AN ASSESSMENT OF THE APPLICABILITY OF ENTERPRISE RESOURCE PLANNING SYSTEMS TO MAKE-TO-ORDER COMPANIES

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Abstract

Many vendors of Enterprise Resource Planning (ERP) systems claim that their products are widely applicable – configurable to meet the needs of any business, whatever the product or service offering. However, producers of high-variety and bespoke products, such as Make-To-Order (MTO) companies, present particular challenges to implementation and it remains unclear whether ERP systems can cater for their needs. This paper provides an assessment of the applicability of ERP to the MTO sector. In assessing applicability, we consider factors such as the planning and control stages of relevance to MTO companies, and the typical size and supply chain positioning of MTO companies. The assessment concludes that there is a significant gap between the requirements of MTO companies and the functionality of ERP systems. One such gap is between the customer enquiry management and design and engineering processes of MTO companies and those supported by ERP systems.

Keywords: Enterprise Resource Planning (ERP); Make-To-Order (MTO); Small and Medium sized Enterprise (SME); Applicability.

1 INTRODUCTION

When implemented effectively, Enterprise Resource Planning (ERP) systems enable a company to integrate the information used throughout the organization (see, for example, Davenport 1998). ERP systems can lead to business benefits such as real-time data, synchronised decision-making, improved visibility, and increased automation of routine tasks. ERP systems have traditionally been implemented by large companies but vendors have begun to market their products towards Small and Medium sized Enterprises (SMEs). This is coupled with increasing pressure on many SMEs by large customers to adopt ERP. Moreover, while many ERP vendors claim that their systems are configurable to meet the needs of any business, producers of high-variety and bespoke products, such as in the Make-To-Order (MTO) sector, present particular challenges. Despite the wide applicability of ERP systems, it is unclear whether they can cater sufficiently for the needs of MTO companies.

Implementing an ERP solution is expensive and has been criticized for causing deep changes in culture and organizational behaviour. Given that many MTO companies are SMEs with limited financial resources, they are particularly vulnerable if implementation is unsuccessful. As a result, choosing whether to implement an ERP system is a difficult but important decision.

This paper provides an assessment of the applicability of ERP to the MTO sector. While several studies of the ERP literature have previously been presented, these either do not focus on the MTO sector, or seek to assess the applicability of ERP systems, or give sufficient attention to recent developments in the fast moving ERP industry. This paper has a particular interest in studies of the impact of company size or industry-specific characteristics on ERP, and recent developments, including add-ons to core ERP systems. We do not seek to focus on broad implementation issues or to provide a detailed historical description of the evolution of ERP systems. For an overview of

implementation issues, see Umble *et al*. (2003); for a detailed historical perspective on ERP, see Rashid *et al*. (2002) and Jacobs and Weston (2007).

The remainder of this paper is organized as follows. Section 2 defines the characteristics and requirements of MTO companies before Section 3 provides an overview of ERP systems, including recent extensions to their core functionality. Section 4 then assesses the fit between the characteristics of MTO companies and the functionality of these systems. Section 5 identifies some of the gaps in the literature in need of further research before the paper concludes in Section 6.

2 CHARACTERISTICS OF THE MAKE-TO-ORDER (MTO) SECTOR

Choosing whether to produce 'to-stock' or 'to-order' is a strategic decision (Amaro *et al.* 1999). Positions along the continuum (e.g., Make-to-Stock (MTS), Assemble-to-Order (ATO), MTO, and Engineer-to-Order (ETO)) are separated by the order penetration, or customer de-coupling, point (OPP, see Olhager and Ostlund 1990, Olhager 2003). In a MTS or ATO setting, finished goods or components are held in anticipation of demand while in an ETO or a MTO setting, design and production are driven by customer orders. The above are the most commonly referred to production strategies; however, many others exist. For example: Design-To-Order and Make-To-Print (DTO and MTP, e.g., Hill 1993); Build-To-Order (BTO, e.g., Gunasekaran and Ngai 2005); Configure-To-Order (CTO, e.g., Chen *et al.* 2003); and, Finish-To-Order (FTO, e.g., Wikner and Rudberg 2005).

This paper chooses to refer to only one - MTO – but uses this in a broad sense. In our definition (see also Hill 2000, p. 379), MTO is an 'umbrella term' referring to companies that produce bespoke products and products customized to the specifications of a particular customer but not repeated on a regular basis or in a predictable manner. This definition incorporates DTO, MTP and ETO, but is separated from MTS, and ATO. The following describes the characteristics and requirements of MTO companies as defined above, to be considered in determining ERP applicability.

- *Production Planning and Control (PPC) Stages*

The following stages are critical to the order processing cycle in MTO companies:

  - *Customer Enquiry Stage:* where a customer provides an invitation-to-tender for a particular product to prospective suppliers, requiring the determination of a price and due date. For MTO firms, planning and control must begin here as each order can be different.
  - *Design and Engineering Stage:* where detailed design and engineering planning takes place for accepted orders. This stage is of particular relevance for DTO and ETO strategies.
  - *Job Entry Stage:* where the production of a confirmed order is planned, including: material requirements, purchasing and shop floor routing.
  - *Job Release Stage:* a decoupling phase, where the firm decides when to start producing, to prevent confirmed orders at the job entry stage from entering the shop floor immediately.
  - *Shop Floor Dispatching Stage:* where detailed shop floor scheduling is determined and jobs are sequenced on the shop floor, e.g., via job prioritization.

- *Shop Floor Configuration of MTO Companies*

Common shop floor configurations are Pure Flow Shop (PFS), General Flow Shop (GFS), General Job Shop (GJS) and Pure Job Shop (PJS), differing in terms of flow direction and processing flexibility. Job shop configurations are suitable in customised production contexts, such as the MTO industry (Stevenson *et al.* 2005) but can lead to complex planning problems. The PFS and GFS configurations are more suitable for continuous processes or assembly line manufacturing (i.e. MTS or ATO).

- *MTO Companies and the Supply Chain*

MTO companies are often positioned towards the upstream end of supply chains (SCs), serving large, powerful customers. Given this position, information about end-customer demand is limited and customers often outsource work to their upstream suppliers at short notice; hence, rush orders are

common place. Stevenson *et al*. (2005) and Stevenson and Hendry (2007) explain that the presence of rush orders is likely to affect the type of PPC solution appropriate to MTO companies and highlight the importance of web-based practices that promote coordination within SCs.

The importance of effective Supply Chain Management (SCM) practices for MTO companies is demonstrated by the following examples:

- Information sharing and coordination along the SC can facilitate cost reduction and improved due date adherence (Sahin and Robinson 2005);
- Effective knowledge sharing in the SC can be a competitive advantage (Hicks *et al.* 2000);
- Purchasing as a percentage of total cost is argued to be higher for MTO than MTS. Hence, supplier relations can be highly significant, having an impact on a firm's ability to satisfy customers (Jahnukainen and Lahti 1999).

- *MTO Companies and Product Customization*

The degree of customization is closely related to shop configuration and the OPP (Hayes and Wheelwright 1979). MTO companies conduct *pure* and *tailored* customization (Lampel and Mintzberg 1996) which need a high degree of customer interaction and cause long and variable lead times.

Amaro *et al*. (1999) define two types of MTO companies in relation to customisation: Repeat Business Customisers (RBCs) and Versatile Manufacturing Companies (VMCs). A RBC provides customised products on a continuous basis over the length of a contract while a VMC manufactures a high variety of products but competes for each order separately. Both types provide customisation, but the RBC is able to establish more stability by enticing customers into a more predictable and committed relationship (Stevenson and Hendry 2007).

- MTO *Company Size*

Many MTO companies are SMEs (SMEs, see: Amaro *et al.* 1999, Stevenson *et al.* 2005). According to the EU Commission (2003), medium, small and, micro-sized companies have less than 250, 50 and 10 employees or a turnover less than €50, €10 and €2 million, respectively. Micro-sized companies are argued to be too small to require the implementation of an ERP system and are therefore not considered further in this paper.

- *MTO* Market *Characteristics*

Brown and Bessant (2003) argue that market demand for customized products is now greater than ever before. This growing market results in short product life cycles and requires a company to have a wide product range. Product specifications are often unpredictable and demand can be uncertain. MTO companies have to perform a continuous search for new business while simultaneously satisfying existing customers. The volatility of the MTO market is demonstrated by the strike rate (the percentage of tenders which become firm orders) which for MTO companies can be very low (e.g., %15 in the case in Stevenson 2006).

3 CHARACTERISTICS OF MODERN ERP SYSTEMS

Davenport *et al.* (2004) define an ERP system as a "packaged software application that connects and manages information flows within and across a complex organization, allowing managers to make decisions based on information that truly reflects the current state of their business". Today's ERP systems stem from Material Requirements Planning (MRP) and Manufacturing Resource Planning (MRP-II).

MRP, developed by Plossl and Wight (1971), is the core material requirements planning system, achieving step-by-step netting, lot-sizing, time phasing and BOM explosion. It is quite straightforward yet this simplicity can lead to extreme "system nervousness" (Orlicky and Plossl 1994). Moreover, the original MRP concept did not perform detailed and capacitated planning of resources. 'Closed Loop

MRP' emerged to address capacity planning problems and to introduce a hierarchical planning structure. MRP was extended to include primary business functions (e.g., marketing, human resources, accounting and finance) and the data supporting them was integrated into a single, central database. This systembecame known as MRP-II (Wight 1981), is the hierarchical capacity-constrained manufacturing planning system with automated primary business functions. The key difference between MRP-II and ERP is that the latter is not only designed for the needs of the manufacturing sector – but for any company in any sector, e.g., healthcare, banking and education. It is the company-wide system designed to plan and control all business functions across an enterprise. ERP's market penetration was accelerated by factors such as its ability to enable the minimization of time spent on manual tasks, and concerns over the year 2000 (Y2K) compliancy of previous legacy systems.

As predicted by Davenport (2000), the functionality of ERP systems has continued to grow and their scope has begun to extend from internal processes (e.g. transaction automation and internal planning) to collective and external processes in the wider network. This trend has led to the term "Extended ERP" or "ERP-II" (Rashid *et al.* 2002, Botta-Genoulaz *et al.* 2005) to refer to add-ons to the core internally-facing ERP system and a shift from transaction-oriented to analytically-oriented systems. It is the combination of ERP with one or more analytical add-ons, extending the functionality of ERP beyond internally-oriented processes.

- *Supply Chain Management Software*

Many companies have focussed on their core competencies, outsourcing other operations to firms in the SC. This has increased the reliance on SC partners. As a result, firms are taking an increasing interest in the wider SC; software to support SCM has thus been demanded. ERP is becoming the process-oriented transaction backbone for intra- and inter-company SCM (de Kok and Graves 2003).

Early examples of SCM software supported logistics and inventory management in the SC but were not well integrated with other systems. Today, with information integration, the main role of SCM software is in cost reduction and improved: efficiency, service and customer relationships (Davenport and Brooks 2004).

- *Advanced Planning and Scheduling Software*

Despite its name, an Enterprise Resource *Planning* system does not concentrate on resolving planning issues but rather business process management and transactional activities (Fleischmann *et al.* 2002). In contrast, Advanced Planning and Scheduling (APS) systems address manufacturing planning and scheduling problems based on hierarchical planning principles (Stadtler and Kilger 2002). Available-to-Promise (ATP) and Capable-to-Promise (CTP) functionality is also incorporated in APS systems. ATP refers to determining the availability of 'uncommitted' finished goods inventory (FGI) at certain points of time in the planning horizon; CTP indicates remaining slack capacity after available capacity has been matched with committed customer orders (Ball *et al.* 2004).

'Advanced' ATP (AATP) broadens the functionality and scope of ATP from production capacity planning and support for order quotation activities to also include raw material and distribution capacities (Chen *et al.* 2002). ERP and APS vendors provide both AATP and CTP since it is important to consider both quantity and due date quotation issues based on the resources of the whole SC (Pibernik 2005).

- *Customer Relationship Management Software*

Customer Relationship Management (CRM) software has emerged more recently than ERP and SCM; the original concept was introduced as "one-to-one marketing" by Peppers and Rogers (1993). Using CRM software, a company can compile data on customers and analyze it in order to sell more goods or services, and to do so more efficiently (Bose 2002). CRM possesses its own infrastructure and can be implemented and utilized without ERP system support; however, ERP is thought to be a supportive structure for the growing needs of CRM. Thus, many ERP vendors have invested in developing or acquiring CRM add-ons; many ERP vendors are now also major CRM vendors.

- *Other Software Extensions to ERP*

In addition to the three key extensions above, the following may be of relevance to MTO companies:

- *Collaborative Planning, Forecasting and Replenishment (CPFR) software:* both a strategy and a supply chain solution for joint decision making via information sharing, marketing, sales, and production. CPFR is mostly restricted to fast moving consumer goods and the retail industry.
- *Customer Enquiry Management (CEM) software:* focuses on due date and price estimation. SAP R/3 is said to contain a CEM-like component within its order management module (Knolmayer *et al.* 2002, Xiong *et al.* 2006). It is also reportedly used for automating order entry, processing customer orders and tracking order status.
- *Product Configuration (or 'Variant Generator') software:* is an increasingly used add-on. Even many small-sized ERP vendors now provide it via the Internet. The typical example is a computer retailer's website used as an interface between the end-customer and suppliers; the customer selects components they would like and the suppliers receive the order simultaneously (e.g., the computer assembly case in Fleischmann and Meyr 2003).
- *Product Lifecycle Management (PLM) software*: enables a company to bring innovative products to market effectively (Møller 2005). PLM incorporates: Product Design Support (PDS), including cost estimation, product development, and prototyping; and, Product Data Management (PDM), enabling a company to manage product-related information more effectively throughout the lifecycle of a product.

Section 2 above defined the requirements of the MTO sector before Section 3 described ERP and its extensions. Following this, Table 1 summarizes the requirements and characteristics of MTO companies, lists the functionality provided by ERP, and raises a series of research questions (RQ1A-RQ6A) to be considered.

4 ASSESSING THE RELEVANCE OF ERP TO THE MTO SECTOR

This section seeks to explore the available literature on ERP, and its extensions, in contexts which demonstrate one or more of the characteristics of the MTO sector, as outlined in Section 2. Firstly, with a focus on SMEs, the impact of company size on ERP adoption is explored; then, the characteristics and requirements of MTO companies (whatever their size) are compared with the business processes supported by core ERP systems; finally, the relevance of ERP extensions to the characteristics of MTO companies are considered.

4.1 ERP Adoption in SMEs

Company size is a factor which influences a wide range of issues, which has been explored in many different streams of the Operations Management literature. The large company market for ERP systems is arguably reaching saturation point – many large organizations have either implemented ERP or are in the process of implementing ERP.

Mabert *et al.* (2003) studied the impact of company size on ERP adoption through a series of case studies and interviews. In addition, the authors presented five propositions on the impact of company size on ERP adoption and then conducted a survey to test those propositions. However, the propositions are relatively straightforward and do not advance our understanding of the impact of company size on ERP adoption substantially. Nonetheless, the work is important as it emphasized the need to study the impact of company size on ERP adoption, leading to several other studies and national perspectives on ERP adoption in SMEs. After Mabert *et al.* (2003), studies of ERP adoption in SMEs in several different countries have been conducted in recent years. For example: Morabito *et al.*'s (2005) survey of Italian SMEs, Argyropoulou *et al.*'s (2007) survey of Greek SMEs, and Finnish SMEs surveyed by Laukkanen *et al.* (2007).

Table 1: Summary of MTO characteristics and issues for ERP systems to support

Characteristics		
1. Planning and Control Stages	Summary of MTO Issues	The full range of planning and control stages are important for MTO production (customer enquiry, design and engineering, job entry, job release, and shop floor dispatching).
	ERP System Provision	Through combining ERP with extensions, support for quoting, design and engineering, job entry & release, and dispatching stages is possible (ATP & CEM, product configurator & PLM, MPS and shop floor scheduling).
	Emerging Research Question(s)	RQ1A: Can ERP provide sufficient support at the customer enquiry stage to help quote accurate delivery dates? RQ1B: Can ERP provide a suitably flexible platform to plan and control complex design and engineering activities? RQ1C: Can ERP provide sufficient support for the job entry and release stages of MTO companies?
2. Shop Floor Configuration	Summary of MTO Issues	Job shop configuration is typical in MTO companies but can lead to planning and control complexity.
	ERP System Provision	MRP-driven replenishment support provided but may be unsuitable for a job shop environment.
	Emerging Research Question(s)	RQ2A: Can ERP systems provide a suitably flexible solution for dynamic job shop production environments?
3. The Supply Chain	Summary of MTO Issues	Many MTO companies are positioned upstream in the supply chain; rush orders are prominent.
	ERP System Provision	Internet-enabled supply chain information sharing and co-ordination functionality offered by ERP extensions.
	Emerging Research Question(s)	RQ3A: Can the functionality of ERP software, and its extensions, provide sufficient planning and control support for handling rush orders effectively?
4. Product Customization	Summary of MTO Issues	Highly customized production typical, including repeat but also unpredictable one-off manufacturing.
	ERP System Provision	Product life cycle and product configuration software available; customer relation management software is available.
	Emerging Research Question(s)	RQ4A: Is the product configuration and PLCM software effective for highly customized, and one-of-a-kind, products? RQ4B: Can ERP help MTO firms to develop customer relations (and turn one-off customers into repeat purchasers)?
5. Company Size	Summary of MTO Issues	A significant proportion of MTO companies are SMEs with relatively simple organisational structures; ERP adoption factors may also differ and IT budgets are smaller than in large organisations.
	ERP System Provision	Many ERP systems claim to be for all business sizes; a variety of pricing structures and user licences are available.
	Emerging Research Question(s)	RQ5A: Are SMEs in need of, or sufficiently complex to require, large-scale integrating mechanisms such as ERP?
6. Market Characteristics	Summary of MTO Issues	Uncertain market features, high levels of competition, and a low strike rate are typical.
	ERP System Provision	It has been claimed that ERP systems can provide a source of competitive advantage, although in some contexts they are now the 'industry standard'.
	Emerging Research Question(s)	RQ6A: Can ERP help MTO companies, including MTO SMEs, to increase their competitiveness in the market?

National perspectives on ERP adoption enrich the literature in many ways. In addition to supporting proposed theory and highlighting the impact of company size, they also uncover cultural and national issues previously over-looked in the literature. Olhager and Selldin (2003) report that, unlike in some other countries, Swedish companies generally prefer European and Swedish ERP vendors over huge global vendors. Sheu *et al*. (2004) conducted a study on national differences in ERP adoption through case study research of companies. The authors found that ERP adoption can be more difficult in Europe than in North America due to complex European corporate and national cultures. Perhaps the reason why Olhager and Selldin (2003) found that Swedish firms prefer local vendors is that, by doing so, these firms seek to eliminate these cultural and national obstacles. To the best of our knowledge, there is no research which explores ERP adoption by UK SMEs; while Koh and Simpson (2007) questioned the suitability of ERP for SMEs in the UK, the survey and interviews conducted by the authors have a different focus - diagnosing uncertainty in SMEs using ERP. Developing a body of knowledge from different national perspectives, including the UK, would help to further our understanding of the impact of company size with cultural and national differences on ERP adoption. Buonanno *et al*. (2005) investigated the relationships between business complexities, organizational change and ERP adoption, and explored the impact of seven factors on ERP adoption. The authors found company size to be the only significant factor.

To conclude the above discussion, company size has recently been recognized as a factor that affects ERP adoption. This is a topical area of research, given that ERP vendors have begun to market their products towards SMEs. At present the fit between ERP and SMEs appears inconclusive. Company size influences the structure of many company-wide activities, affecting a company's internal and external dynamics; therefore, it is understandable that this is an important factor in the adoption of integrating mechanisms such as an ERP system. Although there have been several recent studies of the relationship between company size and ERP adoption, most of these have ignored the impact of the order penetration point. However, the order penetration point has a substantial impact on planning at the firm and supply chain level (Fleischmann and Meyr 2003). It would be valuable to revisit the data collected in the studies reviewed in this subsection and acquire further information from the respondents on the order penetration point and manufacturing strategy of the companies in order to provide a richer insight into this topic for MTO SMEs.

4.2 ERP and MTO Production

ERP systems contain a wide variety of modules and subcomponents for various decision support and transaction automation purposes. The MTO sector consists of companies with idiosyncratic processes specific to an industry or an individual firm. Therefore, it is important to explore whether ERP systems are able to meet the requirements of MTO companies (e.g., through flexibility).

A successful adoption of ERP in a MTO company relies on an ability to customize the system and set appropriate parameters in each of the major primary ERP modules such as accounting, finance and human resources. This is an important issue that makes ERP systems internally consistent and externally reliable but, to date, there is no literature available which focuses on this issue. The key characteristic that differentiates MTO companies from producers of more standard products is the production process, therefore, what follows focuses on the applicability of ERP functionality to a MTO companyfrom a production perspective.

Hendry and Kingsman (1989) and Stevenson *et al*. (2005) reviewed the literature to consider PPC applicability to the MTO sector, in which MRP-II and ERP were investigated, respectively. Despite considering the planning modules of MRP-II systems unsuitable for MTO companies, Hendry and Kingsman (1989) found them useful for the integration of production and marketing functions. However, a lack of functionality to support the customer enquiry stage was highlighted as a significant gap. Stevenson *et al*. (2005) evaluated the applicability of ERP systems to the MTO sector according to shop configuration and contract type (i.e. RBC or VMC). Again, despite some gaps, ERP was found to be generally suitable due to its wide availability and e-business capabilities. The authors did not,

however, provide a sufficiently in-depth analysis of the fit between ERP and MTO companies at each planning and control stage. Deep *et al.* (2008) conducted a case study investigation of the factors affecting ERP system selection by a MTO company. While this provides a useful insight, it fails to provide a comprehensive review of the relevant literature or to consider the full range of order processing activities of relevance to MTO companies. The following is an attempt to address this:

- *Customer Enquiry Stage:* is a key planning and control phase for MTO companies – if due dates are to be adhered to, it is important that they are determined appropriately. Given high-variety and bespoke production, quoting standard lead times is considered inappropriate. CEM systems have been presented in the literature by Hendry and Kingsman (1993), Park *et al.* (1999) and Xiong *et al.* (2006); other relevant studies conducted by the authors include: (e.g. Hendry 1992, Kingsman *et al.* 1996, Park 2002, Xiong *et al.* 2003). No attempt has been made to incorporate the functionality of these particular contributions within an ERP system. Stevenson *et al.* (2005) suggested that MRP does not provide sufficient support for managing customer enquiries in a MTO context, despite its Rough Cut Capacity Planning and Capacity Requirements Planning modules. The major tool contained within ERP systems to support customer enquiry management is AATP/CTP; however, there is a need to evaluate its effectiveness in practice.
- *Design and Engineering Stage:* is especially important for ETO and DTO firms (incorporated in the broad definition of MTO used in this paper). Rudberg and Wikner (2004) provided a framework to forecast the lead time required for activities in this stage using a database of historical activities and considering the workload. While valuable, discussion of the framework is limited; there is insufficient detail for others to apply the method in practice. Olsen and Sætre (2007) conducted an action research project in a growing ETO company experiencing typical problems of bespoke production (e.g., setting reliable prices, determining realistic due dates, and coping with increasing demand.). The company considered a number of ERP systems but was unable to find a truly suitable system. ERP implementation in the company was unsuccessful – the vendor offered to build a 'product configurator' but this was considered unsuitable and the company developed their own in-house design and engineering solution. This suggests that the ERP systems available provide insufficient support for tailored and pure customization.
- *Job Entry and Release Stages:* Control at job entry and job release supports adherence to the due dates negotiated at the customer enquiry stage. Breithaupt *et al.* (2002) reported that job release mechanism was previously included in the SAP R/2 system and the systems of other local ERP vendors in Germany. To our knowledge, contemporary ERP systems do not contain these mechanisms and no further information on this issue is available in the literature.
- *Shop Floor Dispatching Stage:* The dispatching phase can be considered the least important stage in the PPC hierarchy if sufficient control is provided at the higher levels. Several authors have stressed this, suggesting that with job release, dispatching can be decentralized to the shop floor supervisor (Tobin *et al.* 1988, Stevenson and Hendry 2006). Jonsson and Mattsson (2003) agree that this is a suitable method for MTO companies but also suggested using a prioritized 'dispatching list' method. Meanwhile, Kingsman (2000) suggested a simple prioritization rule like first-come-first-served is sufficient.

To conclude the above discussion, in order to be suitable for the MTO sector, a system must be based on a concept which provides support throughout most of the production planning and control stages and is suitable for the general job shop (Stevenson *et al.* 2005). One such approach is Workload Control; therefore, if ERP systems provide a good fit with the needs of MTO companies in other respects (e.g., integrating departments) then research should be conducted which seeks to embed Workload Control within the structure of ERP systems.

4.3 Extended ERP and MTO Production

The available literature on the role of MTO companies in SCs, and on MTO SCs is limited. As a result of the typical SC position and leverage of MTO companies, 'last minute' requests are commonplace. This requires responsive SC practices, including in purchasing, and a planning and control system

capable of handling rush orders. Stevenson *et al*. (2005) and Stevenson and Hendry (2007) stressed the importance of web-based SCM practices and referred to Cagliano *et al.* (2003) in arguing that the Internet can be feasible for SMEs. Hence, aligning the core ERP system of an organization with software for SCM may be beneficial but further research is required. Jahnukainen and Lahti (1999) reported that the overall performance of a MTO supply chain may suffer if supply chain control practices and information management are inadequate, even if firm-level performance is good.

APS can support collective planning through planning and optimizing the supply chain (Fleischmann and Meyr 2003). This is yet to be studied sufficiently in a MTO context; however, Deep *et al.* (2008) recently found APS to be relevant to MTO companies due to its capacity management structure and analytical planning functionality. SCM software may be of benefit to MTO companies in general and to MTO supply chains but APS appears to lack sufficient support for due date and price determinations in a MTO context; the design and engineering stage is also not supported. A key strength of APS is its sophisticated shop floor scheduling functionality; however, if earlier stages are properly supported, the need for this is reduced.

The case study reported by Deep *et al.* (2008) also explained that the case company's 'ERP system selection committee' originally decided to implement a product configurator for repeat orders. However, a significant proportion of the company's work is reported to be bespoke and ETO; hence, the product configurator does not provide an effective solution for the full range of manufacturing activities performed by the firm. Other companies are also likely to follow a mix of strategies (ETO, MTO, MTP, MTS, etc); therefore, this presents a significant challenge.

Muda and Hendry (2002) state that RBCs usually aim to establish contracts which run long enough for them to take advantage of some of the efficiencies gained by MTS companies. However, RBCs also require flexibility and are constantly negotiating new contracts with new or existing customers. CRM applications may help to convert VMCs into RBCs through facilitating stable and long term relationships. However, there is a need to conduct research to improve the utilization of extensions to ERP. This discussion also implies that product life cycles may vary in length. It is unclear whether the PLM software extensions to ERP systems would add value where life cycles are short; research is required which explores this in greater depth.

To conclude the above discussion, the fit between the requirements of the MTO sector and the functionality of ERP and these extensions is limited in parts and unclear in others - MTO-specific solutions do not exist in the ERP market. Extensions to ERP systems such as for SCM and CRM have received limited attention to date. Table 2 provides a summary of the systems considered in this paper and summarizes the justification for our assessment of the applicability of these systems to MTO companies with reference back to the research questions raised in Table 1 (i.e., RQ1A-RQ6A).

5 CONCLUSION

This paper contributes to the available literature by providing an assessment of the applicability of ERP and its extensions to the MTO sector, building on the assessment of ERP by Stevenson *et al.* (2005), adding greater depth. Though ERP systems are gradually becoming recognized as standard solutions world-wide for certain industries, this does not mean that they suit all members of those industries. Applicability has been explored by considering: firstly, issues relating to the impact of company size; secondly, the characteristics and requirements of MTO companies (whatever their size); and, thirdly, the relevance of ERP extensions to the characteristics of MTO companies.

The assessment concludes that, in many areas, there is a significant gap between the requirements of MTO companies and the functionality of ERP systems. One such gap is between the customer enquiry management and design and engineering processes of MTO companies and those supported by ERP systems. The current research of the authors focuses on surveying MTO companies in the UK that have either implemented or are currently implementing an ERP system to test this assessment. The rationale is to determine whether there is a need for more MTO companies to adopt an ERP system.

Table 2: An assessment of the applicability of ERP systems to MTO companies

Software	Features Applicable to MTO Companies	Gap between Software and MTO Companies
Enterprise Resource Planning	Wide availability; Transaction automation; Departmental integration (RQ5A); E-business capabilities (RQ5A, (RQ6A).	A lack of sufficient support for the customer enquiry stage (RQ1A); A lack of sufficient support for the design and engineering stage (RQ1B); Job entry and release stage support no longer available (RQ1C); MRP-driven replenishment strategy unsuitable for job shop production (RQ2A). The need for departmental integration in a SME is limited (RQ5A).
Supply Chain Management	Web-enabled SC info sharing and coordination may improve ability to cope with rush orders (RQ3A).	Implementing ERP systems, and extensions such as for SCM, can be an expensive and high-risk strategy for MTO SMEs (RQ5A).
Advanced Planning and Scheduling	Supply chain planning and scheduling solutions (RQ3A).	Inability of ATP to support price determinations (RQ1A); The effectiveness of APS in a MTO context remains unclear (RQ1A-C); Implementing ERP systems, and extensions such as for APS, can be an expensive and high-risk strategy for MTO SMEs (RQ5A).
Customer Relationship Management	CRM software can help to build stable and long term relationships with the right customers; this may also increase strike rate (RQ4B, RQ6A).	Implementing ERP systems, and extensions such as for CRM, can be an expensive and high-risk strategy for MTO SMEs (RQ5A).
Collaborative Planning, Forecasting and Replenishment	None (see Gap between Software and MTO Companies)	Not suitable for the MTO sector, but widely applicable to the fast-moving consumer goods market.
Customer Enquiry Management	Transaction automation functionality at the customer enquiry stage (RQ1A).	Functionality provides automation rather than decision support (RQ1A).
Product Configurator	Software may be relevant to firms with a mix of production strategies and to MTO companies employing strategy close to ATO (RQ4A).	Functionality allows buyers to customize products over only a limit range; hence, has limited relevance, especially for products where design and engineering is bespoke, e.g., ETO firms (RQ1B).
Product Lifecycle Management	Cost estimation and product data management functionality for the customer enquiry and design and engineering stages (RQ1A, RQ4A).	The effectiveness of PLM systems in a MTO context remains unclear (RQ4A); Implementing ERP systems, and extensions such as for PLM, can be an expensive and high-risk strategy for MTO SMEs (RQ5A).

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