increases waiting times for products. In order to be able to handle high variability in demand and products, QRM advises companies to operate at 80 percent capacity on critical resources [13].

3.1.4 Enterprisewide Application

QRM emphasizes time-based thinking throughout the organization, creating a unified management strategy for the entire enterprise. Extending beyond traditional efforts to optimize shop floor operations, QRM applies time-based management principles to all other parts of the organization [11].

- **Material Planning**

QRM criticizes commonly used material planning and scheduling systems such as Material Requirements Planning (MRP), Manufacturing resource planning (MRP II), and Enterprise resource planning (ERP) for not incorporating system dynamics in their analysis and not accounting for the cost of long lead times [12]. QRM recommends simplifying existing MRP systems to a Higher Level MRP (HL/MRP) concerned with high-level planning and coordination of material and not with detailed scheduling of operations [12].

- **Production Control**

To coordinate and control flow within the QRM structure and HL/MRP, QRM utilizes POLCA (Paired-cell Overlapping Loops of Cards with Authorization) [14]. POLCA is a card-based shop floor control system, designed as the QRM alternative to Kanban. POLCA differs from commonly used Kanban systems in the type of signal it sends to move jobs/material through the shop floor. POLCA constitutes a capacity signal, showing that a cell is ready to work on a new job, whereas Kanban systems rely on inventory signals designed to replenish a certain quantity of parts [15].

- **Supply Chain**

QRM recommends that MCT be included as a significant factor in sourcing decisions [16]. Long supplier lead times can incur "hidden" costs such as high inventory, freight cost for rush shipments, unplanned engineering changes creating obsolete inventory, and reduced flexibility to respond to demand changes [12].

3.2 Material Requirements Planning (MRP) System

Orlicky [17] developed and defined MRP as a group of procedures through which the components could not [18]:

- to be drifted,
- to satisfy to the demand and
- to be calculated correctly

taking for base the customers' demand and the plans of previous production.

In this case study, MRP is neither the strategy for lead-time reduction, nor the solution to be deployed. MRP is required to align with QRM techniques in order to accelerate the movement of jobs and information across the enterprise. It provides real time information to whoever needs it. The captive data helps to identify the non-value added time that can be reduced or eliminated. MRP is in a unique position to achieve this because of the implementation across the company and its vast ability to extend and integrate manufacturing functions.

Taking into considerations from Wight [19], the elements that the system MRP/MRPII include are:

- the manufacture environment
- the structure of the products
- the lead teams
- the planning horizon

Table 2: Strategic Paradigm for Manufacturing Management and their Drivers [3]

Drivers	Current Mass Manufacturing	Lean Manufacturing	Responsive Manufacturing	Mass Customization	Agile Manufacturing
Market	Homogeneous	Stable	Competition based on time and the diversification of products	Customized product	Unpredictable
Targeted Customer	Regard price as the main competitive differential	Require price, quality and variety of similar products	Seek speed, dependability and a lot of variety, i.e., responsiveness	Require customization	With the widest possible variety of requirements that can change
Principles/ Enablers	Focus on clients who require low prices; focus on product standardization, but allowing some distinction; focus on operational efficiency/high productivity; highly specialized work.	Focus on quality; focus on offering the customer a wide distinction of similar products, with low diversification; focus on identifying and eliminating waste; adopting *just-in-time* as a production control strategy, made up of various principles (pulled production etc.); autonomation.	Focus on meeting the needs of customers who prioritize product diversification, response time and meeting deadlines; adopting a production control strategy that focuses time based competition, in an environment with a wide range of products.	Focus on meeting fragmented demand, for different needs/ requirements; reducing product development cycle and product life cycle; customer participation in all steps of the product life cycle.	Focus on identifying new business opportunities; management based on key competences; developing abilities to deal with change and uncertainty; virtual enterprise.

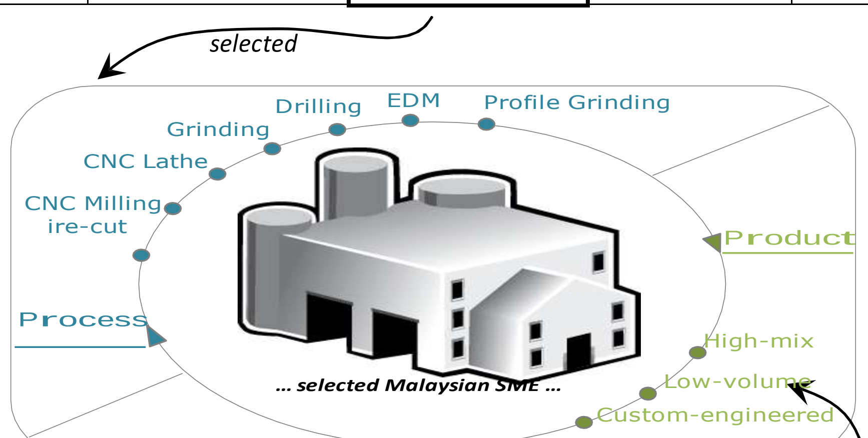

Figure 1: Metal Fabrication Factory with MTO and Job Shop Environment

Table 3: Taxonomic Comparison of Manufacturing Paradigms [4]

Feature	TPS	Lean / 6 σ	Agile Manufacturing	Mass Customization	Holonic Manufacturing	QRM
Customization				✓	✓	✓
Flexibility			✓	✓	✓	✓
Inventory reduction	✓	✓				✓
Lead Time		✓	✓	✓		✓
Organization-focus		✓	✓			✓
Quality	✓	✓	✓			✓
Reconfigurability			✓		✓	
Responsive			✓	✓	✓	✓
Waste elimination	✓	✓	✓			

- the sales forecasts
- the master production plan
- the production capacity
- the determination of the replacement lots and
- additional aspects as the pegging, the processing type (net change or regenerative)
- the calculation of safety's stocks

4.0 CONCLUSIONS

Many companies are keen to reduce manufacturing lead time but the influential factors are not always understood. While the lead time reduction can indeed be a challenging task due to many causes and their complexities, the companies that are interested to adopt QRM need to understand the basic principles, when applied correctly, can yield the desired results. Though QRM is proven in many high-mix and low-volume companies, the company must prudently decide which strategies and tools can be used to meet their distinctive environment. Like other initiatives, QRM is a continuing effort and it requires total commitment across the enterprise to ensure its success. The framework presented in this paper shared how QRM can be adopted in the SMEs by providing the tools and means for implementation. In future work, each step of the framework can be tested in the real environmental conditions of SME to assess its effectiveness with proven examples and data.

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