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Enterprise Resource Planning systems: An assessment of applicability to Make-To-Order companies

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ABSTRACT

Many vendors of Enterprise Resource Planning (ERP) systems claim their products are widely applicable–configurable to meet the needs of any business, whatever the product or service offering. But Make-To-Order (MTO) companies, which produce high-variety and bespoke products, have particularly challenging decision support requirements and it remains unclear whether ERP systems can meet their needs. This paper takes a contingency-based perspective of ERP adoption, assessing the fit or alignment between ERP functionality and a MTO production strategy. MTO features considered include: decision support requirements at critical Production Planning and Control (PPC) stages, idiosyncratic market-related features, typical company size and supply chain positioning, and shop floor configuration. It finds a substantial gap or misalignment between ERP functionality and MTO requirements; for example, between decision support provided by ERP systems and the decision support required by MTO companies at the customer enquiry and design & engineering stages. A research agenda for improving alignment is outlined, with implications for academics, MTO managers and ERP software developers. This includes: developing decision support tools that reflect the customer enquiry management activities of MTO companies; embedding MTO-relevant PPC concepts within ERP systems; and, conducting an in-depth empirical study into applications of ERP systems in MTO companies, assessing their performance impact.

1. Introduction

When implemented effectively, Enterprise Resource Planning (ERP) systems can provide business benefits such as real-time data availability, improved visibility, and increased task automation [1–3]. Many ERP vendors claim that such benefits can be accrued by any organisation, as their systems are generic, i.e. configurable to meet the needs of any business, whatever the product or service offering. But the literature suggests that Make-To-Order (MTO) companies, which produce high-variety and bespoke products, present particular challenges [e.g. 4–6]. Thus, despite the claims of ERP vendors, it remains unclear whether ERP can cater sufficiently for the needs of MTO companies. This paper takes a contingency-based perspective [7] to assess the alignment between the functionality of contemporary ERP software modules and the requirements of MTO companies.

The alignment of ERP solutions with operational needs has been studied previously by [8]. The authors showed that overall performance/satisfaction becomes weaker if the operational strategy (context) is misaligned with the ERP adoption strategy. However, no further in-depth studies have been conducted to identify which modules within ERP solutions show adequate fit with which operational needs. In addition, few reviews of planning and control concepts or information systems have focussed specifically on the needs of MTO companies. One exception was provided by Bertrand and Muntslag [4] who presented a review of the applicability of MRP-II to bespoke production environments, specifically the Engineer-To-Order (ETO) sector; however, an update of this work is required. A second was provided by Stevenson et al. [5] who suggested that ERP may be a suitable solution for MTO companies but that further research is required. The paper reviewed and assessed a wide range of concepts and, therefore, did not go into great depth on any one concept. More recently, Deep et al. [6] conducted a case study investigation of the factors affecting the selection of an ERP system by a MTO company. The authors demonstrated that more research is required towards assisting firms in determining the applicability of ERP. The paper itself did not provide a sufficiently comprehensive review of the available literature or consider the full range of MTO company

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characteristics that are likely to affect ERP adoption. Other reviews which focus specifically on ERP include those by Esteves and Pastor [9], Al-Mashari et al. [10], Jacobs and Weston [11], and Moon [12]. While these studies provide greater depth, they do not either: take a contingency approach based on production strategy; seek to assess the applicability of ERP systems; or give sufficient attention to recent developments in this fast-moving industry (e.g. the emergence of ERP add-ons for supply chain and customer relationship management).

Therefore, a contemporary assessment of the applicability of ERP to the MTO industry is required. In response, this paper contributes by assessing this fit with the aim of conceptually, identifying MTO decision support requirements, the functionality of widely available ERP modules, and gaps between the two. A systematic literature review assists this assessment and a research agenda is proposed. 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. [13]; for a detailed historical perspective on ERP, see Rashid et al. [14] and Jacobs and Weston [11].

The remainder of this paper is organised as follows. Section 2 explains the methodology followed to systematically select papers to review and to assess the applicability. Section 3 defines the characteristics and decision support requirements of MTO companies before Section 4 provides an overview of the functionality of ERP systems, including recent extensions to their core functionality. Section 5 assesses the fit between the requirements of MTO companies and the functionality of these systems. Section 6 identifies gaps in the literature in need of further research before the paper concludes in Section 7.

2. Methodology

The research methodology described below consists of two parts. Section 2.1 explains the process used to systematically identify literature on ERP functionality and MTO requirements before Section 2.2 describes how the fit between the two is assessed.

2.1. Systematic review process

The principles of conducting a systematic literature review have been followed in selecting papers [15,16]. International peer-reviewed journal articles were sourced from the ABI/Inform (ProQuest), Business Source Premier (EBSCO) and Science Direct (Elsevier) academic databases. No constraint was applied on the date or journal of publications. The use of search strings "Enterprise Resource Planning" and "Make-To-Order" (limited to titles, keywords and abstracts) separately revealed more than 10,000 hits for each. The two phrases were also searched together and combined with several sub-category phrases such as "Advanced Planning and Scheduling" and "Engineer-To-Order"; which helped to narrow down the results but the number of articles was still unmanageable. We further decreased this to a final list of 144 studies using systematic search criteria [15]. We excluded studies with no particular focus on the contingency factor of production strategy on critical success factors and transactional functionality of ERP systems (e.g. accounting or financial control); and focused instead on studies with a high citation index which focus on MTO-specific needs and decision making stages through case studies; surveys; mathematical or conceptual models.

The final 144 articles are classified in Table 1. At a high level, they are grouped into those that focus on ERP research, those that focus on MTO decision requirements, and those that address both topics. There are 9 papers in the third category, for which the primary topic is one of review and assessment and, hence, no further subcategories were determined. The studies focusing on ERP research were further divided into those that reviewed and classified ERP research; and those that looked at: future concepts; ERP extensions, ERP such as Supply Chain Management (SCM) and Advanced Planning and Scheduling (APS) (as defined in Section 4);

Table 1
List of literature reviewed in this paper.

Categories	References
ERP Research	
Review and Classification	Davenport [2]; Gupta [115]; Klaus et al. [116]; Esteves and Pastor [9]; Mabert et al. [68]; Rashid et al. [14]; Shehab et al. [117]; Botta-Genoulaz et al. [72]; Jacobs and Weston [11]; Moon [12]
Future Concepts	Davenport [71]; Markus et al. [118]; Chen [88]; Rashid et al. [14]; Al-Mashari [10]; Jacobs and Bendoly [119]; Davenport and Harris [120]; Jacobs and Weston [11]; Koh et al. [3]
Extended ERP (SCM, APS, CRM and others)	Davenport [71]; Stratman [121]; Bose [86]; Rigby et al. [122]; Stadtler and Kilger [78]; Tarn et al. [123]; Wiers [124]; Akkermans et al. [76]; Fleischmann and Meyr [80]; Kovács and Paganelli [125]; Ptak and Schragenheim [126]; Addison [127]; Davenport and Brooks [73]; Rigby and Ledingham [128]; de Búrca et al. [129]; Møller [91]; Stadtler [97]; Hendricks et al. [77]; Watts et al. [130]; Lee et al. [131]; Ou-Yang and Hon [132]; Hicks [93]; Hvolby and Steger-Jensen [133];
National and Cultural Perspectives	Adamand O'Doherty [134]; Mabert et al. [107]; Olhager and Selldin [69]; Baki and Cakar [135]; Koh and Simpson [136]; Morabito et al. [108]; Lee et al. [137]; Argyropoulou et al. [110]; Chien et al. [138]; Laukkanen et al. [109]; Ketikidis et al. [139]; Snider et al. [70]; Bayraktar et al. [140]
SME ERP Adoption	Van Everdingen et al. [141]; Mabert et al. [107]; Muscatello et al. [142]; Buonanno et al. [113]; de Búrca et al. [129]; Koh and Simpson [136]; Olsen and Sætrea [60]; Raymond and Uwizeyemungu [106]; Koh et al. [143]
Sector/Industry Application	Wiers [124]; David et al. [99]; David et al. [84]
MTO Research	
Customer Enquiry	Tobin et al. [102]; Hendry and Kingsman [33]; Hendry and Kingsman [144]; Hill [145]; Hendry and Kingsman [20]; Kingsman et al. [146]; Kingsman et al. [21]; Easton and Moodie [147] Moodie [22]; Cakravastia and Nakamura [23]; Olhager [148]; Stevenson et al. [5]; Stevenson and Hendry [39]; Hendry et al. [114]; Stevenson and Silva [149]; Zorzini et al. [26]; Hendry [105]
Design & engineering	Wortmann [30]; Lampel and Mintzberg [150]; Amaro et al. [56]; Spring and Dalrymple [151]; Rudberg and Wikner [32]; Hvam et al. [152]
Job Entry, Job Release and Dispatching	Hendry and Kingsman [33]; Bertrand and Muntslag [4]; Enns [47]; Oosterman et al. [48]; Kingsman [42]; Kingsman and Hendry [27]; McKay and Wiers [153]; Stevenson et al. [5]; Hendry et al. [114]; Stevenson and Silva [149]; Soepenberg et al. [154]; Boulaksil and Fransoo [155]; Olhager [156]
Non-PPC	Muda and Hendry [104]; Wikner and Rudberg [157]; Dekkers [158]
ERP and *MTO Research*	
Review and Assessment	Bertrand and Muntslag [4]; Wortmann [30]; Jonsson and Mattsson [103]; Stevenson et al. [5]; Koh and Simpson [112]; Olsen and Sætrea [60]; Olsen and Sætreb [94]; Deep et al. [6]; Hicks and McGovern [93]

national and cultural perspectives; ERP adoption by Small and Medium sized Enterprises (SMEs); and, specific sector/industry applications. The majority of the papers focusing on MTO decision requirements are sub-divided according to Production Planning and Control (PPC) stages, i.e. customer enquiry; design & engineering, job entry/job release and dispatching. In addition, three papers that address broader, strategic MTO issues are also included – these are labelled "Non-PPC" in Table 1.

From Table 1, it can be seen that the majority of papers look at ERP systems or MTO companies in isolation, with few articles addressing ERP issues in a MTO context. This corroborates the need for further research which takes a contingency-based perspective as further described below.

2.2. Assessment of fit or applicability

To assess applicability, we relate ERP software provision to MTO Decision Support Requirements (DSR) via the matching (also called selection) concept of fit [17,18] which is conceptualised within the contingency theory literature [7].

Two prominent classifications of fit have been proposed by Drazin and van de Ven [18] and Venkatraman [17] based on the configuration of the relationships between contextual (or contingency), response and performance variables. Briefly, a *contextual variable* represents situational characteristics which, in this study, correspond to the requirements of a manufacturer due to its MTO production strategy. A *response variable* is the organisational or managerial actions taken in response to current or anticipated contingency factors, which is represented by certain ERP mechanisms and solutions developed in response to these requirements as the anticipated contingency factors. Finally, the *performance variables* are the dependent measures and represent specific aspects of effectiveness that are appropriate to evaluate the fit between contextual variables and response variables for the situation under consideration.

As reviewed by Sousa and Voss [7] in the context of OM research, these prominent classifications of fit include a form referred to as the *selection* (or *matching*) form, where fit is sought between context and response without reference to a criterion (performance) variable. This means that we focus on aligning context and response; and can assume that, if this is done well, then performance will improve. In this study, the assessment of fit takes place as a conceptual match as shown in Fig. 1. Namely, a single context/single response fit is examined; thus, no additional responses (e.g. quality management) or performance output (e.g. on-time delivery) are considered. However, as the decision support requirements of a MTO company are affected by its characteristics, the single MTO context is itself complex and includes consideration of factors such as company size and supply chain positioning.

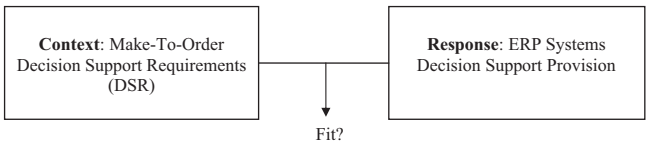

Fig. 1. The selection (matching) theoretical framework used in this study.

To investigate the fit, the context and response variables are defined and examined conceptually using the literature. To achieve this, the decision support requirements of MTO companies and of widely available ERP systems are defined in Sections 3 and 4, respectively (and summarised in Table 2) before Section 5 examines the fit (see, e.g. Table 4).

3. Decision support requirements of the MTO sector

There are various definitions of the diverse production strategies presented in the literature. This paper focuses on MTO but defines it in a broad sense. In our definition, see also [19,p. 379], MTO is an 'umbrella term' referring to companies that produce bespoke and customised products to particular customer specifications but not repeated on a regular basis or in a predictable manner. Therefore, the term includes Engineer-To-Order (ETO) but excludes Make-To-Stock (MTS) and Assemble-To-Order (ATO). While we incorporate ETO within our definition of MTO, if an author uses the term "ETO" we retain this distinction when reviewing the literature. The following subsections identify the

Table 2
Summary of context (MTO decision support requirements) and response (ERP systems to support).

	Context: Summary of MTO DSRs	Response: ERP System Provision
1. Planning and Control Stages	The full range of planning and control stages is important for MTO production: Customer enquiry management: Generating due date and pricing alternatives in response to customer enquiries Design & engineering Flexibility in design & engineering Job Entry: Capacity planning and control for confirmed orders, including materials purchasing Job Release: Introducing a job release stage for shop floor control Dispatching: Compatibility with human decision making on the shop floor scheduling.	Support for quoting, design & engineering, job entry, shop floor scheduling: Available/Capable-To-Promise and the CEM module Product configurator and Product Lifecycle Management, Material Requirements Planning and Advanced Planning and Scheduling – Finite scheduling functionality on the shop floor
2. Shop Floor Configuration	Job shop configuration requires system flexibility to handle such a complex manufacturing setting.	–
3. The Supply Chain	Many MTOs are positioned mid and upstream in supply chains, thus rush orders are prominent. Sharing up-to-date information across the supply chain is critical.	Web-enabled supply chain information sharing Co-ordination functionality
4. Company Size	A significant proportion are SMEs, thus having relatively simple organisational structures and limited IT budgets	Many claimed to be for all business sizes A variety of pricing and licences available
5. Market Characteristics	Managing customer relations to increase repeat business.	Customer Relationship Management software is known as the 'industry standard' in some sectors. Claimed to provide a source of competitive advantage

characteristics and requirements of MTO companies to aid in our assessment of ERP applicability. It begins by examining the PPC stages of relevance to MTO companies before investigating further important factors: shop floor configuration, supply chain positioning, company size, and market features.

3.1. Planning and control stages of MTO companies

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

- *Customer Enquiry Stage*: where a customer provides an invitation-to-tender or request for quotation for a particular product to prospective suppliers, requiring the determination of a price and due date. These decisions require: the estimation of lead times; the archiving and retrieval of product data; the assessment of available design/production skills and facilities; the estimation of costs/profit margins; and effective coordination and communication between all departments involved in the activities listed above [20–26]. For MTO companies, PPC must begin here as each order may be different and decisions made here affect subsequent stages [27]. This may be complex as there are often outstanding bids awaiting confirmation and capacity planning must take this potential future load into account. In addition, Bill of Material (BoM) structures are not always fully available during this early planning stage, and only gradually become certain, especially for ETO companies [4–6,28]. Therefore, corresponding IT solutions need to be flexible to enable appropriate capacity planning given BoM uncertainty.
- *Design & Engineering Stage*: where more detailed design & engineering planning takes place for accepted orders. This stage is of particular relevance for an ETO strategy but little research has been conducted into the design & engineering stage, despite its impact on the total lead time [29]. Wortmann [30] contributed by comparing the information system requirements of MTS and ETO companies. In a MTS context, complete, consistent and up-to-date basic product information is more likely to be available as the product is likely to have been made before. The author highlighted an ability to be able to document aspects of product development throughout the order processing cycle as a key feature of an ETO-compliant system. Bertrand and Sridharan [31] suggested that, together with assembly, the design & engineering stage can be the bottleneck operation in aggregate planning; however, the authors' study was limited to subcontract manufacturers. Rudberg and Wikner [32] proposed a framework for the MTO order-promise process, indicating that forecasting and order fulfilment mechanisms are needed for the design and specification functions as well as the production functions.
- *Job Entry Stage*: where the production of a confirmed order is planned, including material requirements, purchasing and shop floor routing. Four particularly important MTO planning requirements are identified from the literature. Firstly, the IT solution needs to allow for specification changeability, given that BoM structures are often only planned at this stage and only gradually become certain [4–6,28]. Secondly, the ability to skilfully incorporate the effect of forecasts on actual plans is essential, considering that many MTO companies deal with a mix of repeat and one-off orders [6,33,34]. Thirdly, it is essential to plan capacity, taking into account any capacity constraints. This is essential to ensure that due dates are feasible, and aids in determining whether it is necessary to re-negotiate due dates with customers—this may be particularly important when there has been a long delay between a bid being made and an enquiry being confirmed [5]. Finally, ETO firms can sometimes require project management techniques and relevant IT support, when a majority of orders are for large projects [4,28,34].
- *Job Release Stage*: a decoupling phase, where the company decides when to start producing a particular job by controlling its release onto the shop floor. The need to control the job release stage was identified by Wight [35] in order to avoid the 'untimely' release of jobs, which can result in a 'vicious cycle' of work-in-process accumulation known as the "lead time syndrome" [36]. This stage (in isolation) has received far more attention in the literature than the preceding stages [see 37,38]; however, it is arguably the entire integrated PPC process from enquiry to delivery which determines the performance of a MTO company. At the order release stage, further PPC may be needed to ensure sufficient capacity is available to allow jobs to be released in time for them to meet their due dates. Thus, MTO companies require this planning stage as part of a hierarchical system [39].
- *Shop Floor Dispatching Stage*: where detailed shop floor scheduling is determined and jobs are sequenced on the shop floor, e.g. via job prioritisation. This is a well-studied research area for which many algorithms have been developed and many reviews published [e.g. 40–42]. However, some authors have argued that simple mechanisms (e.g. first-in–first-out) may be preferred in a MTO context, with control left to highly skilled labour if the preceding hierarchical planning stages are appropriately controlled [43].

Thus, the decision support requirements of a MTO firm include specific support at each of the above stages, which suggests that an appropriate IT solution should include the following fundamental features: effective mechanisms to generate alternative pricing and due date plans to deal with customer enquiries, including aggregate planning and control that takes unconfirmed bids into consideration; flexibility to be able to document aspects of product development throughout the order processing cycle, which begins at the design & engineering stage; effective capacity planning and control when a job is confirmed at the job entry stage; incorporation of a job release decision point in planning; and, compatibility with human decision making when scheduling on the shop floor (i.e. dispatching). In addition, the solution needs to enable a high level of coordination amongst departments playing a critical role in the MTO planning stages [33].

3.2. 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 [44,45]. In a PFS, all jobs follow the same sequence of operations; in a GFS, all jobs flow in the same direction but can visit a subset of machines. In a PJS, jobs can start and finish at any work centre and no dominant flow direction dominates; in a GJS, routings are multi-directional but a dominant flow exists. Job shop configurations are suitable in customised production contexts, such as the MTO industry [5,46] but lead to complex planning problems given, for example, that load balancing can be more difficult. PFS and GFS configurations are more suitable for continuous processes or assembly line manufacturing (i.e. MTS or ATO). Authors such as Enns [47] and Oosterman et al. [48] have highlighted the importance of taking workflow direction on the shop floor into consideration when choosing appropriate job release and shop floor scheduling rules.

Therefore, given that the job shop (i.e. PJS and GJS) is a typical configuration on the shop floor of MTO companies, the decision support requirements of such companies include the flexibility to support such a complex shop floor setting. In this context, detailed

scheduling can be inappropriate as it may be difficult to predict the arrival times of jobs at particular machines, and so a more aggregate, dynamic planning approach is needed.

3.3. MTO companies and the supply chain

MTO companies are often positioned towards the upstream end and midstream of supply chains, serving large, powerful customers [49,50]. Given this position, information about end-customer demand is limited and customers often outsource work to their upstream suppliers at short notice; hence, rush (i.e. short-notice or urgent) orders are commonplace. Stevenson et al. [5] and Stevenson and Hendry [51] explained that the presence of rush orders is likely to affect the type of PPC solution appropriate to MTO companies and highlighted the importance of web-based practices that promote information and knowledge sharing within supply chains.

It is also acknowledged that some supply chains consist exclusively of MTO companies, i.e. "MTO supply chains" – capital goods manufacturing is a common example [e.g. 52,53]. Sahin and Robinson [53] highlighted the value of information sharing and coordination in MTO supply chains; similar results are presented by Robinson et al. [54] and confirm the value of using web-based practices. Hence, developing buyer–supplier relationships built on information sharing and coordination can be an important part of an effective supply chain. Information sharing within supply chains can lead to several benefits for MTO companies: Sahin and Robinson [53] stated that information sharing and coordination along the supply chain can facilitate cost reduction and improved due date adherence in MTO supply chains. Regarding ETO companies, Hicks et al. [52], found that effective knowledge sharing in supply chains can be a competitive advantage. Finally, Jahnukainen and Lahti [55] argued that purchasing as a percentage of the total cost is higher for MTO than MTS companies; hence, relations and information sharing by MTO companies with suppliers can be highly significant and this, in turn, has an effect on a firm's ability to satisfy its customers.

To conclude, in supply chains containing MTO suppliers either entirely or partially, information sharing is of paramount importance for coordination.

3.4. MTO company size

Many MTO companies are SMEs [5,56]. SMEs are a major contributor to supply chains and to the EU and UK economies, representing 99% and 99.9% of all enterprises, respectively [57,58]. According to the EU Commission [59], a medium-sized company has less than 250 employees or a turnover of less than €50 million (and/or an annual balance sheet total of less than €43 million); a small-sized company has less than 50 employees or a turnover of less than €10 million (and/or an annual balance sheet total of less than €10 million); while a micro-sized company has less than 10 employees or a turnover of less than €2 million (and/or an annual balance sheet total of less than €2 million). 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.

As many MTO companies are SMEs, some important SME-related ERP adoption issues may be relevant in this context. For example, limited IT budgets and a lack of permanent IT employees could be argued to influence the applicability of some ERP systems [60].

3.5. MTO market characteristics

The current market demand for customised products is argued to be greater than ever before. This growing market results in short product life cycles and requires a company to have a wide product range [61]. 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, i.e. the percentage of tenders which become firm orders, which for MTO companies can be very low (e.g. %15 in the case in 25).

Amaro et al. [56] define two types of MTO companies (Repeat Business Customisers—RBC, and Versatile Manufacturing Companies—VMC) in relation to contract type which has a direct impact on market strategy. 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. Therefore, the RBC is able to establish more stability by enticing customers into a more predictable and committed relationship [51]. In terms of their supply chain position, RBCs are generally located upstream in supply chains, while VMCs operate in all levels of supply chains.

It is especially important for RBCs to retain existing customers, while it can be crucial for VMCs to explore new markets. Dealing with high numbers of existing and potential customers may require software support to manage data and promote sales to achieve these aims.

3.6. Implications for decision support requirements

Key characteristics of companies employing a MTO production strategy have been identified above and the decision support requirements for each have been discussed accordingly. Overall, amongst the identified production planning and control stages, the customer enquiry stage can be considered to be the most critical as it deeply affects the subsequent stages (e.g. order entry and release). The design & engineering stage is also especially critical for ETO companies, while the job entry stage is a key point at which capacity planning is undertaken as jobs are confirmed. The job release stage, a decision point before the release of jobs onto the shop floor, can be a beneficial phase to improve control over activities on the shop floor and enable skilled shop floor personnel to employ simplified and autonomous dispatching.

Additionally, these companies are mostly SMEs requiring affordable solutions. Job shop configuration is a typical setting and, hence, the corresponding software needs to be flexible enough to support activities in this type of complex shop floor setting. These companies are mostly positioned midstream and upstream in supply chains, and this makes MTO companies prone to (and most affected by) any changes that their customers may make to their production plans. Therefore, software needs to enable successful and up-to-date information sharing. Finally, MTO companies need to constantly entice new customers, or to convert one-off jobs into repeat business, due to competitive and volatile market conditions. Information systems have become an indispensible part of manufacturing but a good fit is needed. Thus, software solutions applicable to this idiosyncratic production strategy are essential. The next section provides a state-of-the-art review of contemporary ERP functionality before the fit between the two is examined in Section 5.

4. Functionality of modern ERP systems

Davenport et al. [62] defined an ERP system as a "packaged software application that connects and manages information flows within and across a complex organisation, allowing managers to make decisions based on information that truly reflects the current state of their business". As ERP systems stem from the Material Requirements Planning (MRP) and Manufacturing Resource

Planning (MRP-II) systems of the 1970s and 1980s, the functionality of these elements are first described briefly.

Basic MRP mechanisms, as developed by Plossl and Wight [63], determine purchasing and production requirements from a given BoM, but can be overly simplistic leading to extreme 'system nervousness' [64]. However 'Closed Loop MRP' provides a three-tiered hierarchical structure, incorporating long-, mid- and short-term capacity planning phases from forecasting to scheduling and dispatch [65]. Finite scheduling and infinite loading are commonly available capacity tools [34]. In addition, Available-To-Promise (ATP) functionality is an important element within this structure, defined as a method of checking the availability of products in response to a customer enquiry. Ball et al. [66] described ATP as a business function which is becoming increasingly important with the advent of e-business, MTO strategies and high-variety product offerings. Advanced ATP (AATP), a more sophisticated version of ATP, is an increasingly important concept in the era of SCM and will be described in Section 4.2. MRP II [67] integrates primary business functions (such as marketing, human resources, accounting and finance), and the data supporting these functions, using a single, centralised database. However, most MRP-II packages do not fully integrate all the processes of a typical manufacturing company; for example, features missing include transportation and distribution planning and dynamic scheduling of production resources in real-time.

A key feature of ERP is its applicability to various sectors, e.g. healthcare, banking and education, although authors such as Jacobs and Weston [11] have suggested increasing the number of pre-configured sector and industry-specific packages. ERPs widespread introduction into companies was accelerated, for example, by the benefits of automating manual tasks, integrating fragmented organisational structures after large-scale mergers and acquisitions, and concerns over the year 2000 (Y2K) and euro currency compliancy of legacy systems. Typically, the most implemented modules within the core structure of ERP systems are financial accounting and control, purchasing, sales and distribution, materials management, production planning, human resources, and quality management [68–70].

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 [71]. This trend has led to the term "Extended ERP" or "ERP-II" [14,72], referring to add-ons to the core internally facing ERP system and a shift from transaction-oriented systems to more analytical systems. ERP adopters, having realised the benefits of ERP, are beginning to explore extensions to core ERP functionality [12]; such extensions are explored in the following subsections.

4.1. Supply chain management (SCM) software

SCM software facilitates information integration with supply chain partners, aiding cost reduction and improved efficiency, service and relationships with customers [73]. Early examples of SCM software supported logistics functions and aided the management of inventory in the supply chain but were not well-integrated with ERP [73]. Bowersox et al. [74] suggested the main reason to be the insufficient scope and flexibility of ERP systems to support supply chain functionality.

Over the last decade, ERP has been considered the process-oriented transaction backbone for intra- and inter-company SCM software [75]. Yet, Akkermans et al. [76] questioned the practical value of combining ERP with SCM. The authors conducted a Delphi study with 23 executives from various industries and concluded that ERP systems have an inappropriate structure and are too rigid to support SCM activities. Given advancements in technology, future research should reapply the Delphi or another method adopted by Akkermans et al. [76] and assess whether the criticisms remain valid.

Hendricks et al. [77] studied the impact of SCM, CRM and ERP investments on the long term stock price performance and profitability of firms. The authors found evidence to support the claim that ERP can improve profitability but not stock price. SCM systems, on average, led to improvements in both stock price and profitability. While valuable, the study explored each system independently. Exploring the impact on performance of the use of the SCM software as an integral part of ERP would also be valuable.

4.2. Advanced planning and scheduling (APS) software

APS software is developed to address manufacturing planning and scheduling problems based on hierarchical planning principles [78]. Thus, it is a company-wide software system making use of analytical approaches to address company-wide and supply chain planning problems. APS has similarities with the planning and scheduling functionality in MRP-II, e.g. in terms of hierarchical planning and capacity-constrained structure; the "advanced" part of APS comes from addressing the decision support insufficiency of ERP [79].

Available-to-Promise (ATP) and Capable-to-Promise (CTP) functionality is also incorporated within APS systems. While ATP refers to determining the availability of any 'uncommitted' finished goods inventory, CTP indicates remaining slack capacity after available capacity has been matched with committed orders [66]. Akkermans et al. [76] anticipated an advanced futuristic function of ATP/CTP systems, suggesting that it will not only help companies check the ability to meet customer orders (based on availability or capability), but will also offer to build a 'specific supply chain' for the incoming customer enquiry. Fleischmann and Meyr [80] and Kilger and Schneeweiss [81] stressed the influence of the order penetration point on the applicability of ATP.

'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 capabilities [82]. ERP and APS systems support both AATP and CTP since it is important to consider both quantity and due date quotation issues based on the resources of the whole supply chain rather than on the finished goods inventory of an individual firm [83].

The available literature on APS systems is scarce [e.g. 75,78,84]. While valuable, these contributions lack sufficient details on several aspects of the APS concept. A much greater body of literature, e.g. on the inner-workings of APS systems and on the application of APS in practice, is required.

4.3. Customer relationship management (CRM) software

Conceptually, CRM is a business practice centred around customer needs [85]. CRM software, developed to address these needs, is used to compile data on customers and analyse it in order to sell more goods or services, and to do so more efficiently [86].

CRM can be implemented and utilised without ERP; however, ERP is thought to be a supportive structure for the growing needs of CRM. Chen and Popovich [87] stressed that ERP's back-office functionality (i.e. manufacturing, inventory and financial applications) is a significant feature to support CRM's front-office functionality (i.e. Sales and Distribution and Service applications). As a result, many ERP vendors have invested in CRM add-ons and are now also major CRM vendors [88].

While Hendricks et al. [77] found that SCM systems lead to improvements in both stock price and profitability on average, CRM showed no evidence of an improvement in either of these two

measures. Again, the study explored CRM's benefits independently; examining the impact on performance of using CRM software in conjunction with ERP would also be valuable.

4.4. Other software extensions to ERP

In addition to the three key extensions to ERP described above, the following are also reported in the literature and may be of relevance to MTO companies:

- *Customer Enquiry Management (CEM) Module*: focuses on due date and price estimations. SAP R/3, for example, is said to contain a CEM-like component within its order management module [34,89]. It is also reportedly used for automating job entry, processing customer orders and tracking order status.
- *Product Configurator (PC) (or 'Variant Generator') Software*: an increasingly used add-on to ERP. Even many small-sized ERP vendors now provide this via the Internet [90]. The typical example is a computer retailer's website being used as an interface between the end-customer and suppliers; the customer selects the components they would like and the suppliers receive the order simultaneously [e.g. the computer assembly case in 80].
- *Product Lifecycle Management (PLM) Software*: enables a company to bring innovative products to market effectively [91]. 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 [92,93].

Fig. 2 illustrates the evolution of ERP from MRP and incorporates extensions like SCM software and smaller add-ons such as PLM software.

4.5. Implications for ERP decision support functionalities

In summary, while a vast amount of literature exists on ERP and its predecessors, literature is only now beginning to emerge which explores extensions to ERP. More research is required which explores combining ERP with the various add-ons and which focuses on particular industry sectors. Table 2 summarises the decision support requirements of MTO companies (context variable) and lists the widely available functionality provided by ERP systems (response variable), thus making a preliminary assessment of potential matches. The literature evidence regarding the effectiveness of these matches is discussed below.

5. Assessing the fit between ERP and the MTO sector

This section seeks to assess the fit between the functionality of ERP systems and the requirements of MTO companies, structured around the latter context variable. In Sections 5.1–5.4, the match is examined between the requirements at the critical planning stages of MTO companies, as identified in Section 3. Similarly, this match is examined for the supply chain operations and customer relations of the sector in Sections 5.5 and 5.6, respectively. Finally, given that many MTO companies are SMEs, Section 5.7 explores aspects of fit that may be affected by company size. Note that shop floor configuration is not discussed explicitly in this section, but is an important consideration at various planning stages.

5.1. ERP support at the customer enquiry stage

As previously described, customer enquiry management is a key planning and control phase for MTO companies—if due dates

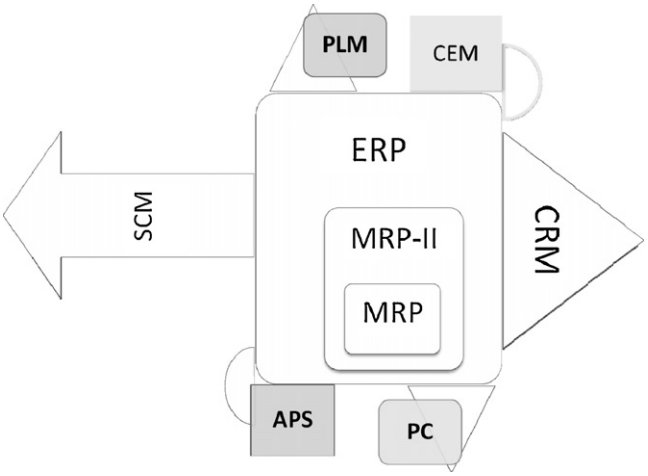

Fig. 2. The scope of ERP systems, major extensions and add-ons.

are to be adhered to, it is important that they are determined appropriately. The major analytical tool contained within ERP systems to support customer enquiry management is ATP/CTP. In fact, ATP is used to handle MTS order promising issues with a 'yes-or-no answer'; but, CTP and AATP are especially important in MTO order promising [81]. Fleischmann and Meyr [80] and Pibernik [83] stress the necessity of detailed production planning and order promising integration in a complex MTO case but no attempt to explore this match in detail was provided in either study. Therefore, there is a need to explore the effectiveness of AATP/CTP in practice and Pibernik [83] claimed that such research should consider the effect of production strategy in the design of ATP/CTP systems.

MRP is another tool used at this stage. However, Stevenson et al. [5] argued that MRP does not provide sufficient support for managing customer enquiries in a MTO context. A more obvious tool for this stage is the CEM tool and many MTO companies are reported to utilise the CEM functionality of ERP systems for entering orders into the system and their transactional automation, but *not* for decision support [89]. Finally, coordination across departments has been argued to be essential for dealing with customer enquiries [33]. This is a requirement which ERP systems are able to support given the common database used across an organisation [6].

In summary, there is evidence of use of ERP systems at the CEM stage to automate existing processes, but little literature evidence of improved decision support using existing ERP functionality, and hence more research is required.

5.2. ERP support at the design & engineering stage

The design & engineering stage is especially important for ETO and design-to-order companies, which are incorporated in the broad definition of MTO used in this paper. The importance of this stage has been described in the literature but little research has been conducted to explore this phenomenon or to explicitly incorporate design & engineering within planning and control structures. Rudberg and Wikner [32] provided a rare contribution, proposing a framework to forecast the lead time required for design & engineering activities using a database of historical activities and by considering the current workload. While valuable, discussion of the framework is limited; there is insufficient detail for others to apply the method in practice. Another contribution was made by Olsen and Sætre [94] who conducted an action research project in a growing ETO company which was experiencing typical problems of bespoke production (e.g. setting reliable

prices, determining realistic due dates, coping with increasing demand, and accommodating the customisation requirements of each order). The company considered a number of ERP systems but was unable to find a system suitable for this set of problems. In particular, an inability to cope with product customisation at the design & engineering stage was noted. ERP implementation in the company was unsuccessful–the vendor offered to build a 'product configurator' but this was considered unsuitable and the company developed its own in-house design & engineering solution.

The case study reported by Deep et al. [6] 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 was bespoke and ETO; hence, the product configurator did 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, MTS, etc.); therefore, this presents a significant challenge. This suggests that the available ERP system product configurators provide insufficient support for MTO and ETO production strategies.

Hicks and McGovern [93] conducted a recent study on the potential functionality of PLM for ETO companies. Some specific modules of PLM (e.g. design change control and capability maturity models) were found to show particular promise for helping ETO companies manage the product life cycle. However, while certain functionalities such as cost estimation and concurrent product development can be useful for MTO companies, it is unclear whether the PLM software extensions to ERP systems would add value when life cycles are short; further research is required which explores this in greater depth. The cost and complexity of this add-on may also exceed the budget limitations/requirements of SMEs, thus further research to assess its effectiveness for MTO SMEs is required.

5.3. ERP support at the job entry stage

Where ERP relies purely on an MRP-driven replenishment strategy, this is quite unsuitable for MTO production. Lead times for each component are assumed to be deterministic, which in many contexts is unrealistic. Moreover, processes are assumed to be independent of each other which is likely to be impractical, especially for industries employing configurations other than an assembly line or a mass production strategy [95,96].

APS software can support collective planning through planning and optimizing the supply chain [80]. Some authors suggest that APS systems are broadly applicable packages that provide company-wide planning and scheduling, especially at the job entry stage [97,98]. However, few authors have researched into industry- and sector-specific APS solutions; notable exceptions include Deep et al. [6] and David et al. [84,99]. Deep et al. [6] found APS to be relevant to a single MTO case company due to its capacity management structure and analytical planning functionality; however, the detailed requirements at the job entry stage were not investigated. David et al. [84] explored the applicability of ERP and APS systems for managing production in the aluminium conversion industry. Both studies found major limitations in the fit with the aluminium conversion industry; consequently, the expected benefits were not fully realised in either case. Therefore, further studies on the fit between APS and the requirements of the MTO sector at the job entry stage need to be conducted, comparing the planning and scheduling requirements of the sector with the functionality of APS systems.

5.4. ERP support at the job release and dispatching stages

Breithaupt et al. [100] reported that the job release mechanism of load-oriented manufacturing control, a particular Workload Control methodology developed in Hanover and described by Bechte [101], was previously included in the SAP R/2 system and the systems of other local ERP vendors in Germany. However, to the best of our knowledge, contemporary ERP systems (including those provided by SAP today) do not contain this mechanism or other variants of Workload Control and no further information on this issue is available in the literature. More research should be conducted to understand how the job release mechanism was embedded into SAP R/2 and why it is no longer available. If the function was removed due to poor performance, this may be explained by the use of job release independent of other tiers of hierarchical Workload Control methodologies (e.g. at the customer enquiry stage).

The dispatching phase can be considered the least important stage in the planning and control hierarchy for MTO companies, if sufficient control is provided at the higher levels. Several authors have stressed this, suggesting that with job release, dispatching can be decentralised to the shop floor supervisor [39,102]. Jonsson and Mattsson [103] agreed that this is a suitable method for MTO companies but also suggested implementing a 'dispatching list' method, where advised priorities are given to the shop floor. Meanwhile, Kingsman [43] suggested a simple prioritisation rule like first-come–first-served is sufficient. Although the effectiveness of these policies may vary, providing a sophisticated dispatching mechanism – such as a finite scheduling system – within an ERP system is arguably not necessary for MTO production if the prior stages are controlled.

5.5. Extended ERP and MTO supply chains

As a result of the typical supply chain positioning (and leverage) of MTO companies, short-notice requests are commonplace. This requires responsive supply chain practices, including in purchasing, and a PPC system capable of handling rush orders. Stevenson et al. [5] and Stevenson and Hendry [51] stressed the importance of web-based SCM practices to enable this. Furthermore, information integration is a major feature of SCM software, which can play an important role in employing responsive and concurrent supply chain practices. For example, regarding the importance of information sharing and integration to MTO supply chains, a rare contribution to the literature was made by Jahnukainen and Lahti [55]. They claimed 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'. Subsequent findings appear to support this view. For example, Sahin and Robinson [53] and Robinson et al. [54] performed simulation studies which showed significant cost reduction (47.6%) for the MTO supply chain as a result of information sharing, coordination and e-replenishment. Although these studies did not explicitly refer to ERP, they imply that aligning the core ERP system of an organisation with software for SCM may be beneficial. However, further research is needed to assess the effectiveness of the SCM ERP extension in a MTO context in practice.

5.6. Customer relationship management in a MTO context

Two types of MTO company defined by Amaro et al. [56] are the Repeat Business Customiser (RBC) and Versatile Manufacturing Company (VMC), as outlined in Section 3.5. For RBCs, developing long-term relationships with customers can be important. Muda and Hendry [104] stated 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, while VMCs may want to increase repeat business opportunities [105]. Both company types also require flexibility and are constantly

negotiating new contracts with new or existing customers. It could be argued that CRM applications may help to convert VMCs into RBCs through facilitating stable and long term relationships and to increase the strike rate of MTO companies. However, there is no literature evidence on the effectiveness of CRM add-ons for these purposes, and hence there is a need to conduct research to gain an understanding of the fit between this ERP extension and the market characteristics of the MTO sector.

5.7. ERP adoption in SMEs

Company size is a factor influencing a wide range of issues and has been explored in many different streams of the OM literature [106]. In the context of ERP adoption and company size, studies have been conducted in several different countries with similar results. For example, Mabert et al. [107] studied the impact of company size on ERP adoption in North American companies and found evidence that: large firms tend to employ more of the functionality offered by ERP systems and customise the software more than smaller firms; and, large firms think more strategically about ERP adoption than small firms, which have more tactical concerns. The findings of Morabito et al.'s [108] survey of Italian SMEs are consistent with these findings. Similarly, in a Finnish context, Laukkanen et al. [109] found that the expected impact of ERP on intra-firm processes is high for all firms but that midsize and large organisations expect more from ERP in terms of external processes than small firms. Argyropoulou et al. [110] surveyed the importance of the operational requirements, logistics fulfilment and financial capabilities of Greek SMEs on ERP adoption with many similarities with the study of Finnish SMEs by Laukkanen et al. [109]. Snider et al. [70] identified some SME-specific critical success factors by comparing successful and unsuccessful ERP implementations in five Canadian SMEs. Part-time dedication of the employee to the implementation project, the lack of a formal implementation strategy, a low level of software customisation and poor communication amongst team members were identified as distinctive factors seen in SME case companies compared to large firms. Thus there is a growing body of literature that suggests that company size is a significant factor to consider when assessing the applicability of ERP.

In addition to highlighting the impact of company size, some ERP related studies have also uncovered cultural and national issues previously over-looked in the literature. Olhager and Selldin [69] report that, unlike in some other countries, Swedish companies generally prefer European and Swedish ERP vendors over huge global vendors. Sheu et al. [111] conducted a study on national differences in ERP adoption through case study research of companies using ERP systems provided by global vendors. The authors found that ERP adoption can be more difficult in Europe than in North America due to complex European corporate and national cultures. Hence, it seems that universal solutions provided by global ERP vendors have created additional implementation problems. This suggests that the reason why Olhager and Selldin [69] found that Swedish firms prefer to choose local vendors is that, by doing so, these firms seek to avoid these cultural and national obstacles. To the best of our knowledge, there is no research which explores ERP adoption in UK SMEs; while Koh and Simpson [112] questioned the suitability of ERP for UK SMEs, the survey and interviews conducted by the authors have a different focus - diagnosing uncertainty in SMEs using ERP. Developing a greater body of knowledge from different national perspectives, including the UK, would help to further our understanding of the impact of company size and both cultural and national differences on ERP adoption.

No studies identified in the literature focus specifically on the issue of company size within a MTO context. However, Buonanno et al. [113] considered the 'level of diversification' (whether a firm considers diversification as a source of competitive advantage). Although they described this as an indicator of market strategy, it could also be argued to be linked to production strategy. They investigated the relationships between business complexities, organisational change and ERP adoption by surveying 366 firms and explored the impact of seven factors (including company size and the level of diversification) on ERP adoption. The authors found company size to be the only significant factor affecting ERP adoption. Previous research had also found the level of diversification to have a significant effect on the complexity of information flows, thereby affecting ERP adoption; however, the authors did not find this in their study. This contradiction could be as a result, for example, of further national or cultural issues or due to differences in questionnaire design.

In summary, company size has recently been recognised as a factor affecting 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 on the relationship between company size and ERP adoption, most have ignored the impact of production strategy. However, the order penetration point has a substantial impact on planning at the firm and supply chain level [80]. 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 production strategy of the companies in order to provide a richer insight into this topic for MTO SMEs.

To conclude the discussion above, Tables 3 and 4, respectively, provide a summary of: the key studies which partially explore ERP adoption in a MTO context; and, the assessment of the fit between the context variable (decision support requirements of the MTO sector) and the response variable (the functionality of ERP and its add-ons or extensions).

Table 3 demonstrates that consideration of the MTO context is an emerging area but that a greater body of knowledge should be developed. Table 4 shows that most of the widely available ERP features conceptually fail to match the requirements of manufacturers employing the MTO production strategy. For example, widely available modules for CEM appear to provide support for automating the entry and processing of orders but lack sufficient support for CEM planning and pricing. New modules and add-ons such as PLM, product configurator, APS, SCM and CRM are seen as potentially helpful tools at different stages of planning. However, it remains unclear whether they are applicable to MTO purposes and would result in improved performance since limited research has been conducted so far. While basic ERP system planning tools (e.g. MRP) are mostly suitable for the MTS production strategy, the majority of the potentially 'good' extensions are offered as extra solutions which may be too expensive for companies with limited IT budgets. Therefore, MTO-specific IT solutions need to become more widely available as well as MTS-compatible ERP systems. The key gaps in the literature that emerge from this discussion are summarised in Section 6.

6. Gaps in the literature—improving alignment

Seven key areas in need of further research emerge from the above discussion in order to improve alignment between ERP systems and the needs of MTO companies:

Table 3
Summary of key ERP studies of relevance to a MTO context.

Study	Topic	Firm size	Manufacturing strategy of the firm(s)	Research methodology			Summary
				Method	Data	Size	
Bertrand and Muntslag [4]	PPC	N/A	ETO	Conceptual	N/A	N/A	Assessment of MRP-II suitability to ETO firms and a proposed framework.
Wortmann [30]	IS	N/A	ETO	Conceptual	N/A	N/A	IS comparison for ETO and MTS production, and an ETO data-structure proposition.
Jonsson and Mattsson [103]	PPC	Various	Various	Conceptual, Survey	Q	84	Assessment of PPC applicability to different production environments.
Mabert et al. [107]	ERP	Various	Various	Case Study, Survey	I, Q	12, 482	Investigation of the impact of organisation size on ERP adoption.
Stevenson et al. [5]	PPC	N/A	MTO	Review	N/A	N/A	Review and assessment of PPC applicability to MTO production.
Buonanno et al. [113]	ERP	SME	Various	Survey	Q	366	Investigation of factors influencing ERP adoption in SMEs compared to large companies.
Koh and Simpson [112]	PPC, ERP	Various	Various	Survey	Q	108	Diagnosis of uncertainties in SMEs using ERP systems.
Olsen and Sætre [60]	ERP	SME	ETO	Conceptual, Case Study	I	1	Proposition of an alternative in-house company-wide software framework for SMEs.
Olsen and Sætre [94]	ERP	SME	ETO/MTO	Case Study, Action Res.	I, M	2, 2	Proposition of proprietary company-wide software based on four case studies for niche companies
Deep et al. [6]	ERP	SME	MTO	Case Study, Action Res.	I, M	1	Investigation of factors influencing ERP selection by a MTO SMEs.
Hicks and McGovern [93]	PLM	Various	ETO	Conceptual	N/A	N/A	Identification of design & engineering needs in ETO firms to manage the product life cycle.

Topic: ERP – Enterprise Resource Planning; SCM – Supply Chain Management; PPC – Production Planning and Control; IS – Information System; PLM – Product Lifecycle Management.
Firm size: SME – Small and Medium sized Enterprises; Various – SMEs to large organisations.
Compt. strategy: SC – Supply chain; Various – from MTS to ETO
Data collection: I – Interview; Q – Questionnaire; M – Meeting.

Table 4
An assessment of the applicability of ERP systems to MTO companies.

Context variable (DSR)	Response variable (ERP functionality)	Fit
Customer enquiry management (CEM)	ERP CEM functionality, ATP, AATP and CTP	A lack of sufficient support for the CEM stage; provides automation in entering orders rather than decision support. Inability of ATP to support MTO due date determinations while the effectiveness of using AATP and CTP mechanisms in a MTO context remains unclear.
Design & engineering (D&E)	Product Configurator	Software may be relevant to companies with a mix of production strategies and to MTO companies employing a strategy close to ATO production. Functionality allows buyers to customise products over only a limited range; hence, has limited relevance, especially for products where D&E is bespoke, e.g. ETO firms.
	Product Lifecycle Management (PLM)	Cost estimation and product data management functionality for the customer enquiry and D&E stages. The effectiveness of PLM systems in MTO context, where product life cycles may vary greatly, remains unclear; Implementing PLM, can be an expensive and high-risk strategy for MTO SMEs.
Job entry	Material Req. Planning (MRP) Advanced Planning and Scheduling	MRP-driven replenishment strategy unsuitable for job shop production. APS promises various planning and scheduling solutions. Yet, the effectiveness of APS systems for planning and scheduling in a MTO context remains unclear; Implementing APS, can be an expensive and high-risk strategy for MTO SMEs.
Job release and dispatching	Relevant ERP modules	Job release stage support no longer available within ERP systems. Various dispatching policies available, yet simple and flexible in working simultaneously with the manual scheduling of shop floor employees can be preferred if prior stages are controlled.
MTO supply chains	Supply Chain Management	Internet-enabled SC information sharing and coordination may improve ability to cope with rush orders. Implementing SCM can be an expensive and high-risk strategy for MTO SMEs.
Customer Relationship in MTO context	Customer Relationship Management	CRM software can help to build stable and long term relationships with the right customers; this may also increase the strike rate of MTO companies. Implementing CRM can be an expensive and a high-risk strategy for MTO SMEs.
Other	Enterprise Resource Planning	Wide availability; Departmental integration; E-business capabilities. The need for departmental integration in a SME is limited.

- *MTO-Specific CEM Tool for ERP Embedment*: The value of available AATP and CTP mechanisms for supporting customer enquiry management in the MTO sector has been questioned. This is a growing field of research but the available simple techniques, such as ATP, are best suited to a MTS production strategy. Furthermore, there is no evidence in the literature on the effectiveness of AATP and CTP in practice, and hence further research is needed to explore this. However, it is suggested that it may be necessary to develop a MTO-specific CEM tool, which can be embedded within an ERP system to support decisions on pricing, due date setting and capacity planning.
- *Support for the Design & engineering Stage*: The design & engineering stage, of high importance to producers of bespoke products, has received little attention in the literature. Further research is required to develop design & engineering planning tools. PLM add-ons may contain some functionality in this area but no conceptual or empirical evidence in support of its effectiveness has been presented in the literature to date.
- *APS Applicability to the MTO Sector*: While an APS system is seen as a potentially helpful tool for MTO companies, the literature is scarce. An empirical study of APS in the MTO sector, which explores idiosyncratic sector and industry-specific issues in its adoption, should be conducted.
- *Managing Customer Relationships in the MTO Sector*: CRM is an emerging area but is in need of further research, both for MTO companies in general and SMEs in particular. CRM systems that help MTO companies to turn one-off customers into repeat-purchasers (where appropriate) are required.
- *MTO Supply Chain Management*: MTO-specific supply chain research is quite limited. Furthermore, the literature lacks studies on the use of ERP and SCM systems in MTO supply chains and on supplier management in a MTO context.
- *National Perspectives on SME Adoption of ERP*: ERP adoption by SMEs is an increasingly popular area of research at the pre-, actual- and post-implementation phases. Local and national issues affect this process; hence, further research is required which conducts comparative analysis of ERP adoption in different countries. To the best of our knowledge, no studies on ERP adoption by SMEs in the UK, for example, have been conducted.
- *Embed a MTO-Relevant PPC Concept in an ERP System*: PPC concepts of relevance to MTO companies should be embedded within ERP systems. The Workload Control method of PPC has been argued to be highly suitable for the MTO sector [5,114] and should be (re-)embedded and tested in an ERP system.

7. Conclusion

Although vendors of commercialised ERP systems have claimed that their software is widely applicable, the literature has questioned applicability to MTO companies. Drawing on key literature, this paper has adopted a contingency-based approach to assess the fit between the decision support functionality of ERP systems and the decision support requirements of MTO companies. Although ERP could provide benefits to MTO companies, it is also clear that there is a misalignment in some key areas, such as between the decision support provided by ERP systems and the decision support required by MTO companies at the customer enquiry and design & engineering stages. Building on this, a research agenda has been outlined to improve the alignment between ERP systems and the needs of MTO companies. This includes: developing decision support tools that reflect the customer enquiry management activities of MTO companies; and, embedding MTO-relevant PPC concepts within ERP systems.

The agenda has clear implications for researchers, as well as for developers of ERP software, and is also of relevance to managers in MTO companies. For example, addressing these research gaps will increase the applicability of ERP systems to the MTO sector, improving: information management, competitiveness and the ability to align planning and control decisions with those made by firms in the wider supply chain.

In addition to the seven research areas described in the preceding section, future research could also build on the assessment conducted in this paper. For example, we have focused on assessing ERP as a generic software solution but research could also analyse particular packages, e.g. large-scale solutions offered by SAP or scaled down solutions aimed at the mid-market. The assessment could also be revisited in time: given the rate at which software is developed, it may be important to re-evaluate our conclusions in the future. Empirical data could also be collected to validate our conclusions, e.g. to statically test fit and impact by collecting data via a survey on performance variables in addition to the context and response variables used in this study.

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