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Enterprise Resource Planning Systems: An Assessment of Applicability to Make-To-Order Companies

by

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Abstract

Many vendors of Enterprise Resource Planning (ERP) systems claim their software is 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, leading to questions about the effectiveness of ERP. This thesis takes a contingency-based perspective, assessing both the applicability and impact of ERP systems on MTO companies. A theoretical assessment is first provided based on a comprehensive literature review. This suggests a substantial misalignment does exist between ERP functionality and MTO requirements and calls for empirical research into the applicability and impact on ERP systems on MTO companies.

This thesis addresses this gap through a mixed method study in which a survey is followed by case research. The survey is both explanatory and exploratory and compares MTO with Make-To-Stock (MTS) companies. Significant differences are found between the adoption of ERP systems in MTO and MTS companies. At an exploratory level, for example, MTO companies find ERP system selection more difficult than MTS companies while many non-adopters, particularly MTO non-adopters, claim ERP would not suit their needs. At an explanatory level, for example, Customer Enquiry Management (CEM) and Customer Relationship Management (CRM) are the best-utilised functionality by MTO companies, leading to improved performance but the effectiveness of Product Configurator (PC) and Product Lifecycle Management (PLM) functionality could not be demonstrated. The case study research involved two MTO adopters and one MTO non-adopter. While two cases had implemented ERP, only high-level functionality was in operation to get an overview of the status of company resources and processes. This is because there is not only a

gap between the software available and MTO decision support requirements, but also between the expertise required to utilise the software and that found in small MTO companies in practice.

Finally, this thesis has focused on comparing decision support requirements with ERP functionality and performance at a given planning stage. Future research should investigate the knock-on effects of planning at one stage on the effectiveness of planning at subsequent stages.

Keywords: *Enterprise Resource Planning; Make-To-Order; Survey; Case Study.*

Publications

Parts of this work have been published in the following:

An Assessment of the Applicability of Enterprise Resource Planning Systems to Make-to-Order Companies, *Proceedings of the 6th European and Mediterranean Conference on Information Systems (EMCIS)*, 2009, 13-14 July, The Crowne Plaza, Izmir, Turkey, with Stevenson, M., and Hendry, L. (Full Paper Available online)

Investigating the applicability and impact of enterprise resource planning systems: The effect of production strategy, *Proceedings of the 18th European Operations Management Association (EurOMA) Conference*, 2011, 3 - 6 July, Cambridge, UK, with Stevenson, M., and Hendry, L. (Full Paper Available on Conference Compact Disc)

Part of this work has been submitted for publication:

Enterprise Resource Planning Systems: An Assessment of Applicability to Make-To-Order Companies, *Computers in Industry* (submitted), with Stevenson, M., and Hendry, L.

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List of Abbreviations

ATO	Assemble-To-Order
AATP	Advanced Available To Promise
APS	Advanced Planning & Scheduling
ATP	Available To Promise
AVE	Average Variance Extracted
B2B	Business To Business
BTO	Build-To-Order
CEM	Customer Enquiry Management
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CRM	Customer Relationship Management
CTP	Capable To Promise
CVR	Content Validity Ratio
D&E	Design & Engineering
DD	Due Date
DS	Decision Sciences
DSR	Decision Support Requirement
EFA	Exploratory Factor Analysis
EJIS	European Journal of Information Systems
ERP	Enterprise Resource Planning
ETO	Engineering-To-Order
GFI	Goodness-of-Fit Index
GFS	General Flow Shop
GJS	General Job Shop
IJOPM	International Journal of Operations and Production Management
IJPR	International Journal of Production Research
ISJ	Information Systems Journal
JOM	Journal of Operations Management
MISQ	MIS Quarterly
MRP	Material Requirements Planning
MRP-II	Manufacturing Resource Planning
MS	Management Science
MSOM	Manufacturing and Service Operations Management
MTO	Make-To-Order
MTS	Make-To-Stock
OE	Order Entry
OM	Operations Management
ORR	Order Review & Release
PC	Product Configurator
PLM	Product Lifecycle Management
POM	Production and Operations Management
PPC	Production Planning & Control
PRL	Proportional Reduction in Loss
RMSEA	Root Mean Square Error of Approximation
SCM	Supply Chain Management
SEM	Structural Equation Modelling
SME	Small To Medium-sized Enterprise
WLC	Workload Control

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Chapter 1: Introduction

When implemented effectively, Enterprise Resource Planning (ERP) systems can provide business benefits such as real-time data, improved visibility, and the increased automation of routine tasks (Davenport, 1998; Gupta & Kohli, 2006; Koh *et al.*, 2008). Many ERP vendors claim that such benefits can be accrued by any type of organisation, as their systems are generic; that is, configurable to meet the needs of any business - whatever the product or service offering. However, the literature suggests that producers of high-variety and bespoke products, such as in the Make-To-Order (MTO) sector, present particular challenges (e.g., Bertrand & Muntslag, 1993; Stevenson *et al.*, 2005; Deep *et al.*, 2008). Thus, despite the wide applicability claim of ERP system vendors and the high adoption rate of ERP systems in industry, it is unclear whether ERP can cater sufficiently for the needs of the manufacturing sector, particularly MTO companies.

The alignment of ERP solutions with operational needs has been studied previously (Bendoly & Jacobs, 2004). These 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 the MTO industry. One exception is Bertrand & Muntslag (1993); the authors presented a review of the applicability of MRP-II to bespoke production environments, specifically the Engineer-To-Order (ETO) sector. While valuable, an update to this work is required. Another contribution was provided by Stevenson *et al.* (2005), but their paper reviews and assesses the applicability of a wide range of planning and control concepts to MTO companies and, therefore, does not go into great depth on any one concept. The paper suggests that ERP may be a suitable solution for MTO companies but that further research is required. More recently, Deep *et al.* (2008) conducted a case study investigation of the factors affecting the selection of an ERP system by a MTO company. The paper demonstrated that more research is required towards assisting firms in determining the applicability of ERP, but it did not in itself provide a sufficiently comprehensive review of the available literature or consider the full range of MTO company characteristics that are likely to affect ERP adoption. Other reviews which focus specifically on ERP include those by Esteves & Pastor (2001), Al-Mashari *et al.* (2003), Jacobs & Weston (2007), and Moon (2007). 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 the fast-moving ERP industry (e.g. the emergence of add-ons to ERP packages for supply chain and customer relationship management). Therefore, an assessment of the applicability of ERP systems to the MTO industry, focusing on contemporary issues in ERP systems, is required. As a basis for comparison, such work should also consider the applicability to Make-To-Stock (MTS) companies.

This thesis addresses this research gap by assessing the applicability of modern ERP software to MTO companies by the taking a contingency-based perspective (Sousa & Voss, 2008). That is, the ERP adoption phenomenon is examined for companies employing the MTO and MTS production strategies, but with a main focus on the MTO sector. Before describing the research aims and objectives further, we first define key terms used throughout this thesis.

1.1 Defining Key terms

As this thesis takes a contingency-based approach, dependent upon production strategy, we first define what is meant by the term "production strategy" and explain the difference between the MTO and MTS sectors. Secondly, it is important to define what is meant by the term "ERP".

1.1.1 Production Strategy

The choice between implementing ERP and continuing to use a customary legacy solution is strategic, just like the choice between producing 'to stock' or 'to order' (Amaro *et al.*, 1999; Slack *et al.*, 2010). The latter choice also strongly affects the way a company carries out its manufacturing planning and control activities (Vollmann *et al.*, 1992). Conventionally, ETO, MTO, Assemble-To-Order (ATO) and MTS are the recognised production strategies (Hill, 2000; Slack *et al.*, 2010). Building on this, Olhager (2003) identified the concept of Order Penetration Point (OPP)—also called the Customer Order Decoupling Point (Olhager & Ostlund, 1990; Welker *et al.*, 2008)—in a manufacturing continuum ranging from MTS over ATO and MTO to ETO (Figure 1.1).

This study uses the term MTO in a broad sense for the companies that produce bespoke products which are customized to meet individual customer specifications. Hill (2000) provided a more comprehensive description of a typical MTO company overlapping with this study's definition of the MTO production strategy:

Figure 1.1. OPP: dotted and straight lines depict the forecast-driven and order-driven activities, respectively. (source: Olhager, 2003)

> *"MTO businesses are usually involved in the provision of special (that is, will not be repeated) products and services. In addition, some companies decide to meet demand for standard (that is, repeat) items only on a MTO basis. Either way, a MTO response means that inventory will not be held either as part finished or finished items. What may be held in stock are the materials and components that form all or part of an item".*
>
> Hill (2000, p. 379)

The definition of MTO in this thesis includes all production strategies from ETO to MTO. Therefore, the literature on all these companies is also embraced under the term MTO production strategy, which is used as an umbrella term in this thesis. A detailed analysis and review of MTO companies and their decision support requirements at critical planning stages is presented in the next chapter and reflects this broad definition.

In contrast, for MTS companies, the order penetration point takes place at a later stage (Olhager, 2003; Welker *et al.*, 2008). Finished goods are made ahead of demand in line with sales forecasts. Customer orders are met from inventory; therefore, they are often able to (Hill, 1993, p. 125-6; Slack *et al.*, 2010):

- Purchase and produce in large batches,
- Operate continuous production methods,
- Maintain low and less varying set up times, and
- Accumulate a finished goods inventory from which to rapidly satisfy demand.

ATO represents a hybrid production strategy for which parts and subassemblies are made according to forecasts while the final assembly of the products is delayed until customer orders have been received (Song & Zipkin, 2003). Under such an ATO production strategy, components and subassemblies are made to stock. The term MTS production strategy is also used as an umbrella term in this thesis to include both the ATO and MTS definitions given above. Thus, the terms MTO and MTS are used as contrasting production strategies in the discussions and analyses to enable comparisons.

1.1.2 Enterprise Resource Planning Systems

Davenport *et al.* (2004) defined 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". ERP systems stem from the Material Requirements Planning (MRP) and Manufacturing Resource Planning (MRP-II) systems of the 1970s and 1980s (Jacobs & Weston, 2007). The evolution of ERP itself continued with the addition of several functionalities from 'back-office' to 'front-office' business processes, including for human resource management, purchasing, finance and accounting, marketing, customer support and e-business. Figure 1.2 provides a complete overview of the scope of an ERP system with a single powerful database integrating business processes together:

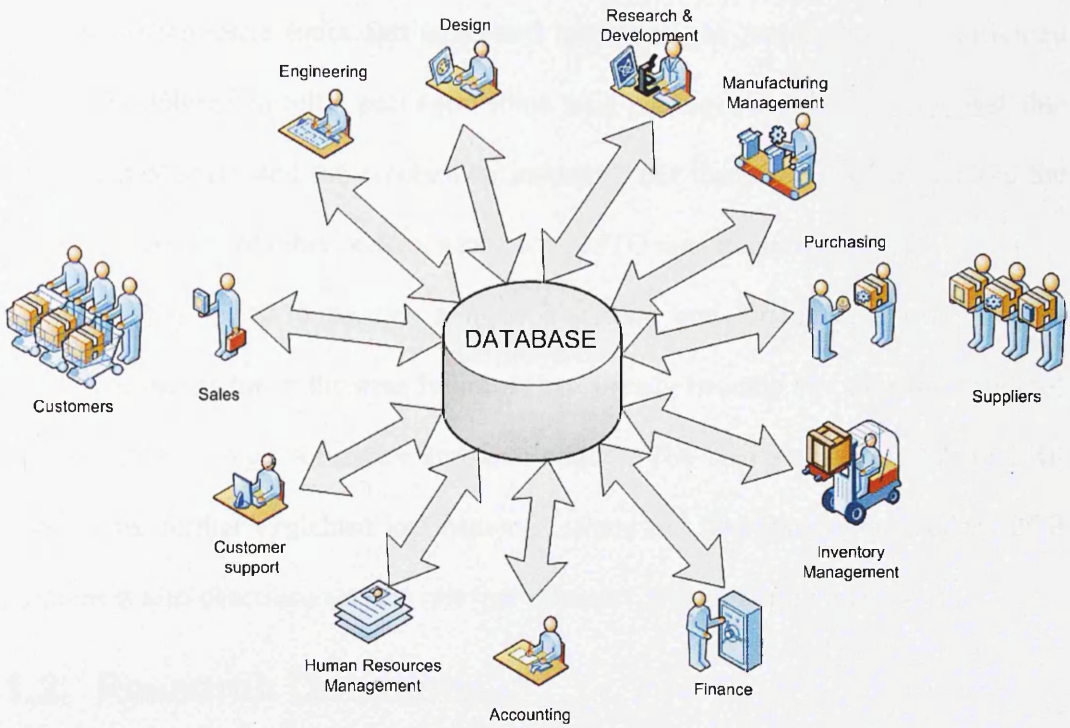


Figure 1.2. A complete picture of an ERP system with back-office and front-office business functions. Adapted from Davenport (1998, p. 124)

ERP systems are being widely adopted in practice. Typical motivations behind adoption are replacing legacy systems, simplification, standardisation, and gaining strategic advantage (Mabert *et al.*, 2000; Van Everdingen *et al.*, 2000; Mabert *et al.*, 2003; Olhager & Selldin, 2003). ERP's wide availability, capability to support e-business activities and integration are the features applicable to every manufacturing company including the MTO sector.

Some studies have considered the applicability of ERP to certain sectors or company types; see, for example, Rashid *et al.* (2002) and Jacobs & Weston (2007) who provided historical reviews of ERP systems. Rashid *et al.* (2002) highlighted the need to explore ERP in small companies. Mabert *et al.* (2003) and Muscatello *et al.* (2003) have since conducted pioneering studies on the impact of company size on ERP adoption. Jacobs & Weston (2007) emphasized the need to minimize implementation cycle times and suggested increasing the number of pre-configured sector and industry-specific packages; some such packages are now readily available (e.g. for healthcare and the automotive industry), but there is a need to explore the ERP requirements of other sectors, such as the MTO manufacturing sector.

ERP is likely to become a more important and fundamental issue for the manufacturing sector in the near future. It has already become an 'industry standard' in some sectors (e.g., aerospace and automotive). The characteristics of these ERP systems are further explained in Chapter 2, where the functionality of modern ERP modules is also described and the relevant literature is reviewed in more depth.

1.2 Research Questions

As discussed above, this thesis takes a contingency-based perspective (Sousa & Voss, 2008) to assess the alignment between the functionality of modules available in modern ERP systems and the production strategy of a company. The effect of production strategy is assumed to be linked to the relevant decision support requirements of a company employing a certain production strategy. Given the potential difficulties of MTO ERP adoption compared to MTS (Bertrand & Muntslag, 1993; Stevenson *et al.*, 2005; Deep *et al.*, 2008), the emphasis of this thesis is on MTO decision support requirements, whilst the research also aims to make comparisons between the applicability of ERP to MTO and MTS production strategies.

The overarching research question is as follows:

RQ (1): How does the production strategy of a company affect ERP applicability?

To answer this question, a mixed methods empirical research methodology (survey study followed up by case research) is applied, focusing on companies in the UK. Considering the current scarce amount of research in the field, firstly an ***exploratory*** survey is designed to seek an answer to the following sub research question:

RQ (1a): What are the differences in ERP adoption between MTO and MTS companies?

Here, the aim is to collect background information on the ERP environment of the manufacturing sector in the UK and to detect the differences in ERP adoption between the two main production strategies via descriptive statistics.

In addition, the second and main purpose of the survey is to conduct ***explanatory*** research. To this end, a theoretical framework is developed in Chapter 4 as a deductive element of this research. The aim is to assess the fit between decision support requirements and the functionality of widely available modules of ERP and to observe its impact on company performance. This part of the thesis aims to answer the two sub research questions below:

RQ (1b): What is the relationship between the decision support requirements, intensity of use of ERP tools and company performance?

RQ (1c): Do these relationships vary with respect to production strategy?

These explanatory and exploratory parts were prepared consecutively, but with the survey data collected in the same questionnaire. The results lead the study to question the fundamentals of the 'what' questions above through the following 'why' question via case study research:

RQ (1d): Why do these relationships differ?

1.3 Outline of Thesis Chapters

The remainder of this thesis is organised as shown in Table 1.1 below:

Table 1.1. Organisation of the Thesis

Chapter 2	Reviews the literature to conceptually assess the fit between MTO decision support requirements and the functionality of widely available modules of ERP, and to identify the research gaps in the existing ERP/ MTO related literature.
Chapter 3	Provides an overview of the research strategies in the field, such as survey, case, delphi, action research and ground theory; and presents the selected methodology, which involves a rigorous survey research followed by three case studies.
Chapter 4	Describes the theoretical basis for the conceptual model and develops hypotheses to be tested; and, then, describes the process used to operationalise the theoretical constructs as well as the development and validation of the survey instrument used to collect the data used to test the hypotheses.
Chapter 5	Provides the descriptive statistics on ERP adoption by the sampled UK companies; and, explores the differences between companies employing a MTO and MTS production strategy in ERP adoption.
Chapter 6	Tests the hypotheses in the theoretical framework for the identified planning stages; interprets the results of the explanatory part; and, presents their contribution.
Chapter 7	Unpacks the reasons behind the ERP adoption and non-adoption of MTO companies, the reason why MTO companies find system selection difficult, and the reason why they cannot benefit from the planning tools of ERP through three case studies.
Chapter 8	Summarises the key research findings and contributions for each chapter; and, outlines future research.

Chapter 2: Literature Review

3.1 Introduction

This chapter assesses the applicability of ERP to the MTO industry 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. It does not aim to focus on broad implementation issues or to provide a detailed historical description of the evolution of ERP systems.

The remainder of this chapter is organised as follows. Section 3.2 explains the methodology followed to systematically select papers to review and to assess the applicability. Section 3.3 defines the characteristics and decision support requirements of MTO companies before Section 3.4 provides an overview of the functionality of ERP systems, including recent extensions to their core functionality. Section 3.5 assesses the fit between the requirements of MTO companies and the functionality of these systems. Section 3.6 identifies gaps in the literature in need of further research before the chapter concludes in Section 3.7.

3.2 Approach to the literature review

The approach to reviewing the literature described below consists of two parts. Subsection 3.2.1 explains the process used to systematically identify literature on ERP functionality and MTO requirements before Subsection 3.2.2 describes how the fit between the two is assessed.

3.2.1 Systematic Review Process

The principles of conducting a systematic literature review have been followed in selecting papers (Tranfield *et al.*, 2003; Pittaway *et al.*, 2004). 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. It is further decreased to a final list of 144 studies using systematic search criteria (Tranfield *et al.*, 2003). 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) are excluded; and instead studies with a high citation index which focus on MTO-specific needs and decision making stages through case studies, surveys, mathematical or conceptual models are focused on. In other words, the ERP literature is the supplementary resource in this study. The main reason is that the particular focus on Production Planning and Control (PPC) in a MTO environment is the starting point for research. Thus, firstly, MTO decision support requirements for PPC purposes are identified; and then ERP literature is consulted whenever any corresponding tool is sought to match the MTO needs.

The final 144 articles are classified in Table 2.1. 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), Advanced Planning and Scheduling (APS), etc (as defined in Section 3.4 below); 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 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 the table.

From Table 2.1., 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.

3.2.2 Assessment of Fit or Applicability

To assess applicability, this thesis relates ERP software provision to MTO Decision Support Requirements (DSR) via the matching (also called selection) concept of fit (Drazin & van de Ven, 1985; Venkatraman, 1989) which is conceptualised within the contingency theory literature (Sousa & Voss, 2008).

Two prominent classifications of fit have been proposed by Drazin & van de Ven (Drazin & van de Ven, 1985) and Venkatraman (Venkatraman, 1989) 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

Table 2.1. List of literature reviewed in this paper

Categories	References
ERP Research	
Review & Classification	Davenport, 1998; Gupta, 2000; Klaus *et al.*, 2000; Esteves & Pastor, 2001; Mabert *et al.*, 2000; Rashid *et al.*, 2002; Shehab *et al.*, 2004; Botta-Genoulaz *et al.*, 2005; Jacobs & Weston, 2007; Moon, 2007
Future Concepts	Davenport, 2000; Markus *et al.*, 2000; Chen, 2001; Rashid *et al.*, 2002; Al-Mashari, 2003; Jacobs & Bendoly, 2003; Davenport & Harris, 2007; Jacobs & Weston, 2007; Koh *et al.*, 2008
Extended ERP (SCM, APS, CRM and others)	Davenport, 2000; Stratman, 2001; Bose, 2002; Rigby *et al.*, 2002; Stadtler & Kilger, 2002; Tarn *et al.*, 2002; Wiers, 2002; Akkermans *et al.*, 2003; Fleischmann & Meyr, 2003; Kovács & Paganelli, 2003; Ptak & Schragenheim, 2003; Addison, 2004; Davenport & Brooks, 2004; Rigby & Ledingham, 2004; de Búrca *et al.*, 2005; Møller, 2005; Stadtler, 2005; Hendricks *et al.*, 2007; Watts *et al.*, 2008 ; Lee *et al.*, 2008; Ou-Yang & Hon, 2008 ; Hicks, 2009; Hvolby & Steger-Jensen, 2010;
National & Cultural Perspectives	Adam& O'Doherty, 2000; Mabert *et al.*, 2003; Olhager & Selldin, 2003; Baki & Cakar, 2005; Koh & Simpson, 2005; Morabito *et al.*, 2005; Lee *et al.*, 2006; Argyropoulou *et al.*, 2007; Chien *et al.*, 2007; Laukkanen *et al.*, 2007; Ketikidis *et al.*, 2008; Snider *et al.*, 2009; Bayraktar *et al.*, 2009
SME ERP Adoption	Van Everdingen *et al.*, 2000; Mabert *et al.*, 2003; Muscatello *et al.*, 2003; Buonanno *et al.*, 2005; de Búrca *et al.*, 2005; Koh & Simpson, 2007; Olsen & Sætre, 2007a; Raymond & Uwizeyemungu, 2007; Koh *et al.*, 2009
Sector/Industry Application	Wiers, 2002; David *et al.*, 2005; David *et al.*, 2006
MTO Research	
Customer Enquiry	Tobin *et al.*, 1988; Hendry & Kingsman, 1989; Hendry & Kingsman, 1991; Hill, 1991; Hendry & Kingsman, 1993; Kingsman *et al.*, 1993; Kingsman *et al.*, 1996; Easton & Moodie, 1999; Moodie, 1999; Cakravastia & Nakamura, 2002; Olhager, 2003; Stevenson *et al.*, 2005; Stevenson & Hendry, 2006; Hendry *et al.*, 2008; Stevenson & Silva, 2008; Zorzini *et al.*, 2008; Hendry, 2010
Design & Engineering	Wortmann, 1995; Lampel & Mintzberg, 1996; Amaro *et al.*, 1999; Spring & Dalrymple, 2000; Rudberg & Wikner, 2004; Hvam *et al.*, 2006
Job Entry, Job Release & Dispatching	Hendry & Kingsman, 1989; Bertrand & Muntslag, 1993; Enns, 1995; Oosterman *et al.*, 2000; Kingsman, 2000; Kingsman & Hendry, 2002; McKay & Wiers, 2003; Stevenson *et al.*, 2005; Hendry *et al.*, 2008; Stevenson & Silva, 2008; Soepenberg *et al.*, 2008; Boulaksil & Fransoo, 2009; Olhager, 2010
Non-PPC	Muda & Hendry, 2002; Wikner & Rudberg, 2005; Dekkers, 2006
ERP & MTO Research	
Review & Assessment	Bertrand & Muntslag, 1993; Wortmann, 1995; Jonsson & Mattsson, 2003; Stevenson *et al.*, 2005; Koh & Simpson, 2007; Olsen & Sætre, 2007a; Olsen & Sætre, 2007b; Deep *et al.*, 2008; Hicks & McGovern, 2009

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 & Voss (2008) 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 the study focuses on aligning context and response; and it is assumed 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 Figure 2.1. 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.

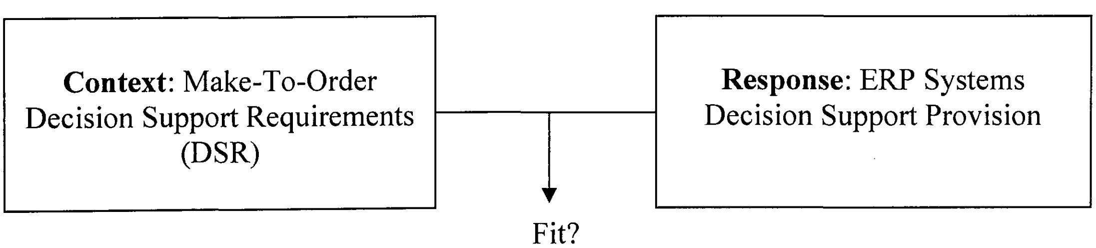


Figure 2.1. The selection (matching) theoretical framework used in this study.

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 3.3 and 3.4, respectively (and summarised in Table 2.2) before Section 3.5 examines the fit (see, e.g. Table 2.4).

3.3 Decision Support Requirements of the MTO Sector

There are various definitions of the diverse production strategies presented in the literature. This chapter focuses on MTO but defines it in a broad sense. As discussed in the introduction chapter, MTO is used as 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 ETO is incorporated within the definition of MTO in this thesis, if an author uses the term "ETO" this distinction is retained when reviewing the literature. The following subsections identify the characteristics and requirements of MTO companies to aid in the 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.

3.3.1 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 (Hendry & Kingsman, 1993; Kingsman *et al.*, 1996; Moodie, 1999; Cakravastia & Nakamura, 2002; Calosso *et al.*, 2004; Stevenson, 2006; Zorzini *et al.*, 2008). For MTO companies, PPC must begin here as each order may be different and decisions made here affect subsequent stages (Kingsman & Hendry, 2002). 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 (Bertrand & Wortmann, 1992; Bertrand & Muntslag, 1993; Stevenson *et al.*, 2005; Deep *et al.*, 2008). 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 (Land & Gaalman, 2009). Wortmann (1995) 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 & Sridharan (2001) 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 & Wikner (2004) 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 (Bertrand & Wortmann, 1992; Bertrand & Muntslag, 1993; Stevenson *et al.*, 2005; Deep *et al.*, 2008). 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 (Hendry & Kingsman, 1989; Knolmayer *et al.*, 2002; Deep *et al.*, 2008). 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 (Stevenson *et al.*, 2005). Finally, ETO firms can sometimes require project management techniques and relevant IT support, when a majority of orders are for large projects (Bertrand & Wortmann, 1992; Bertrand & Muntslag, 1993; Knolmayer *et al.*, 2002).

- *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 (1970) 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" (Mather & Plossl, 1978). This stage (in isolation) has received far more attention in the literature than the preceding stages (see Wisner, 1995; Bergamaschi *et al.*, 1997); 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 (Stevenson & Hendry, 2006).
- *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., Blackstone *et al.*, 1982; Błażewicz *et al.*, 1996; McKay & Wiers, 2003). 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 (Kingsman, 2000).

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 (Hendry & Kingsman, 1989).

3.3.2 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 (Haskose *et al.*, 2004; Henrich *et al.*, 2004). 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 (Safizadeh *et al.*, 1996; Stevenson *et al.*, 2005) 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 (1995) and Oosterman *et al.* (2000) have highlighted the importance of taking work flow 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.

3.3.3 MTO Companies and the Supply Chain

MTO companies are often positioned towards the upstream end and midstream of supply chains, serving large, powerful customers (Gunasekaran & Ngai, 2005; Prasad *et al.*, 2005). 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.* (2005) and Stevenson & Hendry (Stevenson & Hendry, 2007) 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. Hicks *et al.*, 2000; Sahin & Robinson, 2005). Sahin & Robinson (2005) highlighted the value of information sharing and coordination in MTO supply chains; similar results are presented by Robinson *et al.* (2005) 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 & Robinson (2005) 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.*,(2000) found that effective knowledge sharing in supply chains can be a competitive advantage. Finally, Jahnukainen & Lahti (1999) 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.

3.3.4 MTO Company Size

Many MTO companies are (SMEs, see: Amaro *et al.*, 1999; Stevenson *et al.*, 2005). SMEs are a major contributor to supply chains and to the EU and UK economies, representing 99% and 99.9% of all enterprises, respectively (EU Commission, 2006; UK BERR, 2007). According to the EU Commission (EU Commission, 2003), 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 thesis.

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 (Olsen & Sætre, 2007a).

3.3.5 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 (Brown & Bessant, 2003). 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 Stevenson, 2006).

Amaro*et al.* (Amaro *et al.*, 1999) 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 (Stevenson & Hendry, 2007). 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.

3.3.6 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 3.5.

3.4 Functionality of Modern ERP Systems

Basic MRP mechanisms, as developed by Plossl & Wight (1971), determine purchasing and production requirements from a given BoM, but can be overly simplistic leading to extreme 'system nervousness' (Orlicky & Plossl, 1994). 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 (Vollmann *et al.*, 1992). Finite scheduling and infinite loading are commonly available capacity tools (Knolmayer *et al.*, 2002). 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.* (2004) 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 Subsection 3.4.2. MRP II (Wight, 1981) 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 & Weston (2007) have suggested increasing the number of pre-configured sector and industry-specific packages. ERP's 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 & control, purchasing, sales & distribution, materials management, production planning, human resources, and quality management (Mabert *et al.*, 2000; Olhager & Selldin, 2003; Snider *et al.*, 2009).

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 (Davenport, 2000). This trend has led to the term "Extended ERP" or "ERP-II" (Rashid *et al.*, 2002; Botta-Genoulaz *et al.*, 2005), 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 (Moon, 2007); such extensions are explored in the following subsections.

3.4.1 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 (Davenport & Brooks, 2004). 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 (Davenport & Brooks, 2004). Bowersox *et al.* (1998) 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 (de Kok & Graves, 2003). Yet, Akkermans *et al.* (2003) 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.* (2003) and assess whether the criticisms remain valid.

Hendricks *et al.* (2007) 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.

3.4.2 Advanced Planning and Scheduling (APS) Software

APS software is developed to address manufacturing planning and scheduling problems based on hierarchical planning principles (Stadtler & Kilger, 2002). 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 (Stadtler, 2002).

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 (Ball *et al.*, 2004). Akkermans *et al.* (2003) 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 & Meyr (2003) and Kilger & Schneeweiss (2005) 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 (Chen *et al.*, 2002). 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 (Pibernik, 2005).

The available literature on APS systems is scarce (e.g., Stadtler & Kilger, 2002; de Kok & Graves, 2003; David *et al.*, 2006). 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.

3.4.3 Customer Relationship Management (CRM) Software

Conceptually, CRM is a business practice centred around customer needs (Buttle, 2004). CRM software, developed to address these needs, is used to compile data on customers and analyze it in order to sell more goods or services, and to do so more efficiently (Bose, 2002).

CRM can be implemented and utilised without ERP; however, ERP is thought to be a supportive structure for the growing needs of CRM. Chen & Popovich (2003) 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 & Distribution and Service applications). As a result, many

ERP vendors have invested in CRM add-ons and are now also major CRM vendors (Chen, 2001).

While Hendricks *et al.* (2007) 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.

3.4.4 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 (Knolmayer *et al.*, 2002; Xiong *et al.*, 2006). 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 (Forza & Salvador, 2002). 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 Fleischmann & 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 (Liu & Xu, 2001; Hicks & McGovern, 2009).

Figure 2.2 illustrates the evolution of ERP from MRP and incorporates extensions like SCM software and smaller add-ons such as PLM software.

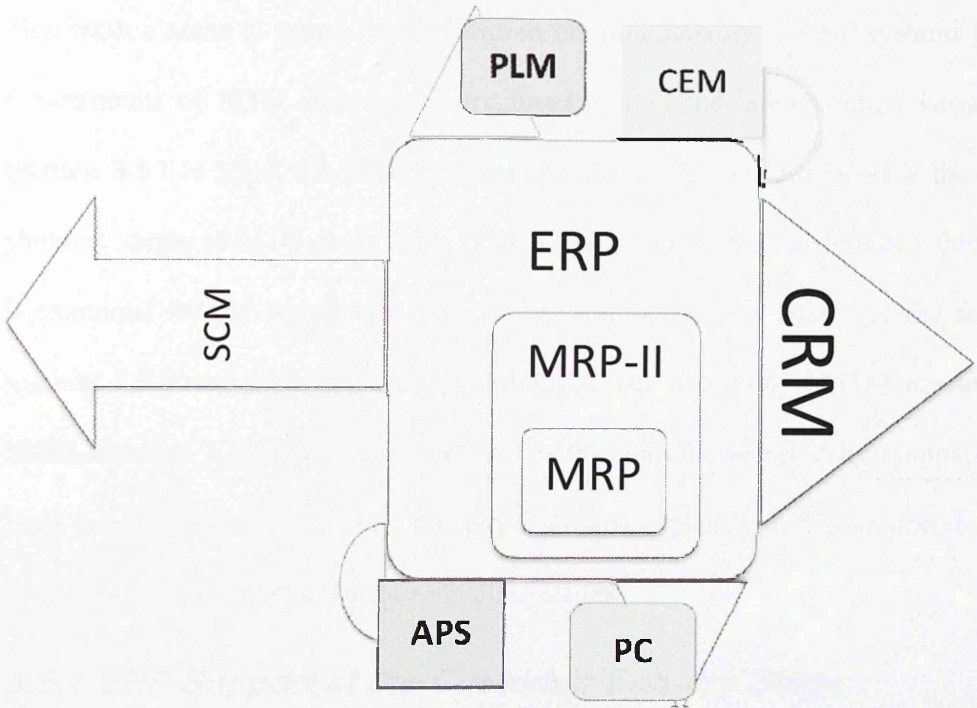


Figure 2.2. The scope of ERP systems, major extensions and add-ons

3.4.5 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 2.2 below 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.

3.5 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 3.5.1 to 3.5.4, the match is examined between the requirements at the critical planning stages of MTO companies, as identified in Section 3.3. Similarly, this match is examined for the supply chain operations and customer relations of the sector in sections 3.5.5 and 3.5.6, respectively. Finally, given that many MTO companies are SMEs, Section 3.5.7 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.

3.5.1 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 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 (Kilger & Schneeweiss, 2005). Fleischmann & Meyr (2003) and Pibernik (2005) stress the necessity of detailed

Table 2.2. 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:	Support for quoting, design & engineering, job entry, shop floor scheduling:
	Customer enquiry management: Generating due date & pricing alternatives in response to customer enquiries	Available/Capable-To-Promise & the CEM module,
	Design & Engineering Flexibility in design & engineering	Product configurator & Product Lifecycle Management,
	Order Entry: Capacity planning and control for confirmed orders, including materials purchasing	Material Requirements Planning & Advanced Planning and Scheduling
	Order Release: Introducing a job release stage for shop floor control	-
	Dispatching: Compatibility with human decision making on the shop floor 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.	Web-enabled supply chain information sharing
	Sharing up-to-date information across the supply chain is critical.	Co-ordination functionality
4. Company Size	A significant proportion are SMEs, thus having relatively simple organisational structures & 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

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 (2005) 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.* (2005) 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 (Xiong *et al.*, 2006). Finally, coordination across departments has been argued to be essential for dealing with customer enquiries (Hendry & Kingsman, 1989). This is a requirement which ERP systems are able to support given the common database used across an organisation (Deep *et al.*, 2008).

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.

3.5.2 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 thesis. 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 & Wikner (2004) 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 & Sætre (2007b) 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.* (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 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 & McGovern (2009) 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 like 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.

3.5.3 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 (Cooper & Zmud, 1989; Cooper & Zmud, 1990).

In contrast, the study by Berry & Hill (1992) linking market requirements, via the production strategy, to the design of PPC systems, argues for the suitability of time-phased MRP mechanism to MTO as a material planning approach. Thus, for example, the study concludes that firms with high-volume standardised products typically would choose a MTS, rate-based JIT material planning approach, and a pull-type shop floor control approach; whereas firms with many low-volume, customized products would choose a MTO, time-phased MRP material planning approach, and a push-type shop floor control approach. However, an important parameter, namely demand predictability, was ignored. Newman & Sridharan (1995), who similarly investigated the link between PPC and the manufacturing environment, suggest that when demand is stable and predictable, any material planning approach works. However, while MRP may be an appropriate choice with unstable (i.e., highly fluctuating) but largely predictable demand; it is particularly unsuitable when demand is unpredictable (being either steady or variable). Given that demand is often unpredictable in a MTO environment, this research supports the earlier argument that MRP-driven replenishment is not suitable in this case.

APS software can support collective planning through planning and optimizing the supply chain (Fleischmann & Meyr, 2003). Some authors suggest that APS systems are broadly applicable packages that provide company-wide planning and scheduling, especially at the job entry stage (Stadtler, 2005; van Nieuwenhuyse *et al.*, 2011). However, few authors have researched into industry- and sector-specific APS solutions; notable exceptions include Deep *et al.* (2008) and David *et al.* (2005; 2006). Deep *et al.* (2008) 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.* (2006) 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.

3.5.4 ERP Support at the Job Release and Dispatching Stages

Breithaupt *et al.* (2002) reported that the job release mechanism of load-oriented manufacturing control, a particular Workload Control methodology developed in Hanover and described by Bechte (1988), was previously included in the SAP R/2 system and the systems of other local ERP vendors in Germany. However, to this researcher's 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 (Tobin *et al.*, 1988; Stevenson & Hendry, 2006). Jonsson & Mattsson (2003) 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 (2000) 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.

3.5.5 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.* (2005) and Stevenson & Hendry (2007) 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 & Lahti (1999). 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 & Robinson (2005) and Robinson *et al.* (2005) 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.

3.5.6 Customer Relationship Management in a MTO Context

Two types of MTO company defined by Amaro *et al.* (1999) are the Repeat Business Customiser (RBC) and Versatile Manufacturing Company (VMC), as outlined in Section 3.3.5. For RBCs, developing long-term relationships with customers can be important. Muda & Hendry (2002) 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 (Hendry, 2010). 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.

3.5.7 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 (Raymond & Uwizeyemungu, 2007). 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.* (2003) 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 (2005) survey of Italian SMEs are consistent with these findings. Similarly, in a Finnish context, Laukkanen *et al.* (2007) 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.* (2007) 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.* (2007). Snider *et al.* (2009) 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 & 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 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 & Selldin (2003) 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 this researcher's knowledge, there is no research which explores ERP adoption in UK SMEs; while Koh & Simpson (2007) 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 the 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.* (2005) 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 (Fleischmann & 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 production strategy of the companies in order to provide a richer insight into this topic for MTO SMEs.

To conclude the discussion above, Table 2.3and Table 2.4, 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 2.3 demonstrates that consideration of the MTO context is an emerging area but that a greater body of knowledge should be developed. Table 2.4 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 3.6 below.

Table 2.3. Summary of key ERP studies of relevance to a MTO context

Study	Topic	Firm Size	Manuf. strategy of the firm(s)	Research Methodology			Summary
				Method	Data	Size	
Bertrand & Muntslag (1993)	PPC	N/A	ETO	Conceptual	N/A	N/A	Assessment of MRP-II suitability to ETO firms and a proposed framework.
Wortmann (1995)	IS	N/A	ETO	Conceptual	N/A	N/A	IS comparison for ETO and MTS production, and an ETO data-structure proposition.
Jonsson & Mattsson (2003)	PPC	Various	Various	Conceptual, Survey	Q	84	Assessment of PPC applicability to different production environments.
Mabert *et al.* (2003)	ERP	Various	Various	Case Study, Survey	I, Q	12, 482	Investigation of the impact of organisation size on ERP adoption.
Stevenson *et al.* (2005)	PPC	N/A	MTO	Review	N/A	N/A	Review and assessment of PPC applicability to MTO production.
Buonanno *et al.* (2005)	ERP	SME	Various	Survey	Q	366	Investigation of factors influencing ERP adoption in SMEs compared to large companies.
Koh & Simpson (2007)	PPC, ERP	Various	Various	Survey	Q	108	Diagnosis of uncertainties in SMEs using ERP systems.
Olsen & Sætre (2007a)	ERP	SME	ETO	Conceptual, Case Study	I	1	Proposition of an alternative in-house company-wide software framework for SMEs.
Olsen & Sætre (2007b)	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.* (2008)	ERP	SME	MTO	Case Study, Action Res.	I, M	1	Investigation of factors influencing ERP selection by a MTO SMEs.
Hicks & McGovern (2009)	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 & 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 2.4. 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 & 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 & 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.

3.6 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:

- *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 this researcher's 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 (Stevenson *et al.*, 2005; Hendry *et al.*, 2008) and should be (re-embedded) and tested in an ERP system.

3.7 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 chapter 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 remainder of this thesis improves the assessment in this chapter by incorporating the "performance" into the contingency model and empirically testing the framework through a mixed methods approach. The next chapter describes the research methodology followed throughout the thesis.

Chapter 3: Research Methodology

3.1 Introduction

This chapter provides the methodological approach adopted in this study.

The following section (Section 3.2) presents a summary of the alternative methods to select the most appropriate ones given the aims of this study, as provided in Chapter 1. The set of methods to be used throughout this thesis are then determined and justified. Section 3.3 describes the research design for the selected methods while leaving the further discussion, such as the theoretical framework, to be covered in the next chapter. Section 3.4 concludes this chapter by outlining the entire research approach to be followed throughout the remainder of this thesis.

3.2 Methodology Selection

Alternative research strategies summarised in Table 3.1 below can be conducted on either a longitudinal or cross-sectional basis, depending on the purpose. Yet, some of them are more helpful when conducted over a long period (e.g., ethnography), and some for a short period (e.g., survey). Each has pros and cons; the decision should be made according to the research focus.

A mixture of research methods can also be a desirable choice to overcome the weaknesses of one by complementing the other. Mixed methodology, which is underutilised but more widely encouraged in the field recently, further discussed in the following subsection.

Table 3.1. Alternative Empirical Research Strategies

Research Strategy	Appropriate use
Survey	*Exploratory*: for preliminary insight into a topic *Descriptive*: for documentation of a phenomenon *Explanatory*: for testing a model/concept
Case Study	Understanding of the nature of the phenomenon (Observational based)
Action Research	Understanding of changes in the phenomenon (Participation based)
Delphi	Forecasting future of a phenomenon
Grounded Theory	Understanding of the nature of the phenomenon for theory development (Observational based)
Ethnography	Understanding of the nature of the phenomenon (Participation and observational based)

3.2.1 Mixed Methods

In disciplines employing empirical methods, the use of multiple methods is highly preferred for several reasons: First and foremost, it is aimed at using complementary strengths of methods to compensate for the weaknesses in each single one (Jick, 1979). Such form of research strategy was first considered as one of the techniques of validity such as convergent validation, Multi-Method/Multi-Trait (Campbell & Fiske, 1959) or triangulation (Webb *et al.*, 1966). This is particularly called *Methodological Triangulation* by Denzin (1970) who classified the types of triangulation as (a) Data, (b) Investigator, (c) Theory, and (d) Methodological triangulation. Briefly, Data triangulation is related to enhancing the validity and reliability of data; Investigator triangulation concerns eliminating the use of single interviewee bias; Theory triangulation is the way of approaching data with multiple perspectives and hypotheses in mind. Finally, Methodological (across-method) triangulation employs more than one research method in a study.

Taylor & Taylor (2009) examined the OM literature in its last five years. One of the aims was to identify the distribution of utilised research methods, see the trend in the field, and contribute to debates for a future direction. As a result, the authors found that Survey (30%) and Case study (28%) were the two most frequently used methods (each used on its own). Yet, Mixed Methods were applied in 29 papers out of 310 which they describe "*to be very low, and suggest a need for greater consideration of mixed methods to provide some triangulation* [...] *As regards the way forward for the utilisation of research methods in OM, increased exploitation of mixed methods seems essential to provide alternative viewpoints of complex OM issues.*" (Taylor & Taylor, 2009). Additionally, Burgess *et al.* (2006) sampled and reviewed 100 journal publications using the keyword "Supply Chain Management"; and similarly on the use of methodological tools, they argued that "*The lack of mixed-methods could have an adverse impact on the development of the field.*" Boyer & Swink (2008) stress the importance of using multiple research methods to get a true picture of a phenomenon as much as possible. "*It is our strong belief that multiple approaches are required in order to develop a holistic understanding of operations and supply chain management phenomena.*"

For example, survey and case study research are the methods that their collective use has been widely acknowledged; and therefore, highly prevalent in mixed methods research. Jick (1979) listed various authors who have advocated the viability and necessity of such linkages between *survey* and *case study* and their agreement on the contributions of one to the other. For example, referring to Diesing (1971), it is stated that the variety of combinations is so great that survey and case research are better viewed as two ends of a continuum complementing each other's drawbacks rather than two distinct methods. At this point, it can be helpful to summarise the characteristics and objectives of both methods to show their strengths and weaknesses. Methodological papers by Jick (1979), Flynn *et al.*, (1990), Gable (1994), Meredith (1998), Malhotra & Grover (1998) and Benbasat *et al.*, (2002) are used to summarise these points in Table 3.2.

Though the combination of two widely-utilised methods is adopted, the *sequence* they follow is also worthy of discussion. Research employing surveys following case studies are common in several disciplines (e.g., social sciences, MIS, marketing, etc.). This is mainly performed so to build a theory from case study research, and then surveying the population (or a sample of it) to test its generalisability through fit with the data coming from this population (Jick, 1979; Tashakkori & Teddlie, 1998). On the other hand, the opposite sequence of two methods is particularly preferred to modify, extend or confirm a theoretical framework. The aim when conducting a case study following a survey is in twofold (Voss *et al.*, 2002):

- *Examine the findings more deeply; and,*
- *Cross-validate the findings of the survey.*

For the former reason, the researcher can freely scrutinise the topic without to the rigid limitations of using a strict questionnaire. The latter is aimed at increasing (internal) validity. Besides, both gain more importance; especially when sample size and response rate (i.e., power of analysis) is low.

Table 3.2. Summary of characteristics and objectives of two consecutive strategies in this study (Miles & Huberman, 1994)

Survey (1st Method)	Case Study (2nd Method)
Quantitative and Statistical	Not usually quantitatively oriented (data through observation, triangulation, and logic)
Remotely conducted, or interview-based	Phenomenon studied in its natural setting
High power of analysis enables generalisability	Questionable generalisability
Representativeness is especially important for generalisability	Representativeness is relatively important depending on the aim of the case research
Strictly structured questionnaire may lead miss important points	Enables better understanding of the nature and complexity of the complete phenomenon
Used for exploratory and explanatory purposes	More powerful in exploratory nature
Intends to *measure* variables in the sample and statistically infer relationships	Intends to observe the processes and use logic to deduce or infer relationships

Gable (1994) argued that "the main disadvantage of conducting the case studies after the survey is that they do not contribute to the model building exercise". However, many eminent mixed methods researchers, such as Tashakkori & Teddlie (1998) and Jick (1979), consider such sequence as a part of the continuous researching process. For example, Voss *et al.* (2002) explained that "*Case studies can be used as a follow-up survey research in an attempt to examine more deeply and validate empirical results*" under the title "theory extension/refinement" rather than "theory testing".

The following section introduces the details of the mixed methods design used throughout this study.

3.2.2 Mixing survey and case research

This subsection determines and justifies this study's adopted approach regarding the research question and the aims of this thesis.

The primary concern of this study is to investigate the ERP adoption phenomenon regarding the perspective of production strategy as a contingency factor. Here, the ERP adoption process refers to both the selection and effectiveness of the system. Therefore, this thesis is interested in showing whether the production strategy phenomenon is a significant contingency factor in the ERP adoption process or not.

To do so, two main points are aimed as suggested in the Literature Review Chapter: The first one is to explore the field as comprehensively as possible. There are a number of emerging studies on the contingent importance of production strategy in ERP adoption (e.g., Bendoly & Jacobs, 2004; Deep *et al.*, 2008), and separately academic research on ERP is growing. Besides, ERP vendors have targeted particular segments (e.g., SMEs) due to shrinkage in the global and large companies' market. Though this shows the popularity of this subject, yet, there is still a lack of literature on the issue of applicability. Especially, pros and cons of ERP adoption in the MTO sector have not been clearly understood yet. What proportion of the MTO/MTS sector has adopted ERP? Why do MTO non-adopters stay away from ERP? What were the motivations of MTO/MTS adopters to implement ERP? Which functions have the MTO/MTS adopters preferred the most (and the least)? Enabling a comparison between two production strategies is important for contributing to our understanding of the impact of production strategy on ERP adoption. To find answers to these questions, exploratory-based techniques are needed.

The other aim is to test the assessment of fit provided in the literature review. Briefly, theoretical and empirical content in the literature is used to evaluate the relevance of a complex information system (i.e., ERP) to a particular sector of industry (i.e., MTO/MTS). Thus, testing the theoretical assessment is important in order to validate (or modify) it through using a suitable method.

As a result, the aim is to explore the field in breadth and explain the distinction between the MTO and MTS production strategy in ERP adoption in depth. These require a large sample; firstly, to get an overview of the adoption phenomenon in the manufacturing sector; and, secondly to fit the scope of the assessment. Thus, at this initial stage conducting case research, action research or other similar strategies would not serve these aims.

To achieve the goals above, firstly, the MTO sector's distinction for ERP adoption needs to be shown. Thus, a comparative approach can help see the situation. In this case, non-MTO companies (i.e., MTS and ATO) have to be considered as well. That would extend the breadth of the study, but in return more meaningful and comparable results can be drawn. In fact, such an extension plan also coincides with this study's aims on exploration in breadth rather than in depth. Secondly, this theoretical assessment has not been conducted merely based on the idiosyncratic characteristics of a few MTO companies. But instead, the characteristics and requirements of the sector are considered in general. Therefore, a large number of companies in the research sample is desired to fit the scope of the assessment. Thus, at this initial stage, conducting a series of case studies, for instance, would not help answer this study's research questions. However, it can be very helpful at the follow-up stage to scrutinise the findings from exploratory and assessment parts.

All in all, the survey method is the most suitable for the first part of this study. It helps this research cover a wide range of respondents through a large sample size. Therefore, it is both cost and time effective to achieve the goals above. It is planned to be used for both exploratory and theory testing purposes. For the former, some descriptive statistics are sought, such as the usage and intensity of ERP functions in MTO adopters in comparison with MTS adopters. This could only be achieved through a survey study. For the latter, on the other hand, it is aimed to draw statistical inferences (inductive statistics) concerning the impact of ERP and its extensions on the performance of adopters and to compare them with respect to their production strategies. A sufficient sample size is important for sound statistical conclusions regarding our assessment. Yet another advantage can be the attractiveness of this topic to respondents. ERP is a popular theme which can always be in any executive's agenda as an investment opportunity. Therefore, companies might be interested in the findings and get in touch for further collaboration via a survey study.

Afterwards, a case research is conducted to follow the survey. Yin (2009) argues that a single-case study is more applicable to an under-researched subject, whereas multiple-case designs can be desirable when the intent of the research is descriptive, theory building, or theory testing. An example for the single case study is the study by Deep *et al.* (2008) on the ERP selection factors for MTO SMEs. On the other hand, studying multiple cases is preferred chiefly for theory building and secondly for further exploration. The number of case studies to be conducted and more discussion on the design of the case research are provided in the next section after the survey design.

3.3 Research Design

This section provides the research design in twofold as survey and case research. As a guideline; firstly, the 'ideal' attributes of a rigorous survey (Forza, 2009) are described and exemplified, then this study's response to all these attributes is summarised. The following chapter provide details on how the survey is conducted and how these points are addressed. Similarly, the follow-up case study design starts with broadly, and the details are provided in the Case Study chapter. Finally, the entire methodological path is outlined before this chapter ends.

3.3.1 Survey Design

Attributes of a Rigorous Survey

The twofold aim of this study's surveying choice has recently been explained: exploration and testing the assessment. Both are equally important. Thus, the instrumentation of each needs to be constructed on a scientific basis. It is aimed to design both parts to get comparable results with respect to the production strategies of sampled companies. Before providing the survey design, it shall be useful to identify some traits that a 'well-designed' survey should have. Later, in the next subsection, the exploratory part of the survey is introduced. Finally, the step-by-step stages of the explanatory part are provided.

The literature provides a collection of techniques from theory building to tips for improving response rates on survey research. While all are valuable, a list of attributes for a meticulous survey did not appeared in the OM field until the study by Malhotra & Grover (1998). The authors assessed the survey-based studies published in JOM, DS, MS and POM. A framework comprising 17 attributes of an 'ideal' survey was presented. While covering them all, Forza (2009) extends it to a longer checklist of 37 items. Both studies group similar attributes. Yet, the difference is that Malhotra & Grover (1998) classified them in terms of error types (sampling, measurement, etc.); while Forza (2009) groups the steps of conducting a survey. The latter provides a clearer and more organised guide with in-depth descriptions and its step-by-step procedure. Since Forza (2009) covers the items by Malhotra & Grover (1998), a summary of his stepwise collection of attributes is provided only.

The first step comprises of items "prior to the survey design" as *unit of analysis*, and checking for clearly stated *operational definitions* and *hypotheses*. The unit of analysis is the basic examined unit. It can be a system, organisation or an individual, where the respondent is usually the latter (Flynn *et al.*, 1990). A theoretical model is considered as essential (especially for explanatory) or convenient (for exploratory) in a survey study (Dubin, 1978; Wacker, 1998). Theoretical model is composed of concepts, also called constructs. Constructs are linked to each other according to the aims of research. If a link between two constructs is investigated, the constructs' role (e.g., independent, dependent) and the direction of their relationships are stated as a proposition. Operationalisation and hypothesising are the processes of transforming the theoretical model (constructs and propositions, respectively) into an empirical domain (observable elements) in order to make it measurable. Forza (2009) emphasises the importance of stating operational definitions and hypotheses clearly before the survey design.

The second step starts the survey design by "defining the sample". A *sample frame* is required to include every possible representative group of the targeted population. *Random sampling* is also vital, to enable the sample to represent the population of interest. Determining the minimum required *sample size* is another important subject in the sample definition. The sample size is linked to the significance level and statistical power of the test. High statistical power, which can be achieved through high sample size, increases the probability of making correct decisions. However, considering the issue of a low response rate, estimating a minimum sufficient sample size is more sensible than trying to get as many responses as possible. Verma & Goodale (1995) stressed the importance of a pilot study and recommend using its results to calculate the sample size required to get a reasonable power level in the full-scale study. *Reproducibility of the sampling procedure*, showing how scientific a study is, is possible only if the sampling process is clearly described.

The next step is the "questionnaire development". A questionnaire is comprised of questions, also called items, which can seek either *perceptual* or *objective* information from the respondent. In some cases, the researcher might necessarily need an objective answer while, in others, perceptual questions can be preferred due to some difficulties in getting objective answers or measuring objectively. Perceptual questions are not based on factual information but feelings; hence the answer may vary depending on the respondent. Thus, these items need special attention when included in a questionnaire. *Multi-item measurement* (using more than one question for a construct) can be a solution. This is done for higher reliability of results, such as smoothing fine distinctions between the respondents. While doing so, the set of items need to capture *all aspects of the concept in balance*. That is, there should not be any missing or extra items so in order to cover the concept entirely. Another technique is the *use of triangulation* as a cross validation of base data. For example, when the unit of analysis is the company itself, surveying multiple respondents in a company can be called triangulation (Malhotra & Grover, 1998). It allows the researcher both to check the answers to objective questions, and to average out the answers to perceptual questions.

Another important issue in the questionnaire design stage is to select a *proper type of scaling*, i.e., appropriate options in the answers. The scale choice depends on the ease with which both the respondent can answer and the subsequent analyses can be done. Yet another one is that survey items need to consistently address the chosen unit of analysis, and the respondents should be properly selected. For example, if a hierarchically low-level employee is selected when the unit of analysis is determined to be the entire company, this may lead to a risk of collecting inaccurate or incorrect data, called *ecological fallacy*. A final check of *wording*, visualising, and making the questionnaire easier-to-follow and more comprehensible are final retouches at this stage. If fortunate enough to have *readily-developed (and preferably validated) measures*, they can ease and accelerate the design process.

"Measure quality assessment" is the following step which mainly includes satisfying the issues of validity and reliability in the survey design. Validity refers to the extent to which we can accurately measure what we intend to measure. Reliability refers to the extent to which a measuring procedure yields the same results on repetition. To compare; while a lack of validity leads to systematic error (bias), a lack of reliability leads to random error (Carmines & Zeller, 1979). *Content validity* refers to the extent to which the measure spans the domain of the construct's theoretical definition (Hinkin, 1998). Content validity can be satisfied through an extensive literature review and it can be assessed through evaluations of a panel of subject-matter experts. Two possible ways are widely used. In one, the experts are asked to consider each item individually and evaluate its degree of representativeness to its corresponding construct. The items with the lowest fit are discarded or modified according to the comments. In the other case, the experts are provided with separate lists of constructs and items, and are asked to match them accordingly. The content validity is also called face validity when these evaluations are on a loose and informal basis (e.g. experts only check the questionnaire roughly, e.g. whether it "looks like" it is proper). Another validation can be conducted within the field to get similar opinions of practitioners. It is called *field-based pre-testing* of a questionnaire's performance to eliminate clarity and wording problems. *Pilot data,* which can also be used to improve reliability, is collected to eliminate unclear points by the help of a smaller sample of respondents before going to full-scale surveying. *Reliability* assessment shows the amount of measurement error in the results (as a random error). Therefore, evaluating the results of a questionnaire repetitively-answered by the same respondent would provide the data for an ideal assessment, while not realistic. So, more realistic but approximate techniques have been developed. Among them, Cronbach's alpha is a simple and popular technique (Cronbach, 1951). The technique assumes that a set of items (belonging to the same construct) should show a correlation since they measure responses to the same concept. Low correlations between items would indicate that their construct is unreliable. *Construct validity* basically refers to whether a measure is consistent within itself (convergent) and sufficiently distinct from other measures (discriminant). The one difference from content validity is that construct validity uses the scores to assess correlations among items. Finally, an eventual *confirmation* of existing measures before distribution of the questionnaire can be performed.

Yet another phase in surveying is related to "collecting data". An indication of the *response rate* gives an idea about the sample frame and the selection error. The higher the response rate is, the better and sounder the conclusions that are drawn. Full coverage in terms of the response rate is important but almost impossible. Thus, the researcher needs to show the indifference of non-respondents from respondents on key characteristics. Malhotra & Grover (1998) recommend to estimate *response bias* by sampling a group of non-respondents (or through secondary sources) and comparing them with respondents.

"Analysing data" is a requirement which can be done in twofold to observe and interpret the results of the survey. One is called the preliminary data analysis, which involves deducing descriptive statistics (e.g., frequency, central tendency) and visual summaries (e.g., histograms, boxplots) from the data. The other is to apply significance tests to hypotheses. There are various types of tests for different purposes (t-tests and ANOVA for comparison; canonical correlation and multiple regression for seeking correlation, etc.). Forza (2009) stressed the importance of selecting the most *appropriate methods to hypotheses*. Besides, there are certain *assumptions of every testing* technique (like normality assumption) which need to be satisfied for accurate results. Before analysing the effect of outliers, any other influencing factors need to be considered and modified if needed. Another error can occur when statistical power is not sufficient to draw conclusions. *Statistical conclusion error* mainly depends on the sample size which is the factor for establishing adequate power for a test.

The final stage is the "interpretation of the results". *Internal validity* is simply required in order not to be mistaken when drawing conclusions. Even if a dependent variable is found to 'cause' an independent variable, the researcher needs to be sure that it is actually not because of other dependent variables. It is advised to do it by informal discussions to show why alternate explanations cannot be likely (Malhotra & Grover, 1998). We draw conclusions through making *inferences* from the results using various test techniques. Every inference holds a probability of making statistical error. On testing hypotheses, it can happen because the researcher either rejects a null hypothesis although it is true (type I error) or accepts a null hypothesis although the alternative hypothesis is true (type II error). The probability of a type I error is α (generally taken as 0.05 and 0.01), and also called the significance level. The probability of a type II error is β, and statistical power (the prob. of accepting the true hypothesis) is equal to $1-\beta$. α and β values are oppositely related. When the researcher wants to secure the significance of results and thus selects a lower α value, then the power of the test is negatively influenced by that selection (requiring a larger sample size to be sure about that significance). Verma & Goodale (1995) stated that no agreement exists about a 'good' level of statistical power. While 0.50 is certainly too low, a power of 0.90 requires a very high sample size. A power of 0.80 and 4:1 ratio of β to α is considered as reasonable and realistic (Verma & Goodale, 1995; Forza, 2009). The final point which Forza (2009) argues for is validity of the results for other populations.

For a summary and exemplification, Table 3.3 shows all these attributes and their usages in the relevant literature. All evaluated studies have conducted cross-sectional surveys. Ticks (✔) marked under the author names show the formally described (or confirmed) corresponding attributes. Whereas, cross (✕) means a failure in fulfilling the corresponding attribute or a question mark (?) is used when any attempt to achieve an attribute is not reported.

Although the relevant literature is scarce, the studies on ERP provided in the table above show a spectrum of different approaches to conducting surveys. Despite the emergence of ERP implementations since the mid-1990s, academic research and survey studies in this area are relatively new (Mabert *et al.*, 2003). The use of surveys in ERP adoption research started with surveying 2,647 European midsize companies by Van Everdingen *et al.* (2000). While valuable as an exploratory study, it lacks a scientific approach regarding the approach to building, checking and purifying the instrument, and making inferences from the results. Other exploratory surveys were conducted by Mabert *et al.* (2000), Olhager & Selldin (2003) and Mabert *et al.* (2003). We can observe that some have addressed the needs for sampling and pilot studies and some have not; however, several attributes are not discussed in the papers,

Table 3.3. Malhotra & Grover (1998) and Forza's (2009) attributes of an 'ideal' survey applied to relevant literature

Ideal Survey Attributes		Relevant Survey-based Literature					
		Van Everdingen *et al.* (2000) Exploratory	Mabert et al. (2000) Exploratory	Stratman & Roth (2001) Explanatory	Mabert *et al.* (2003) Explanatory	Olhager & Selldin (2003) Exploratory	Buonanno *et al.* (2005) Explanatory
Prior to design	1. Unit of analysis clearly defined	✔	✔	✔	✔	✔	✔
	2. Operational definitions clearly stated	✕	✕	✔	✔	✕	✔
	3. Research hypotheses clearly stated	✕	✕	✔	✔	✕	✔
Defining the sample	4. Sample frame defined and justified	✔	✔	✔	✔	✔	✔
	5. Random sampling used from the sample frame	✔	✔	?	✔	?	✔
	6. Minimum required sample size estimated	?	?	?	?	?	?
	7. Reproducibility of the sampling discussed	✕	✕	✕	✕	✕	✕
Developing measurement instruments	8. Existing validated measures adapted	?	?	?	?	?	?
	9. Need for objective and perceptual questions discussed	✕	✕	✔	✕	✕	✕
	10. Appropriate wording checked	?	?	?	?	?	?
	11. Perceptual items' coverage of the concept discussed	✕	✕	✔	✕	✕	✕
	12. Instrumentation consistently reflects that unit of analysis	✔	✔	✔	✔	✔	✔
	13. Compatibility of the scales used for measuring discussed	✕	✕	✔	✕	✕	✕
	14. Respondent places answers easily and reliably checked	?	?	?	?	?	?
	15. Respondent(s) chosen appropriate	✔	✔	✔	✔	✔	✔
	16. Any form of triangulation used to cross validate results	?	?	✔	✔	?	?
	17. Multi-item variables used	?	✔	✔	✔	✔	?
	18. Handcrafting questionnaire for presentability discussed	✕	✕	✕	✕	✕	✕

		Van Everdingen *et al.* (2000) Exploratory	Mabert *et al.* (2000) Exploratory	Stratman & Roth (2001) Explanatory	Mabert *et al.* (2003) Exploratory	Olhager & Selldin (2003) Exploratory	Buonanno *et al.* (2005) Explanatory
Collecting data	19. Response rate over 20%	✔ (>75.0%)	× (9.6%)	× (13.0%)	× (9.6%)	✔ (37.2%)	× (18.5%)
	20. Non-response bias estimated	?	?	✔	?	?	?
	21. Inconsistent and uncertain data cleaned	?	?	✔	✔	✔	✔
	22. Effect of missing data on results discussed	×	×	×	×	×	×
	23. Necessity of any treatments of data discussed (pooling)	×	×	×	×	×	×
Assessing measure quality	24. Content validity assessed	?	?	✔	✔	?	✔
	25. Field-based pretesting of measures performed	?	?	✔	✔	?	?
	26. Reliability assessed	?	?	✔	?	?	✔
	27. Construct validity assessed	?	?	✔	?	?	?
	28. Pilot data used for purifying measures	?	✔	✔	?	?	✔
	29. Confirmatory methods used	?	?	✔	?	?	?
Analysing data	30. Appropriateness of tests for hypothesis testing discussed	×	×	×	×	×	✔
	31. Adequacy of tests for the available data discussed	×	×	×	×	×	✔
	32. Test assumptions satisfied	?	?	?	?	?	✔
	33. Effect of outliers and other factors discussed	×	×	×	×	×	×
	34. Sufficient statistical power to reduce statistical conclusion error (e.g., at least sample size of 100)	✔	✔	× (79)	✔	✔	✔
Interpre-tation	35. Internal validity of the findings established	?	?	✔	?	?	✔
	36. Acceptability of inferences discussed	×	×	✔	✔	×	✔
	37. Applicability of results to other populations discussed	×	×	×	×	×	×

Type of survey research: Exploratory (orange) *or* Explanatory (blue). (continued) especially for measurement and sampling errors. Stratman & Roth (2001) conducted a scientifically thorough survey-based study, but the sample size and the response rate were not enough to come up with statistically 'powerful' conclusions. The major contribution of the paper was the development of a set of ERP competence constructs, together with a rigorously validated measurement questionnaire to capture data on these constructs. The study by Buonanno *et al.* (2005) is another one close to being 'ideal'. Its drawback is the over-simplistically prepared single-item questionnaire, while the results were meticulously analysed and reported.

Malhotra & Grover (1998) also evaluated the use of the 17 attributes they identified in their own study for 25 survey-based OM studies. They showed, for example, that only 64% stressed the importance of theory-driven survey research and only 28% have used triangulation. None applied confirmatory methods for data analysis; and, formal assessments of reliability and construct validity were undertaken in 48% and 40% of these 25 survey-based studies, respectively. Meanwhile, the use of pilot data was found to be low (28%), and the field-based pretesting by real-world experts for item clarification was again not so prevalent (36%). The remaining attributes were used in over 60% of the 25 studies. However, necessity of each 'ideal' attribute for a rigourous study should be discussed. Rungtusanatham *et al.* (2003) re-investigated using the same framework as Malhotra and Grover (1998). They covered a broader time frame (1980-2000) and a wider literature content (285 papers from six core OM journals). However, the authors did not consider all attributes but only the unit of analysis, reliability, construct validity and triangulation. They found their usage increasing slightly, but not significantly.

It is therefore concluded that it is not always possible to achieve all of the characteristics of an 'ideal' study. However, it is important to consider all of the 'ideal' attributes and to implement them wherever possible. The limitations of a study can then be acknowledged if some issues are not fully addressed for practical reasons. The following table (Table 3.4) summarises our responses to all those attributes in this study. These responses are explained in detail as the process of conducting a rigorous survey comes step by step in the following chapters (Chapter 4, 5 and 6) of this thesis:

As summarised in the table, printed questionnaires were sent to executives in a single plant (the unit of analysis). The main reason is that the respondents, all of which are high-level managers (e.g., managing directors, operations and IT managers), would answer the questions of relevance to various departments in their companies. An option to fill the survey online was also provided. Follow-up reminders were made through emailing the respondents. 123 companies with a 10% adjusted response rate have responded the survey.

This study comprises both exploratory and explanatory items which are dominantly perceptual questions. Perceptual questions are much more preferable to the objective ones in order to avoid "no opinion" answers as much as possible. This led us to use multi-item variables to maintain consistency in the results by smoothing their variation. The exploratory part comprises the questions which are widely used in the literature for similar purposes (Mabert *et al.*, 2000; Stratman, 2001; Mabert *et al.*, 2003; Olhager & Selldin, 2003). On the other hand, to the best of our knowledge, the literature does not contain any validated measures particular to our problem in the explanatory part. So, the explanatory items were prepared and validated to fill this gap which could possibly be useful to some studies on the applicability of ERP to other sectors in the future.

Table 3.4. Summary of the "Attributes of a rigorous survey" and our responses to each

	'IDEAL' SURVEY ATTRIBUTES	RESPONSES
Prior to design	1. Unit of analysis (UoA) clearly defined	The entire company is our unit of analysis. Specifically, it is the plant from which the respondent is responsible.
	2. Operational definitions clearly stated	The constructs (MTO decision support requirements, intensity of use of ERP, and improved MTO performance) and dimensions were structured upon a theoretical assessment made in the literature review chapter. The variables were all defined and operationalised utilising the relevant literature content.
	3. Research hypotheses clearly stated	The relationships between the constructs were hypothesised in order to be tested via the instrument in the explanatory part.
Defining the sample	*4.* Sample frame defined and justified	Sample is composed of all manufacturers (i.e., MTOs and non-MTOs) who have or have not adopted ERP (and its extensions, if present) to enable comparison with each other. No particular industry, but the entire manufacturing sector (except food) targeted.
	5. Random sampling used from the sample frame	Within the restrictions of the company database quality, a stratified random sampling was performed regarding the industry, company size and respondent profile. However, it has not been possible to achieve this regarding the ERP adoption or company type information due to the loss of such information in the available commercial databases.
	6. Minimum required sample size estimated	Exploratory bivariate and univariate analyses required at least a total sample size around 52 cases for a sufficient statistical power (i.e., larger than 0.8) at a large effect size (0.8) and 0.05 alpha level. On the other hand, the structural model needs at least the eight times of the number of latent variables as a rule of thumb. Besides, calculations have shown that considering the degrees of freedom and model fit at least 200 cases are considered as appropriate. However, the model is simplified and reduced from second to first-order to get acceptable and interpretable results.
	7. Reproducibility of the sampling discussed	Current sampling procedure can easily be reproduced by other researchers for any meta-analysis or testing provided analysis results. It can be improved by being able to control stratifying the ERP adoption and company type.
Developing measurement instruments	8. Existing validated measures adapted	While exploratory part of the questionnaire has been composed of items frequently used in the OM literature; to our knowledge, no validated items, used in the explanatory part particular, to our research exist.
	9. Need for objective and perceptual questions discussed	All concepts have been perceptually measured, since the access to objective measures has been extremely limited due to business customs and confidentiality. To reduce subjectivity, multi-item measurement applied where appropriate.
	10. Wording appropriate	Wording has been checked several times by the researchers and colleagues (totally five people), and asked experts to leave comments during content validity stage. No particular complaint on the wording received after the pilot and full-send out.
	11. Perceptual items' coverage of the concept discussed	Coverage of the perceptual items on corresponding concepts are discussed and referred on theoretical framework building and operationalisation.
	12. Instrumentation consistently reflects UoA	The instrument items are prepared to be answered by high level managers to reflect the unit of analysis.

Developing measurement instruments	13. Compatibility of the scales used for measuring discussed	Exploratory part consists of open-ended, ranking type, multiple-choice and Likert scales; and the explanatory part included only Likert scales. These scales were chosen to enable the measurability of the intended concepts.
	14. Respondents can place answers easily and reliably in the scale	No particular complaint on the ease or respondent-friendliness of the questionnaire has been received in the pilot or full-scale application stages of the survey instrument.
	15. Respondent(s) chosen appropriate	Choosing high level managers (e.g. IT and operations managers), who are thought to be the most knowledgeable in their organisations, would increase getting meaningful information and decrease random or even bias error.
	16. Any triangulation for cross-validation	Case studies (plant visits and interviews) are planned to cross-validate the results.
	17. Multi-item variables used	Multi-item variables were created in the questionnaire where appropriate due to the use of perceptual questions.
	18. Handcrafting questionnaire for presentability discussed	A colour print, watermarked questionnaire consisting of descriptions, figures, well arranged and sectioned questions with comment boxes of adequate size has been sent out.
Collecting data	19. Satisfactory response rate	Data collection has resulted an adjusted response rate around 10%. However, techniques to improve response rates and current followed approach have been well-discussed and followed, possible reasons for low rate discussed.
	20. Non-response bias estimated	Non-response bias has not been directly estimated since non-respondents and their characteristics could not be obtained. Instead, the characteristics of the respondents in the first wave results have been compared with the subsequent wave results. No significant difference has been observed.
	21. Inconsistent and uncertain data cleaned	Cases having missing/uncertain responses and showing inconsistency were cleaned and marked accordingly for not including the analysis on creating the codebook in the statistics software, where appropriate.
	22. Effect of missing data on results discussed	A small amount of data in a few cases (less than %3) was missing. Majority of missing data was noticed in explanatory part. Since there observed a random pattern of missing data distribution, inconsistent and uncertain data was already cleaned, and the SEM software was employed for missing data estimation; the effect is not thought to be significant.
	23. Necessity of any treatments of data discussed	Missing data has been coded as "missing" on SPSS to be accordingly excluded from the bivariate and univariate analyses. On the other hand, the missing data was estimated using AMOS's estimation tools where appropriate. No further treatments (such as aggregation or transformation) have been applied.
Assessing measure quality	24. Content (or face) validity assessed	Content validity is assessed by consulting academics and practitioners using the manual sort method in three rounds which gradually resulted a high enough content validity estimate.
	25. Field-based pretesting of measures	A pilot study is conducted in advance to a full-scale sent-out to improve the measurement capability and wording.
	26. Reliability assessed	Reliability is estimated by measures of Cronbach's alpha, WLJ and AVE; all showing the instrument's adequacy.
	27. Construct validity assessed	Discriminant, convergent and criterion-related validities are assessed and well discussed.

Assessing measure q.	28. Pilot data used for purifying measures or Existing validated measures adapted	The instrument included both types of measures. The pilot results have been used to purify and adopt them before full-scale send-out.
	29. Confirmatory methods used	SEM technique has been applied in the explanatory part of the study, Besides, another confirmatory method CFA is applied to help assess the reliability and construct validity
Analysing data	***30.*** Appropriate of tests for hypothesis testing discussed	The suitability of univariate tests (for descriptive indications), bivariate tests (for group-wise comparison) and multivariate tests (for confirmatory analysis) were found adequate and discussed in detail at the end of each relevant section in the Analysis Chapter (i.e., Section 1.1.2, Section 1.2.2, and Section 2.11, respectively).
	31. Adequacy of tests for the available data discussed	An advantage of SEM is that model fit and other measures for simultaneously testing adequacy besides hypothesis testing. The exploratory analyses were also adequate for simpler tests such as t-test or one-way ANOVA.
	32. Test assumptions satisfied	Non-parametric tests have been applied when parametric tests' assumptions are violated (e.g., normality).
	33. Effect of outliers and influencing factors discussed	Since all the options were restricted in multiple choice questions with 5 or fewer predetermined options or 7-point Likert scales, there have not been observed extreme outliers to be treated. Instead, the existing outliers were well-suited in normal distributions of the data.
	34. Sufficient statistical power to reduce statistical conclusion error (e.g., at least sample size of 100)	Exploratory bivariate and univariate analyses have shown sufficient statistical power (larger than 0.8) at a large effect size (0.8) and 0.05 alpha level. On the other hand, due to lowered sample size and comparatively complex formation of the structural model sufficient statistical power could not be attained. However, the model is simplified and reduced from second to first-order to get acceptable and interpretable results.
Interpretation	*35.* Internal validity of the findings	The causal links amongst the constructs have been discussed and significant ones interpreted for internal validity. Both significant and nonsignificant relationships were identified, and reasons were discussed. Alternatively, follow-up interviews planned for further studies are going to be used for assessing the internal validity.
	36. Acceptability of inferences discussed	While acceptability of inferences is high in the exploratory findings through univariate and bivariate analyses, SEM of particular stages may need further evidence (i.e., larger sample size) for more confident generalisability to intended population.
	37. Applicability of results to other populations discussed	This study majorly commenced to investigate the MTO firms, then extended to the manufacturing sector to enable comparison with non-MTOs. Therefore, it would not be sensible to interpret the results regarding, for example, service sector since, first of all, the items are targeted to reflect the manufacturing sector. However, the (DSR-USE-PERF) theoretical framework can be applicable to different realities where use of a system/mechanism is judged for improved performance associated with its need from the user.

Content validity assessment and a pilot study are conducted to have the items of the explanatory part externally examined for clarification, especially since there is no existing similar study for reusing its items or benchmarking. Reliability and construct validity are also assessed to show the data adequacy for the actual analysis. On the other hand, such assessments are not necessary in the exploratory part, as they are measures which have already been validated and used several times in the literature (Mabert *et al.*, 2000; Stratman, 2001; Mabert *et al.*, 2003; Olhager & Selldin, 2003); and also having explorative nature.

On analysing the data, the suitability of univariate tests (for descriptive indications) and bivariate tests (for group-wise comparison) for the exploratory part and multivariate tests (for confirmatory analysis) for the explanatory part were found adequate. The statistical power of the analyses was calculated; thus, the data was transformed to get acceptable and interpretable results, where possible. Finally, internal validity of the findings, acceptability of inferences and applicability of results to other populations were discussed to enable a better follow-up case study investigation.

The following two subsections introduce the survey design in twofold: exploratory and explanatory (theory testing).

Exploration

As discussed before, the MTO sector is in need of special attention in terms of the ERP adoption. Exploring this applicability would only be meaningful with comparable results. In this study, the comparisons are based on two major groups: company type (MTO vs MTS) and their ERP adoption statuses (adopter vs nonadopter).

While taking a contingency-based approach and being interested in both ends of the production strategy, we are particularly interested in MTO companies which have adopted or are currently adopting ERP. Additionally, we aim to explore both MTS adopters and MTO non-adopters for a comparative study. Thus, a stratified sampling approach is more suitable than an unstructured one to include all those types. The reason for aiming to cover such a spectrum is that a comparison on the MTS side is needed to show the distinctive situation of the MTO sector in the ERP adoption. The differences between the adopters and non-adopters can show whether there is enough evidence for MTOs to adopt ERP. It is expected that the functionalities adopted by MTO and MTS companies would be different, since their importance to MTS and MTO is different (e.g., the applicability of a customer enquiry tool and MRP).

The survey instrument (questionnaire) is prepared to enable comparisons (see Appendix A). The relevant questions are generic and answerable by all types of adopters and non-adopters. Nineteen questions in Section 1 are aimed at collecting company background information. They ask for information like company size, type of production process, supply chain position and ERP adoption status.

Items in Section 2 aim to collect the decision support requirements of respondents. These perceptual Likert-scale questions are directed to adopters and non-adopters as well as MTO and MTS companies. Depending on the company's ERP adoption level, the questionnaire continues or ends at the end of Section 2. The following sections are for adopters only. Section 3 intends to measure the intensity of use of ERP tools and Section 4 aims to measure the performance after using these tools.

Results for the exploratory part mainly involve descriptive statistics to provide summaries on our sample and the measures. The presentation of the results would also be supported by graphical and tabular visuals (e.g., bar and pie charts, tables, etc). On the other hand, the results of the explanatory part are firstly tested for reliability and validity through principal factor analysis and structural equation modelling, which are further explained and discussed in the following subsection.

Testing the Assessment

Here a step-by-step development of the explanatory part is provided. It starts by building a theoretical model in the first place. The model is for depicting the concepts which we are interested in, and the relationships that we aim to investigate. Then, the operationalisation of these concepts takes place. Briefly, it is the process of transferring the theoretical concepts into empirical measures to enable testing the relationships of interest in the empirical domain. Thirdly, the operationalised measures and relevant relationships are combined in the form of testable statements, called hypotheses. Finally, a questionnaire as the survey instrument is built upon all to facilitate data collection, analyses and interpretations for the research question.

The next chapter explains and illustrates the theoretical part and goes on the discussion of the operationalisation part and onwards of the survey study in full detail.

3.3.2 Case Study Design

To complement the surveying effort, a case research is used to scrutinise the results of the survey analysis and understand any inconclusive points. The nature of this follow-up empirical inquiry is exploratory and partially seeks validation of survey results. Like survey research, this part also involves multiple processes, such as defining the case research objective, case selection, interview protocol design, data analysis and interpretation. Chapter 7 starts with case research objectives and provides the details on all these points above.

3.4 Research Outline: A Three Stage Approach

This section summarises the research design by providing an overview of the methodological approach taken in this study. Basically, the research is conducted in three phases: (1) development of the fit framework and survey instrument, (2) statistical testing of several models developed within the framework using survey data, and (3) exploratory follow-up case studies to bring additional insight into the issues surrounding ERP system applicability considering the effect of production strategy.

Stemming from Churchill's (1979) framework on surveying, which was improved by Menor & Roth (2007), this study adapts and combines it with our case research process as shown in Figure 3.1.

The thesis continues with Chapter 4 by applying the aforementioned methodological process to answer the research questions of this thesis.

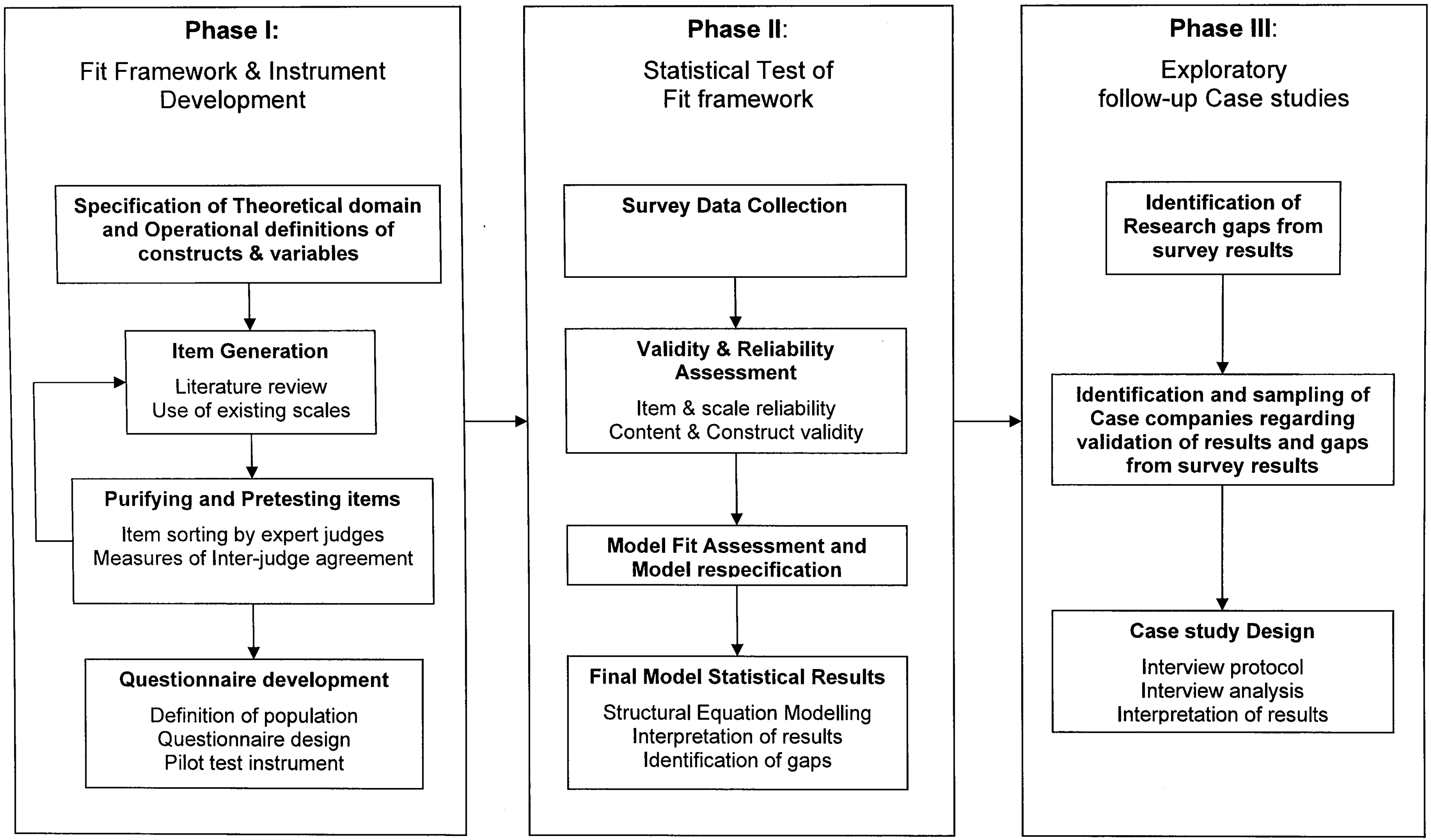


Figure 3.1. Overview of Research Approach

Chapter 4: Survey Design: Testing the Applicability

4.1 Introduction

In this chapter, a step-by-step development process of the explanatory part of the survey is provided. To lay the background for analysis and interpretation in the next chapter, the following steps will be covered:

(1) It starts by building a *theoretical framework*. The aim of the framework is to examine the constructs and their relationships with regard to the research questions of this thesis.

(2) Then, *operationalisation* of these concepts takes place. Briefly, it is the process of transferring the theoretical concepts into empirical measures to enable testing of the relationships of interest in the empirical domain.

(3) Thirdly, the operationalised measures (items) and relevant relationships are combined in the form of testable statements, called *hypotheses*.

(4) Fourthly, items are tested for *content validity* through asking ten academics and practitioners to apply the manual sort technique in three rounds.

(5) A *questionnaire* as the survey instrument is built upon all to facilitate the data collection, their analyses and interpretations for the research questions.

(6) The instrument is *pilot*ed to further improve the scale.

(7) Then, the *data* is collected and several techniques are applied to improve *response rate*.

(8) Finally, measurement quality of the collected data is assessed for reliability and validity (i.e., unidimensionality, convergent, discriminant and criterion-related validity) before the results are presented in the next chapter.

4.2 Theoretical Framework

A theory forms the background of an empirical study when a deductive approach is employed, as is the case in this study. Forza (2009) considers theoretical frameworks not as a requirement, but a helpful means to facilitate communication often depicted through a schematic diagram. The theoretical framework developed in this study has been based on the applicability assessment carried out in the literature review. The fit form of "*selection*", where fit is sought between context and response without reference to a criterion (performance) variable, is amended to the "*mediation*" (or "*interaction*") form of fit, where the response variable becomes a significant intervening mechanism between the antecedent (context) and the consequent (performance) variable. Thus, the intensity of use of ERP modules is treated as a mediator in a system of relationships between the decision support requirements and performance. In other words, the framework links together:

(i) The decision support requirements of companies (context);

(ii) The functionality provided by ERP systems (response);

(iii) Company performance (performance).

The decision support requirements relate to the needs of companies at the various planning stages (e.g. job entry); the functionality of ERP systems relates to the various modules of ERP (e.g. CEM, and CRM); company performance explores the impact of using the system (e.g. on time delivery and strike rate).

The theoretical framework which links these together is shown in Figure 4.1:

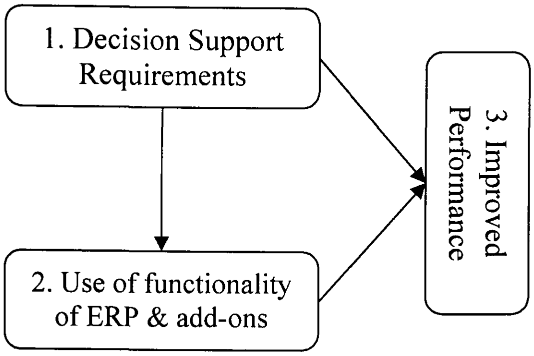


Figure 4.1. Theoretical framework

The construct on the upper side contains the dimensions of MTO company characteristics and requirements. It is basically presented in twofold: planning stages specific to MTO production and some important elements in the MTO sector. This construct is built through use of the recognised MTO-oriented literature spread over the last twenty years or more (e.g., Tobin *et al.*, 1988; Hendry & Kingsman, 1989; Bertrand & Muntslag, 1993; Amaro *et al.*, 1999; Stevenson *et al.*, 2005; Wikner & Rudberg, 2005; Olhager, 2007; Hendry *et al.*, 2008). Its dimensions were defined and explained in-depth in the previous chapter. All these dimensions imply not only the particular requirements of MTO companies at certain stages, but also the conditions in which they survive (e.g., customised product market & upstream supply chain tasks).

The construct on the lower side comprises the basic components and extensions of a typical ERP system. Basic elements are generally provided within the ERP systems by vendors without additional cost. Extensions are the add-ons provided either by the main ERP vendor or third party vendors to extend the capabilities of the system. All these elements are built primarily using the established literature on ERP (e.g., for ERP: Davenport, 1998; Klaus *et al.*, 2000; Rao, 2000; and for extensions: Fleischmann *et al.*, 2002; Akkermans *et al.*, 2003; Al-Mashari, 2003; Møller, 2005; Stadtler, 2005; Jacobs & Weston, 2007). Besides, some vendor-sided information (such as product launch advertorials) is also considered, e.g., SAP (Business One and mySAP) and Oracle (JD Edwards Enterprise One) among global vendors; Exel (EFACS E/8) among local vendors.

The purpose of this theoretical model is to generate predictions about the empirical domain. Propositions are concerned with these predictions, which are converted into hypotheses in the following subsections. Before that, these theoretical dimensions are transformed into observable and measurable elements through a process called *operationalisation* in the following section.

4.3 Operationalisation of the Concepts

This section operationalises the theoretical framework presented above for all the seven stages provided in the literature review. But first, it is important to be clear on the definition of "constructs", "variables" and "items" and the hierarchical relationship between the three terms. A *construct* is a theoretical concept which a researcher wishes to measure so that the relationships between different constructs can be investigated. A construct must be clearly specified. Once specified, constructs can be translated into measurable variables – this process is called the 'operationalisation' of constructs. Thus, a *variable* is an operationalised construct. A variable should span the definition of its construct without going beyond it. If a single variable is not sufficient to span the definition, a construct can be represented by more than one variable (i.e., multi-variate).

Each question within a survey instrument that is used to measure a variable is called an *item*. Items are designed to acquire either an objective answer (e.g., based on reporting factual information) or a perceptual one (e.g., relating to a respondent's feelings towards a subject). Where a survey is interested in factual information, single-item measurement is possible; but if the survey is largely perceptive, the multi-item measurement of a variable is important. Multi-item measurement can be used to cross-check responses, smooth the effect of response inconsistencies, and add confidence to the measurement of variables. Where multi-item measurement is used, items need to be consistent with each other since they collectively represent the same variable.

The following subsections concern the item generation process using these terms and present a series of theoretical propositions and hypotheses. Observable measures are developed for each of the three main constructs of the framework:

- Each construct is multi-dimensional. For example in Figure 4.1, Construct 1 includes the decision support requirements at the customer enquiry stage, the design & engineering stage, and so on; Construct 2 includes the functionality of ERP systems for managing customer enquiries, for product configuration, etc; and, Construct 3 includes measuring performance in terms of order winning performance, conformance to product specifications, and so on.
- Each dimension consists of at least one variable; for example: the decision support requirements of MTO companies at the customer enquiry stage consists of due date setting support, pricing support, process coordination and process automation.
- Each variable consists of multiple items, given that all the items in the explanatory part of the survey are perceptual measures. Respondents are asked to indicate their level of agreement for each item using a 7-point Likert scale. A 7-point Likert scale is preferred because 'even-point' scales, e.g., with 4 or 6 points, do not provide sufficient scope for respondents to have neutral or indifferent feelings towards an item while a 7-point scale reduces bias against extreme responses more than 3 or 5-point Likert scales (Dillman, 2007). Depending on the type of

question, the scale ranges, for example, from “strongly disagree” to “strongly agree” or from “not at all” to “to a great extent”.

Discussion is structured around the PPC stages in MTO companies, beginning with requirements at the CEM stage, and identifies the variables and items contained within each of the three constructs at each stage. The three constructs in context and the corresponding variables are summarised in Table 4.1. It is important to note that this table shall be slightly changed (some variables removed) after the suggestions from subject-matter experts during the content validity assessment (4.4).

The following subsections describe the operationalisation process of each dimension and provide the hypotheses for each derived from the propositions (relationships) between the constructs.

4.3.1 Customer Enquiry Management

The CEM stage involves quoting a competitive price, reliable and realistic due date, and therefore has a critical impact on company performance (Kingsman *et al.*, 1996; Hicks *et al.*, 2001). The theoretical framework for evaluating the effectiveness of ERP systems, and APS add-on functionality, for managing customer enquiries in a MTO context is illustrated below (Figure 4.2).

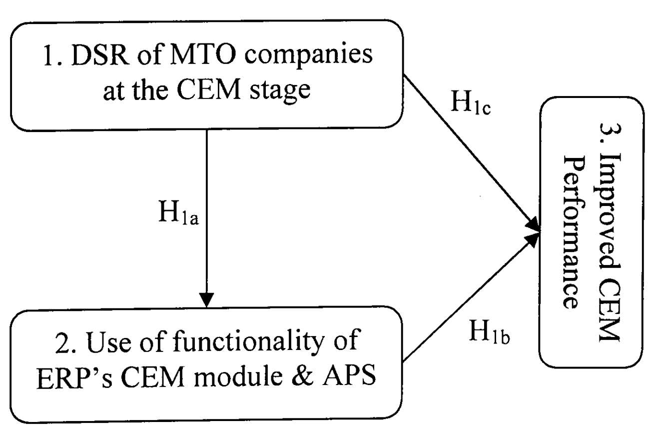


Figure 4.2. The framework for Customer Enquiry Management

Table 4.1. Scale Development: Constructs, Dimensions and Variables

Dimensions	The Three Constructs in Context		Variables
1. Customer enquiry stage	1.1	Decision support requirements (DSR) of MTO companies at the customer enquiry stage	Due Date Setting Pricing Decisions Internal Coordination External Coordination Automation at CEM Stage [*removed*]
	1.2	Customer enquiry management functionality via ERP and APS	ERP CEM module Available/Capable-to-Promise Product Lifecycle Management
	1.3	Improved performance at the CEM stage in MTO companies	Productive Aspects (e.g., on time delivery) Economic Aspects (e.g., cost reduction)
2. Design and engineering	2.1	DSR of MTO Companies at the Design and Engineering Stage	Documentation Archive Integrative Solution [*removed*] Internal Coordination External Coordination Flexibility In Design
	2.2	Product Customisation Functionality via ERP	Productive Aspects Product Lifecycle Management
	2.3	Improved Product Customisation Performance	Satisfaction with the Product customisation Technical Productivity
3. Order entry	3.1	DSR at the Order Entry Stage	Confirmed Order Re-evaluation Aggregate Planning Operational Planning Project Management
	3.2	MRP & APS Functionality via ERP	Material Requirements Planning Advanced Planning and Scheduling
	3.3	Improved Planning Performance at the Order Entry Stage	Due Date Adherence via Effective Planning Resource Utilisation [*removed*] Coping with Uncertainty [*removed*]
4. Order review and release	4.1	DSR at the Order Review and Release (ORR) Stage	Need for an Order Release Stage IT Support at the Order Release Stage Interaction with Other Stages
	4.2	Planning at the ORR stage via ERP	ORR support of ERP Advanced Planning and Scheduling
	4.3	Improved Control Performance in MTO Companies	Due Date Adherence via Order Release Control of Orders on the Shop Floor
5. Dispatching	5.1	DSR on the Shop Floor	Rule Simplicity Interaction with Other Stages
	5.2	Scheduling Functionality via ERP and APS	SF Scheduling support of ERP Advanced Planning and Scheduling
	5.3	Improved Dispatching Performance	Due Date Adherence via Dispatching
6. Customer relationship management	6.1	DSR for Developing Customer Relations	Customer Database Marketing through Communicat'n [*removed*] Need for Improved Relationships
	6.2	CRM Add-ons to ERP	Customer Relationship Management
	6.3	Improved Customer Relationship Performance of MTO Companies	Satisfaction of Existing Customers New Customer and Market Exploration Profitability (e.g., Return on investment)
7. Supply chain management	7.1	DSR for Supply Chain Management	Supply Chain Coordination (with Buyers) Procurement (from Suppliers) Coping with Rush Orders [*removed*] Compatibility
	7.2	SCM Add-ons to ERP	Supply Chain Management
	7.3	Improved SCM of MTO Companies	Improved Order Management Uncertainty Management [*removed*] Profitability

Construct 1 relates to the decision support requirements of MTO companies at the customer enquiry stage. This includes the primary need for support to compete in the market and to promise profitable prices and realistic due dates. These needs lead to several requirements, such as tools for: accurate lead time estimation, capacity and availability checks, organising archival data on previous tenders, coordinating internal and external processes and the automation of certain CEM processes.

Construct 2 relates to the functionality of ERP systems (and their add-ons or extensions, such as APS) which it has been claimed can support decisions at this stage. For example, Knolmayer *et al.* (2002) and Xiong *et al.* (2006) explain that SAP R/3 is said to contain a CEM-like component within its order management module which is also reportedly used for automating order entry, processing customer orders and tracking the status of orders. APS, an important planning extension to ERP systems, also claims to offer enquiry management tools such as Available-To-Promise (ATP), Advanced ATP and Capable-To-Promise (CTP). Note that APS systems have been developed to address a variety of planning needs at a strategic, tactical and operational level. In this subsection, only CEM-related functionality is considered; other functionalities of APS will be discussed when relevant to the particular stage in question.

Construct 3 relates to the effect of ERP and APS systems on the performance of the customer enquiry stage. This includes productive aspects such as delivery performance and economic aspects such as the strike rate. Table 4.2 summarises the content of all three constructs. This is provided with reference to a limited number of studies, selected as being the most relevant and representative of all the key variables. The leftmost column shows the construct names (i.e., decision support requirements, ERP functionality and improved performance measures), to its right corresponding variables are labelled. In the middle column of the table, elements of each variable are captioned and defined. Some variables contain definitions of more than one element, while some have only one. When it is the latter case, the name of the variable is same with its element which is denoted by an asterisk. Similarly, in the following subsections, further tables are provided for each dimension, such as design and engineering, order entry, etc.

For CEM, the research seeks to determine the extent to which the functionality of ERP systems can satisfy the CEM decision support requirements of MTO companies; and, the effect of ERP on company performance at the customer enquiry stage. Based on the literature review, it is expected that ERP systems will be able to provide automation and coordination at the customer enquiry stage but insufficient support for pricing and due date setting, which significantly affect company performance. This leads to the proposition (P_1), as outlined below; the hypotheses that follow here are the relationships anticipated between the three constructs repeated for each considered ERP functionality at this stage; namely, CEM module, ATP, CTP and PLM.

P_1. The CEM tools of ERP and PLM systems provide coordination and automation, improving integration and responsiveness at the customer enquiry stage, but they do not provide sufficient support for the due date and pricing decisions of MTO companies.

ERP's CEM functionality	H_{1a}: The level of decision support requirements has a positive impact on the intensity of use of ERP's CEM functionality.
	H_{1b}: The intensity of use of ERP's CEM functionality has a positive impact on performance at the CEM stage.
	H_{1c}: The level of decision support requirements has a positive impact on performance at the CEM stage.
ERP's ATP functionality	H_{1d}: The level of decision support requirements has a positive impact on the intensity of use of ERP's ATP functionality.
	H_{1e}: The intensity of use of ERP's ATP functionality has a positive impact on performance at the CEM stage.
	H_{1f}: The level of decision support requirements has a positive impact on performance at the CEM stage.

ERP's CTP functionality	H_{1g}: The level of decision support requirements has a positive impact on the intensity of use of ERP's CTP functionality.
	H_{1h}: The intensity of use of ERP's CTP functionality has a positive impact on performance at the CEM stage.
	H_{1i}: The level of decision support requirements has a positive impact on performance at the CEM stage.
PLM add-on	H_{1j}: The level of decision support requirements has a positive impact on the intensity of use of ERP's PLM functionality.
	H_{1k}: The intensity of use of ERP's PLM functionality has a positive impact on performance at the CEM stage.
	H_{1l}: The level of decision support requirements has a positive impact on performance at the CEM stage.

4.3.2 Design and Engineering

When manufacturing bespoke or highly customised products, design and engineering activities can potentially take place at any point in the production cycle of an order, from the customer enquiry stage (e.g., when estimating lead times, labour and machine costs) to last minute changes on the shop floor. Moreover, whether a company is designing, engineering and manufacturing a one-off product or making a repeat product on a MTO basis, product customisation plays a key role. Thus, product customisation - a key competitive advantage in the MTO sector - is handled through design and engineering processes which may require specialist software, such as product configurator and Product Life Cycle Management (PLM) software tools, to manage some or all of the activities. The corresponding theoretical framework for testing the effectiveness of ERP systems, including product configurator software and add-ons such as PLM software, for supporting design and engineering in a MTO context is illustrated below (Figure 4.3):

Table 4.2. Customer Enquiry Management stage

				Cheng & Gupta, 1989	Hendry, 1992	Hendry & Kingsman, 1993	Kingsman et al., 1996	Easton & Moodie, 1999	Cakravastia & Nakamura, 2002	Knolmayer et al., 2002	Xiong et al., 2006	Zorzini et al., 2008
Decision Support Requirements	Due Date setting		*Lead time estimation.* Total work content calculation of the quoted orders (required number of hours, operations, waiting times between consecutive operations, etc.) is essential and computerisation of the estimation process can bring responsiveness.	✔	✔	✔		✔	✔			✔
			Workload information. Measurement of the company workload, which is defined as the time required to process all of the orders currently in the company order book.	✔	✔	✔	✔	✔	✔			✔
			Product data archive. A product information database that includes all the detailed information (especially the price and due date quoted, any extra cost accrued, timely delivered) of previously fulfilled products.				✔		✔	✔		✔
			Multi-dimensional capacity check. Ability to check the available skills and facilities to produce any demand before deciding to bid.							✔		
			Simulation. Ability to evaluate multiple orders at a time through what-if analyses; through determining alternative due dates for a set of potential orders, estimating their costs, and determining a profit margin considering customer relationships and market conditions.				✔			✔	✔	
	Pricing		*Pricing/Cost:* Ability to check the feasibility of being able to produce the order with the current workload at different delivery times and evaluate any extra costs above the standard allowances.				✔	✔	✔	✔		✔
			Pricing/Profit: Need for determining the profit margin depending upon various factors: complexity of cost estimation and configuration, chance of winning the order, customer relationships, the company's recent needs for more profitability, etc.				✔		✔	✔		✔
	Coordination	Int.	*Communication: intra-firm.* Need for a level of coordination via meetings or a platform depending upon the size of the orders (e.g., large projects, or small and similar jobs).				✔			✔		✔
		External	*Supplier monitoring.* Up-to-date information on the availability of suppliers and/or subcontractors, when needed.							✔	✔	✔
			Communication: inter-firm. Rapid coordination with suppliers and/or subcontractors for purchasing negotiations during managing the enquiries or after the orders are confirmed.								✔	
	*		*Automation.* Ability to computerise product information entry for responsiveness.							✔	✔	
Potential ERP Functionality	ERP's CEM module		*Order entering:* ERP can automate data entry, process customer ordering, and keep track of order status.							✔	✔	
			Coordination: Integrative feature of ERP is also a background for intra-firm and inter-firm coordination.							✔	✔	
			Archive. Integrated database of historical data for designs, lead times, costs, customer records, and supplier and subcontractor records.					✔		✔		
	*		*Available/Capable-to-Promise.* Availability and capacity checks for order promising through ERP and APS.							✔	✔	
	PLM		*Price Estimation:* Some PLM add-ons provide price estimation tools through evaluation of material and capacity cost.							✔		
Performance Indicators	Productive aspects		*On time delivery* performance (to avoid earliness and lateness to minimise inventory and reputation effects, respectively).				✔	✔	✔	✔		✔
			Customer enquiry responsiveness (shorter time to process a quotation).				✔			✔		✔
			More organised product data, customer and supplier records which help to better manage customer enquiries.							✔		✔
			Improved internal coordination and information sharing among the company departments (especially marketing, production planning, purchasing).							✔		✔
	Economic aspects		*Improved forecasts* in estimating costs and profit margins.				✔	✔	✔	✔		✔
			Proportion of the quotations that become firm orders (*strike rate*).		✔	✔	✔	✔				✔
			Cost reduction and *delivery time improvement* in *procured materials* (e.g., through better coordination and wider range of acquired suppliers).				✔					✔

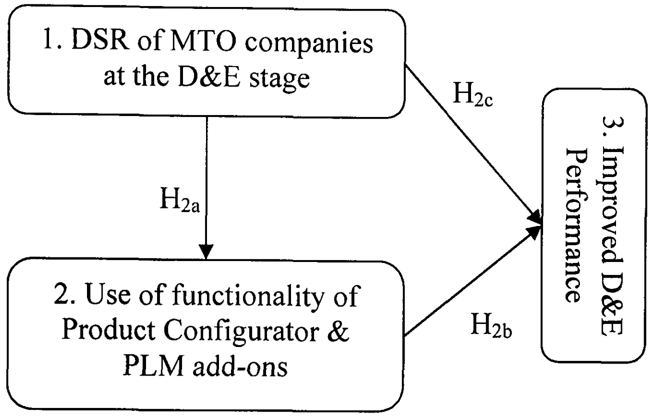


Figure 4.3. The framework for design and engineering

Construct 1 represents the decision support requirements for design and engineering in a MTO context. From the literature (e.g., Forza & Salvador, 2002a; Zorzini *et al.*, 2008; Hendry, 2010), it follows that some requirements are particularly important. These include internal coordination between personnel in different departments (especially between manufacturing and sales), tools to integrate information and systems across business functions, the availability of historical information and documentation on similar past orders, and external coordination with customers and suppliers.

Construct 2 corresponds to the functionality of ERP systems and their extensions which claim to address these needs. The two aforementioned modules included in ERP systems (or added-on) are Product Configurator (also known as variant generator) and PLM. Product configurator software translates customer needs into product information using predetermined product class and configuration rules (Forza & Salvador, 2002b; Knolmayer *et al.*, 2002; Hvam *et al.*, 2006). PLM is known for enabling companies to bring innovative and profitable products to market more effectively (Møller, 2005). It incorporates Product Data Management (PDM) systems which had earlier emerged and were aimed at collecting and organising product information through the integration of different databases, providing various interfaces and supporting different hardware platforms (Knolmayer *et al.*, 2002).

Construct 3 relates to the impact of ERP on the performance of the D&E processes. The key performance measure here is customer satisfaction, including an assessment of whether the product conforms to the customer's specifications or expectations. In terms of the back-office performance, technical productivity is also considered. Table 4.3 summarises the content of the three constructs.

The adoption of an ERP system contains a paradoxical risk, especially for design and engineering activities when products are highly customised. Implementation usually involves tailoring the software to meet the needs of the company, or changing the business processes of the company to align them with the business processes supported by the software, or both. Most SMEs, however, cannot afford to tailor the software; so when there is a poor fit between the system and the requirements, SMEs are forced to change their business processes to fit the standardised software (Mabert *et al.*, 2003; Argyropoulou *et al.*, 2007; Olsen & Sætre, 2007; Raymond & Uwizeyemungu, 2007). It remains unclear whether the situation described above can satisfy or improve the D&E activities of MTO companies or whether these companies are forced into a rigid structure that restricts innovation and the design of new products. Hence, an ERP system may increase the responsiveness and efficiency of D&E tasks but may restrict creativity and flexibility.

Therefore, by examining the decision support requirements, functionality supported by ERP systems, and the impact on performance, the research seeks to understand the extent to which the design and engineering requirements of MTO companies are satisfied by the software. While a product configurator application is

Table 4.3. Design and Engineering stage

			Wortmann, 1995	Hameri & Nihtilä, 1998	Hicks et al., 2001	Forza & Salvador, 2002a	Forza & Salvador, 2002b	Knolmayer et al., 2002	Rudberg & Wikner, 2004	Hvam et al., 2006	Olsen & Sætre, 2007b	Olsen & Sætre, 2007a
Decision Support Requirements	*	*Product Information database.* Broad product range and component combinations lead to manually unmanageable data archives. Storing and accessing historical information and documentation on similar past orders is vital in design and engineering practices.	✓	✓		✓		✓	✓			✓
	*	*Integrative solution.* Tools to integrate information and systems across business functions become essential when conformity and timing is crucial. Transferring design and engineering information to customers and/or suppliers can manually be clumsy, and system or means support may become important.					✓	✓				✓
	*	*Intra-firm communication.* Internal coordination among staff in different departments (esp. between manufacturing & sales).		✓	✓	✓		✓		✓		✓
	*	*Inter-firm communication.* External coordination with customers and suppliers. It facilitates concurrent engineering, which is especially important for vertically integrated and outsourcing MTO companies.			✓			✓				
	*	*Design flexibility.* The system should not force the user to enter complete, consistent and up-to-date basic product data, but rather be flexible against frequent changes through the product's cycle.	✓									
Potential ERP Functionality	PC	*Product Configurator* serves as a repository of information about the structure and functionality of the product as well as lifecycle information.					✓	✓	✓	✓		
		Product Configurator provides searching functionality to find previous designs and drawings.					✓	✓	✓	✓		
	PLM	*Product Lifecycle Management* system includes product data management which is an integrated and efficient way of collecting, storing and sharing product information internally and externally.		✓				✓	✓			
		PLM assists new product development and innovation in design.		✓				✓				
Performance Indicators	*	The key measure here is considered to be *customer satisfaction*, including an assessment of whether the product confirms to the customer's specifications.								✓		✓
	Tech. Productivity	*Technical productivity* in terms of product *documentation* release. Documentation and archiving can be handled automatically which reduce the workload of technical personnel.		✓		✓	✓		✓	✓		
		Technical productivity in terms of *product design* activities. On receiving a previously designed item, the system can detect the similarity. This reduces duplicated effort for similar design requests. It also increases a technician's productivity for the design of large and complex products.		✓		✓	✓					

expected to improve the efficiency of the design and engineering of repeat products, it may also limit the flexibility of design and engineering practices. But PLM may be a useful application for both repetitive and one-off products to collectively store, retrieve and share product data information and enable improved internal and external integration. This leads to Proposition 2 (P_2), as outlined below followed by the hypotheses:

P_2. The product configurator tool available within the ERP systems adopted by MTO companies, which require support in order to coordinate activities when products are non-repeat and complex, can provide formalisation and some efficiency gains but limits creativity and flexibility leading to lower specification quality and customer satisfaction. PLM is also valuable when products are non-repeat but applicability is greater for both the design and engineering software tools when repeat orders dominate.

Product Configurator	H_{2a}: The level of decision support requirements has a positive impact on the intensity of use of the product configurator add-on.
	H_{2b}: The intensity of use of the product configurator add-on has a positive impact on performance at the design & engineering stage.
	H_{2c}: The level of decision support requirements has a positive impact on performance at the design & engineering stage.
PLM add-on	H_{2d}: The level of decision support requirements has a positive impact on the intensity of use of the PLM add-on.
	H_{2e}: The intensity of use of the PLM add-on has a positive impact on performance at the design & engineering stage.
	H_{2f}: The level of decision support requirements has a positive impact on performance at the design & engineering stage.

4.3.3 Order Entry

In a MTO context, order entry refers to the stage at which a company 'wins' an order and it is re-evaluated to determine whether it should be accepted, rejected or the due date and/or price renegotiated. This stage is needed because of the varying time between a quotation being made and a customer's decision as to whether to accept or reject the quotation; this can vary from the same day to several months or longer. If an order enters the system, the focus is on planning to adhere to the agreed due date; the main planning tasks, such as determining material and processing requirements, take place at this stage. Therefore, the key decision support requirements relate to capacity planning, shop floor routing, determining processing requirements, and the procurement of materials from external suppliers and subcontractors. The figure below illustrates the conceptual framework for investigating the usefulness of ERP/MRP and APS systems at the order entry stage in a MTO context (Figure 4.4):

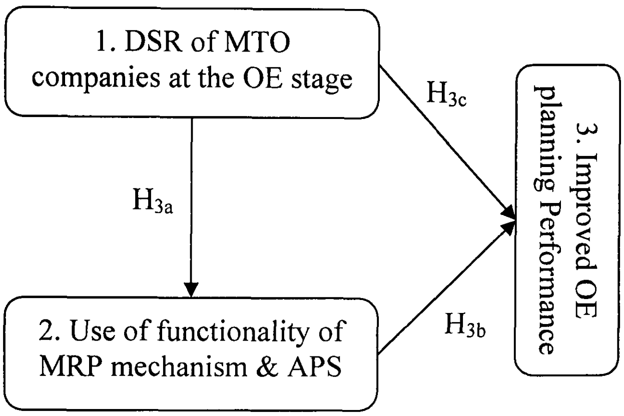


Figure 4.4. The framework for order entry

Construct 1 relates to the decision support requirements of this stage. The re-evaluation of an order upon entry (as described above) is generally followed by two consecutive steps: aggregate and operational planning. While aggregate planning concerns the medium-term matching of required resource capacity with available capacity, operational planning relates to the coordination of materials and the scheduling of capacity utilisation (Bertrand & Muntslag, 1993; Carravilla & de Sousa, 1995). A further requirement can be a software solution to apply project management techniques, especially when ETO production takes place. Construct 2 focuses on the two applications most relevant to this stage: MRP and APS (the latter first introduced in Section 4.1 in the context of CEM). ERP systems stem from MRP which provides functionality for determining required production and procurement; therefore, assessing its impact on performance in MTO companies is important. In addition, APS, which claims to address various stages of order processing, is seen as a state-of-the-art solution for production planning and is a popular add-on to ERP. Construct 3 relates to the impact on performance and focuses on due date adherence to agreed (or quoted) due dates, the utilisation of resources, and the ability to cope with uncertainty. Table 4.4 summarises the content of the three constructs.

Table 4.4. Order Entry Stage

Construct	Sub-construct	Description	Hendry & Kingsman, 1989	Bertrand & Wortmann, 1992	Bertrand & Muntslag, 1993	Wortmann et al., 1996	Knolmayer et al., 2002	Stevenson et al., 2005	Deep et al., 2008
Decision Support Requirements	*	*Confirmed order re-evaluation.* Re-considering the acceptance/rejection of the orders just after the customer confirmation is the order entry stage's functionality together with the regular mid-term planning. Addressing that requires to re-consider capacity, priority, cost and other parameters, because of the high possibility of change of earlier circumstances in which a particular quote has been made.						✓	
	Aggregate Planning	*Flexible aggregate planning.* BOM structures are not always available during the planning stages, and gradually become certain; esp. common for ETO. MRP type of replenishment mechanisms is not thoroughly functional. Planning tools which are more flexible and compliant to BOM uncertainty and specification changeability can be beneficial.		✓	✓			✓	✓
	Aggregate Planning	*α ·Backlog + β ·Forecast.* Ability to weigh the importance of forecasts and plan the backlog in detail. Master schedule is planned based more on backlog than forecasts which makes these plans hardly changeable. Besides, capacity planning is required for contingent orders.	✓				✓		✓
	Opr'nal Planning	*Machine loading.* Finite loading is the capacity concerning way of detailed planning based on the MS. Its major disadvantage is the lack of control on managing orders based on prioritisation. Yet, it is preferable compared to the impracticality of infinite loading.	✓	✓		✓			
	*	*Project management* techniques and relevant IT support can help (esp. for ETO), as every order can be as big as a customised project.		✓	✓		✓		
ERP Functionality	MRP	*Material Requirements Planning* (MRP) is the basic planning modern in modern ERP systems. It offers incapacitated production and procurement planning through simple BOM explosion principle. Other major disadvantages are its forecast-driven mechanism, high sensitivity reaction to changes in any part of the schedule, and complete BOM requirement to give any results.	✓	✓	✓	✓	✓	✓	✓
	APS	*Advanced Planning & Scheduling* (APS) systems, in fact, derive from the basic MRP, but also include several additional functions. Its main paradigm in the software market is the capacity concerning and hierarchical approach to production planning at various levels (i.e., long, mid and short-term).						✓	✓
	*	*Project management:* ERP can monitor costs and work schedule on a project-by-project basis.			✓		✓		
Performance Indicators	*	*On-time delivery* is the primary measure for production efficiency. Despite the fact that it is a generic performance indicator (attributable to every stage of order processing), adherence shown at this stage comprises a vital share of any success or failure.	✓	✓			✓	✓	✓
	*	*Resource utilisation* is vital as well-acknowledged. The measures are the balanced and effective use of resources (machine and human), shortened queuing times, and utilisation of well-monitored supplier and subcontractor capacities.	✓		✓		✓		
	*	*Reduced uncertainty.* Demand uncertainty and the hardly controllable factors (e.g., specification and due date changes, and rush orders) constitute the major challenge in production planning in the MTO sector.		✓		✓		✓	

Although MRP has previously been considered unsuitable for MTO planning purposes (Cooper & Zmud, 1990), contemporary evidence is required. Meanwhile, the value of APS in a MTO context remains unclear. Deep *et al.* (2008) argue that APS can be a relevant solution for MTO SMEs but provides no empirical evidence to support this claim. One of the aims of this research is therefore to contribute to understanding the applicability of APS to MTO companies. This leads to Proposition 3 (P_3), as outlined below; hypotheses are also provided.

P_3. MTO companies, which require support in order to cope with both aggregate and operational planning, may improve production planning performance (e.g., due date adherence) using APS systems but will not improve production or procurement planning using the MRP functionality contained within ERP systems.

MRP	H_{3a}: The level of decision support requirements has a positive impact on the intensity of use of ERP's MRP functionality.
	H_{3b}: The intensity of use of ERP's MRP functionality has a positive impact on performance at the order entry stage.
	H_{3c}: The level of decision support requirements has a positive impact on performance at the order entry stage.
The APS add-on	H_{3d}: The level of decision support requirements has a positive impact on the intensity of use of the APS add-on.
	H_{3e}: The intensity of use of the APS add-on has a positive impact on performance at the order entry stage.
	H_{3f}: The level of decision support requirements has a positive impact on performance at the order entry stage.

4.3.4 Order Review and Release

The Order Review and Release (ORR) stage controls the inflow of orders to the shop floor and originates from the work of Wight (1970). The basic idea is to hold orders back from the shop floor in a pre-shop pool and release them in time to meet delivery dates without leading to excess congestion on the shop floor. The main aim is to delay the start of an order without delaying its completion. A variety of order review and release policies have been proposed in the literature (Bergamaschi *et al.*, 1997). In contrast to other production planning and control stages, it is unclear whether this stage is typically considered in practice in a formal way or if it is contained within contemporary ERP systems. Therefore, the aim of the following framework is to further explore the existence of formal order review and release mechanisms in ERP systems and to assess their effectiveness in a MTO context when present (Figure 4.5):

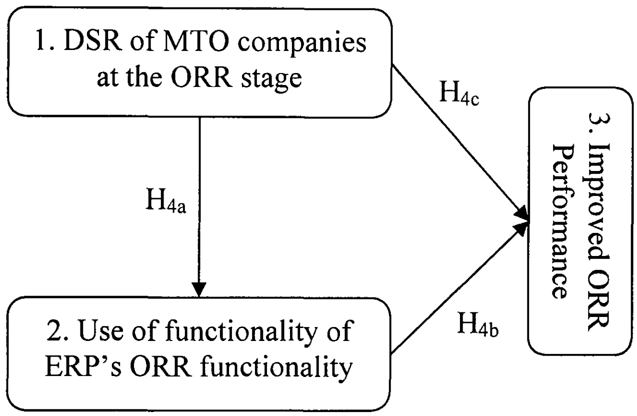


Figure 4.5. The framework for order review and release

Construct 1 relates to the DSRs at the ORR stage. First of all, the need for a release stage must be considered. If orders are formally withheld from the shop floor in a pre-shop order pool, the corresponding decision support requirements are also sought in order to control their release. These decision requirements include deciding on the type of release mechanism to evaluate which order in the pool to release, and finding the relevant parameters for that mechanism (e.g., maximum released workload levels, periods between releases, etc). Also, interactions between consecutive planning and control stages (e.g., between order entry and order release or order release and dispatching) affect decisions (Wisner, 1995; Yücesan & de Groote, 2000), thus integrated decision support can be important. Construct 2 represents the potential functionality of ERP systems at this stage. Since ERP is an integrated system, it can monitor the workload at the order entry stage and on the shop floor before and after the release stage. Using this information to manage order release should increase control over the physical flow of goods within the company. Construct 3 represents the impact on typical performance measures such as reduced WIP, costs and congestion. Moreover, in assessing the impact on performance, the research must consider whether the overall lead time has been reduced through the use of an ORR stage or whether the lead time has been shifted from the shop floor to the pre-shop pool. Table 4.5 summarises the content of all three constructs.

Breithaupt *et al.* (2002) explain that an ORR mechanism was previously contained with the design of some ERP systems, including the SAP R/2 system. The research seeks to investigate whether there is any evidence that this functionality, argued to be of importance to MTO companies, is still contained within the design of contemporary ERP systems and what impact it has on performance. This leads to Proposition 4 (P_4) and the following hypotheses.

P_4. If contained within an ERP system and used, order review and release functionality can play an important role in supporting the planning and scheduling tasks of MTO companies, which require such a decoupling stage between order entry and dispatching, thereby improving control and due date adherence.

ERP's ORR functionality	H_{4a}: The level of decision support requirements has a positive impact on the intensity of use of ERP's ORR functionality.
	H_{4b}: The intensity of use of ERP's ORR functionality has a positive impact on performance at the order review and release stage.
	H_{4c}: The level of decision support requirements has a positive impact on performance at the order review and release stage.

4.3.5 Dispatching

The dispatching stage is where shop floor scheduling takes place and jobs are sequenced in front of machines on the shop floor. The aim of the research at this stage is to test the impact of the shop floor scheduling tools contained within ERP systems (and APS add-on functionality) on the performance of MTO companies, as illustrated below (Figure 4.6):

Table 4.5. Order Review and Release stage

			Bechte, 1988	Hendry & Kingsman, 1991	Philipoom et al., 1993	Wisner, 1995	Bergamaschi et al., 1997	Sabuncuoglu & Karapinar, 1999	Breithaupt et al., 2002
Decision Support Requirements	*	*Release pool.* It is a common practice is to keep jobs in the planner's office ready for batch releasing to the shop floor. This will prevent high work-in-process, and aid the foreman in scheduling. Such practice can be embedded into an IS as a release stage.	✓	✓					✓
	IT Support	*Release mechanism.* The potential benefits of holding work in a pool will only be fully realised if coupled with a job-releasing methodology. Several parametric (e.g., periodic, load limited), and sensitivity-based (e.g., priority, capacity sensitive) policies are available. A system can include a few basic policies, and needs to be easily programmable for any specific one.		✓			✓	✓	
		Parameterisation. Almost each order release policy needs a set of parameters and order-specific information for better release decision support. Unfortunately, due to varying conditions; dynamic capacity, priority and parameter adjustments are required, so are tools for capacity monitoring, simulation and optimisation.			✓	✓	✓	✓	
	*	*Complex interaction.* Significant interactions between order release and other decision variables (e.g., dispatching, due date setting) have been found. An integrated system can prevent isolated decision making, and promote coordination to preserve feasibility.		✓		✓			
ERP Functionality	ERP	*Virtual existence.* A complete theoretical framework of MRP-II includes an order release stage as a gate from mid-term planning stage to operational planning on the shop floor. An old version of SAP systems (SAP R/2) and other commercial ERP packages are reported to contain a release stage, yet its contemporary use within the ERP systems is unclear.							✓
		Detailed and up-to-date information. Release mechanisms often work superior when high quality information is provided. Robust performance is possible by accessing detailed and up-to-date sales and shop floor information owing to ERP's integrated central DB.							✓
Performance Indicators	*	*Due Date adherence.* Reduced lateness and shortened lead times are significant performance measures which are concerned at the order release stage as well.	✓	✓		✓		✓	
	Control	*Typical measures.* Reduced WIP, costs and congestion; and increased capacity utilisation are important performance indicators and all crucial to MTO. Fewer jobs on the shop floor means that the dispatching task is easier and urgent jobs are more likely to be noticed and dealt with accordingly.	✓					✓	
		Research paradox. The possible inverse performance reaction of a manufacturing system to an order release policy is often sometimes observed (esp. in the lead time), while other measures can be improved. Such an outcome needs to be avoided.						✓	✓

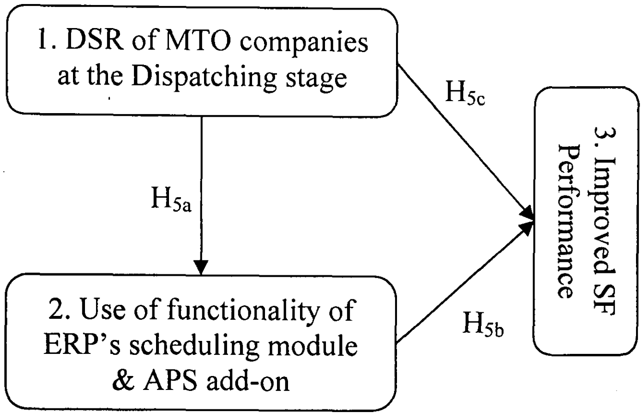


Figure 4.6. The framework for dispatching

Construct 1 relates to the decision support requirements of MTO companies at the stage of dispatching on the shop floor. The support currently available for dispatching does not consider labour constraints while skilled labour is important in MTO production (Blackstone *et al.*, 1982). Significant interaction of dispatching with consecutive decision points has been found (Wisner, 1995; Yücesan & de Groote, 2000; McKay & Wiers, 2003), thus an integrated information system can help planners see the big picture for sound decisions. Construct 2 relates to the provision of ERP and APS systems at this stage. Tempelmeier (2001) reports that the APS tools available for scheduling use only 'general purpose' algorithms, i.e., algorithms which are broadly 'satisficing'; this makes their performance impact unclear and they are unlikely to result in the best solution in a specific context. For example, meta-heuristics (e.g., genetic algorithms), constrained planning and approaches based on the theory of constraints are primarily used for detailed scheduling (Tempelmeier, 2001; David *et al.*, 2006). Construct 3 relates to the impact of ERP and APS systems on performance at this stage and is measured in terms of the effect on daily adherence to operation completion dates on the shop floor and final delivery dates. Table 4.6 summarises the content of all three constructs.

The research seeks to investigate the support level of currently available ERP systems' dispatching functionality for requirements and the impact on delivery performance. This leads to Proposition 5 (P_5) and the following hypotheses.

P_5. MTO companies, which require support in order to cope with dispatching decisions, may improve delivery performance (e.g., due date adherence) using ERP's shop floor scheduling functionality for dispatching.

ERP's scheduling functionality	H_{5a}: The level of decision support requirements has a positive impact on the intensity of use of ERP's shop floor scheduling functionality.
	H_{5b}: The intensity of use of ERP's shop floor scheduling functionality has a positive impact on performance at the dispatching stage.
	H_{5c}: The level of decision support requirements has a positive impact on performance at the dispatching stage.
The APS add-on's scheduling	H_{5d}: The level of decision support requirements has a positive impact on the intensity of use of APS's shop floor scheduling functionality.
	H_{5e}: The intensity of use of ERP's ATP functionality has a positive impact on performance at the dispatching stage.
	H_{5f}: The level of decision support requirements has a positive impact on performance at the dispatching stage.

Table 4.6. Dispatching stage

			Blackstone et al., 1982	Błażewicz et al., 1996	Jain & Meeran, 1999	Wiers, 2002	McKay & Wiers, 2003	Pinedo, 2005
Decision Support Requirements	*	*Simplification.* Dispatching can easily turn into a complex problem (in fact, well-known as NP-hard) when treated as the major issue in planning. This is particularly true in a job shop environment. Thus, a system should encourage simple and effective rules.	✔	✔				
	*	*Labour constraint.* The main assumption of most dispatching rules is scarcity of machine resource only and labour is not treated as a constraining factor. The presence of high skilled worker is as crucial as the machine in the MTO production. Thus, a system deploying a dispatching rule on the shop floor needs to consider the labour availability.	✔					
	*	*Interaction with other stages.* Dispatch decisions are made in the light of preceding planning and scheduling results. Accessibility to these prior plans through an integrated system is important to see the big picture and be prepared for uncertainty.					✔	
ERP Functionality	ERP	*ERP functionality.* ERP has a hierarchical production planning module which covers from demand planning to order release. Yet, the component to provide specific solutions for detailed scheduling is generally left insufficient (e.g., plainly generic) by the developers.				✔	✔	✔
	APS	APS *functionality.* Shop floor scheduling mechanisms are an important part of APS systems at the short-term planning stage.				✔		
Perf. Ind.	*	*Daily schedule adherence.* The main objective of dispatching is to keep up with the planned due dates in the short term. Therefore, the aim is to minimise any cost likely to come as tardiness, lateness, and WIP.	✔	✔	✔			✔

4.3.6 Customer Relationship Management

Customer Relationship Management (CRM) is an "umbrella term" for an add-on platform which brings together various applications (e.g., knowledge management systems and tools which analyse sales promotions and track customer satisfaction levels) that can lead to 'better' and longer term relationships with customers (Bose, 2002; Chen & Popovich, 2003; Buttle, 2004). It has also been defined as a set of tools to help users acquire and retain customers, or to cross-sell to customers through one or more "touch points"; for example, a call centre, sales person, branch, the Internet, or via e-mail (Smith, 2004). The following framework illustrates the relationship between the decision support requirements of MTO companies for CRM, the functionality of CRM add-on, and the impact on performance in MTO companies (Figure 4.7):

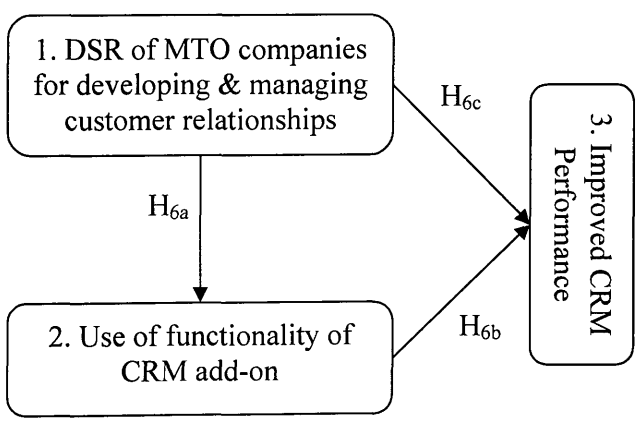


Figure 4.7. The framework for Customer Relationship Management

Construct 1 relates to the decision support requirements of MTO companies for developing and managing customer relationships which are arguably greater than ever before due to globalised markets and increasing ranges of products and services. Considering the often low strike rate of MTO companies, exploring new markets and acquiring new customers is important. An equally critical competence is maintaining and developing relationships with existing customers.

Construct 2 relates to the functionality of CRM add-on for developing and managing customer relationships. This includes the provision of a comprehensive database to 'personalise' provision for customers (e.g., customer-specific quotations) and to assess customers (e.g., loyalty, profitability, and credit history). In addition, data mining solutions are provided to create customer preference patterns, to examine buying habits and to predict market conditions using operations research tools such as linear programming and neural networks (Knolmayer *et al.*, 2002).

Construct 3 corresponds to the impact on CRM performance in MTO companies. It includes detecting strike rate improvements and assessing the impact on the ability to gain new customers and improve the satisfaction of existing customers. Return on CRM investment is also important since solutions are generally expensive, especially for SMEs. Table 4.7 summarises the content of the three constructs.

MTO companies operate in competitive markets; therefore, it is argued that strike rates are typically low, making it essential to continuously explore new markets and keep customer satisfaction levels high. CRM software could be a valuable tool for supporting this requirement; however, whether CRM tools can provide enough of a return on investment for MTO SMEs with limited financial resources is unclear. For example, Hendricks *et al.* (2007) studied the impact of SCM, CRM and ERP investments on the long term stock price performance and profitability of firms and found no evidence of improvement in either measure for CRM investment. Moreover, the value of tools for retaining customers in a MTO context where a customer may only require a particular job on a one-off basis is questionable and in need of further empirical evidence. This leads to Proposition 6 (P_6) and the following three hypotheses:

P_6. The CRM add-ons used by MTO companies that need IT support for better communication and marketing may provide support for customer retention (e.g., by enticing one-off customers into longer term relationships) and the exploration of new markets; but the high cost of CRM add-ons and the implementation effort required may lead to an insufficient return on investment.

CRM add-on	H_{6a}: The level of decision support requirements has a positive impact on the intensity of use of the CRM add-on.
	H_{6b}: The intensity of use of the CRM add-on has a positive impact on the customer relationship management performance.
	H_{6c}: The level of decision support requirements has a positive impact on the performance for managing customer relationships.

4.3.7 Supply Chain Management

Effective Supply Chain Management (SCM) relies on integrated information to ease and support coordinated decision making activities for every chain member (upstream and downstream), and relies on the latest and most complete information (Davenport & Brooks, 2004). The aims of SCM include cost reduction, efficiency gains, and enhanced buyer-supplier relationships. In addition to the importance of supply chain coordination, it is argued that many MTOs are located towards the upstream end of several supply chains and often receive short notice demands from customers to quickly supply products or components. Therefore, the focus of this study is on investigating the level of support that ERP systems and SCM add-ons can provide for MTO companies with a particular focus on the ability to handle rush orders. The following framework seeks to assess the effectiveness of ERP systems and SCM add-ons to improve the performance of MTO companies (Figure 4.8):

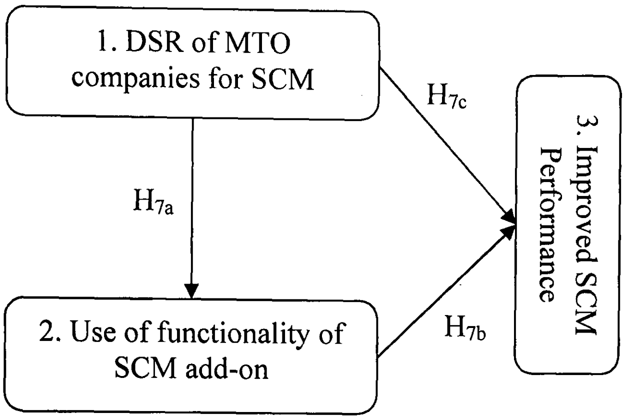


Figure 4.8. The framework for Supply Chain Management

Table 4.7. Customer Relationship Management

			Rigby et al., 2002	Knolmayer et al., 2002	Muda & Hendry, 2002	Xu et al., 2002	Chen & Popovich, 2003	Deep et al., 2008
Decision Support Requirements	*	*Customer Database.* Globalised markets and increased range of product and service options enforce companies to cope with a large size of customer base now.					✓	✓
	*	*Generating more enquiries* than average can mean more sales. The low strike rate makes the sector depend on continuous market search and satisfy the existing customers to the highest possibility.			✓			
	*	*Prolonged relationships.* Gaining contracts over a period of time would be a sign of world class manufacturing through obtaining repeat orders and consequent efficiency. An analytical relationship improvement system can be helpful to entice the potentially most profitable one-off customers into longer relationships.			✓			
ERP Functionality	CRM	*Several ways of communication* can be utilised in CRM. These, technically called, 'touch points' are the Internet, e-mail, sales, call centres, direct mail, advertising, telemarketing operations, fax, pagers, stores and kiosks.	✓	✓		✓	✓	
		Customer assessment. CRM applications are argued to help companies assess customer loyalty and profitability on measures such as repeat purchases, money spent and longevity.	✓				✓	
		Analytics is argued to be a valuable offer through various CRM applications. They are developed to compete on the vastly collected customer data (from simply accessible contact information to key habits and preferences), to attract the new and entice the present.	✓					
Performance Indicators	*	*Customer satisfaction* is a vague and latent, but critical measure. It is an ultimate aim which brings all one-to-one marketing efforts and eventually the CRM systems into their existences. Though customer satisfaction can hardly be measured, truthful perceptual thoughts of high level managers can give an idea of how well the customer needs addressed towards the use of CRM.		✓				
	New Customers & Markets	The number/percentage of *formerly one-off and lately committed* customers can contribute the overall company performance.	✓				✓	
		The *strike rate improvement*, gained after CRM implementation, can give an idea of the performance in the exploration of new markets and customers.			✓			
	*	*Profitability.* Although recent studies shows no significant improvement in the *return on CRM investments* for a variety of large companies, perceptual answers of managers can give a descriptive statistic about MTO SMEs who have installed CRM.					✓	

Construct 1 represents the decision support requirements of MTO companies for SCM. This includes support to improve coordination between supply chain members, such as by facilitating the sharing of information. But support is also required in order to improve the ability of MTO companies to cope with supply chain effects, most specifically support to improve the ability to handle rush orders. The ability to quickly respond to the arrival of rush orders or prospective rush orders is important; this includes the sales department as well as the production and planning units. Jahnukainen & Lahti (1999) reported that, on average, 70-80% of the total cost of manufacturing is accounted for by procurement expense in a typical MTO company (overall, for all manufacturing strategies, Knolmayer *et al.* (2002) report this figure to be 60-70%). Thus, supporting procurement activities is of critical concern in such a competitive business environment while production planning, which represents the planning of all other in-house activities, continues to be an enduring challenge.

Construct 2 relates to the functionality of add-ons to ERP systems, such as SCM and APS systems. One way in which a MTO company would be able to better handle rush orders would be if the planned schedules of other jobs (non-rush orders) could be revised, potentially including changing planned delivery dates, so that rush orders could be accommodated. Construct 3 relates to the impact on performance, such as the improved ability to handle rush orders through the use of SCM and APS tools, i.e., to meet the due dates of rush orders without affecting the due date adherence of other jobs. Table 4.8 summarises the content of the three constructs.

Table 4.8. Supply Chain Management

			Jahnukainen & Lahti, 1999	McGovern et al., 1999	Hicks et al., 2000	Akkermans et al., 2003	Davenport & Brooks, 2004	Sahin & Robinson, 2005	Stevenson et al., 2005
Decision Support Requirements	*	*Coordination.* Establishing a good level of coordination (i.e., information sharing, channel alignment and flexibility) is needed for developing the relationships and for coordinating with both the suppliers and buyers..				✓			✓
	*	*Rush orders.* A prioritised incoming order affects the delivery dates of currently processed orders, mainly because of lacking labour and/or machine capacity. The perfect information in coordination and collaborative planning helps cope with rush orders.	✓						
	*	*Supplier selection.* Limiting the number of suppliers is frequently advised to minimise continual supplier assessment, goods inwards inspection, etc. Determining the set of suppliers requires significant historical and analytical analyses.	✓		✓				
	*	*Procurement.* Majority of the manufacturing cost is accounted for by procurement expense in a typical MTO company. Thus, a system in point should address the common MTO procurement planning problems such as reducing time on routine paperwork and price negotiations, and better controlling the suppliers in selecting, contracting and training them.	✓						
	*	*Multi-buyer complaint solution.* It is known that large and powerful buyers often force their suppliers to use ERP and/or associated SCM add-on solutions to be in line with their own for the ease of communication and control. Having lots of different buyer-supplier relations in various supply chains, a particular solution should provide a generic advantage in this context.		✓					✓
Potential ERP Functionality	ERP	*ERP supported* SCM functionality is more meaningful to manage cross-functional processes, especially on a large scale. SCM cannot efficiently perform without a shared foundation of information through completely separate systems used in different departments of the company. Thus, internal business process integration and information sharing via ERP better support SCM practices.				✓	✓		
	SCM	*The Internet's* promise of instant and platform-independent communication among systems is the biggest plus towards the efficiency of every SCM application.					✓		✓
		The dilemma of outsourcing is to work with either few but reliable suppliers or plentiful but less controllable suppliers. The coordination is enabled in both ways in today's *SCM technology* while each has complexities and advantages.					✓		
		Cost reduction is the major offered feature of SCM through supply chain coordination. This can help companies reduce costs due to slow inventory turnover, minimise delivery delays and improve supplier and customer relationships.					✓	✓	
Performance Indicators	Improved Order Management	*Cost cutting measures* constitute the most important part of supply chain performance measures though it can be hard to get even an approximate objective answer.	✓				✓		
		Inventory turnover is an important measure for companies highly dependent on raw material and component supplies. Order-driven short term inventory of a typical MTO company should not have poor (slow) inventory turnover.	✓				✓		
		Improvement in the delivery time and *reduced lateness* are generic but also important measures for SCM practices.	✓				✓	✓	✓
	*	The amount of *reduced uncertainty* gives valuable clues of the SCM success.		✓					✓
	*	The amount of good *supply chain strategies developed* and deployed through SCM add-ons can be a crucial but latent performance indicator. Yet, a perceptual answer is quite valuable on a Likert scale.			✓				

With advances in technology, collaborative tools are more readily available, and with increasingly dispersed supply chains are arguably more valuable than ever for promoting collaborative planning and improving responsiveness in the supply chain. SCM add-ons fall into this category and may help to improve the flow of information across the supply chain, improving the early detection and awareness of rush orders by MTO companies. Urgent orders force planners into re-planning and re-scheduling; this can require what-if analyses and simulation in order to compare and evaluate alternative options for changing the plan. It is argued that APS add-ons to ERP systems can also fulfil this requirement. However, whether these systems can provide enough of a return on investment for MTO SMEs with limited financial resources and limited ability to influence the wider supply chain is unclear. This leads to Proposition 7 (P_7) and the following hypotheses:

P_7. The SCM add-on to ERP system used by MTO companies, which require IT to support collaboration and to analyse, simulate & re-plan schedules, can improve coordination between supply chain members and the ability to handle rush orders.

SCM add-on	H_{7a}: The level of decision support requirements has a positive impact on the intensity of use of the SCM add-on.
	H_{7b}: The intensity of use of the SCM add-on has a positive impact on performance regarding the supply chain operations.
	H_{7c}: The level of decision support requirements has a positive impact on performance regarding the supply chain operations.

4.3.8 Item Generation

The next step is the generation of items for the explanatory part. While doing that, all the variables identified and described in Table 4.2 to Table 4.8 are used as a guideline and multiple items are generated for each variable. The full list of items is provided in Appendix 1. Note that, only the variables denoting of the use of ERP modules and extensions consist single item; because they are intended to measure the intensity of use perceptually, thus kept short.

The content validity assessment of these items is conducted below where the fit between the generated items and their corresponding variables are tested through expert opinions.

4.4 Content Validity of Measures

A survey can only be useful when its instrument (the questionnaire) is meaningful to respondents. That is, the *wording* is important, and the *content validity* (the items' coverage of constructs) has to be established. The researcher generates a pool of items with his or her own confidence; but to assure content validity, consulting subject-matter experts (also called judges) is advised (Nunnally & Bernstein, 1994; Rungtusanatham, 1998). It is well-acknowledged that measures must be demonstrated to be "content valid" before they can be held to be any other type of valid (Rossiter, 2008; Forza, 2009).

The aim of this section is to provide a review of those available techniques to select the most appropriate. The following subsection provides two main methods of collecting expert opinions. Content validity data collected through each method is analysed further by some techniques. Review of both these methods and techniques is followed by their applications to this study.

It is noted that only the items used in the explanatory part of the survey have been assessed using the content validity methods described below; since none of the questions have been validated by other researchers before. On the other hand, the exploratory part has factual questions widely used in similar studies such as company background information and ERP implementation strategies.

4.4.1 Methods and techniques to collect & analyse expert opinions

Two main collection methods are common in the literature (Hardesty & Bearden, 2004). In the first method called *Item Rating*, the judges are asked to indicate whether each item is individually representative of its construct (e.g., clearly representative, somewhat representative, or not representative) using a Likert scale (Zaichkowsky, 1985). All items are provided as already categorised under their properly defined and labelled constructs. Items having low average representativeness may either be discarded or modified. First subheading below describes the most commonly used analysis technique (*Lawshe's Content Validity Ratio*) when expert opinions are collected through this method.

Another method is called *Q-sort*. Here, judges are asked to sort the randomly ordered items (i.e., showing no sign of categorisation) into the fittest constructs (Davis, 1989; Hinkin, 1995; Hensley, 1999). The definition and labels of constructs, into which the judges will sort the items, might either be provided or not. When not provided, they are asked to group the items by themselves and label the groups accordingly (Moore & Benbasat, 1991). Thus, via the Q-sort method, the researcher also gets the chance to compare his or her labels with judges'. Thus, it is the best and the most developed technique to evaluate content validity in the literature. The most commonly used analysis techniques, when expert opinions are collected through Q-sort method, are provided in the following subsections starting from the second subsection called "contingency table".

The general aim of using these methods is to establish which item should be into which construct from the judges' perspectives. Yet another purpose is the elimination of leading questions, ambiguous items, double meanings and unnecessary jargon (Venkatraman & Grant, 1986). This is helpful to find any superfluous items (to discard them for parsimony) as well as weaknesses in some of the constructs' original definitions. Both methods can also be applied in several rounds each time using different sets of experts.

Lawshe's Content Validity Ratio

Items that do not represent a construct's content very well (i.e., receiving low rankings) can be eliminated, while making sure not to reduce the representativeness of the item pools. For analysing the Item Rating method's results, any item seen as other than being clearly representative might need modification or be discarded. Similarly, expert points given to item representativeness can be averaged and a number of the lowest rated items can be reconsidered to retain in the questionnaire. Lawshe's (1975) Content Validity Ratio (CVR) provides a simple and commonly used formula to calculate an adequacy indicator for each item individually.

$$CVR_i = \frac{n_e - N/2}{N/2} \tag{1}$$

where the n_e is the number of experts indicating item i is "clearly representative" and N is the total number of experts. As a result of this formula, CVR values range between −1 and +1. Thus, when fewer than half say "clearly representative", the CVR is negative. Similarly, when half say "clearly representative" and half do not, CVR is zero. CVR values closer to +1 indicate that experts are in agreement that the item is clearly representative. Content Validity Index (CVI) is an overall content validity measure which is simply the mean of the CVR values of the retained items.

Contingency Table

For analysing Q-Sort results, due to the complexity of validity test (e.g., sorting) more involved techniques are available and in use. Amongst those, *Contingency Table* is a cross tabulation of two experts' sorting results to detect the pairwise degree of agreement. Over a sample of N items, each expert's classifications give rise to a frequency distribution (i.e., the number of items allocated to each of k variables). The following presentation exhibits the method clearly (Figure 4.9):

	Coded Variable	*Judge A*					
		1	*2*	*3*	...	*k*	
	1	Agree		Disagree*			$f_{2,1}$
	2		Agree				$f_{2,2}$
Judge B	3			Agree			$f_{2,3}$
	:				Agree		:
	k					Agree	$f_{2,k}$
		$f_{1,1}$	$f_{1,2}$	$f_{1,3}$	...	$f_{1,k}$	Marginal distributions

* Any off-diagonal cell represents a disagreement among judges; for example, item(s) in this cell were categorised into 3 by judge A, but into 1 by judge B.

Figure 4.9. A template of Contingency Table

This technique is particularly effective to detect any individual items differently categorised by the judges (either from each other or from the researcher's categorisation). Besides, pairwise judgements can be aggregated to observe the overall distribution of items to constructs.

Percentage of Agreement

When researchers use multiple judges to evaluate the convergence of their coding, another most commonly used measure of inter-judge reliability is the simple *Percentage of Agreement* (also called *Raw Agreement*) between two or more judges. It is very easy to compute and convenient to be intuitively interpreted. Obviously, the smaller the number of categories is, the greater the likelihood of higher agreement becomes. However, it also has the potential to mislead, due to its simple intuitive interpretation.

Cohen's Kappa

To overcome the shortcomings of the simple proportion of agreement statistics, the ratio called Cohen's Kappa (κ) has been developed (Cohen, 1960). It is the most widely used measure of inter-judge reliability in the literature. The basic formula is as follows:

$$\kappa = \frac{F_O - F_C}{N - F_C} \tag{2}$$

This time N is the total number of judgments made by each expert. F_0 is the number of judgments on which the judges agree. F_c is the number of judgments for which agreement is expected by chance. The following example illustrates the application, especially the latter term F_c being the vaguest (Figure 4.10):

		Judge A		
		1	*2*	
Judge B	*1*	30	20	50
	2	10	40	50
		40	60	100

Figure 4.10. An example for Cohen's κ to evaluate inter-judge reliability

According to this example, F_0 is found to be 70 (= 30 + 40), the total number of agreed categorisation. To calculate F_c, (the number of random agreements) it is noted that judge A put forty of the items into category 1 and sixty to category 2. Thus, 40% of the time judge A allocates an item to category 1. Similarly, judge B put fifty of the items into category 1 and fifty to category 2. Thus, 50% of the time judge B allocates an item to category 1. Therefore, the probability that both of them would categorise an item to 1 randomly is (40 × 50) / 100 = 20 and the probability that both of them would categorise an item to 2 is (60 × 50) / 100 = 30. Thus the number of randomly agreed items is 50 = (20 + 30). Finally, κ value is 0.40 = (70 − 50) / (100 −

50). Therefore, while the raw agreement gives a result of 0.70 in this example, Cohen's Kappa argues that when the chance factor is deducted it is actually an agreement of 0.40 in the end.

Cohen's formula takes as given the marginal distributions between categories exhibited by each of the judges. This has been considered as the major shortcoming assumption which was also recognised by himself (Cohen, 1960; Perreault & Leigh, 1989). Therefore when the marginal probability distribution is known and used in the formula, it becomes more reliable through an improved chance factor.

Perreault & Leigh's "Reliability index"

Cohen's formula is found to be overly conservative because of the approach it estimates agreement frequencies expected by chance (Perreault & Leigh, 1989). It still ignores to incorporate the number of categories in the formula. Additionally, even though the formula seems to give an output range of reliability between zero and one, in some special cases it becomes impossible to find a scenario to get 1.0 reliability whichever way one distributes the agreement. Perreault & Leigh (1989) introduced a new inter-judge reliability formula to overcome these limitations. $\mathbf{I_r}$ is the measure called the "reliability index" ranging from 0.0 (no reliability) to 1.0 (perfectly reliable).

$$I_r = \sqrt{\left(\frac{F_0}{N} - \frac{1}{c}\right)\left(\frac{c}{c-1}\right)} \qquad (3)$$

where c is the number of coding categories. If $F_0/N < (1/c)$, I_r is set to zero.

It is only applied to paired observation of judges. So, the average of all paired reliability indices gives a measure to compare (e.g., among rounds). An estimated standard deviation (s_I) is also provided which enables to form a confidence interval , in essence a test of the significance of the reliability index (Perreault & Leigh, 1989,

p. 143). More important than all above, the authors aimed to find a measure which would be suitable to marketing research rather than to psychometrics or simple decision making processes. For example, as mentioned before to have a better working Cohen's κ, given set of marginal probability distributions is essential. But, for marketing research a priori knowledge of the distribution is generally not possible which is also correct for operations management. In fact, in many situations, getting an estimate of the distribution of responses across categories is a key reason for doing the research in the first place (Perreault & Leigh, 1989). Therefore, the reliability index can be considered as the most applicable measure to the operations management research amongst the available ones. That is also why it has become the most popular in the OM field after it became in marketing.

Proportional Reduction in Loss

The final measure considered for content validity evaluation of judges is called Proportional Reduction in Loss (PRL). Given the proportion of inter-judge agreement, F_0 / N, Rust & Cooil (1994) estimated the probability, p, that each judge chooses correctly. The formula to calculate p below was rearranged to build a generalised form of Perrault & Leigh's reliability index, extended from considering paired agreements of judges to multiple agreements.

$$\hat{p} = c^{-1}(1 + \sqrt{(cA - 1)(c - 1)} \qquad (4)$$

where A is the proportion of inter-judge agreement. If F0/N < (1/c), $\hat{p}$ is set to c-1. Direct calculation of the PRL measure from $\hat{p}$ can be quite involved, thus Rust & Cooil (1994) also propose a practical table search-based method. The PRL values are suggested to be comparable with Cronbach's alpha (e.g., a very reliable agreement is over 85%). The table below shows an example from their study (Table 4.9):

Table 4.9. A PRL example of multiple judgments, adopted from Rust & Cooil (1994)

EXAMPLE DATA: QUALITATIVE JUDGMENTS									
	Judges				1&2	1&3	2&3		
	1	2	3	Consensus	Agree?	Agree?	Agree?	Agreements	Total
1	D*	D	C	D	Yes	No	No	1	3
2	A	A	A	A	Yes	Yes	Yes	3	3
3	C	C	C	C	Yes	Yes	Yes	3	3
4	B	B	B	B	Yes	Yes	Yes	3	3
5	B	A	A	A	No	No	Yes	1	3
6	A	A	A	A	Yes	Yes	Yes	3	3
7	D	D	C	D	Yes	No	No	1	3
8	C	C	D	C	Yes	No	No	1	3
9	A	B	B	B	No	No	Yes	1	3
10	D	C	C	C	No	No	Yes	1	3
							Total	**18**	**30**

Proportion of Inter-judge Agreement (A) = 18/30 = 0.6
*Categories are coded as A, B, C and D; as totally four.

4.4.2 Assessment

Overall, each technique comes with some advantages and disadvantages considering the assumptions made and the contexts to which it is applied. Nevertheless, the trustworthiness of the measures increases as new techniques are developed in time to address their predecessors' shortcoming points. The following table (Table 4.10) summarises the measures considered in this study respectively. Their advantages and disadvantages are also provided. Thus, the most preferable measures are Perreault & Leigh's index and PRL considering their similarity, and also the suitability to operations management research. Even so, the other techniques are also applied and provided in the final table.

4.4.3 Application of Content Validity Techniques

Finding an 'ideal' subject-matter expert is not a simple task due to the cross-disciplinary nature of this survey. Nevertheless, the Q-sort method was preferred to get the maximum benefit from totally ten judges although it is more challenging to them. The judges are asked to assign a pool of items to corresponding construct/dimensions to which they think of as relevant. Following that, they are also asked to rate those items' degree of representativeness to which they are allocated. Although Hensley (1999) suggests the Q-sort technique especially for new scale development (not existing in the literature), considering the huge initial size of our item pool (3 constructs, 7 dimensions, 58 variables and 127 items) providing the definitions and labels can prevent 'smothering' the experts with an unmanageable task of item grouping, sorting and labelling.

Table 4.10. Popular measures of content validity with pros and cons

	Advantages	**Disadvantages**
Lawshe's Content Validity Ratio	Simple to calculate and evaluate individual items	Considers only the best scores and ignores mid-level evaluations. Provides a limited overall picture by just averaging CVRs of all items
Contingency Table	Visually helpful to observe agreements amongst pairs of judges Helps to see the overall distribution when pairwise tables are aggregated	Hard to present when there is a large number of constructs/dimensions. Fails to provide a single overall measure to enable comparisons unlike the following four ones.
The Percentage of agreement	Simple to calculate and interpret Reliable range between 1.0 and 0.0	Fails to detect any random agreement to occur by chance Ignores the influence of the number of coding categories
Cohen's Kappa (κ)	Includes the chance factor within the agreements Popular and widely applied	Takes the observed category frequencies as given Unreliable range (may not reach 1 even if there is perfect agreement) Overly conservative
Perreault & Leigh's reliability index (I_r)	Incorporates the number of categories	Considers pair-wise agreements of judges only
Proportional Reduction in Loss (PRL)	Generalises the reliability index computation to multiple agreements of judges	

Three, four and three judges were involved respectively in three rounds to check content validity of the items, respectively. They are asked to sort randomised questions to the relevant categories. In this and following rounds, the judges are selected to be quite familiar with the Make-To-Order field and Enterprise Resource Planning systems. The group mainly consists of academics and PhD students of

Operations Management particularly working on the MTO area, and an ERP consultant (Figure 4.11):

Round 0	**Round 1**	**Round 2**
Yuan Huang[1]	Prof. Sinan Kayaligil[2]	Asisst. Prof. Serdar Bakal[2]
Dr Mark Stevenson[1]	Assist. Prof. Sedef Meral[2]	Hurdogan Gunes[3]
Prof. Linda Hendry[1]	Assoc. Prof. Haldun Sural[2]	Asisst. Prof. Ferda Cetinkaya[4]
	Assoc. Prof. Tayyar Sen[2]	

[1] Lancaster University, Department of Management Science, UK; [2] Middle East Technical University, Industrial Engineering Department, Turkey; [3] ERP consultant and salesman, Turkey; [4] Çankaya University, Industrial Engineering Department, Turkey.

Figure 4.11. Expert Judges and their affiliation round by round

The first step above is called "Round 0" as the experts have already been familiar with the content of the study, but seen the full list of items to be tested their content validity. The form provided to these judges is given in Appendix 2. Particular to this round only, the item replacement technique is applied in a hierarchical approach. Namely, the judgements made at the *variable* level (e.g., A1: Due date setting) are aggregated to the corresponding *dimension* level (e.g., A: Customer enquiry management) for a particular construct. For example, when an item which is thought to belong to A2 is assigned to A1, for now this is considered as correctly assigned. The aim is to detect the most wrongly interpreted items, even diverging from its construct dimension. The aggregate item placement table for the dimension level of decision support requirements construct in Round 0 is shown below (Figure 4.12). Three judges have categorised 62 items for the decision support requirements construct in this instance. Therefore, the total number categorisations is three times the number of items, namely 186. The diagonal cells show the number of items matched correctly. Whereas, the off-diagonal cells show the number of items categorised by the judges as opposed what was thought by the researcher.

			ACTUAL CATEGORY									
			A	*B*	*C*	*D*	*E*	*F*	*G*	*X*	Actual Total	Hits
JUDGES' CATEGORY	*Customer Enquiry Management*	*A*	37	1	3				2	2	45	82%
	Design and Engineering	*B*	1	26		1				2	30	87%
	Order Entry	*C*	2	1	20		1			3	27	74%
	Order Review and Release	*D*		1		13				1	15	87%
	Dispatching	*E*					18				18	100%
	Managing Customer Relations	*F*						19		2	21	90%
	Supply Chain activities	*G*	2		2	1	1	1	22	1	30	73%
	Doesn't fit any category	*X*									**Sum:** 186	**Avg:** 85%

Figure 4.12. Item placement ratios for the dimensional level of decision support requirements construct at Round 0.

All judgments of three experts are aggregated into a single item replacement table in which judges' own categorisations are cross tabulated with the actual ones. This level was performed to find out the most wrongly categorised items. The table above is also a printed demonstration of the item replacement tabulation. Normally, it is not possible to exhibit it here at the variable level due to the number of variables used. Together with the examination of variable level judgments, 127 items in the beginning of Round 0 is reduced to 102 items in the end. The misunderstood items were either re-written or discarded assuring that the coverage of items in their constructs was not affected. Lawshe's CVR and Contingency tables were only used to make these decisions.

This hierarchical approach was not repeated in Round 1 and 2. Namely, all evaluations were only made in the detailed variable level. After each round, content validity measures were computed. The summary of all rounds are provided in the table below (Table 4.11).

Table 4.11. Overall content validity measures evaluated for each round.

	Round 0 (3 judges, 127 items)	**Round 1 (4 judges, 102 items)**	**Round 2 (3 judges, 89 items)**
The Percentage of agreement	75.3%	65.5%	76.0%
Cohen's Kappa (κ)	0.74	0.64	0.75
Perreault & Leigh's reliability index (I_r)	0.86	0.78	0.86
Proportional Reduction in Loss (PRL)	~0.97 ($\hat{p}$ = 0.74)	~0.91 $\hat{p}$ = 0.66)	~0.98 ($\hat{p}$ = 0.76)

At first sight, the drop in Round 1 can be observed. The indications are quite good in both Round 0 and 2. As aforementioned, one of the most important reasons to address content validity is to decrease the number of items sensibly so that the agreement among the judges should be high enough. Though the success in Round 0 seems to be repeated in Round 2 after a decline in Round 1, the number of questions is quite fewer in round three than one. While the number of questions is decreased, the indicators of content validity are slightly improved. The final value of each measure is well above the amount suggested in the literature (i.e., above 0.7 for Cohen's Kappa, above 0.8 for Reliability index and above 85 for PRL). If Round 0 results were lower than Round 1 results, the above table would show round-by-round gradual improvements. The main reason for that is the use of supervisors' and a similar topic PhD student's help in Round 0. Since they are the most familiar experts than everybody else with this study, they showed similar overall results to the final and presumably the most improved results. Of course, for each round different judges were used in order to let them evaluate the items without any prior knowledge, i.e. no learning effects.

Finally, the number of items has been decreased from 127 to 89 and variables from 58 to 46 in the end of content validity analyses. Three constructs and seven dimensions have been kept constant. Overall, Proportional Reduction in Loss and Perrault and Leigh's reliability index, being the most reliable and suitable ones for this study, together show a good level of validity to go for pilot study.

4.5 Collecting Data

This subsection provides the sampling approach, the techniques which have been applied to improve the response rate and to handle the non-respondents and associated bias for the full scale data collection. It also lays a background for the piloting test discussed in the next subsection (4.6).

The contact list for the piloted sample was a list of managers which were then enrolled to an executive programme held by the Manufacturing Institute in cooperation with Lancaster University Management School. The list for the full scale was procured from a business-to-business (B2B) contact information (i.e., name and position of the contact person, company email and postal addresses) provider company, called Info UK (www.infouk.com). In fact, there are several contact database providers. The one selected for this study was determined by searching through internet and forum pages, looking for advices to find the most reliable and recently updated one. All companies are included on the list only once represented by a single contact. Although Bowman & Ambrosini (1997) and Barnes (2001) find single-respondent research "unreliable", and "doubtful" to provide a rich data set; this rather reduces "efficiency". In fact, due to the low quality of the commercially available company contact databases (discussed in detail on handling non-respondents) is the actual constraint, which provides single respondent per organisation only, the efficiency further reduces regarding the effort for accessing other contacts. Considering the total effort and energy available during the data collection stage, this has been rather spent to increase the response rate.

The questionnaire is provided in Appendix 3.

4.5.1 Sampling

The sampling frame of this study consists of the manufacturing companies in the UK. Although the research is particularly focused on ERP-using MTO companies, no restrictions to the sample have been considered to enable comparisons with other segments (i.e., non-adopters, and MTS companies). UK companies in all industries of the manufacturing sector (except food) have been included. Food manufacturers are excluded for two reasons. Firstly, they are potentially far from being MTO manufacturers so that it would not be possible to compare them among themselves (e.g., small number of MTO food manufacturers against large number of MTS food manufacturers while considering their use of ERP). Secondly, whilst searching for company contact databases we noticed that the number of food manufacturers dominates the other industries of the manufacturing sector in the UK. Though a small number of these contacts could have been added to the sample, there was still a probability that they can unnecessarily dominate the responses.

4.5.2 Response Rate

Obviously, a low response rate increases the bias of the results. Many reviews of survey research suggest various levels of response rate as 'good enough' to use for analysis. Malhotra & Grover (1998) define response rates under 20% as undesirable by referring Yu & Cooper (1983). However, co-citation and historical analyses of surveying (e.g., Rungtusanatham *et al.*, 2003; Roth, 2007; Roth *et al.*, 2007; Taylor & Taylor, 2009) have shown that this empirical research method has exponentially been popular since 1980s in the field of OM. This has also caused the practitioners to be 'bombarded' by questionnaires directly related to this growth, which decreased the response rates in general. Since the mid of 1990s, mail surveys with response rates over 30% are the exception and not the rule (Alreck & Settle, 1995). Alreck & Settle (1995), therefore, state that large-scale survey response rates are often only about 5–10%. Similar results are observed in the studies which are the key to this study's aims (e.g., Mabert *et al.*, 2000, 9.6%; Stratman, 2001, 12.5%) while some successful examples were also observed (e.g., Olhager & Selldin, 2003, 37.2%). All share the common points that they are ERP surveys targeted at industrial respondents.

Techniques used to improve response rate have been reported for several disciplines which extensively utilise surveying method (e.g., sociology, marketing and management). The following points are compiled from several relevant studies in the literature (Kanuk & Berenson, 1975; Yu & Cooper, 1983; Jobber, 1986; Roth & BeVier, 1998; Greer *et al.*, 2000; Frohlich, 2002). These studies have conducted experiments on the use of these techniques (e.g., with control groups and statistically testing the differences), done meta-analyses (analysis of analyses) of previous studies to carry out their own, and conducted a survey on surveys to study business respondents' perspectives of mail surveys:

Monetary incentives: The reviews above show that studies offering monetary incentives to potential respondents have had superior impact on responses against the ones having no such an incentive. Pre-paid and promised monetary incentives are two ways. Either the interviewer pays (or the questionnaire letter contains) some certain amount to the respondent; or it could be paid after the questionnaire is filled (straight away as in the pre-paid case, or after a prize draw). In conclusion, meta-analyses of those studies suggest that either prepaid or promised monetary incentives can be associated with markedly higher response rates.

Non-monetary incentives: They are offerings which include a premium or reward having no direct monetary value. Small nonmonetary gifts, survey reports, offering further promises for collaboration are some examples. Gifts appear to increase response among respondents, but the impact is not as effective as the monetary incentives. It is also suggested that enclosed incentives work much better than promises for non-monetary incentives. Finally, offering free survey reports does not appear to increase response rates, and in one review paper it was shown to have even a negative but non-significant impact on response rates.

Anonymity: This issue have been conflictingly reported in the literature. While some studies (Kanuk & Berenson, 1975; Yu & Cooper, 1983) and related references state that "the promise of anonymity to respondents has no significant effect on response rates" (Kanuk & Berenson, 1975), others claim that "granting both anonymity and confidentiality increased response still further" (Yu & Cooper, 1983).

Questionnaire length: Though all reviews have found no significant relationship between questionnaire length and response rate, the length of a questionnaire is commonly believed to reduce response rates. Dillman (2007) recommends that mailed surveys be limited to no more than four pages. Jobber (1986) states that a potential industrial respondent may be much more sensitive to the length of the questionnaire (and the time it takes to complete it) than a member of the general public completing it at home. This was also observed when piloted respondednts were further contactted and asked what they have thought about the length. Their general insight promotes the shorter as the more appealing.

Visuality of the questionnaire: Few studies have examined the effects of colour, reproduction, and questionnaire size (dimensions of paper) and found no significant differences in response rates. The proposition quoted in support of using coloured questionnaire is that such a questionnaire will look more professional on a businessman's desk than white paper, but controlled tests denies such an idea.

Type of postage: Several types of postage have been compared including the number of stamps on the envelope, first vs second class, etc. The most common hypothesis that has been tested is whether a stamped return envelope leads to a higher response than a business reply (only incur a cost if used) or a non-stamped return envelope. Although there is evidence to suggest that a return envelope with no stamp is equally as effective as one with a stamp for presidents of large corporations; stamped return envelope does encourage response because it facilitates questionnaire return and it even results in higher returns than business reply envelopes.

Advance notice: According to several studies testing the effectiveness of preliminary notice, higher response rates are associated with sending advance notice to respondents. It is reported to increase responses even better if the initial contact is brief and the purpose is made clear. To sum up, the literature agrees that advance notice is important especially when the respondent's perceived relevance in the study is low.

Follow-ups: Higher response rates are also associated with follow-up reminders to respond. It is strictly advised that up to three waves of reminders should be used. It is described as "the most potent technique yet discovered for increasing the response rate" (Scott, 1961). It is also suggested that advance notice and follow-ups are somewhat interchangeable; therefore, the advance notice should be counted as one follow-up.

Deadlines: Jobber (1986) reviewed four studies having demonstrated that no significant increase may be expected by using deadlines. Literature agrees that stating deadlines do not cause any significant increase in the response rate. On the other hand, Kanuk & Berenson (1975) suggest that it may help to accelerate the rate of questionnaire return.

Personalisation: Personalised cover letter and/or address of mail surveys has been associated with higher response rates. While some studies suggest that the various methods of personalised surveys are associated with response rates four to nine percentage points over control groups, some show no significant difference with "Dear Sir/Madam" salutation on the cover letter. However, except a few studies the conclusion is that personalisation has no clearcut advantage in terms of improved response rates. For example, neither personal inside addresses nor individually signed cover letters significantly increased response rates; personally typed cover letters proved to be somewhat effective in most cases cited, but not in all.

Salience (Interestingness): Salience was defined as "a topic that dealt with an important issue that was also current or timely" (Roth & BeVier, 1998). Survey on surveys by Greer *et al.* (2000) has shown that the most important inducement factor was firstly ranked as the research content by business respondents. All other reviews agree that it significantly affects the response rate when the subject is interesting or timely beneficial to the respondent.

University sponsorship: Official or "respected" sponsorship tends to increase response (Kanuk & Berenson, 1975). University sponsorship is also acknowledged to promote the credibility of a survey study. This point was also made as the second most important inducement factor for business respondents (Greer *et al.*, 2000).

Day of the week received: As one of the unique methods tested, Greer *et al.* (2000) identified Monday to Wednesday as the "early week", and Thursday to Friday as the "later week". The results of the effect of day of the week suggest that day of the week the respondent receives the questionnaire has no impact on response willingness. However, the authors believed that when questionnaires arrive during the early week, recipients should be more willing to respond since there is still 'enough' time left to complete the questionnaires before the end of the week.

Here, this paragraph summarises the overall effort in this study to improve the response rate. Two prize draws were announced on the cover letter as 'promised' *monetary incentives*: one £100 shopping voucher for the pilot sample and one £500 shopping voucher for the full-scale send out. An executive summary report was also offered as a *non-monetary incentive* to the respondents who would be interested to get. *Anonymity* and confidentiality was assured. The *questionnaire* was 9 pages long colour printed on double sided A4 papers, and posted *second class* together with a second class stamped return envelope inside an A4 size envelope (unfolded). A *visually attractive* questionnaire design was intended to be reader friendly as much as possible (e.g., introduction, descriptions, signposts, figures, section breaks). Neither an *advance notice* nor a *follow*-up could be made by posts since that would substantially increase the cost given the research budget. Instead, one advance notice and three follow-ups were sent by email to the sample portion whose generic company email addresses were available (i.e., 1088 out of 1634). The number of returns from postal questionnaires was far superior to online responses in the full-scale collection (78 vs. 26). No *deadline* was determined to return the completed questionnaire back. Labels of the postal envelopes (e.g., name, surname and postal address) and cover letter of the email reminders (e.g., greeting) were *personalised*. *University* and M*anagement School's name* and *logo* were used on the envelopes and questionnaires. Postal questionnaires were sent on the early days (Monday and Tuesday) of a week by 2nd class. Email follow-ups were sent out both early and late days of following weeks.

For the bounced replies (e-mail that is returned to the sender as undelivered for some reason; around 300 emails in this case), their email addresses and names corresponding to the company position were updated. Their survey invitations were resent separately.

The number of all attempted contacts is 1684. To test the database reliability, randomly selected hundred respondents' details were re-collected manually through internet search and 38% were found not to match with the contact details in the purchased contact database. Similarly, Stock *et al.* (2000) claim an 'effective' response rate after they found that around 50% of the contact names from the mailing list were not valid respondents. Applying the same approach leaves approximately 1,044 contacts whom we hope they have received the posts onto their desks. Considering 111 responses in total, this effectively makes a 10.6% response rate for the full scale data collection.

4.5.3 Handling non-respondent and non-respondent bias

Non-respondents should be (at least partially) identified to avoid any bias which may occur if the respondents cannot represent the surveyed sample (Lambert & Harrington, 1990). The reality of non-response bias on results can be checked by identifying the non-respondents to see whether they are different from the respondents. These can be company characteristics (such as company size, location and industrial sector) or research-related information (e.g., ERP use, production strategy).

This can be done in two ways:

1. Insisting on surveying at least a randomised sample of non-respondents (e.g., by phoning). If applying the full-questionnaire would not be possible, then a condensed questionnaire could be used to get some results help the researcher compare with respondents'.
2. Testing differences between first wave results and late returns. This method puts forward the idea that the people, who eventually decided to reply lately, could have stayed as non-respondents but they are somehow convinced by reminders, or other techniques applied (Armstrong & Overton, 1977).

The former way was not possible due to the length of the questionnaire. To test for non-response bias using the latter technique, the data were split into two groups, where the surveys received sooner (the first wave) represented the non-respondents and those received later (all the remainder) represented the respondents. The responses to eight questions are selected for statistical comparisons. These are questions about company size (number of employees and sales turnover), production strategy (MTS vs. MTO), 'typical' routing on the shop floor, supply chain position, industrial sectors, ERP efforts (user, installer, nonuser, etc.), and adopted ERP modules among users.

Firstly, t-tests were conducted to compare two groups (for $\alpha = 0.05$). The results on the left hand side of Table 4.12 shows the (parametric) t-test results for the first six questions. Since the hypotheses are tested to see whether the mean differences are zero or not (i.e., H_0: $\mu = 0$, H_a: $\mu \neq 0$), two-tailed *t* statistics and *p*-values should be considered. To see the indifference between the means of two samples, two-tailed *p*-values should be larger than 0.05 (i.e., the α value). Yet, before going for t-tests equal variances assumption should be verified. Therefore, F-tests have been conducted to see whether variances are equal or not. Only F-test for the number of employees showed that the variances of on time and late return results are significantly different, so t-test assuming unequal variances was applied. For the remaining five, the variances were found to be equal, so t-tests assuming equal variances were applied. The *p*-values for all results are larger than 0.05. This means there is no significant difference between on time and late return results in terms of question means.

Table 4.12. Parametric and nonparametric tests for group comparison

	Parametric test		Nonparametric test		
	p-value (t-Test[1])	*p*-value (F-Test[2])	Chi-Square	df	Asym. Sig.
Number of employees	0.45	0.01	5.48	5	.360
Sales Turnover	0.12	0.05	7.38	5	.194
Production strategy	0.10	0.27	2.27	5	.811
Shop Floor Routing	0.12	0.24	4.85	4	.303
Supply Chain position	0.23	0.13	4.32	4	.364
ERP efforts	0.34	0.51	4.17	4	.383
Industrial Sector	-	-	8.25	10	.604
Adopted ERP Modules	-	-	7.32	10	.695

[1]Two-Sample Assuming Unequal Variances, [2]F-Test Two-Sample for Variances

Industrial sectors and ERP modules are compared by column charts (Figure 4.13 and Figure 4.14). The very same observation can also be made via stem-leaf charts.

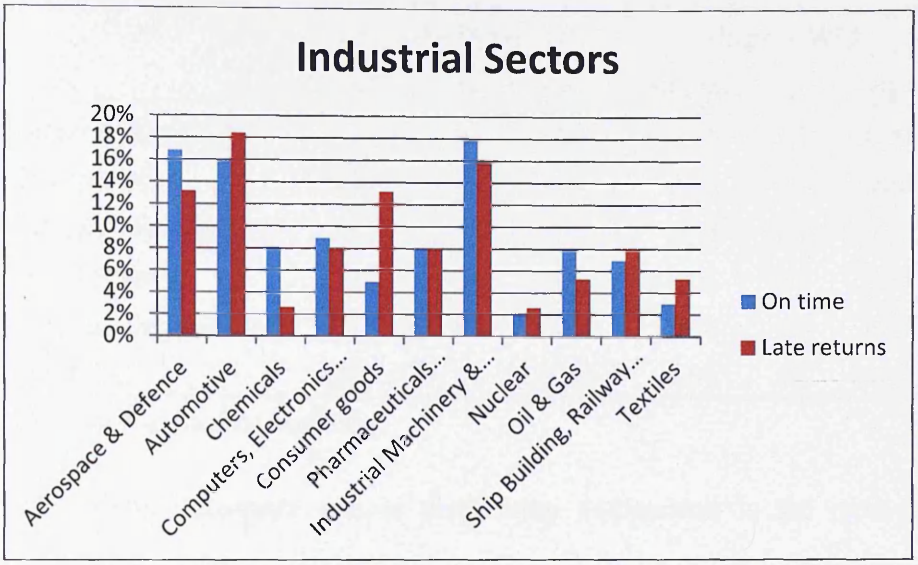


Figure 4.13. Distribution of industrial sectors for on time and late return results

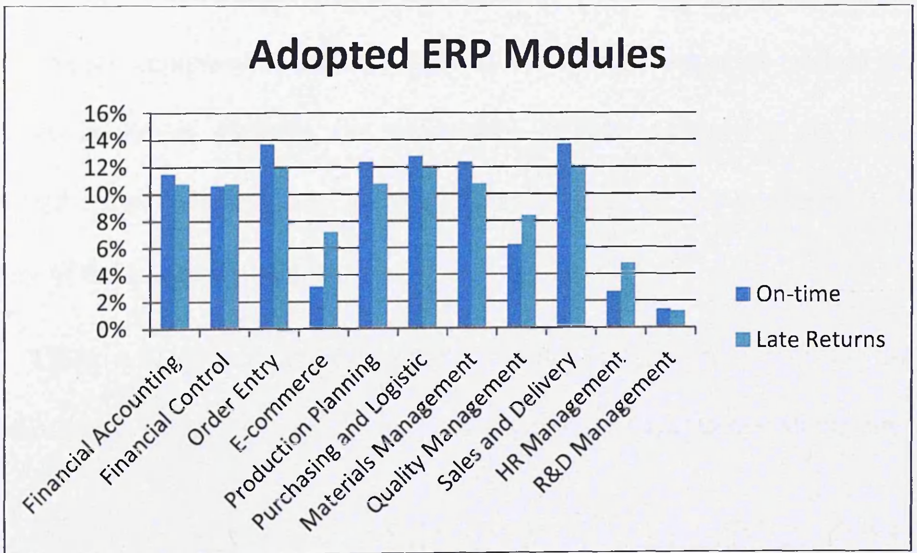


Figure 4.14. Distribution of modules (amongst users) for on time & late return results

T-tests have shown that no non-response bias has been observed. However, normality as the basic and the most important assumption is observed to be violated via normality tests applied to both on time and late return results (Table 4.13). Both normality tests of Kolmogorov-Smirnov and Shapiro-Wilk (which is more reliable, and therefore used when size of the sample is less than 50) show that data are not normally distributed.

Table 4.13. Tests of normality for on time and late return results

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Number of Employees	.257	64	.000	.786	64	.000
Sales Turnover	.285	64	.000	.838	64	.000
Production strategy	.192	64	.000	.923	64	.001
Typical Routing	.233	64	.000	.866	64	.000
Supply Chain position	.289	64	.000	.808	64	.000
ERP efforts	.322	64	.000	.696	64	.000

[a]. Lilliefors Significance Correction

Therefore, chi-square sample distribution comparison is the most proper solution to test the indifference of two groups of data when non-normal data needs to be considered. In this nonparametric goodness-of-fit test, the observed and expected frequencies are compared in each category to test that all categories contain the same proportion of values. Namely, the proportions of each category of on time return results are tested whether they are significantly equal to the proportions of each category of the late return results.

Table 4.12 above also shows that on time and late return results for each question do not differ significantly since all asymptotic significance values are above 0.05.

To conclude, regardless of the fact that the data is not normally distributed the significance of indifference between means of two groups of data tell that there was no non-response bias in the data.

4.6 Pilot testing the questionnaire

Piloting aims to let the researcher experience applying a survey questionnaire to a small-scale sample before embarking upon any full-scale. While some authors pilot to purify measures as doing a field-based pre-testing, others prefer to pilot a "ready-to-send" questionnaire (Churchill, 1979; Malhotra & Grover, 1998; Forza, 2002; Menor

& Roth, 2007). To explain the latter explicitly, finalised questionnaires are sent to a small sample of target audience to experience administration procedures, to think about sampling and non-respondent handling issues, and to conduct preliminary analysis of measures. Forza (2009) reports the lack of such efforts in the field of operations management.

In this pilot study, the finalised questionnaire was sent to a small sample of potential respondents to experience the points in the latter technique mentioned above. The following sections provide discussions regarding this experience. The first subsection (4.6.34.6.24.6.1) provides preliminary descriptive analyses for each individual question, and cross tabulated question pairs of the most relevance. The second subsection (4.6.2) reflects the administration experience gained at the pilot stage, and the third subsection (4.6.1) discusses the sampling and non-respondent handling topics.

4.6.1 Sampling ideas

Sampling issue has not been seriously considered in the pilot study since companies from an up-to-date existing list were contacted in the first place. Therefore, no sampling strata were identified in advance. To be more careful in the full-scale surveying, some important stratification types are identified. They are *company size*, *industry/sector*, *manufacturing strategy* (e.g., MTO or MTS) and *the use of ERP* (user/nonuser). Regarding the business contact information databases available, the only controllable strata are company size, industry/sector and position of the respondent. Unfortunately, it is not possible to know the status of ERP efforts and manufacturing strategy of the companies in advance unless a complete enumeration to be made after accessing the database.

There are some crucial points desired to be accomplished through this survey by the help of stratification. The major aim is to understand the effectiveness of ERP systems used by the MTO SMEs. For sound results, comparisons with the opposite cases are obviously necessary. Therefore, it is sought to compare the need for a decision support system, intensity of its use and production performance between ERP users and nonusers, MTO and non-MTOs, and SMEs and large organizations. Industry types are also important but still not absolutely critical when the potential respondents contribute the manufacturing sector as a general rule in the economy.

To be more confident about the sampling, the listed companies can be searched online or phoned to learn more about their ERP adoption statuses and manufacturing strategies. In fact, it neither practical nor feasible in such a small-scale research to do this for the full scale survey with a couple of thousand companies. Following that a sampling frame can be constructed.

4.6.2 Administration

In the pilot test, randomly selected four respondents who have left contact details were called back to get feedback about the clarity of instructions and questions, the length of the questionnaire, and administration of the survey. The general impression of them about the clarity of the text was good. Namely, they told that they have not had particular problems in understanding the instructions and the questions nor found them in too much jargon. However, they found the questionnaire a bit too long while only one respondent disagreed with that. Regarding the administration, the respondents told that if they received such a questionnaire from an unknown source, they would show more willingness to participate by post rather than email. Although the pilot questionnaire was sent only via an email list, the full scale study is going to be sent via both email and post (i.e., a printed questionnaire with the web-based link provided in the introduction, if the respondent prefers so).

One of the advantages of web-based surveying is the availability continuous tracking for individual responses such as completion date, time spent, and if incomplete, the place where respondent dropped the survey. The non-respondents who opted out the survey mostly dropped it after reading the cover page (7 out of 13). There can be several reasons to drop the survey at this stage other than finding it uninteresting. For example, five out of the remaining six respondents, who have started the survey, dropped it at least at the start of the explanatory part. This is most probably due to the length of the survey. However, despite this fact the response rate in the pilot study is at quite a good level, 19 duly completed out of 37 sent questionnaires (51%). Regarding the sample size, Forza (2009) exemplifies the number of responses as 15 being probably enough for an exploratory observation of measurement, and a piece of administration experience through the pilot study. Regarding the high response rate, the main reason is that the piloted sample was a list of managers which were then enrolled to an executive programme held by the Manufacturing Institute in cooperation with Lancaster University Management School.

Majority of the respondents have somehow been interested in ERP systems (i.e., users and installers). However, in the first-time emailing of the questionnaire to 37 potential respondents in total, only 4 responses were available until the first reminder. First reminder has helped to add 9 more responses. After the second (final) reminder 4 new complete questionnaires have been received. The reason for this dramatic increase after the first reminder is probably the uncertainty of the incentive which was not explicitly mentioned in the cover letter of the first post. It was mentioned as the prize but not pronounced as a certain amount. In the follow-ups, the prize was made certain and flexible to the respondent (i.e., a voucher for the super store of their choice). By this way, the importance of incentive outperformed relevance of the survey topic to the respondent. Obviously, some other factors might have affected that situation as well; for example, previously busy managers having found sparing time after the reminders, or reminders might have been made them think about the seriousness of the study.

4.6.3 Preliminary analysis

25 responses have been collected in the pilot study; however, six of them have opted out of filling the questionnaire completely. Therefore, 19 complete and 6 incomplete responses are available to do some preliminary analyses.

Preliminary analysis of measures through descriptive statistics can let the researcher notice unexpected results and warn against any points which may need purification. The following table (Table 4.14) section goes item by item through the exploratory part of the questionnaire and touches the points which may need any change for the ease of analysis or answering.

There are not any particular problems with the answers of explanatory part when it is cumulatively evaluated. A detailed assessment of the content has already been made, analysed and provided in the previous subsection. While checking the individual responses, few respondents were identified who constantly evaluated the same response (e.g., strongly agree [1] or strongly disagree [7]) to the items within a particular section. Even in a single example, the respondent has strongly disagreed with all the measures of ERP performance but he or she also disagreed with the reversed questions (they should have been reversely evaluated to be consistent) of the same section. Possible actions are advised by Tsikriktsis (2005) such as consulting the

Table 4.14. Preliminary Analysis results for the exploratory part

Question	Preliminary Analyses and Amendments
Q1. Company position	*Retained* as it is. Open-ended style collected 20 different positions out of 25 responses from managers.
Q2 & Q3. Company size (the number of employees and last year's turnover)	*Scales increased* from three choices to six, since results of both were skewed piled up at the final choices. Crosstabulation of the two measures shows a highly significant correlation (χ^2=20.64, df = 6, p = 0.002). Thus, both can be thought as company size measures individually.
Q4. Production strategy	*Retained* as it is. The production strategies were almost evenly distributed. Its crosstabulation with Job routing results (Q7) confirms the relationship between production strategy and shop floor configuration (χ^2=27.44, df = 15, p = 0.025).
Q5. Product Lifecycle	*Discarded.* Difficulty in the understanding of the question was observed as the distribution of the results do not show any similarity with the type of products that companies produce. Normally, one expects a MTO (especially, an ETO) company to have products with short lifecycles which was not the case in most of the responses.
Q6. Industrial sector	*Options rephrased* and *new options added.* The responses are found to be matching with options in UK Standard Industrial Classification identified by UK Office for National Statistics (UK ONS, 2007)
Q7. Job routing	*Retained* as it is. "Not applicable" option was selected in neither of the responses. Yet, this option is still retained for companies who do not actively manufacture but manage subcontracting projects.
Q8. Supply chain position	*Retained* as it is. More than half of the sampled companies serve as OEMs within their supply chains.
Q9. ERP Efforts	*Retained* as it is. This is a critical question which leads the respondent to the relevant branch in the questionnaire. 80% of the respondents are ERP using or implementing comp (salience effect).
Q10. Implementation time period	*Retained* as it is. Well-scaled in terms of the interval lengths consistent with survey studies conducted by Mabert *et al.* (2000) and Olhager & Selldin (2003) on the use of ERP.
Q11 & Q12. Implementation strategy	*Q11 retained* as it is. Dominated by "single package" option. *Q12 discarded.* Unable to provide a good discussion and found inappropriate to analyse in this form
Q13 & Q14. Supported business processes and extensions	*Retained* as they are. Consistent distributions of adoption popularity with the literature (Mabert *et al.*, 2000; Olhager & Selldin, 2003).
Q15. Vendors Preferred	*New vendors added.* SAP was the leading brand (9 out of 18 users). However, remaining 7 predetermined vendors were not ticked but noted down in the "other" box. *Sage, Microsoft Dynamics (Navision), JDA (Western Data Systems)* and *IFS* are added to the predetermined list and others except SAP, Oracle, Exel and Avanté are taken out.
Q16. Reasons to adopt	Only *one new reason added.* "Increased Workload/Business" noted by a respondent, worthwhile to include.
Q17. Reasons not to adopt	*Retained* as it is.
Q18 & Q19. Used and abandoned	*Retained* as it is. No responses received here, but can still be of use in the full-scale study and analysed likewise in Q16 and Q17.

respondent back again for correction, estimating or imputing the answer to resolve the error, dropping that particular question or dropping the entire response. In this case, the possible answer to the reverse case can be estimated as the respondent tended to evaluate the ERP's effect on the company performance with strong disagreement. Besides, any items asked in 'reversed' mode were re-written as consistent with the other related items.

4.7 Assessing Measurement Quality

The quality of a measurement determines the quality of the process of linking abstract concepts to empirical indicators. Given its importance, the question arises as to how a researcher can determine the extent to which an empirical indicator represents a given theoretical concept; this gap is called measurement error.

In survey-based research, *measurement error* is one of the major sources of error (Biemer *et al.*, 1991; Malhotra & Grover, 1998). Therefore, it should be kept at the lowest level and assessed regarding its reliability and validity by using several techniques. The remainder of this report defines, exemplifies and applies these techniques under the sections of Unidimensionality (4.7.1), Reliability (4.7.2), Convergent Validity (4.7.3), Discriminant Validity (4.7.4) and Criterion-related Validity (4.7.5), respectively.

Only Section B (items on Decision Support Requirements) and Section D (items on Performance measures) were assessed for measurement of reliability and validity. Section A of the questionnaire is composed of questions which have been widely used by OM researchers; therefore, validated and reported several times before in the literature (e.g., Mabert *et al.*, 2000; Stratman, 2001; Mabert *et al.*, 2003; Olhager & Selldin, 2003). These questions were also designed to get demographical and background information from the respondents and do not belong to the actual theoretical framework but acts as a complementary set of questions. Besides, Section C consists of questions regarding the intensity of use of ERP system and its extensions (i.e., add-ons) by the respondents. The constructs in Section C are mostly not multivariate and corresponding single variables are mostly not multi-item. Therefore, the validity and reliability analyses in the following sections are performed on Section B and Section D.

The sequential logic of these assessments is described as follows:

(1) *Unidimensionality* of a scale has to be checked before its reliability is examined (Anderson & Gerbing, 1991; Ahire & Devaraj, 2001; Stratman & Roth, 2002; Forza, 2009). This is because most well-known methods of reliability estimation assume that the items already form a unidimensional set (Gerbing & Anderson, 1988);

(2) Then, *Reliability* procedures are applied to test the repeatability of measurements (Carmines & Zeller, 1979);

(3) Thirdly, as a part of construct validity *Convergent validity* is assessed to test the degree to which multiple attempts to measure the same concept are in agreement (Campbell & Fiske, 1959; Bagozzi *et al.*, 1991);

(4) Fourthly, *Discriminant validity* is assessed to test the degree to which measures of different concepts are distinct (Bagozzi & Phillips, 1982). The notion is that if two or more concepts are unique, then valid measures of each should not correlate too highly (Bagozzi *et al.*, 1991); and,

(5) Finally, *Criterion-related validity* is assessed to measure how well scales representing various decision support requirements are related to measures of performance (Flynn *et al.*, 1994)

4.7.1 Unidimensionality

The term unidimensionality is used to denote the fact that only a single 'characteristic' is involved in responses to certain construct (or dimension) items. Namely, at the stage of testing unidimensionality the aim here is to test the consistency amongst the items grouped under their construct. On the other hand, nothing needs to be said about the nature of that characteristic. The only aim is to have every set of items to measure a single construct. Firstly, the available techniques are described. Then, the approach taken in this study is provided. Finally, the subsections provide their applications to this study.

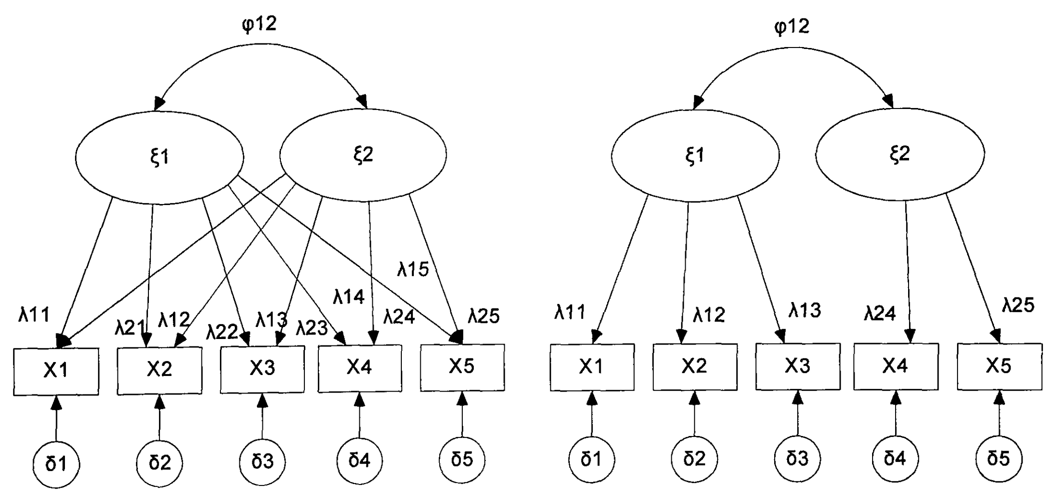
Exploratory Factor Analysis (EFA) method has been commonly recommended and used for testing unidimensionality in several disciplines (e.g., management by Schwab, 1980) and also operations management (e.g., Saraph *et al.*, 1989; Flynn *et al.*, 1994). EFA, also called *Principal Components Analysis*, is used on the entire measurement instrument to extract factors or constructs according to item-factor loadings with no *a priori* specification of items that belong to constructs (Ahire *et al.*, 1996).

As the other common method, the prevalence of Structural Equation Modelling (SEM) technique and advances in its applications reinforced the view about *Confirmatory Factor Analysis* (CFA) method's suitability to test construct validity in general (Malhotra & Grover, 1998). CFA has gained reputation, especially in validity analysis, in the last decade of theory driven survey research (Rungtusanatham *et al.*, 2003). Referring to Gerbing & Anderson (1988) and Jöreskog (1993), Malhotra & Grover (1998) developed a list of 17 ideal survey research attributes and mentioned CFA as relatively new technique. They also applied these 17 attributes to evaluate 25 survey-based OM papers from four journals between 1990 and 1995. They found no studies using confirmatory methods for measurement models, which led them to suggest the need for using CFA for a better theory driven survey research. Rungtusanatham *et al.*(2003), building upon the study of ideal survey attributes by Malhotra & Grover (1998), analysed the survey research in OM historically published in six journals between 1980 and 2000. However, they did not report the intensity of use of CFA but only the rate of validity assessment as 46%. Yet, the highly intensive use of CFA in survey-based research can be observed in OM-related journals (for example, JOM) especially after year 2000 (e.g., Menor & Roth, 2007; Sila, 2007; Bozarth *et al.*, 2009).

In Confirmatory Factor Analysis, each item is specified to load only on one variable, measurement error terms are specified to be uncorrelated with each other, and all variables are allowed to correlate with each other. Goodness-of-fit measures (such as CFI and NFI, related chi-squared estimates and p-values, and factor loadings) are obtained as the result of the analysis to interpret the model's level of fit with the data. Besides, the impact of items on the conceptual variable, namely factor loading of observed indicators on latent variables are obtained. If goodness-of-fit measures for the measurement model are acceptable, the researcher concludes that the indicators adequately measure the intended variables. The indicators showing low factor loadings are eliminated to form more reliable variables having indicators which can explain their latent variable better.

O'Leary-Kelly & Vokurka (1998) state one difference between EFA and CFA as "under EFA, the associations between empirical indicators and latent variables are not pre-specified, whereas in CFA the associations are specified."

The most effective way of explaining the main difference is through a diagrammatic representation of a general EFA model and CFA model. In Figure 4.15, the ξ's are termed *common* factors, reflecting the fact that their common effects are shared across all the empirical indicators (X's) to varying degrees. The common factors (ξ's) correspond to the latent variables and are a linear combination of all the empirical indicators included in the analysis (Hair *et al.*, 1998). Figure 4.15.a has two latent variables (ξ_1 and ξ_2), each comprised of a linear combination of the five empirical indicators (X_1 to X_5). The λ_{ij}'s in the model represent *factor loadings*, the correlation between the *j*th latent variable and the *i*th empirical indicator. The δ's are termed *unique* factors (or errors) and characterize the variance that is unique to each empirical indicator. The unique variance is comprised of both random and specific measurement error which is not shared by the other empirical indicators.



a) Exploratory Factor Analysis Approach b) Confirmatory Factor Analysis Approach

Figure 4.15. Diagrammatical presentation of Exploratory & Confirmatory FA

Finally, the double-headed curve between the two latent variables represents the correlation (φ_{12}) between latent variables. With regard to allowing the latent variables to freely correlate, EFA considers all or nothing. That is, with some EFA techniques, the latent variables are not permitted to correlate (orthogonal techniques such as the most popular called *Varimax*), whereas with others, all variables are free to correlate (oblique techniques such as the most popular called *Direct Oblimin*) (Bollen, 1989). Normally, two latent variables are allowed to correlate (like in the orthogonal case) if the researcher considers two as uncorrelated.

Referring to Figure 4.15.b above, CFA is accomplished by restricting the empirical indicators to load on specific latent variables (ξ's) and to designate which latent variables are allowed to correlate.

In this study, both factor analysis approaches are utilised such that EFA is followed by a CFA to test unidimensionality. The reason for using both approaches is that this study is not about a completely unknown subject to be explored and, the instrument is not merely an unstructured list of questions. However, a theoretical basis has already been demonstrated for why certain empirical indicators should be associated with specific variables, making CFA appropriate for this study. The reason for using two factor analysis approaches is that EFA enables the researcher to easily identify the indicators to be eliminated while testing the conceptually anticipated model through CFA. Thus, CFA which presents certain advantages over the traditional EFA (O'Leary-Kelly & J. Vokurka, 1998) is the actual method applied to assess unidimensionality.

Methodologically, indicators showing low factor loadings in a CFA model are recommended to be dropped (Anderson & Gerbing, 1991; Forza, 2009). However, this does not always improve model fit. The alternative approach used here was empirically tested and found to be more effective than applying CFA on its own (Ahire & Devaraj, 2001). Since EFA results (Table 4.15 to 4.18) are not directly used to eliminate items but to assist the CFA test to achieve levels of adequate goodness-of-fit; no threshold or dropping criteria is determined for EFA. In the CFA models, on the other hand, the item dropping criteria is the level of Goodness-of-Fit (GF). The GF measures (e.g., comparative fit index - CFI) used and the levels sought (e.g., above 0.90 for CFI) are explained in detail in the subsection where unidimensionality is tested using confirmatory factor analysis. To illustrate, the procedure is as follows:

- EFA test helps detect items which may not belong to its dimension or variable. Note that this is only used to observe these odd items. This EFA test is applied in two levels for Section B and D of the questionnaire:
    - Firstly, as a whole to observe the splits among different dimensions (e.g., CEM, Design & Engineering, and so on);
    - Secondly, at the individual dimension level (e.g., by providing only the CEM items) to observe the 'natural' splits among different variables (e.g., due date setting, pricing and so on).
- Then, CFA test is applied for each dimension (e.g., CEM, B1 in Appendix 4). If the goodness-of-fit measures are found below the adequate level (e.g., below 0.90 for CFI), the item which has been found in contradiction with its variable in the EFA results is dropped. When there is more than one (or no) such item, the one with the lowest loading is dropped.
- Thereafter, CFA test is re-applied with the new reduced model to see the change in the level of adequacy. This continues until the adequate goodness-of-fit level is reached.

The procedure above is explained step-by-step in detail in the following subsections. SPSS Statistics 17.0 software is used to perform EFA test. On the other hand, more user-friendly and reliable statistical software focused on Structural Equation Modelling (SEM) is preferred to perform CFA. It is an SPSS add-on called AMOS version 17.0. Other software used for this purpose is called LISREL (the first software of this kind developed by SEM pioneers K.G. Jöreskog and D. Sörbom) and PROC CALIS routine of SAS statistics software.

Unidimensionality test using Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) is performed as the first step of unidimensionality test in order to assist the actual Confirmatory Factor Analysis (CFA). As briefly discussed above, EFA is useful in gaining preliminary insights into theoretical framework structures based on loading patterns of observed indicators to determine the potential components (or factors) within the given set of items. The reason for using CFA, to finalise the unidimensionality analysis, is due to the inability of EFA to specify associations of indicator items to specific constructs which makes it increasingly inappropriate for construct validation. Therefore, CFA, which allows such specifications and allows the researcher to confirm the validity of the resulting model of relationships between indicator items and constructs, is more appropriate (Ahire & Devaraj, 2001).

Table 4.15 shows the varimax rotated EFA results for Section B as a whole. This table is prepared by inputting only the data from Section B and using Dimension Reduction function of SPSS 17.0. Though no prior dimension and variable structure is provided to the software, EFA result recommends it to divide into five components almost in harmony to existing structure of this study.

The items in red (B1.8, B5.2 and B5.3) show the contradicting ones, which are categorised by EFA in theoretically mismatching constructs. Thus, 29 out of 32 items are categorised consistent with the theoretical framework through Exploratory Factor analysis for Section B.

Table 4.15. Exploratory Factor Analysis (Varimax rot.) results with for Section B

B	Component				
	1	2	3	4	5
B2.5	.820	.226	.136	.060	.093
B2.4	.770	.188	.192	.114	.116
B2.3	.705	.371	.017	.123	.174
B2.1	.618	.442	.160	.342	-.010
B2.2	.609	.463	.038	.252	.031
B2.7	.577	.250	-.093	.291	.198
B2.6	.551	.175	-.065	.243	.366
B1.4	.243	.789	.016	.005	.235
B1.1	.336	.663	.109	-.082	.030
B1.9	.059	.612	.106	.142	.251
B1.6	.227	.603	.073	.460	-.063
B1.2	.443	.583	.058	.294	-.067
B1.5	.245	.583	.155	.336	.132
B1.3	.265	.577	.142	.296	.001
B1.10	.468	.575	-.054	.080	.201
B1.7	.060	.401	.273	.394	.141
B4.2	-.008	-.041	.888	-.001	.047
B4.4	.041	-.027	.851	-.007	.015
B4.3	.042	.066	.787	.181	-.111
B5.3	.240	.223	.687	.072	.181
B4.1	.014	.045	.584	.169	.357
B5.2	-.002	.306	.550	-.002	.124
B3.3	.038	.228	.057	.671	.152
B3.1	-.004	.260	.209	.668	.070
B3.5	.293	-.055	.018	.551	.003
B3.2	.215	.154	-.014	.550	-.022
B3.4	.443	-.057	.038	.470	.290
B5.4	.016	.154	.197	.140	.663
B5.5	.509	.049	.059	.012	.656
B1.8	-.165	.489	.052	.223	.574
B5.6	.380	.007	-.032	.055	.564
B5.1	.308	.185	.227	-.116	.558

B1.1–B1.10 = Customer Enquiry Management Decision Support Requirements (DSR), **B2.1–B2.7** = Design & Engineering DSR, **B3.1– B3.5**= Order Entry Stage DSR, **B4.1–B4.4**= CRM DSR, **B5.1–B5.6** = SCM DSR;

The similar analysis is also performed to observe the EFA distribution of items to variables of each dimension within Section B in Table 4.16.

Table 4.16. EFA (Varimax rot.) results with for individual dimensions of Section B

B1	Component			
	1	2	3	4
B1.5	.807	.211	.157	.153
B1.6	.772	.141	.042	.464
B1.10	.632	.401	.329	-.120
B1.4	.614	.398	.484	-.115
B1.1	.142	.860	.158	.050
B1.3	.251	.717	.263	.259
B1.2	.357	.653	.068	.238
B1.8	.106	.066	.847	.214
B1.9	.229	.285	.704	.140
B1.7	.142	.261	.311	.805

B2	Component			
	1	2	3	4
B2.1	.875	.288	.164	.219
B2.2	.874	.224	.312	.159
B2.4	.265	.866	.272	.195
B2.5	.306	.786	.202	.379
B2.7	.278	.254	.866	.251
B2.3	.551	.478	.564	.058
B2.6	.211	.300	.204	.896

B3	Component		
	1	2	3
B3.4	.883	.181	.018
B3.5	.868	.091	.156
B3.1	.067	.934	.047
B3.3	.456	.577	.219
B3.2	.115	.115	.980

B4	Component	
	1	2
B4.4	.904	.113
B4.2	.863	.262
B4.3	.837	.273
B4.1	.224	.971

B5	Component		
	1	2	3
B5.6	.917	.034	.132
B5.5	.854	.057	.295
B5.2	.107	.890	.099
B5.3	-.021	.880	.175
B5.4	.220	.108	.808
B5.1	.167	.169	.804

B1.1–B1.10 = Customer Enquiry Management Decision Support Requirements (DSR), **B2.1–B2.7** = Design & Engineering DSR, **B3.1– B3.5**= Order Entry Stage DSR, **B4.1–B4.4**= CRM DSR, **B5.1–B5.6** = SCM DSR;

Here, the items in red (B1.4, B1.7 and B1.10 of CEM DSR; B3.3 of Order Entry Stage DSR; and, B5.1 of SCM DSR) show the contradicting ones within their constructs, which are categorised by EFA in theoretically mismatching variables. All these analyses are used to assist CFA for improving goodness-of-fit at the second step performed in the following subsection.

Table 4.17 shows the varimax rotated EFA results for Section D as a whole. This table is also prepared by inputting only the data from Section D and using Dimension Reduction function of SPSS.

Table 4.17. Exploratory Factor Analysis (Varimax rotated) results with for Section D

D	Component				
	1	2	3	4	5
D3.6	.829	.293	.109	.344	.040
D3.4	.812	.277	.173	.115	.156
D3.1	.774	.147	.402	.170	.174
D3.2	.768	.103	.268	.146	.321
D3.5	.756	.192	.259	.299	.035
D3.3	.739	.289	.102	-.014	.383
D4.2	.156	.883	.267	.126	.183
D4.3	.138	.875	.257	.179	.054
D4.6	.242	.872	.218	-.106	.115
D4.1	.159	.823	.286	.324	.031
D4.5	.241	.789	.227	-.078	.327
D4.4	.314	.782	.269	.094	.270
D5.3	.186	.338	.852	.166	.132
D5.2	.207	.261	.848	.206	.076
D5.1	.241	.234	.843	.176	.165
D5.5	.116	.344	.779	-.060	.253
D5.4	.168	.398	.768	-.089	.255
D1.4	.068	.122	.060	.823	.252
D2.4	.163	-.029	.308	.718	.109
D1.2	.297	.026	-.140	.705	.312
D1.3	.483	.189	.171	.616	.305
D1.1	.448	.169	.192	.575	.494
D1.6	.239	.122	.191	.233	.769
D2.1	.162	.213	.313	.386	.702
D2.2	.150	.297	.290	.351	.685
D2.3	.231	.184	.414	.472	.625
D1.5	.392	.358	-.035	.320	.530

D1 = Improved CEM Performance, **D2** = Improved Design & Engineering Performance, **D3** = Improved Planning Performance via ERP, **D4** = Improved CRM Performance, **D5** = Improved SCM Performance.

The items in red (D2.4, D1.5 and D1.6) show the contradicting ones, which are categorised by EFA into theoretically mismatching constructs. Thus, 24 out of 27 items are categorised consistent with the theoretical framework through Exploratory Factor Analysis for Section D.

The very similar analysis is also performed to observe the EFA distribution of items to variables of each dimension within Section D in Table 4.18.

Table 4.18. EFA (Varimax rotated) results with for indiv. dimensions of Section D

D1	Component	
	1	2
D1.1	.799	.481
D1.2	.375	.740
D1.3	.796	.438
D1.4	.124	.894
D1.5	.482	.587
D1.6	.896	.101

D2	Component	
	1	2
D2.1	.947	.140
D2.2	.953	.158
D2.3	.813	.439
D2.4	.189	.974

D3	Component	
	1	2
D3.1	.772	.451
D3.2	.855	.329
D3.3	.322	.889
D3.4	.462	.802
D3.5	.873	.356
D3.6	.705	.585

D4	Component		
	1	2	3
D4.1	.919	.289	-.095
D4.3	.918	.289	-.158
D4.2	.892	.237	.322
D4.4	.909	.293	.143
D4.5	.274	.931	-.161
D4.6	.289	.913	.230

D5	Component	
	1	2
D5.1	.942	.221
D5.2	.965	.135
D5.3	.891	.373
D5.4	.226	.944
D5.5	.222	.946

D1 = Improved Customer Enquiry Management Performance, **D2** = Improved Design and Engineering Performance, **D3** = Improved Planning Performance via ERP, D4 = Improved CRM Performance, **D5** = Improved SCM Performance.

Here, the items in red (D1.4 of Improved Customer Enquiry Management Performance; D2.3 of Improved Design and Engineering Performance; D3.2 of Improved Planning Performance via ERP; and, D4.2 and D4.4 of Improved CRM

Performance) show the contradicting ones within their constructs, which are categorised by EFA into theoretically mismatching variables.

All these analyses assist the researcher by providing an insight on the elimination of redundant items on performing CFA for improving goodness-of-fit at the second step in the following subsection. This is explained in detail as it proceeds.

Unidimensionality test using Confirmatory Factor Analysis

The measure of 'good' unidimensionality is the model's goodness-of-fit (GF) with the data. There are several goodness-of-fit measures developed and in use (e.g., LISREL prints 15 and AMOS prints 25 different GF measures), but the choice is still debated in the literature (Shah & Goldstein, 2006). For instance, many consider conventional Goodness-of-Fit Index (GFI) or Adjusted GFI (AGFI), which used to be a common measure (Ahire *et al.*, 1996), are no longer preferred, and even cannot be reported by AMOS. The main reason of their decreasing popularity is that these two measures are hugely affected by sample size (Bollen, 1989). Regarding the sample size for validity and reliability assessments, recommended minimum size of the sample varies according to different sources, but the only agreement says that it should be bigger than the number of variables (Cramer, 2003; Shah & Goldstein, 2006), which is supported in this study (46 variables towards 123 responses).

Concerning the set of goodness-of-fit measures, a variety of selections are frequently reported and provision of at least three measures is recommended in general. Yet, reporting almost all measures is unnecessary (Marsh *et al.*, 1988). This study reports three GF measures as each being a representative of its particular measure set: *Chi-square* along with *p*-value (amongst the GF tests based on predicted vs. observed covariances), *Comparative Fit Index* (amongst the GF tests comparing the given model with a null or an alternative model) and *Root Mean Square Error of*

Approximation (amongst the GF tests penalizing for lack of parsimony). CFI and RMSEA are amongst the measures least affected by sample size (Fan *et al.*, 1999), commonly used in the literature using SEM.

1. *Chi-square* (χ^2) is a classic goodness-of-fit measure to determine overall model fit. A small χ^2 and most importantly a *p*-value greater than 0.05, which means a failure to reject the null hypothesis, is a sign of a good model fit. However, though highly conventional the χ^2 test is also widely recognized to have several drawbacks, such as being sensitive to sample size (Jöreskog, 1969).
2. *Comparative fit index* (CFI) as one of the baseline fit measures (i.e., Normed, Relative and Incremental Fit Indices (NFI, RFI and IFI); Tucker-Lewis index (TLI); and, CFI). CFI adjust itself for small samples (Bentler, 1990); and therefore, likely to give a better indication of fit for this research. By convention, CFI higher than .90 indicates a good model fit (Bollen, 1989) indicating that 90% of the covariation in the data can be reproduced by the given model which also means the scales meet the criteria for unidimensionality.
3. *Root mean square error of approximation* (RMSEA) "incorporates a penalty function for poor model parsimony" and thus becomes sensitive to the number of parameters estimated and relatively insensitive to sample size (Brown, 2006). RMSEA value less than or equal to .05 is thought to indicate a good fit, and the value less than or equal to .08 to indicate an adequate fit, "although these figures are based on subjective judgment and cannot be regarded as infallible" (Arbuckle, 2009).

Table 4.19 show that the constructs, which can be tested for unidimensionality without any *identification* problem, are unidimensional in terms of all three computed measures. Appendix 4exhibit the final measurement models of each construct which are improved by dropping items showing low factor loading through CFA by consulting EFA results above.

Table 4.19. Unidimensionality and Reliability measures for relevant constructs

Construct Scale	Unidimensionality			Reliability		
	χ^2 (*p*-value)	CFI	RMSEA	α	ρ_c	AVE
B1	27.04 (.21)	.98	.046	0.86	0.89	0.51
B2	6.69 (.25)	.99	.058	0.86	0.97	0.78
B3	4.52 (.21)	.98	.069	0.71	0.87	0.58
B4	2.54 (.28)	1.00	.049	0.80	0.93	0.77
B5	4.91 (.18)	.98	.078	0.66	0.92	0.73
D1	6.89 (.14)	.98	.074	0.88	0.91	0.69
D2	.016 (.90)	1.00	.000	0.87	0.94	0.81
D3	8.75 (.12)	.99	.076	0.95	0.96	0.84
D4	.903 (.83)	1.00	.000	0.93	0.98	0.91
D5	.181 (.67)	1.00	.000	0.87	0.97	0.88

Constructs: **B1** = CEM Decision Support Requirements (DSR), **B2** = D&E DSR, **B3** = Order Entry Stage DSR, **B4** = CRM DSR, **B5** = SCM DSR; **D1** = Improved CEM Performance, **D2** = Improved D&E Performance, **D3A** = Improved Planning Performance via ERP, **D3B** = Improved Planning Performance via APS , **D4** = Improved CRM Performance, **D5** = Improved SCM Performance.

Measures: χ^2: Chi-square, **RMSEA**: Root Mean Square Error of Approximation, **CFI**: Comparative Fit Index; **α**: Cronbach's alpha, ρ_c: Composite Reliability, **AVE**: Average Variance Extracted

Appendix 5 lists each item under its constructs and variable with standardised path loading values, corresponding critical ratios (indicates significance of the loadings), mean values and standard deviations of item responses. All except B2.3 are significant at $p < .001$, where B2.3 is significant at $p < .005$.

Figure 4.16 below shows the average standardised path loadings of each construct in this study to give an overall idea on the importance of the items on their constructs.

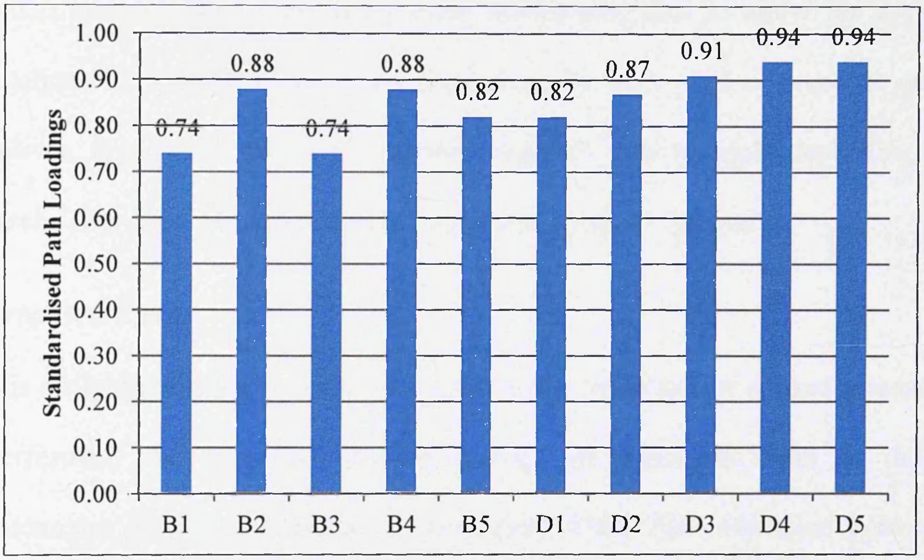


Figure 4.16. Average Standardized Path Loadings of Constructs

4.7.2 Reliability

Reliability is the consistency of results when the phenomenon is intended to be measured more than once. Similar properties of a reliable measurement are expressed as dependability, stability, predictability and accuracy by Kerlinger (1970). Carmines & Zeller (1979) define reliability via these words: "Fundamentally, reliability concerns the extent to which an experiment, test, or any measuring procedures yields the same results on repeated basis".

There are several techniques available to assess reliability including computations of simple to complex formulations. Forza (2009) provides four most common techniques as Test-Retest, Alternative Forms, Split-halves and Internal Consistency which is the most popular of all. Ahire & Devaraj (2001) include another method to this list called Composite Reliability Test, developed by Werts *et al.*(1974). The following subsections assess these methods used to estimate of reliability.

Test-retest

This is the easiest method to estimate reliability such that the researcher applies the very same test to the same people a period of time after it is firstly applied. This period is advised as two weeks by some researchers, thus to allow for day-to-day fluctuations in behaviours to occur. Regarding the issue of low response rate and incentives, this can be one of the hardest reliability tests to apply depending on the research. Therefore, test-retest method is not applicable to this study.

Alternative forms

This is a slightly different version of the test-retest technique. A second measurement is performed after a period of time through an alternative form of the same questionnaire (i.e., via a similar questionnaire). Thus, the correlation between the alternative forms provides the estimate of reliability. This method is also not applicable to this study considering the reason for the test-retest method above.

Split-halves

Split-halves is an approximation to alternative forms technique. A set of items, which is aimed at measuring the same phenomenon, is split into two to test for correlation in order to obtain an estimate of reliability. However, this correlation would be the reliability for each half of the test rather than the total test. Carmines & Zeller (1979) refer to Spearman (1910) for the statistical correction since, normally the total test is twice as long as each half. The appropriate correction formula (also called Spearman-Brown "prophecy formula") is:

$$\rho_{xx''} = \frac{2\rho_{xx'}}{1 + \rho_{xx'}}$$

where $\rho_{xx''}$ is the reliability coefficient of the whole test and $\rho_{xx'}$ is the split-half correlation. For example, when the correlation between the halves is .75 the total test reliability becomes .857. Regarding the correction formula above, it is obvious that reliability coefficient varies between .00 and 1.00.

This method is applicable to this study due to multi-item structure of each variable. Only Section B and D are appropriate to apply the split-halves and the internal consistency tests. The reason it is not applicable to Section C is that Section C variables are generally single-item and merely ask for the intensity of use of ERP modules and add-ons. Besides, Section A questions are exploratory type of questions and are not a part of multi-item structured framework.

Table 4.20 and Table 4.21 summarise results for the split-halves technique. First N/2 items of a variable are selected as part one and the rest as part two. The Split-halves estimate (also called Spearman-Brown coefficient) is used to predict the full-test reliability based on half-test correlations. In SPSS, two Spearman-Brown split-half reliability coefficients are calculated: "Equal length" gives the estimate when both halves have equal numbers of items, and "Unequal length" they are unequal. "Correlation Between forms" values are simply the Pearson correlation of split forms which estimates the half-test reliability. The bottom row on Cronbach's alpha will be described in the following subsection.

All split-halves estimates of variables, except B3, B5 and D5, are above the .70 cut-off threshold which is generally well-acknowledged as the limit for adequate reliability estimate. However, this may be due to the major drawback of split-halves method regarding the coincident instance of splitting the forms. Namely, the estimate for D1 would be different if the split groups were arranged as D1.1, D1.3, D1.5 to D1.2, D1.4, instead of D1.1, D1.2, D1.3 to D1.5, D1.6. The following technique of internal consistency (i.e., Cronbach's alpha) eliminates such a drawback and produce better estimates of reliability.

Table 4.20. Split-halves and Cronbach's alpha reliability estimation for Section B

Reliability Statistics			**B1**	**B2**	**B3**	**B4**	**B5**
Split-halves estimate (Spearman-Brown)	Equal Length		.792	.810	.590	.798	.478
	Unequal Length		.794	.810	.597	.798	.485
Correlation Between Forms			.656	.681	.418	.664	.314
Cronbach's Alpha	Part 1	Value	.821	.836	.582	.575	.579
		N of Items	5[a]	3[c]	3[e]	2[g]	3[i]
	Part 2	Value	.697	.713	.759	.795	.753
		N of Items	4[b]	3[d]	2[f]	2[h]	2[j]
	Total	**Value**	**.855**	**.857**	**.706**	**.801**	**.660**
		N of Items	9	6	5	4	5

a. For items: B1.1, B1.2, B1.3, B1.5, B1.6.
b. For items: B1.7, B1.8, B1.9, B1.10
c. For items: B2.1, B2.2, B2.4.
d. For items: B2.5, B2.6, B2.7
e. For items: B3.1, B3.2, B3.3.
f. For items: B3.4, B3.5.
g. For items: B6.1, B6.2.
h. For items: B6.3, B6.4.
i. For items: B7.2, B7.3, B7.4.
j. For items: B7.5, B7.6.

Table 4.21. Split-halves and Cronbach's alpha reliability estimation for Section D

Reliability Statistics			**D1**	**D2**	**D3**	**D4**	**D5**
Split-halves estimate (Spearman-Brown)	Equal Length		.820	.803	.939	.911	.693
	Unequal Length		.825	.803	.941	.914	.693
Correlation Between Forms			.695	.671	.885	.837	.530
Cronbach's Alpha	Part 1	Value	.878	.943	.896	.949	.922
		N of Items	3[a]	2[c]	3[e]	3[g]	2[i]
	Part 2	Value	.685	.694	.941	.715	.943
		N of Items	2[b]	2[d]	2[f]	2[h]	2[j]
	Total	**Value**	**.879**	**.867**	**.947**	**.933**	**.868**
		N of Items	5	4	8	5	5

a. For items: D1.1, D1.2, D1.3.
b. For items: D1.5, D1.6.
c. For items: D2.1, D2.2.
d. For items: D2.3, D2.4.
e. For items: D3.1, D3.2, D3.4.
f. For items: D3.5, D3.6
g. For items: D4.1, D4.2, D4.3.
h. For items: D4.4, D4.6.
i. For items: D5.1, D5.3.
j. For items: D5.4, D5.5.

Internal consistency using Cronbach's alpha

Retesting a measurement through either the same or an alternative instrument is a serious problem when response rate is a major concern. However, this need can still be satisfied through approximations such as split-halves method, described above.

Splitting a set of items for an estimate of reliability arises a concern about how it can be done, i.e., different separations result different correlation results. The major drawbacks of split-halves and alternative-forms techniques are addressed by another method called *internal consistency* which does not require either splitting or repeating. There are several variants of this umbrella term, yet the most popular was developed by Cronbach (1951). It is expressed as follows:

$$\alpha = \frac{N}{N-1}\left(1 - \frac{\sum_{i=1}^{N} \sigma_{Y_i}^2}{\sigma_X^2}\right)$$

where α is the estimate of the reliability, N is the number of items, $\sigma_{Y_i}^2$ is the sum of item variances and σ_X^2 is the variance of the total composite. This formula alternatively represented as:

$$\alpha = \frac{N \cdot \bar{p}}{1 + (N-1)\bar{p}}$$

where $\bar{p}$ becomes average inter-item correlation amongst the N measurement items under consideration. For example, when a mean inter-correlation of six items is .50, Cronbach's alpha becomes .857. It is mathematically equivalent to the average of estimates of all possible split-half combinations. Regarding the formula above, Cronbach's alpha ranges between .00 and 1.00. It assumes that the items that comprise a scale are *τ-equivalent* (measures have the same true scores, but may have unequal error variances). This says that each item measures the same variable to the same degree. Novick & Lewis (1967) report this as a restrictive assumption that is unlikely to be met in practice. Therefore, when the items of a scale are not τ-equivalent α will be a conservative (i.e., lower bound) estimate of reliability (Carmines & Zeller, 1979).

Nunnally (1978) and Robinson *et al.* (1991) recommended two thresholds as .60 for exploratory work on constructs and .70 for maturing ones. Over .80 is widely considered as highly reliable. This study uses all the items in the instrument for the first time. Therefore, they have not been tested for validity or reliability before. However, they are also not a part of a complete exploratory study (e.g., random list of questions asked to find any correlation or to form a theoretical framework inductively). Therefore, it can be said that .80 limit would be ideal, .70 appropriate and .60 adequate to achieve.

Referring back to Table 4.20 and Table 4.21, Cronbach's alpha values for split forms and total are shown for Section B and D, respectively. The alpha values of split forms are used as auxiliary to check any significant difference of reliability estimate between forms. Here, the important estimate is the total Cronbach's alpha value (in bold). Contrary to the inferior split-halves results of B3 and B5, Cronbach's alpha of all variables are almost above .70 (only estimate of reliability for B5 is .660 which can be considered as adequate since these items have not been validated before). Besides, B1, B2, B4, D1, D2 and D5 are between .80 and .90; and, D3 and D4 are above .90. These tests show that a reliable set of variables have been used in the instrument.

Composite reliability using Werts-Linn-Jöreskog (WLJ) and Average Variance Extracted (AVE)

The WLJ technique, increasingly used in other fields of research (e.g., marketing and strategy), has some advantages over the others used to assess reliability (O'Leary-Kelly & J. Vokurka, 1998). However, its use in OM has been limited for some reason.

The technique utilises Confirmatory Factor Analysis (CFA) to derive a composite (overall) reliability index, which is based on the proportion of variance attributable to only the latent variable i.e., excluding measurement error. Like the previous cases, it ranges between 0.00 and 1.00. As opposed to Cronbach's alpha's τ-*equivalent* assumption this method is less restrictive considering measures as *congeneric* (true scores do not have to be equivalent, but must be perfectly correlated). On the other hand, similar to split-halves and alpha it does not require repeated measurements.

$$\rho_c = \frac{(\sum_{i=1}^{n} \lambda_i)^2 \text{var}A}{(\sum_{i=1}^{n} \lambda_i)^2 \text{var}A + \sum_{i=1}^{n} \varphi_i}$$

where ρ_c is the composite measure reliability index, p is the number of indicators, and λ_i is the factor loading which relates item i to the underlying theoretical dimension A. 0.50 is generally considered as the minimum threshold for establishing satisfactory reliability. Jöreskog (1971) has provided this weighted expression above for reliability that does not assume equal item reliabilities (i.e., *congeneric* rather than *τ-equivalent*) within the context of CFA. For a single unweighted composite for standardised factor loadings, Gerbing & Anderson (1988) provide the following simplified form which is highly preferred for reporting composite reliability in the literature:

$$\rho_{\overline{XX}'} = \frac{\left(\sum_{i=1}^{p} \lambda_i\right)^2}{\left(\sum_{i=1}^{p} \lambda_i\right)^2 + \sum_{i=1}^{p}(1 - \lambda_i^2)}$$

The factor loadings can also be used to estimate another reliability measure called Average Variance Extracted (AVE):

$$AVE = \frac{\sum_{i=1}^{p}(\lambda_i^2)}{\sum_{i=1}^{p}(\lambda_i^2) + \sum_{i=1}^{p}(1 - \lambda_i^2)}$$

It measures the amount of variance captured by a construct in relation to the variance due to random measurement error (Fornell & Larcker, 1981). Therefore, it penalises low factor loadings more than the WLJ estimate. AVE value exceeding .50 indicates that a large amount of the variance is captured by each construct rather than due to measurement error.

Both WLJ and AVE values of each construct are summarised in Table 4.19 under the reliability column next to Cronbach's alpha. All WLJ and AVE values are 0.50 above. Especially, the WLJ estimates (ρ_c) are well above the satisfactory limits.

It should be noted that reliability does not ensure validity. Hair *et al.*(1998) define validity as "the extent to which the indicators 'accurately' measure what they are supposed to measure". Remaining validity assessments, which are called Convergent, Discriminant and Criterion-related Validity, are performed through Sections 4.7.3, 4.7.4 and 4.7.5, respectively.

4.7.3 Convergent Validity

Convergent validity is defined as the extent to which different approaches to construct measurement yield the same results (Campbell & Fiske, 1959). Multitrait-Multimethod (MTMM), by Campbell & Fiske (1959), and nested Confirmatory Factor Analysis (CFA) are two methods used to assess convergent validity. However, both MTMM and CFA require at least two empirical measurements (such as mailed surveys and phone interviews) for each latent variable like the test-retest method (O'Leary-Kelly & J. Vokurka, 1998). However, the multi-method instrument administration has a high cost like reliability (e.g. techniques of test-retest).

Alternatively, there is a widely used alternative technique proposed by Krause *et al.* (2000) which can be performed through this study's single cross-sectional data collection to test convergent validity. This simply considers the indication of convergent validity as the magnitude and sign of the factor loadings of the items onto their respective latent constructs in the CFA measurement models which are run for the unidimensionality assessment reported in Subsection 4.7.1 (Appendix 5). In this study, each loading was in the anticipated direction and magnitude, and each was significantly different from zero at the $p \leq .001$ level.

Besides, content validity assessment (i.e., manual sorts performed by subject matter experts) and tests of reliability (performed above) can also be viewed as two different methods of measuring the same construct (or evaluating measurement scales). Both have produced comparable results in terms of scale reliability and validity (e.g., Proportional Reduction in Loss (PRL) has been provided as an estimate of content validity, and mentioned of its comparability with Cronbach's alpha). Both have shown adequacy of fit between the model and data.

4.7.4 Discriminant Validity

Only when convergent validity is established, the discriminant validity of the measures needs to be examined using SEM, specifically CFA (Bagozzi & Phillips, 1982). There are several methods available towards providing evidence of discriminant validity (Koufteros, 1999; Ahire & Devaraj, 2001; Forza, 2009). While one method compares a construct's *Cronbach's alpha* with the average of its correlations with other constructs (called *Average Interscale Correlation*), the other method builds a confidence interval for φ value of all possible pairs of constructs and examines whether 1.0 is included. (i.e., when covariance between two constructs is different from 1.0, the constructs are discriminant). The most rigorous, and therefore, widely used measure of all employs CFA, such that CFA of all possible pairs of latent variables are produced twice: firstly, in a *constrained* way (the correlation—shown with double-headed arrows—between two constructs is fixed at 1.0) and secondly, in an *unconstrained* way (constructs are allowed freely to correlate). Thereafter, the difference between the χ^2 values of two results is tested for the significance of the statistic (*Constrained* χ^2 minus *Unconstrained* χ^2) for each pair (Venkatraman, 1989).

Table 4.22 exhibits the discriminant validity by five different models examined in this study (i.e., Customer Enquiry Management, Design and Engineering, Order Entry, Customer Relationship Management and Supply Chain Management). Discriminant validity estimates are categorised as different *p*-value levels in terms of their statistical significance. All differences are significant at $p < .05$. Besides, 33 out of totally 42 χ^2 differences are significant at $p < .001$, suggesting strong discriminant validity (Bagozzi *et al.*, 1991). A few comparisons (3 out of 60) are missing due to the low number of items per latent variable making the constrained models under-identified (degrees of freedom are less than zero) which makes it unsolvable:

Table 4.22. Discriminant Validity by Model

(a) *Customer Enquiry Management*

Test	Corr. Est.	Critical ratio	Uncon. χ^2	Cons χ^2	χ^2 diff.
B1a with					
B1b	0.82	4.24	20.6	11.6	9.0**
B1c	0.64	3.12	14.9	1.8	13.1***
B1d	0.62	4.36	40.2	0.9	39.3***
D1a	0.66	3.21	24.4	7.5	16.9***
D1b	0.84	3.40	8.8	4.7	4.1*
B1b with					
B1c	0.61	2.95	18.5	5.6	12.9***
B1d	0.56	4.13	48.6	2.6	46.0***
D1a	0.38	2.02	50.9	19.7	31.2***
D1b	0.73	2.49	19.0	14.0	5.0*
B1c with					
B1d	0.54	3.06	16.8	0.0	16.8***
D1a	0.08	0.42	45.1	3.3	41.8***
D1b	0.48	2.18	16.3	1.2	15.1***
B1d with					
D1a	0.36	2.36	96.6	6.1	90.5***
D1b	0.46	2.76	14.3	0.0	14.3***
D1a with					
D1b	0.83	3.32	12.9	8.7	4.2*

(b) *Design and Engineering*

Test	Corr. Est.	Critical ratio	Uncon. χ^2	Cons χ^2	χ^2 diff.
B2a with					
B2b	0.66	4.70	41.6	0.0	41.6***
B2c	0.38	3.24	97.5	0.0	97.5***
B2d	0.49	3.74	90.6	0.0	90.6***
D2a	0.64	2.46	11.0	5.6	5.4*
D2b	0.73	3.21	4.4	0.4	4.0*
B2b with					
B2c	0.52	4.44	62.1	0.0	62.1***
B2d	0.59	4.40	55.1	0.0	55.1***
D2a	0.07	0.13	20.6	0.2	20.4***
D2b	0.62	2.36	6.0	0.0	6.0*
B2c with					
B2d	0.40	3.65	-	0.0	-
D2a	0.35	1.37	18.0	0.0	18.0***
D2b	0.37	1.86	12.2	0.0	12.2***
B2d with					
D2a	0.02	0.48	20.7	0.2	20.5***
D2b	-0.03	-0.06	14.6	0.0	14.6***
D2a with					
D2b	0.75	4.19	8.8	0.0	8.8**

$^{***}\chi^2$ differences are statistically significant with $p < .001$; ** with $p < .01$; * with $p < .05$

B1a = Due Date setting, **B1b** = Pricing, **B1c** = Internal Coordination, **B1d** = External Coordination; **D1a** = Productive aspects, **D1b** = Economic aspects,

B2a = Documentation archive, **B2b** = Internal Coordination, **B2c** = External Coordination, **B2d** = Flexibility in Design; **D2a** = Productive aspects, **D2b** = Technical productivity

(c) *Order Entry (Production Planning)*

Test	Corr. Est.	Critical ratio	Uncon. χ^2	Cons χ^2	χ^2 diff.	Test	Corr. Est.	Critical ratio	Uncon. χ^2	Cons χ^2	χ^2 diff.
B3a with						B3c with					
B3b	0.57	2.89	5.8	0.0	5.8 *	D3a	0.18	1.99	22.6	0.0	22.6***
B3c	0.27	1.69	47.2	0.0	47.2***	D3b	0.18	1.48	33.1	11.8	21.3***
D3a	-0.14	-0.97	-	0.0	-						
D3b	-0.04	-0.30	191.2	8.1	183.1***						
B3b with						D3a with					
B3c	0.69	2.62	5.8	1.9	3.9 *	D3b	0.86	4.31	60.1	15.7	44.4***
D3a	-0.01	-0.70	5.9	0.2	5.7 *						
D3b	-0.02	-0.68	22.7	16.9	5.8 *						

$^{***}\chi^2$ differences are statistically significant with $p < .001$; ** with $p < .01$; * with $p < .05$

B3a = Confirmed Order Re-evaluation, **B3b** = Aggregate Planning, **B3c** = Operational Planning;
D3a = Intensity of use of MRP, **D3b** = Intensity of use of ERP

(d) *Customer Relationship Management* (e) *Supply Chain Management*

Test	Corr. Est.	Critical ratio	Uncon. χ^2	Cons χ^2	χ^2 diff.	Test	Corr. Est.	Critical ratio	Uncon. χ^2	Cons χ^2	χ^2 diff.
B4a with						B5a with					
B4b	0.48	4.16	136.9	2.5	134.4***	B5b	0.35	1.55	17.1	0.6	16.5***
D4a	0.24	1.12	71.5	0.0	71.5***	B5c	0.15	1.23	59.3	0.0	59.3***
D4b	0.14	0.91	101.4	0.0	101.4***	D5a	0.40	1.73	13.9	0.1	13.8***
D4c	-0.04	-0.26	-	0.0	-	D5b	0.33	1.89	14.8	0.2	14.6***
B4b with						B5b with					
D4a	0.46	2.51	51.9	11.4	71.2***	B5c	0.63	5.31	12.4	0.0	12.4***
D4b	0.35	2.02	96.8	1.4	95.4***	D5a	0.33	1.84	15.9	0.0	15.9***
D4c	0.23	1.42	51.8	4.3	47.5***	D5b	0.38	2.68	16.6	1.0	15.6***
D4a with						B5c with					
D4b	0.95	4.07	4.0	0.1	3.9 *	D5a	0.07	0.58	116.4	0.0	116.4***
D4c	0.55	2.97	49.8	0.0	49.8***	D5b	0.08	0.26	135.1	0.1	135.0***
D4b with						D5a with					
D4c	0.55	2.96	45.4	0.0	45.4***	D5b	0.57	2.57	40.9	0.2	40.7***

$^{***}\chi^2$ differences are statistically significant with $p < .001$; ** with $p < .01$; * with $p < .05$

B4a = Customer database, **B4b** = Need for improved relationships; **D4a** = Satisfaction with existing customers, **D4b** = New customer and market exploration, **D4c** = Profitability

B5a = Supply chain coordination (with buyers), **B5b** = Procurement (from Suppliers), **B5c** = Compatibilit **D5a** = Improved order management, **D5b** = Profitability

4.7.5 Criterion-related validity

Criterion-related validity evaluates the extent to which items in a construct scale are correlated with an external criterion (Nunnally, 1978). Namely, it is a measure of how well scales representing various decision support requirements are related to measures of performance (the criteria) as adapted from Flynn *et al.* (1994).

In order to observe this validity, the decision support requirements variable scores are correlated with the performance variables. This has been performed in three ways by different studies of OM: Multiple Correlation (Saraph *et al.*, 1989), Canonical correlation (Flynn *et al.*, 1994) or Structural equation modelling (Ahire *et al.*, 1996). SEM is preferred to others since it takes measurement error into account by estimating the measurement error variances from the data and model specification. The main reason for not preferring multiple or canonical correlation methods is that they assume perfect measurement, thus may result biased estimates of correlations. Correlations estimated using AMOS 17.0 are provided in Table 4.23 for each model:

Table 4.23. Estimated CFA (SEM) correlations.

(a) SEM estimates of correlations from the CEM model

CEM	**B1a**	**B1b**	**B1c**	**B1d**	**D1a**	**D1b**
B1a	1					
B1b	0.634***	1				
B1c	0.481***	0.415**	1			
B1d	0.535***	0.461***	0.35*	1		
D1a	0.667***	0.575***	0.436**	0.485***	1	
D1b	0.533***	0.459***	0.348*	0.388**	0.702***	1

***** Estimate correlations are statistically significant with $p < 0.001$; ** with $p < 0.01$; * with $p < 0.05$**

(b) SEM estimates of correlations from the Design & Engineering model

D&E-PC	**B2a**	**B2b**	**B2c**	**B2d**	**D2a**	**D2b**
B2a	1					
B2b	0.593***	1				
B2c	0.423**	0.461***	1			
B2d	0.510***	0.555***	0.396**	1		
D2a	0.282*	0.307*	0.219	0.264	1	
D2b	0.252	0.275	0.196	0.237	0.751	1

***** Estimate correlations are statistically significant with $p < 0.001$; ** with $p < 0.01$; * with $p < 0.05$**

(c) SEM estimates of correlations from the Order Entry (Production Planning)

PP-APS	**B3a**	**B3b**	**B3c**	**D3a**	**D3b**
B3a	1				
B3b	0.533***	1			
B3c	0.340*	0.502***	1		
D3a	-0.020	-0.029	-0.019	1	
D3b	-0.016	-0.023	-0.015	0.846***	1

***** Estimate correlations are statistically significant with p < 0.001; ** with p < 0.01; * with p < 0.05**

(d) SEM estimates of correlations from the CRM model

CRM	**B4a**	**B4b**	**B4c**	**D4a**	**D4b**
B4a	1				
B4b	0.674***	1			
B4c	0.599***	0.526***	1		
D4a	0.554***	0.486***	0.912***	1	
D4b	0.328*	0.288*	0.54***	0.499***	1

***** Estimate correlations are statistically significant with p < 0.001; ** with p < 0.01; * with p < 0.05**

(e) SEM estimates of correlations amongst variables of the SCM model

SCM	**B5a**	**B5b**	**B5c**	**D5a**	**D5b**
B5a	1				
B5b	0.195	1			
B5c	0.242	0.456***	1		
D5a	0.181	0.342*	0.424**	1	
D5b	0.155	0.292*	0.362**	0.535**	1

***** Estimate correlations are statistically significant with p < 0.001; ** with p < 0.01; * with p < 0.05**

All of the variables of DSR (Section B-related variables) have statistically significant positive correlations with the variables of improved performance (Section D-related variables) in the CEM and CRM models. Most of the inter-construct relationships in the D&E and SCM models are significant. This provides some support for the third hypotheses (e.g., H_{1c}, H_{2c} and so on) that decision support requirements have a direct impact on performance without considering the mediating effect of the intensity of use of the relevant ERP module/extension. Only the relationships amongst the inter-construct latent variables in the PP (order entry) model are non-significant.

Therefore, there may not be a direct relationship between DSR and performance at this stage in the results.

Table 3.4 in Chapter 3 can help sum up this chapter as it summarises all these points on reliability and validity covered in this chapter and the responses of this thesis to each.

4.8 Conclusion

This chapter has described the development of a reliable and valid measurement instrument designed to collect the survey data needed to test the research questions of this thesis. Scale constructs were initially derived from theory, based upon a comprehensive multi-disciplinary literature review. Scales were then purified through a manual sorting process using panels of expert practitioner judges. A pilot test was conducted to do preliminary analyses and to experiment during a 'mini' data collection period. Finally, full scale survey data collected using the measurement scales was used to evaluate the multi-item scale performance in terms of unidimensionality, reliability, and construct validity.

The next chapter provides the results and interpretations for the exploratory part of the survey.

Chapter 5: Exploratory Results

This chapter presents the results for the first part of the survey (Section A of the questionnaire) through some exploratory (descriptive) analyses. The aim is to provide the respondent profile (i.e., position and department), company demographics (i.e., company size, type, sector, etc.), and ERP environment, if used. This is performed in two ways: firstly, through *univariate* descriptive statistics in Subsection 5.1 by analysing the measured variables individually (each question is treated as a *variable* in the exploratory part of the questionnaire); except Q14 (reasons to adopt ERP system) and Q15 (reasons not to adopt ERP system) which are treated as *multi-variable* questions. Secondly, subsection 5.2 presents *bivariate* analyses performed by looking for correlations and grouping them with respect to their ERP adoption (adopter vs non-adopter) and production strategy (MTO vs MTS) to compare with each other. When the collected data do not perfectly satisfy certain basic assumptions of the widely acknowledged parametric statistical tests (e.g., student's t-test), alternative nonparametric tests are also used (e.g., Mann-Whitney U test). To let the reader follow the statistical procedures more easily, the most widely known (parametric) tests are utilised and presented in the first place, whether the assumptions are satisfied or otherwise; then, if the assumption violation occurs, alternative tests are evaluated and presented at the end of the section. Section 5.3 concludes the exploratory survey analysis and highlights the main points and inferences.

5.1 Univariate Analysis

Univariate descriptive statistics supported with charts and histograms are presented in three subsections: Respondent Profile measured by Q1, Company characteristics measured by Q2 to Q7, and ERP environment measured by Q7 to 16 in the questionnaire.

5.1.1 Respondent Profile

The unit of analysis, as defined and discussed in the Research Methodology chapter, is chosen to be the plant at which the respondent is based (or the company where there is only one plant or location). There is one respondent per unit of analysis; therefore, the respondents' positions become important under the assumption that the higher their position, the more meaningful the results. The issue of 'single respondent' data has been discussed in the Research Methodology chapter.

Table 5.1 below shows that respondents who are fully in charge of their organisations (i.e., managing directors and directors) make up 49% of the total responses. The remaining respondents are also directors or managers of some particular departments which are all directly related to this study (e.g., production, IT, finance, supply chain and operations, etc.). The "other" category in the table consists of directors or managers as well, but all are differently titled regarding their specific departmental unit or responsibility (e.g., supply chain excellence director).

Table 5.1. Respondent's positions

Positions	**Count**	**Perc.**
Managing Director	37	29%
Director	25	20%
Production or Manufacturing Director/Manager	11	9%
IT Director/Manager	6	5%
Operations Director/Manager	6	5%
Finance Director	4	3%
Other	37	29%
Total	*126*	*100%*

5.1.2 Company Characteristics

Company Size

Figure 5.1 and Figure 5.2 below show the distribution of respondents' company size regarding the number of employees and last year's turnover (i.e., in 2008, since the questionnaire was distributed in 2009). The majority of the responding firms have annual revenue between £2 million and £10 million, and fewer than 250 employees. Within this study's sample, micro size companies (less than 10 employees) and very large companies (more than 1000 employees) have taken part to a very small extent compared to companies employing between 11 and 500 people.

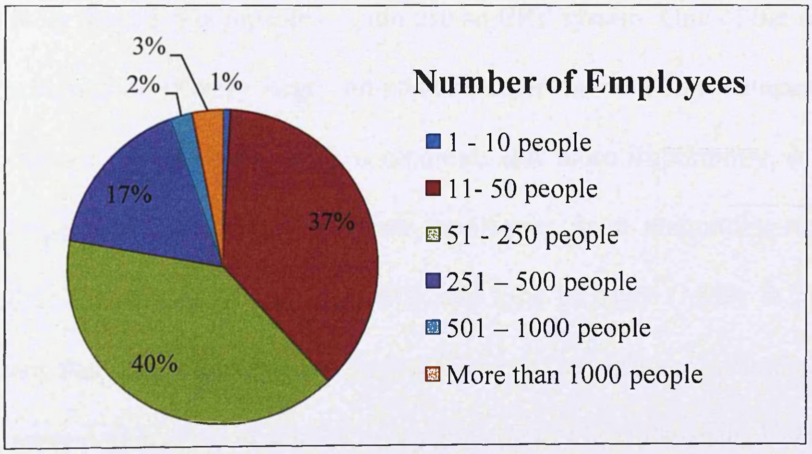


Figure 5.1. Distribution of the number of employees

The six choices in both questions of company size are recoded into a scale from 1 to 6, respectively. Tables in Appendix 6 exhibit detailed descriptive statistics and frequency distributions based on this scale, for this and the majority of other company characteristics discussed in this section.

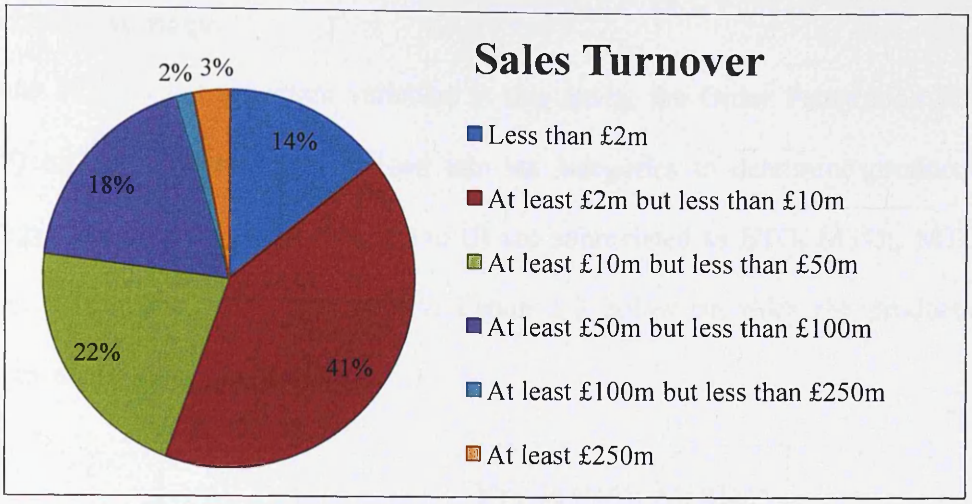


Figure 5.2. Distribution of the sales turnover

The reason for the lack of micro-sized company representation is their deliberate exclusion (see the Survey Design chapter for sampling discussion), since it is very unlikely that such companies would use an ERP system. One of the reasons for a small representation of very large companies is that the available company contact databases did not provide many such companies. But more importantly, it is known that very large organisations restrict their employees from responding to external survey studies for reasons of confidentiality and time pressure (Miles & Huberman, 1994). Given that many surveys are sent to large organisations, personnel are also slower to respond than those in smaller companies (Miles & Huberman, 1994).

Overall, the distribution is agreeable to this study's target as defined and expected to comprise of small, mid and large size companies in the manufacturing sector. Besides, since SMEs are the main target in this study two main dimensions for group comparison are formed—as production strategy (i.e., MTO vs. MTS) and ERP adoption (i.e., ERP user vs. nonuser)—rather than company size (i.e., SME vs. Large companies). However, this does not imply that a few large firms need to be removed; since they constitute a minority in the sample (four amongst 123 firms) and contribute to both production strategy and ERP adoption groups.

Production strategy

As one of the most important variables in this study, the Order Penetration Point (OPP) of the companies was divided into six categories to determine production strategy. The choices of Q4 from (a) to (f) are abbreviated as ETO, MTO_1, MTO_2, ATO_1, ATO_2, and MTS, respectively. Figure 5.3 below provides the production strategy distribution and percentages:

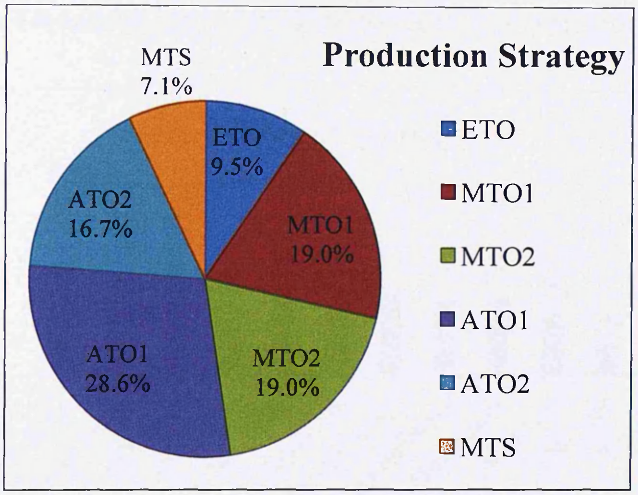


Figure 5.3. Distribution of the production strategy: MTO vs MTS

The percentage of the MTS manufacturers is the lowest in the sample. The main reason for MTS manufacturers constituting a smaller portion than the other types is that; firstly, food manufacturers which are mostly MTS-type (van Donk, 2001), have been excluded from the sample; and secondly, the statement of the MTS choice in the questionnaire (i.e., "All products are standard; orders are fulfilled from inventory") describes a company, having a purely forecast-based planning system, namely, free of any product customisation. Therefore, this is likely to have led the corresponding respondents rather to select ATO_1 or ATO_2.

As introduced and further discussed in the Introduction and Literature Review chapters, respectively; the term Make-To-Order has been redefined to include the first three categories (comprising ETO, MTO_1, and MTO_2). The last three categories are defined as Make-To-Stock (comprising ATO_1, ATO_2, and MTS). Figure 3 shows that MTO and MTS percentages are almost equally distributed (i.e., 47.6% and 52.4%, respectively); they are used in the bivariate and multivariate analyses and enable comparisons.

Industrial sector

The distribution of industrial sectors of the respondents is shown in Figure 5.4 below.

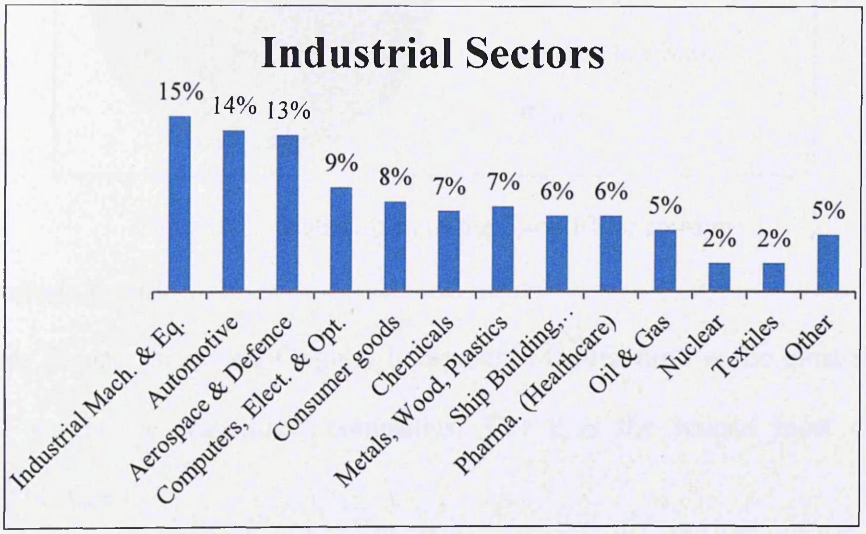


Figure 5.4. Distribution of the industrial sectors

Amongst all the sampled manufacturing sectors; industrial machinery & equipment, automotive, and aerospace & defence are the three most common.

Shop Floor routing

Figure 5.5 below shows the distribution of shop floor routing. Job shop and flow shop configurations are contrasted in four categories. A "not applicable" (N/A) choice was also provided for the respondents having no manufacturing setup within their facility. Though only manufacturers were sampled, some companies turned out to be non-manufacturing branches, e.g. sales operations at a different location in the UK to manufacturing. Five such respondents were identified, each of a different production strategy - two ERP users and three non-users. Job shop and flow shop configurations are almost evenly distributed (i.e., 44% and 52%, respectively).

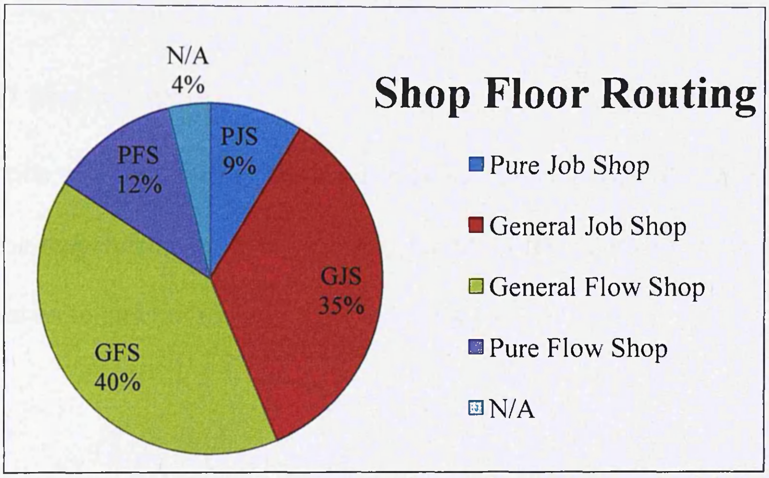


Figure 5.5. Distribution of the Shop Floor routing

Supply chain position

Regarding Figure 5.6 below, Original Equipment Manufacturer is the most common position among the respondent companies. Tier 2 is the second most common followed by Tier 1.

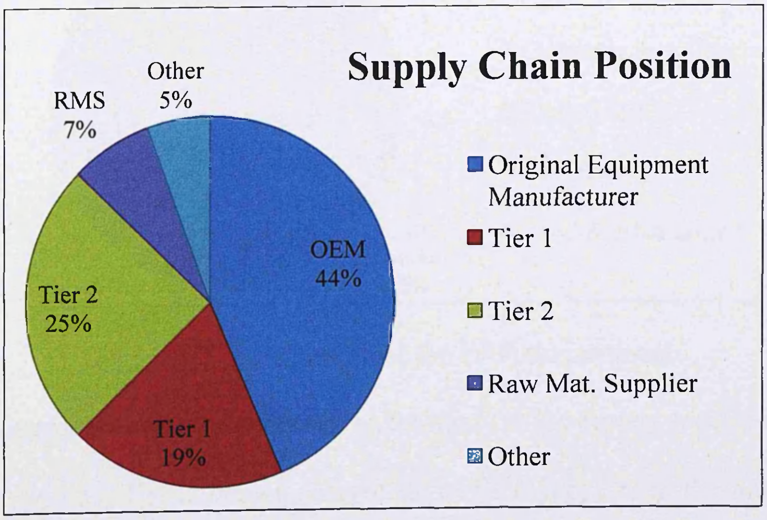


Figure 5.6. Distribution of the Supply Chain Position

Bivariate analysis and cross tabulations showing the relationship and distribution of this variable with the other variables (such as production strategy and industrial sector) are reported in Subsection 5.1.2.

5.1.3 ERP environment

This subsection provides further descriptive univariate statistics on the ERP adoption choices of the respondents such as ERP use; adoption frequency of modules, add-ons, vendors; reasons to and not to adopt ERP systems.

ERP use

Figure 5.7 below shows that the number of ERP using respondents has a higher percentage than nonusers.

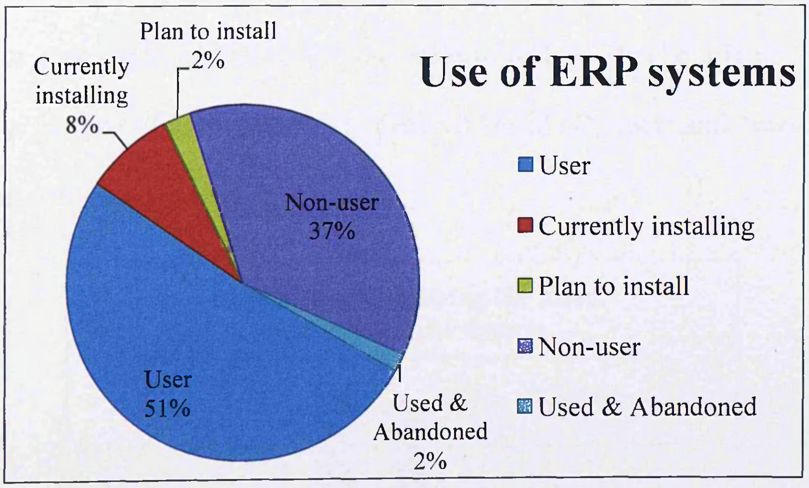


Figure 5.7. Distribution of the ERP environment

This suggests that the "salience" of the study to the survey sample have had an effect on the results. The unknown percentage of ERP adopters in the manufacturing sector within the UK prevents any external comparisons. However, no significant non-respondent bias has been determined in the sample (see the "Collecting Data" section in the Survey Design chapter). On the other hand, the percentage of nonusers is not negligible. When respondents are grouped under the names "users" and "nonusers" for further analyses, the firms that: (i) have already used and abandoned ERP, (ii) are currently installing ERP at the time of the survey send out, or (iii) are using ERP at present, are all grouped as users and the remainder as nonusers. In that case, the percentages become 60.9% and 39.1%, respectively.

Tables in Appendix 7 show detailed descriptive statistics and frequency distributions on the ERP environment of the respondents.

Difficulty in identifying the most suitable system during ERP selection

The overall summary of feelings about the difficulty of identifying the system is shown in Figure 5.8 below on a seven-point Likert scale. The result is normally distributed over the mean corresponding to a value between difficult and neither difficult nor easy (namely, 3 and 4 in the scale from 1 to 7). There is no "extremely easy" reply, but one of each "extremely difficult" (a MTO_2 user) and "very easy" (an ATO_1 user) options on each tail.

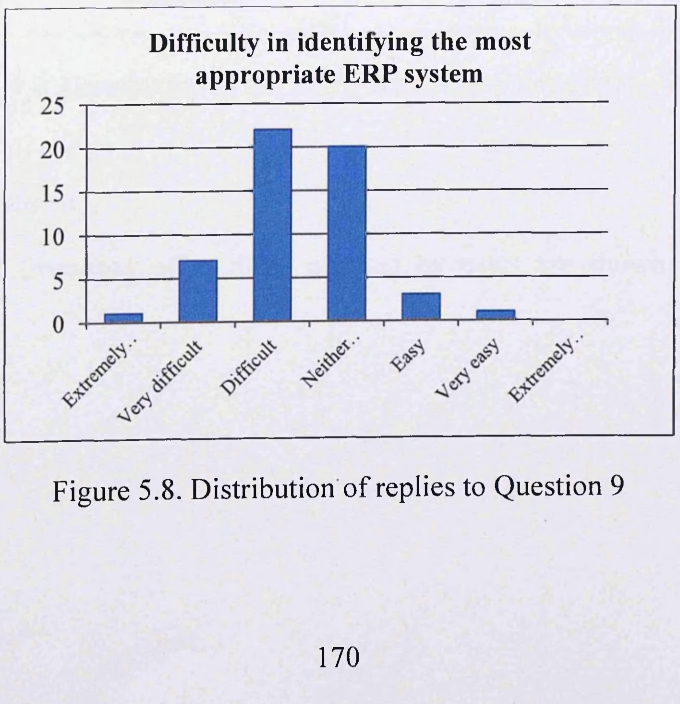


Figure 5.8. Distribution of replies to Question 9

Package Implementation strategy

The respondents' ERP package implementation strategy in terms of the variety of systems is shown in Figure 5.9 below. A single package developed by a single vendor is the most preferred method by 49%. By including the ones with minor add-ons, single package adoption increases up to 82%. Only one respondent has chosen the "Other" option without specifying their own type of package implementation.

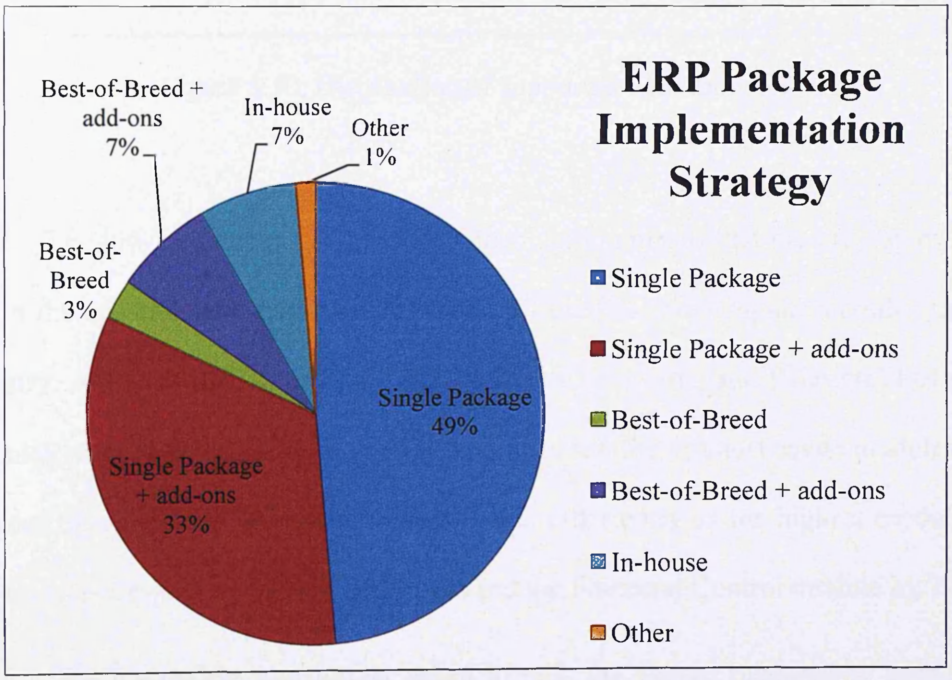


Figure 5.9. Distribution of the ERP Package Implementation Strategy

Supported modules

The range and frequency of modules adopted by users are shown in Figure 5.10 below.

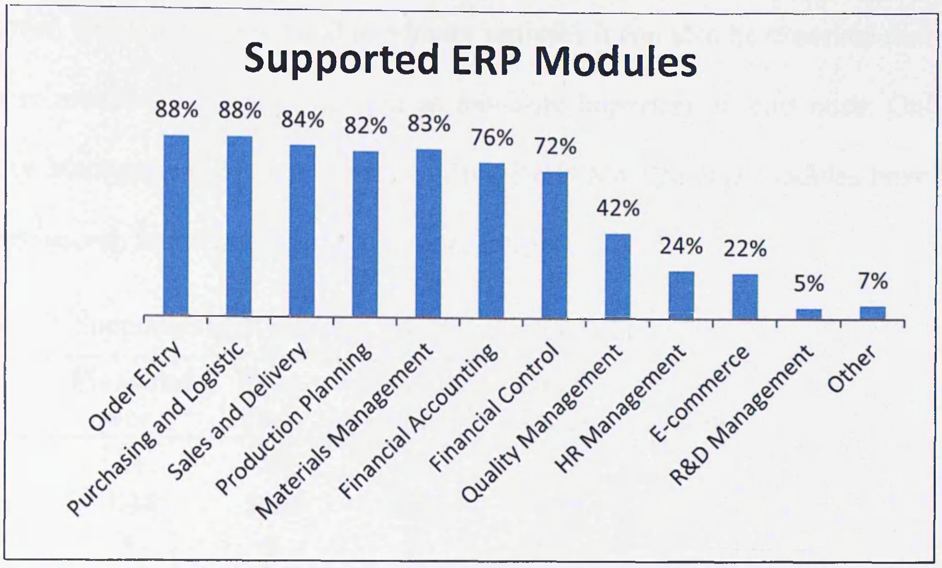


Figure 5.10. Distribution of supported ERP modules

The low percentage (7%) in the "Other" option means that the pre-determined list in the questionnaire has covered almost all the possible adopted modules in the industry. Although the Order Entry, Purchasing and Logistic, and Sales and Delivery modules seem to be the most frequently adopted ones, the leftmost seven modules are adopted by almost all ERP users. For example, order entry as the highest module of this seven is adopted by 88% of ERP users and the Financial Control module by 72%.

The respondent was further asked to rank the chosen modules by assigning "1" to the most important module, "2" to the second most important module, and so on. Ranking statistics, thus measuring the importance of each module to the respondent, are summarised in Table 5.2 below. The lowest mean, median and mode values (i.e., the most important) are observed in the Financial Accounting, Financial Control, Order Entry, and Production Planning modules. Whereas the highest mean, median and mode values (i.e., the least important) belong to the Quality Management, e-commerce, Human Resources and R&D Management modules. These are consistent with the "module popularity" statistics provided in the first part of this question (Q12).

However, through minimum and maximum statistics it can also be observed that most of these modules have been selected as primarily important at least once. Only the Quality Management, Human Resources and R&D Management modules have been ranked second, fourth and fifth at least once, respectively.

Table 5.2. Supported ERP modules *Ranking* Summary Statistics

	Financial Acc.	**Prod. Plan.**	**Financial Control**	**Order Entry**	**Material Man.**
N	54	58	52	62	58
Mean	**3.24**	**3.38**	**3.46**	**4.00**	**4.22**
Med.	3	3	3	4	5
Min.	1	1	1	1	1
Max.	11	8	8	9	8

	Sales & Delivery	**Purch. & Logistic**	**e-comerce**	**Quality Man.**	**R&D Man.**	**HR Man.**
N	60	63	15	30	4	17
Mean	**4.30**	**4.38**	**5.00**	**6.20**	**7.25**	**7.94**
Med.	4	4	5	7	7.50	8
Min.	1	1	1	2	5	4
Max.	8	8	10	9	9	10

The level of Customisation statistics (measuring the degree to which a module is customised from 1 'none' to 4 'major' customisation) are summarised in Table 5.3 below. All the modules have been customised from none to major at least once. While the ones customised most are e-commerce and Quality Management, their sample size is quite small. However, amongst the most frequently adopted modules Production Planning, Sales and Delivery, and Order Entry are the ones customised to high levels.

Tables in Appendix 8 show detailed results of this question including: its importance as a module (ranking) the level of customisation on implementing the module, and providing frequency statistics.

Table 5.3. Supported ERP modules *Level of Customisation* Summary Statistics

	Financial Acc.	**Financial Control**	**HR Man.**	**Purch. & Logistic**	**Material Man.**
N	55	52	17	63	59
Mean	**1.84**	**1.83**	**2.00**	**2.03**	**2.10**
	0.78	0.81	1.06	0.95	1.02
Med.	2	2	2	2	2
Min.	1	1	1	1	1
Max.	4	4	4	4	4

	Sales & Delivery	**Order Entry**	**R&D Man**	**Quality Man.**	**Prod. Plan.**	**e-comerce.**
N	60	63	4	58	30	15
Mean	**2.15**	**2.19**	**2.25**	**2.26**	**2.40**	**2.80**
Std. Dev	0.97	0.98	1.25	1.10	1.22	1.20
Med.	2	2	2	2	2	3
Min.	1	1	1	1	1	1
Max.	4	4	4	4	4	4

Supported ERP extensions

The percentages in Figure 5.11 show the ratio of add-ons to the total number of ERP-using respondents. The most frequently adopted add-on is the CAD system amongst the users followed by CRM, APS and SCM, respectively. Low percentage in the "Other" option means that the provided list has covered almost all the possible extensions adopted in the industry. The "Other" option has noted systems such as Quality System twice and Financial Accounts once. Therefore, it could be lower than 9 percent as these are usually considered as part of the main ERP system rather than add-ons (Mabert *et al.*, 2000). The least implemented add-ons are the Product Lifecycle Management and Product Configurator systems.

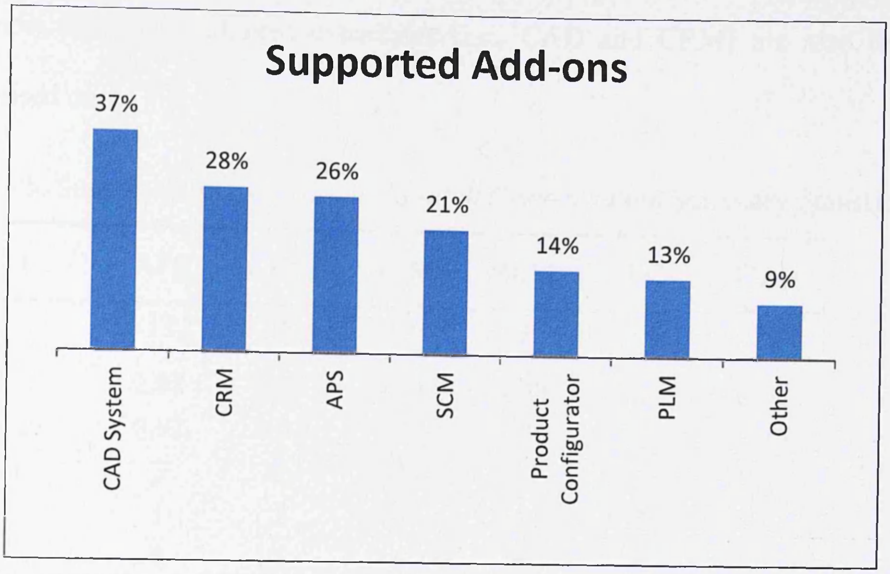


Figure 5.11. Distribution of supported ERP extensions

Ranking statistics are summarised in Table 5.4 below. The lowest mean, median and mode values (i.e., the most adopted) are observed in the Computer-aided Design (CAD), Customer Relationship Management (CRM) and Advanced Planning and Scheduling (APS) systems. Whereas, the highest mean, median and mode values (i.e., the least preferred) belong to the Product Lifecycle Management (PLM), Supply Chain Management (SCM) and Product Configurator (PC) systems. These results are consistent with the prevalence result in the first part of the question.

Table 5.4. Supported ERP extensions *Ranking* Summary Statistics

	APS	CRM	SCM	PLM	PC	CAD
N	11	14	10	6	8	21
Mean	1.73	1.43	2.60	3.00	3.00	1.67
Median	1	1	2	2.50	3	1
Minimum	1	1	1	1	2	1
Maximum	4	3	5	6	6	5

Level of Customisation statistics for the extensions are summarised in Table 5.5 below. All the add-ons have been customised from none to major at least once. While the ones customised most are PLM and APS; their sample size is quite small.

The most frequently adopted extensions (i.e., CAD and CRM) are also the least customised ones.

Table 5.5. Supported ERP extensions *Level of Customisation* Summary Statistics

	APS	**CRM**	**SCM**	**PLM**	**PC**	**CAD**
N	17	19	13	9	11	27
Mean	2.88	2.05	2.46	3.00	2.36	2.07
Std. Dev.	0.92	0.91	1.19	1.00	1.12	1.17
Median	3	2	2	3	2	2
Min.	1	1	1	1	1	1
Max.	4	4	4	4	4	4

Tables in Appendix 8 show detailed results of this question including: importance as an add-on (ranking), the level of customisation on implementing the add-on, and providing frequency statistics.

Vendors Preferred

SAP is by far the most popular ERP vendor amongst the users (Figure 5.12). Coming in fourth place after Microsoft Navision and Sage, Exel EFACS is the only UK-based national ERP vendor. 29 out of 32 vendors marked and noted in the "Other" option are all different vendors. This shows the importance of small-size national ERP vendors such that, when taken altogether, they dominate the market over the most well-known vendors such as SAP. It is also quite surprising that in-house developed ERP systems constitute a very small percentage of the market. A higher percentage of in-house systems might be expected due to the prevalence of human resources in the IT industry and hardware prices coming down with the advance of technology (Olsen & Sætre, 2007a; Olsen & Sætre, 2007b), which can make the system development process easier now than in past decades.

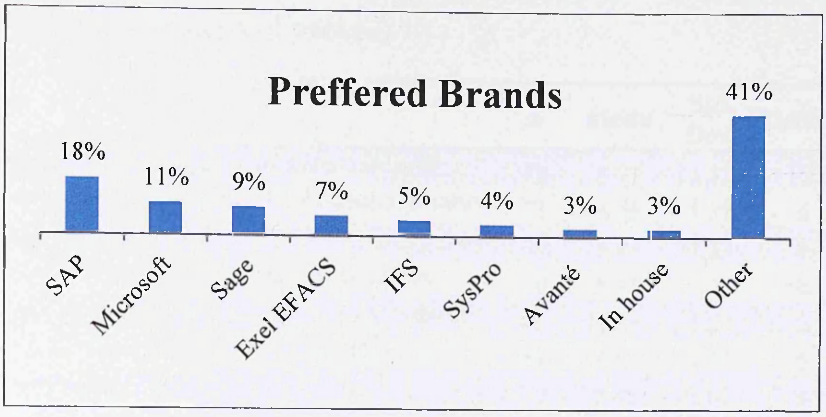


Figure 5.12. Distribution of preferred ERP vendors

Reasons to adopt and not to adopt

In terms of the "to adopt or not to adopt" dilemma in the industry, Questions 14, 15 and 16 are crucial to help understand the range of reasons to consider ERP systems. Do those users carefully examine and select their most appropriate software when they really need it? Or are they influenced by the external factors (e.g., supply chain buyers or competitive forces) to somehow unconsciously start using these complex company-wide IT systems?

Table 5.6 below shows the summary statistics of responses to Question 14 on the reasons to adopt ERP systems. The most strongly agreed reasons to adopt an ERP system for all the respondents (with the highest means, medians and modes, and lowest standard deviations) are the first four statements in the ranked list.

Normally, one expects the first three reasons to be valid for any organisation (e.g., retailers, banks, and service-oriented business). Although it is not so possible to compare this survey's results with other sectors of the economy, the fourth reason (14.d) shows that production planning is also important, along withthe other common reasons to adopt an ERP system, in the manufacturing sector.

Table 5.6. Reasons for adoption (ranked)

Reasons		n	Mean	Std. Dev.	Median	Mode
a)	To simplify and standardise business processes	70	**5.77**	1.12	6	6
b)	To replace legacy systems (old hardware/software)	71	**5.75**	1.51	6	7
c)	To integrate enterprise operations. systems, or data	70	**5.44**	1.33	6	6
d)	To improve production planning effectiveness	70	**5.41**	1.6	6	7
e)	To keep up with competitive forces in the industry	68	4.85	1.55	5	5
f)	To cope with increased workload/business	52	4.62	1.71	5	5
g)	To lower costs	70	4.46	1.63	4	4
h)	To support change/innovation in the company	67	4.34	1.74	4	4
i)	Linked to global activities (support glob.strategy)	69	*3.23*	2.03	3	1
j)	To improve e-commerce activities	68	*3.16*	1.75	3	1
k)	Adoption encouraged (or enforced) by key customers	67	*2.43*	1.49	2	1

The least agreed reasons to adopt an ERP system (resulting lowest means, medians and modes) are the last three statements. Compared to the other reasons, this last option (14.k) can be considered as an external factor. Though it has been identified as the least applicable reason to adopt an ERP system, the effect of competitors' ERP adoption (as another external force) is significantly higher than the effect of key customers.

There is no "other" option additionally noted down by the respondents in the full-scale data collection stage. In fact, Q14's part f (i.e., to cope with increased business/workload) was added after it was suggested during the pilot stage. That is also why there are more missing data in 14.f than the others seen in the table of Appendix 9

Table 5.7 below shows the summary statistics of answers to Question 15 on the reasons not to adopt ERP systems.

There are no clear visual differences amongst the parts of Question 15 regarding the reasons not to adopt an ERP system, except the first statement (ERP would not suit the needs of the company). It is the far most agreed reason while the remaining parts have means, medians and modes around point 4 (neither agree nor disagree). It can be argued that the nonusers are deliberately not adopting an ERP system to avoid any problems with a system that would not suit their needs.

Table 5.7.Reasons for non-adoption (ranked)

Reasons	n	Mean	Std. Dev.	Median	Mode
a) ERP would not suit the needs of the company	37	**5.84**	1.66	7	7
b) Cost of the consultancy for selection, implementation, etc	33	4.76	2.05	5	7
c) Cost of the software solution itself	33	4.58	1.97	5	5
d) Risk of implementation failure	34	4.47	1.94	4	4
e) Current economic climate	34	4.38	2.2	5	7
f) Cost of the training for employees	33	4.27	1.86	5	5
g) Cost of the hardware upgrades required	33	4.24	1.94	4	4

Finally, only two respondents (an ATO_1 and ETO company) replied that they had used and abandoned an ERP system. These particular individual responses are provided in Table 5.8 below. For the ATO_1 (manufacturer of security products and systems) the most strongly agreed reasons to abandon an ERP system are the statements in part a, b, d and e.

On the other hand; while the ETO company strongly agrees with the first statement as with the other abandoner, the statement in part c (the system was unable to meet the needs of our business) has been marked as 7 (strongly agree) on the scale. This behaviour is consistent with the inference made above regarding reason 15.a about not adopting ERP.

Tables in Appendix 9 exhibit more descriptive statistics of answers to Question 14 and 15 about the reasons for adoption and non-adoption.

Table 5.8. 2 responses to Question 16: Abandoning reasons?	Resp. #1 ATO_1	Resp. #2 ETO
a) Significant financial loss due to underestimating implementation costs	7	7
b) Insufficient payback after adoption	7	1
c) The system was unable to meet the needs of our business	4	7
d) High cost of maintenance and training	7	1
e) Lack of personnel capable of using the system	7	5
f) The system was gradually neglected over time	4	1
g) The system was too complex for our company's organisational structure	4	5
h) The system failed to improve the effectiveness of our planning processes	4	5
i) The system failed to improve the efficiency of our transactions	3	5

In the Likert Scale continuum: 1 = Strongly Disagree to 7= Strongly Agree

5.2 Bivariate Analysis

So far, responses to all questions have been summarised and discussed individually; namely, each question has been considered on its own. In this subsection, the aim is to look for any interesting links between questions. In order to achieve that, bivariate relationships amongst the variables are sought through correlation analysis, cross-tabulations, and group-wise comparisons which are statistically tested for significance to generalise from the sample to the population.

Significance testing is categorised under two types: parametric and non-parametric tests. Parametric tests (e.g., Student's t-test and ANOVA) operate under strict assumptions such as observations to be independent of each other, populations are considered having equal variances, measurement scales used as intervals or ratios, and normality is another important assumption. On the other hand, non-parametric tests (e.g., Chi-squared and Kolmogorov-Smirnov) have less assumptions, such as not assuming a particular distribution, , and can be used with nominal and ordinal scales.

In the following discussions when a parametric test's assumptions are violated, non-parametric tests are used.

The power of the analyses and tests is calculated which depends on the type of bivariate analyses. For the analyses in which the sample data is used completely (e.g., correlation) or split into two for group comparison (e.g., MTO vs. MTS), the power is well above 0.80, which is acknowledged to be very adequate by researchers (Forza, 2009). On the other hand, when the whole sample is split into quadrants, the power of comparisons may decrease down to 0.6.

5.2.1 Correlations and Crosstabulations

Correlations

Pearson's correlation (r) values and their indication of significance are provided in Table 5.9 for the ordinal variables measured between Question 2 to 10 (i.e., Q2, Q3, Q4, Q6, Q7, Q9, and Q10).

Table 5.9. Correlation matrix between variables measured through Question 2 to 10

Variables		Q2.	Q3.	Q4a.	Q4b.	Q6.	Q7.	Q9.	Q10.
Q2. Number of Employees	r	1							
	Sign.								
Q3. Sales Turnover	r	0.811**	1						
	Sign.	0.000							
Q4a. Company Type (6 cat.)	r	0.353**	0.379**	1					
	Sign.	0.000	0.000						
Q4b. Company Type (2 cat.)	r	0.298**	0.349**	0.852**	1				
	Sign.	0.001	0.000	0.000					
Q6. Shop Floor Routing	r	0.087	0.163	0.452**	0.293**	1			
	Sign.	0.341	0.075	0.000	0.001				
Q7. SC Position	r	0.011	0.025	0.020	0.001	0.018	1		
	Sign.	0.902	0.783	0.827	0.989	0.845			
Q9. How diff. to select	r	0.151	0.155	0.299*	0.260	0.290*	-0.388**	1	
	Sign.	0.275	0.263	0.028	0.058	0.037	0.005		
Q10. Package Impl. Strategy	r	-0.004	0.017	-0.033	-0.020	0.065	0.085	-0.013	1
	Sign.	0.975	0.889	0.784	0.871	0.596	0.498	0.924	

**. Correlation is significant at the 0.01 level (2-tailed), and *. at the 0.05 level (2-tailed).

The significance of the relationships are indicated at two levels (** at the 0.01 level, and * at the 0.05 level). The production strategy variable, measured by Q4, is used twice in the matrix above: designated by Q4a as itself (in the original six categories), and Q4b as grouped into two main categories (MTO vs MTS). Of course, the relationship between production strategy variables with six and two categories (Q4a and Q4b) is very highly significant (i.e., over .8).

Additionally, the variables indicating the number of employees and sales turnover are very highly correlated. Though the correlation values for the rest are less than 0.5, 9 out of 11 significant correlations are at the 0.01 level and the remaining two are at the 0.05 level.

It is found that the company profile goes from MTO to MTS type as the company size (both the number of employees and sales turnover) increases. Besides, it is also meaningful that if a company is a MTO type, its shop floor routing is identified as a job shop configuration. This is indicated through the significant relationship between the production strategy and shop floor routing variables.

Q9 (difficulty in selecting the most appropriate system) is found to significantly correlate with three variables: Q4 (Production Strategy), Q6 (Shop Floor Routing) and Q7 (supply chain position). All are ordinal variables, and the last correlation is observed to be negative and the first two as positive. That is, downstream firms in supply chains have found it easier to identify the most appropriate system for their organisations compared to upstream firms. At this point, it is interesting to note that production strategy is found to be unrelated to supply chain position. The other two positive correlations with Q9 argues that companies, close to being MTS and having a flow shop routing, find it easier to identify the most appropriate ERP system for their organisations.

Finally, the statements of Q14 (reasons to adopt ERP) and Q15 (reasons not to adopt ERP) are subjected to correlation analysis to observe any sign of significant correlation. The results are presented in two correlation matrices, one matrix for each of these two questions, with levels of significance. For Q14, see Table 5.10.

The highest correlation is found to be between 14.h (*reason to adopt*: to support change/innovation in the company) and 14.i (*reason to adopt*: to keep up with competitive forces in the industry). This can be interpreted such that firms adopting ERP see the implementation as a competitive move in their industry and relate it as a means to support change and innovation in the company. On the other hand, the only significant negative correlation is found to be between 14.d (*reason to adopt*: to replace legacy systems, e.g. old hardware/software) and 14.g (*reason to adopt*: to improve production planning effectiveness). This may indicate that firms which aim at improving production planning performance via implementing an ERP system, either use it alongside existing systems or do not feel that they already have an existing 'system' to replace. This is a potentially interesting point which needs to be explored by further research, e.g., case studies.

For Q1 Table 5.11 is below. Q15's correlation matrix shows a very high correlation amongst its statements except 15.f (reason not *to adopt*: ERP would not suit the needs of the company). This shows a clear picture regarding the internal consistency in this question, since all statements except 15.f are related to economic reasons not to adopt ERP, but 15.f is about the requirements.

Table 5.10. Correlation matrix amongst the options within Q14

		A14.a	A14.b	A14.c	A14.d	A14.e	A14.f	A14.g	A14.h	A14.i	A14.j	A14.k
A14a. To lower costs	r	1										
	Sign.											
A14b. To simplify and standardise business processes	r	.241*	1									
	Sign.	.049										
A14c. To integrate enterprise operations. systems, or data	r	.172	.293*	1								
	Sign.	.167	.017									
A14d. To replace legacy systems (old hardware/software)	r	.013	.006	-.118	1							
	Sign.	.914	.965	.344								
A14e. Linked to global activities (support globalisation strategy)	r	-.168	-.098	.247*	-.002	1						
	Sign.	.182	.436	.045	.990							
A14f. To improve e-commerce (e-procurement & marketing) activities	r	.053	-.031	.123	.004	.462**	1					
	Sign.	.675	.807	.330	.973	.000						
A14g. To improve production planning effectiveness	r	.318**	.088	.084	-.299*	.027	.087	1				
	Sign.	.009	.482	.499	.015	.831	.493					
A14h. To support change/innovation in the company	r	.269*	.266*	.075	-.093	.061	.212	.431**	1			
	Sign.	.032	.034	.553	.466	.632	.093	.000				
A14i. To keep up with competitive forces in the industry	r	.328**	.094	.137	-.140	.007	.141	.516**	.637**	1		
	Sign.	.008	.458	.275	.271	.958	.265	.000	.000			
A14j. Adoption encouraged (or enforced) by key customers	r	-.092	-.036	.068	-.224	.280*	.220	.306*	.134	.251*	1	
	Sign.	.472	.777	.592	.075	.025	.081	.014	.290	.045		
A14k. Other	r	.192	-.044	-.259	.060	-.079	.285*	.355*	.297*	.210	.368**	1
	Sign.	.181	.760	.069	.677	.587	.047	.011	.038	.147	.009	

**. Correlation is significant at the 0.01 level (2-tailed), and *. at the 0.05 level (2-tailed).

Table 5.11. Correlation matrix amongst the options within Q15

		A15.a	15.b	A15.c	A15.d	A15.e	A15.f	A15.g
A15a. Cost of the software solution itself	r	1						
	Sign.							
A15b. Cost of consultancy for selection, imp., etc	r	.951**	1					
	Sign.	.000						
A15c. Cost of the training for employees	r	.852**	.831**	1				
	Sign.	.000	.000					
A15d. Cost of the hardware upgrades required	r	.798**	.811**	.754**	1			
	Sign.	.000	.000	.000				
A15e. Risk of implementation failure	r	.624**	.677**	.600**	.646**	1		
	Sign.	.000	.000	.000	.000			
A15f. ERP would not suit the needs of the company	r	.219	.216	.164	.289	.441*	1	
	Sign.	.221	.227	.360	.102	.010		
A15g. Current economic climate	r	.626**	.687**	.540**	.513**	.313	-.019	1
	Sign.	.000	.000	.001	.002	.076	.915	

**. Correlation is significant at the 0.01 level (2-tailed), and *. at the 0.05 level (2-tailed).

Pearson's correlation is unduly influenced by outliers, unequal variances (homoscedasticity), non-normality, and nonlinearity. All these strict assumptions of Pearson's correlation test are mostly violated by the variables in this study. Therefore, two non-parametric alternative tests are also applied to see any difference. The Spearman's rho and Kendall's tau-b statistics measure the rank-order association between two scale or ordinal variables. They work regardless of the distributions of the variables and are non-parametric alternatives of Pearson's correlation coefficients. When the same variables are subject to Spearman's rho and Kendall's tau-b statistics, correlations are obtained at the same significant levels with the unchanged directions yet with slightly altering magnitudes.

Cross-tabulations

The aim of constructing *cross-tabulations* is to analyse two or more variables on a single table to enable detailed analyses of the relationships and develop some statistics which could not be achieved through univariate analysis or correlation computations.

All group analyses and comparisons with respect to the production strategy (Q4: MTO vs MTS) and ERP adoption (Q8: user vs non-user) are handled specifically in the next subsection. Therefore, analyses out of that range, which are possibly interesting when presented with cross-tabulations (e.g., Q6, Q7, Q9 and Q10), are provided at this point. Especially, the questions allowing multiple selections (i.e., Q5, Q11, Q12 and Q13) are deeply analysed here with each other and with ordinal variables used in the previous section.

12 combinations, thought to be appropriate and interesting for cross tabulation, out of a possible 28, are selected as shown in Figure 5.13 below. Two main selection criteria are adopted. Firstly, most of the combinations are seleected based on the anticipated relationship between pairs; for example, a company's industry may well be related to the supply chain position it serves. Secondly, questions allowing multiple selections (nodes in the second row of the figure below) are compared with each other (4 out of 6). The remaining two combinations are ignored due to dramatically decreased sample size when combining industry with adopted ERP modules or add-ons which have several choices. The nodes denote the questions and the codes on the links between the nodes denote corresponding tables for each combination. The most frequently used variables for combination become the ERP vendor (Q13), Supply chain position (Q7), and Difficulty of selecting an appropriate system (Q9).

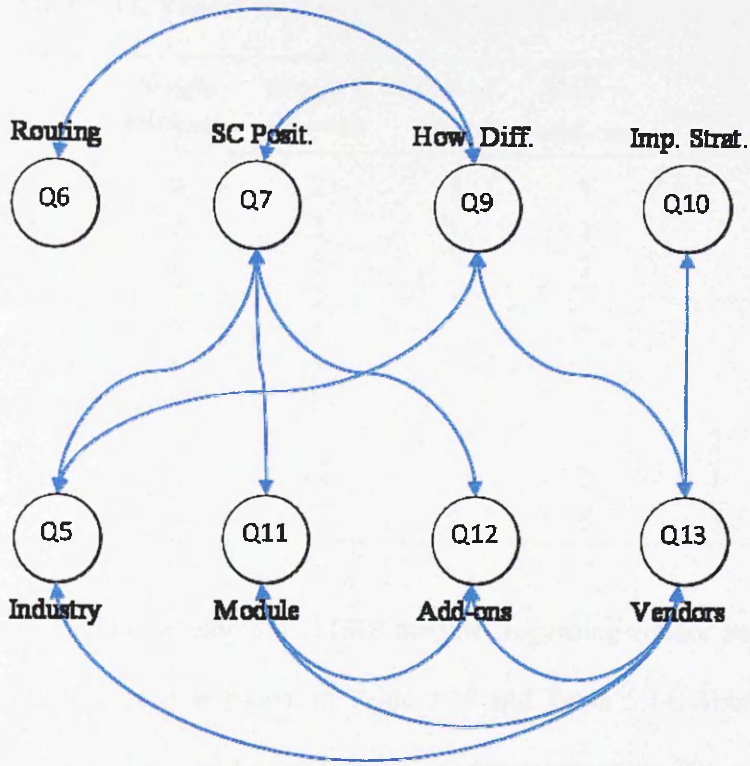


Figure 5.13. Selected questions and cross-tabulations

The first combination is cross-tabulated to observe the distribution of ERP package implementation strategy regarding the vendor (Table 5.12).

SAP has been implemented mainly as a single package (9 out of 14) but it is also the only vendor combined with other systems in a best-of-breed approach. From the vendors which are categorised under the "Other" option, being mostly small and local vendors, a great majority of the respondent companies have implemented ERP systems as a single package with or without add-ons (27 out of 30). Another interesting point is that a great majority of Sage users have adopted at least one add-on besides the Sage system (6 out of 7).

Table 5.12. Vendor vs ERP package implementation strategy

	Single Package	**Single + add-ons**	**Best-of-Breed**	**BoB + add-ons**	**In-house**	**Other**
SAP	9	2	2	1		
MS Navision	2	2		1		
Sage	1	5		1		
Exel EFACS	3	2				
IFS	2	1		1		
SysPro	1	2				
Avanté (Epicor)	1	1				
In-house					2	
Other	15	12		2	1	
Total	*34*	*27*	*2*	*6*	*3*	*0*

The distribution of adoption of ERP modules regarding vendor and extensions added on to those vendors is shown in Table 5.13 and Table 5.14. There is not any accumulation of module or add-on adoption in particular vendors. It can be said that ERP extensions are quite prevalent such that the ERP packages of most of the vendors (either large and global, or small and local) are preferred together with add-ons. The leftmost seven modules are most frequently implemented almost in all vendors. Additionally, the adoption of the Human Resources module by SAP users dominates the rest. This may be because some other smaller vendors may not offer the module.

Frequency-based relationship between the adoption of modules and add-ons are shown in Table 5.15. Although Financial Accounting (FA) is one of the frequently adopted modules, the FA module here is low; interestingly because firms using add-ons adopt the FA module less frequently.

Table 5.13. Vendor vs Adopted add-ons

	CAD	**CRM**	**APS**	**SCM**	**PC**	**PLM**	**Other**	***Σ***	***Avg.***
SAP	5	4	5	4	3	3		*24*	*1.7*
MS Navision		4	2	1	1	1	1	*10*	*2.0*
Sage	1	1	3	3	2	1	1	*12*	*1.5*
Exel EFACS	2	2						*4*	*0.8*
IFS	1		1	1				*3*	*0.8*
SysPro	1							*1*	*0.3*
Avanté (Epicor)	2		1	1	1		1	*6*	*2.0*
In-house	1						1	*2*	*1.0*
Other	11	8	5	3	3	2	3	*35*	*17.5*
Total	*24*	*19*	*17*	*13*	*10*	*7*	*7*		

Table 5.14. Vendor vs Adopted modules

	Order Entry	Pur. & Log	Sales & Delivery	Prod. Plan.	Mat. Man.	Fin. Acc.	Fin. Cntrl	Qual. Man.	HR Man.	E-com.	R&D Man.	Other	*Σ*	*Avg.*
SAP	12	14	12	13	13	12	12	6	9	2	1	1	*107*	*7.6*
MS Nav.	5	5	5	5	5	5	5	1	1	2		1	*40*	*8.0*
Sage	6	5	5	4	4	7	6	1		3	1	1	*43*	*5.4*
Exel	5	4	5	4	4	5	5	3					*35*	*7.0*
IFS	3	4	3	2	3	4	3	1	2				*25*	*6.3*
SysPro	3	2	2	1	2	3	3						*16*	*5.3*
Avanté	2	2	2	1	2	2	1	1					*13*	*4.3*
In-house	2	1	2	2	2			2	1	1	1		*14*	*7.0*
Other	29	28	27	26	27	23	22	14	4	8	1	2	*211*	*105.5*
Total	*67*	*65*	*63*	*58*	*62*	*61*	*57*	*29*	*17*	*16*	*4*	*5*		

Table 5.15. Adopted add-ons vs Adopted modules

	Order Entry	Pur. & Log	Sales & Delivery	Prod. Plan.	Mat. Man.	Fin. Acc.	Fin. Cntrl	Qual. Man.	HR Man.	E-com.	R&D Man.	Other	Σ
CAD	28	27	26	26	27	13	24	18	9	7	2	2	*209*
CRM	20	20	21	19	18	8	15	7	8	7	2	1	*146*
APS	18	19	19	18	17	6	15	8	6	8	1	1	*136*
SCM	15	15	15	14	15	5	11	8	4	5			*107*
PC	11	10	10	10	11	5	11	4	1	4			*77*
PLM	9	9	10	9	9	2	9	6	2	5		2	*72*
Other	*7*	*6*	*7*	*5*	*5*	*6*	*5*	*3*		*1*			*45*
Total	*108*	*106*	*108*	*101*	*102*	*45*	*90*	*54*	*30*	*37*	*5*	*6*	

Table 5.16. Vendor vs Industrial sector

	Ind. Mach. & Eq.	Auto-motive	Aero. & Def.	Comp., Elect. & Opt.	Cons. goods	Chem.	Metals, Wood, Plastics	Ship B., Railway, etc	Pharm. (Healt hcare)	Oil & Gas	Nuclear	Textile	Other	Σ
SAP	1		2	2	3	2		1	2					*13*
MS Nav.	2			1		2	2			1	1		3	*12*
Sage	4	3	2	1		2	1		2	2				*17*
Exel	3	3	4	2	2			1	2	1			1	*19*
IFS		2	1				1		1					*5*
SysPro	3	2	1						1	1			1	*9*
Avanté	1	1	1	1	1	1		1	1	1				*9*
In-house							1						1	*2*
Other	10	10	11	7	3	3	4	7	3	4	2	3	5	*72*
Total	*24*	*21*	*22*	*14*	*9*	*10*	*9*	*10*	*12*	*10*	*3*	*3*	*11*	

Considering the vendor preference within industrial sectors, Table 5.16 suggests that some vendors are particularly preferred in some industries more than others according to our sample. For example, as a UK-based vendor Exel EFACS is preferred mostly by firms of the Aerospace & Defence sector. On the other hand, it is surprising not to see any software by SAP and MS Navision implemented by firms in the automotive sector but mostly shared amongst other vendors. Table 5.17 shows that these sectors also serve in the supply chain positions differently.

Table 5.17. Industrial sector vs Supply chain position

Sectors	**OEM**	**Tier-1**	**Tier-2**	**Raw**	**Other**	**N**	**Perc.**
Industrial Machinery	15	12	9		1	37	7%
Automotive	6	9	16		3	34	14%
Aerospace & Defence	8	8	15		2	33	15%
Computer, Electricals, etc.	7	4	9	1	1	22	9%
Consumer goods	7	3	7	1	1	19	8%
Chemicals	7	4	3	2	1	17	13%
Metals, Wood, & Plastics	8	1	3	4	2	18	2%
Transportation	9	1	5		1	16	5%
Pharmaceutical	6	3	6		1	16	7%
Oil & Gas	5	2	5		1	13	6%
Nuclear	4	1	1			6	6%
Textile	3	2	1			6	2%
Other						0	0%
Totals	*85*	*50*	*80*	*8*	*14*	*238*	*100%*

While firms in the Automotive and Aerospace & Defence sectors mostly serve at Tier-2, the rest of the sectors serve as an OEM or Tier-1 supplier in the first place. Table 5.18 and Table 5.19 present the adoption frequencies of modules and add-ons by the manufacturers serving at different levels of supply chains. No particular module and add-on adoption tendency can be observed with respect to the supply chain position.

Table 5.18. Supply chain position vs Adopted modules

SC Position	Order Entry	Pur. & Log	Sales & Del.	Prod. Plan.	Mat. Man.	Fin. Acc.	Fin. Cntrl	Qual. Man.	HR Man.	E-com.	R&D Man.	Other	*Σ*	*Avg*
OEM	27	28	24	28	26	24	22	12	8	7	4	3	*213*	*3.9*
Tier-1	12	12	11	11	11	11	11	2	2	4		2	*89*	*3.7*
Tier-2	22	19	22	18	20	16	17	16	6	4			*160*	*5.2*
Raw Mat	3	3	3	2	3	2	2	1	2	1			*22*	*2.4*
Other	3	5	4	3	3	5	3	1		1			*28*	*4.0*
Total	67	67	64	62	63	58	55	32	18	17	4	5		

Table 5.19. Supply chain position vs Adopted add-ons

SC Position	**CAD**	**CRM**	**APS**	**SCM**	**PC**	**PLM**	**Other**	***Σ***	***Avg.***
OEM	11	10	9	6	5	4		*45*	*0.8*
Tier-1	3	3	2	2	3		1	*14*	*0.6*
Tier-2	13	6	7	6	3	4	1	*40*	*1.3*
Raw Mat		2	1	1			3	*7*	*0.8*
Other	1		1	1		2		*5*	*0.7*
Total	*28*	*21*	*20*	*16*	*11*	*10*	*5*	*111*	

Difficulty of selecting the most appropriate system amongst the supply chain tiers is interesting to observe (Table 5.20).

Table 5.20. SC position vs Difficulty of selecting the most appropriate system

SC Position	Extremely Difficult	Very Diff.	Diff.	Neither Diff. Nor Easy	Easy	Very Easy	Extremely Easy	*Total*
OEM		1	8	8	3			*20*
Tier-1			3	5		1		*9*
Tier-2	1	4	9	5				*19*
Raw Mat		1	1					*2*
Other		1	1	2				*4*
Total	*1*	*7*	*22*	*20*	*3*	*1*		

The most suitable sample sizes are available for OEM and Tier-2 which implies that while the majority of OEMs find this difficult and neutral, Tier-2 suppliers centre this discussion on the choice "difficult". For industrial sectors and vendors, the distribution of responses to this system selection difficulty question does not show any irregularity towards a particular vendor or sector where the sample size for each is sufficient (Table 5.21and Table 5.22).

Table 5.21. Industrial sector vs Difficulty of selecting the most appropriate system

Sectors	Extremely Difficult	Very Diff.	Diff.	Neither Diff. Nor Easy	Easy	Very Easy	Extremely Easy	*Total*
Industrial Mach. & Eq.	1	4	8	5	1	1		*20*
Automotive	1	2	9	5				*17*
Aerospace & Defence	1	4	7	6	1			*19*
Computers, Elect. & Opt.	1	5	3	2	1			*12*
Consumer goods		3	3	1	1			*8*
Chemicals		1	4					*5*
Metals, Wood, Plastics			2	5	1			*8*
Transportation		2	3	3				*8*
Pharma. (Healthcare)		1	6	1				*8*
Oil & Gas		2	4					*6*
Nuclear			1					*1*
Textiles			3					*3*
Other		1	4	2				*7*
Totals	*4*	*25*	*57*	*30*	*5*	*1*	*0*	

Table 5.22. Vendor vs Difficulty of selecting the most appropriate system

Vendors	Extremely Difficult	Very Diff.	Diff.	Neither Diff. Nor Easy	Easy	Very Easy	Extremely Easy	*Total*
SAP		1	1	2	1			*5*
MS Navision				2	1			*3*
Sage			4	3				*7*
Exel EFACS	1		3	1				*5*
IFS			2	1				*3*
SysPro			2			1		*3*
Avanté		1						*1*
In-house				2				*2*
Other		4	15	6	2			*27*
Total	*1*	*6*	*27*	*17*	*4*	*1*	*0*	

This difference can be observed better via the variables with fewer categories such as shop floor routing; companies where a job shop routing is mostly dominant (which are also mainly MTO), the mean and the distribution is more onto the "difficult" side (Table 5.23).

Table 5.23. Shop floor routing vs Difficulty of selecting the most appropriate system

SF Routing	Ext. Diff.	Very Diff.	Diff.	Neither Diff. Nor Easy	Easy	Very Easy	Ext. Easy	*Total*
Pure Job Shop		1	1	1				*3*
General Job Shop	1	4	12	9				*26*
General Flow Shop		2	7	7	3	1		*20*
Pure Flow Shop			1	2				*3*
Not Applicable			1	1				*2*
Total	*1*	*7*	*22*	*20*	*3*	*1*	*0*	

The cross-tabulations presented above are layered further with production strategy (MTO vs MTS) in the following section. This adds the third dimension to the tables which enables any differences between these groups to be scrutinised. This is left to the following section due to the group comparison.

5.2.2 Comparing Groups

Further bivariate analyses are provided in this subsection through grouping data in two dimensions as *User vs Nonuser* and *MTO vs MTS*. The analyses via comparing groups are handled in three subsections. Firstly, regarding the production strategy (i.e., row-wise in the table above); secondly, ERP environment (i.e., column-wise); and, finally through comparisons of quadrants.

A cross-tabulation of these two categorical variables is provided below (Table 5.24). Since sample counts get dramatically lower when multiple categorised groups are allowed, the cross-tabulations and bivariate analysis of group comparisons are performed regarding two groups, i.e. MTO vs MTS and adopter vs non-adopter.

Table 5.24. Production strategy vs ERP environment Cross-tabulation

			Users			Non-users			
			User	Installer	Aban-doner	Planner	Nonuser	*Sub Total*	*Tot*
MTO	ETO	Count	9		1		2	12	60
		% within ERP eff.	*14.3%*	*0.0%*	*50.0%*	*0.0%*	*4.4%*	*9.8%*	*48.8 %*
	MTO_1	Count	7	1		1	15	24	
		% within ERP eff.	*11.1%*	*10.0%*	*0.0%*	*33.3%*	*33.3%*	*19.5%*	
	MTO_2	Count	16	2			6	24	
		% within ERP eff.	*25.4%*	*20.0%*	*0.0%*	*0.0%*	*13.3%*	*19.5%*	
			36 *(29.3%)*			24 *(19.5%)*			
MTS	ATO_1	Count	16	4	1	1	12	34	63
		% within ERP eff.	*25.4%*	*40.0%*	*50.0%*	*33.3%*	*26.7%*	*27.6%*	*51.2 %*
	ATO_2	Count	9	2		1	8	20	
		% within ERP eff.	*14.3%*	*20.0%*	*0.0%*	*33.3%*	*17.8%*	*16.3%*	
	MTS	Count	6	1			2	9	
		% within ERP eff.	*9.5%*	*10.0%*	*0.0%*	*0.0%*	*4.4%*	*7.3%*	
			39 *(31.7%)*			24 *(19.5%)*			
SubTot		Count	63	10	2	3	45	123	
		% within ERP eff.	*51.2%*	*8.1%*	*1.6%*	*2.4%*	*36.6%*	*100.0%*	
Total		Count	75			48			
		% within ERP eff.	*61.0%*			*39.0%*			

In the analyses, several parametric and non-parametric techniques are applied. *One-way ANOVA* and its non-parametric alternatives are techniques to start analysing with respect to two dichotomous factors. On the other hand, distributions of multiple choice variables (e.g., vendors, modules preferred) are compared through *charts* and *chi-square tests.*

The *One-way ANOVA* technique has been used to test differences in a single interval dependent variable among two, three, or more groups formed by the categories of a single categorical independent variable (also known as *factor*). To exemplify, the dependent variables are the number of employees (Q2), sales turnover (Q3), shop floor routing (Q6), supply chain position (Q7), ERP environment (Q8), how difficult to select (Q9), package implementation strategy (Q10), importance ranking of adopted modules (Q11), importance ranking of adopted add-ons (Q12) , reasons to adopt (Q14), reasons not to adopt (Q15) and the independent categorical variables (i.e., factors) are the production strategy and the ERP effort.

Make-To-Order vs Make-To-Stock

Through One-way ANOVA analysis, significant differences with respect to production strategies are found amongst the six categories (i.e., ETO, MTO_1, MTO_2, ATO_1, ATO_2 and MTS): company size (both number of employees and sales turnover), shop floor routing, Q15.f (The reason not to adopt: ERP would not suit the needs of the company), the importance ranking of the adopted Sales and Delivery module.

Significant differences with respect to production strategies are also found when categories are grouped under two main categories (i.e., MTO and MTS): Company Size (both number of employees and sales turnover), Shop Floor Routing, Q9 (How difficult to select the most appropriate ERP system), Q14.e (*reason to adopt*: Get linked to global activities/support globalisation strategy), Q15.f (*reason not to adopt*: ERP would not suit the needs of the company), and the importance ranking of the adopted PP module.

The main difference between the discussions in the above paragraph is that while the first *one-way ANOVA* detects any difference amongst six categories concerning the investigated variable, the second test makes the comparison for the two main aggregated groups. This thesis is not particularly interested in the differences amongst six production strategies at this point, but in two 'umbrella' terms (i.e., MTO and MTS).

Industrial Sector

Figure 5.14 and Table 5.25 below show the sectoral distributions of two main production strategies and chi-square tests for similarity, respectively. While consumer goods, chemicals, and metal, wood & plastics sectors dominate the MTS type, aerospace & defence and ship building sectors do so for the MTO sector.

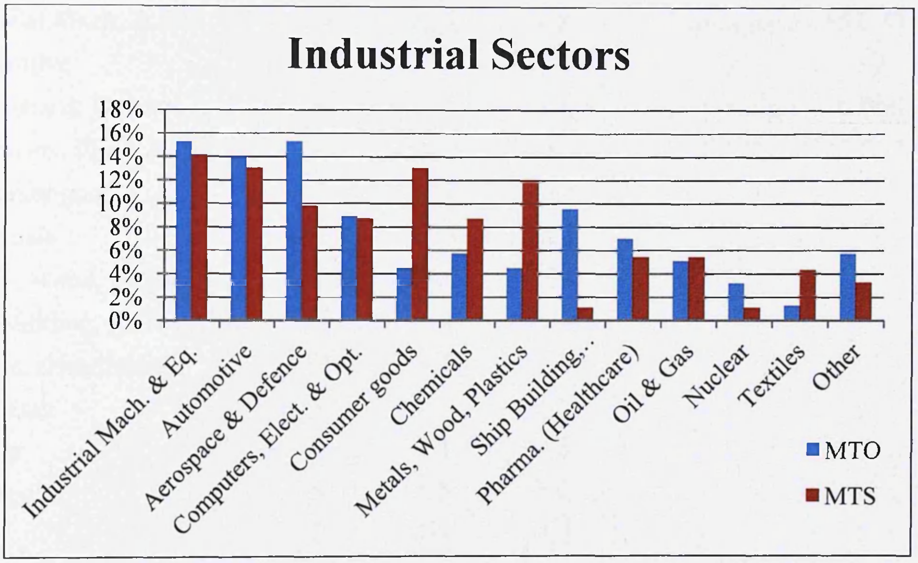


Figure 5.14. Distribution of sectors with respect to production strategy in two groups.

The low significance value shown to the right in the table below (asym. sign.) suggests that the sectoral distribution of MTO companies does differ from the sectoral distribution of MTS companies.

Since all the remaining variables are related to the ERP environment, the remainder of this discussion above is provided under the subsection comparing *MTO user* and *MTS user* quadrants titled “MTO User vs MTS User (2)”.

Cross-tabulations layered with production strategy

The cross-tabulations presented in Section 5.2.1, are further layered with respect to the production strategy as a third dimension, provided in Appendix 10. During analyses, most of the tables did not provide meaningful and interesting results, especially when the available data was further split into subdivisions, which dramatically reduced the sample size per division. Therefore, only the ones being worthwhile to discuss are provided.

Table 5.25. χ^2 test for similarity between sectoral distributions (MTO vs MTS)

	Obs. N	Exp. N	Residual
Industrial Mach. & Eq.	24	22.2	1.8
Automotive	22	20.6	1.4
Aerospace & Defence	24	15.9	8.1
Computers, Elect. & Opt.	14	14.3	-0.3
Consumer goods	7	20.6	-13.6
Chemicals	9	14.3	-5.3
Metals, Wood, Plastics	7	19.0	-12.0
Ship Building, Railway, etc	15	1.6	13.4
Pharma. (Healthcare)	11	7.9	3.1
Oil & Gas	8	7.9	0.1
Nuclear	9	4.8	4.2
Textiles	5	1.6	3.4
Other	2	6.3	-4.3
Total	*157*		

Test statistics	
Chi-square	151.731
df	12
Asym sign	0.000

The first table of Appendix 10 shows that SAP, as the leading ERP vendor, is mostly implemented as a single package (11 out of 14) and very highly preferred by MTS companies (13 out of 14); while MTO companies prefer local vendors and a diverse "package implementation strategy". In the last table, Automotive and Aerospace & Defence sectors are mostly served by Tier-2 suppliers which are predominantly MTO firms. The rest of the sectors serve as an OEM or Tier-1 supplier in the first place.

ERP User vs Nonuser

Significant differences with respect to ERP environment are only found for company size (both number of employees and sales turnover) using *one-way ANOVA* when categories are grouped under the other two main groups (i.e., User and Nonuser). For example, there is no relation between the shop floor routing or supply chain position of a company and its ERP adoption. On the other hand, the other variables measured by Q9 (How difficult to select the most appropriate ERP system), Q14 or Q15 are incomparable since they are answered when the respondent is a user only.

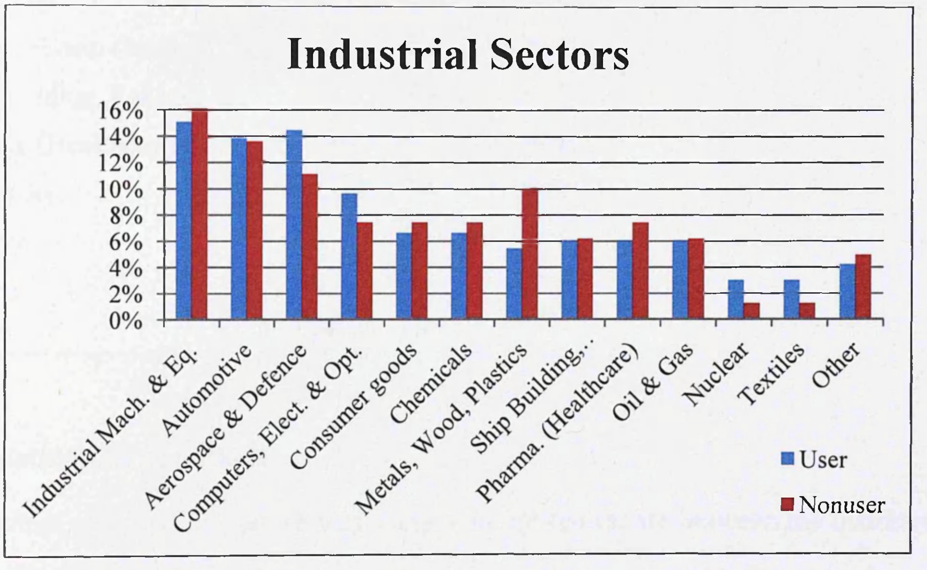


Figure 5.15. Distribution of industrial sectors with respect to ERP adoption.

The only comparable distribution is the individual sectors shown in Figure 5.15 above and the chi-square test below in Table 5.26 which indicates that the distributions are identical. The only mismatch is observed in the metals, wood & plastics sector. Since they are mostly raw material manufacturers and smaller companies in this sample, they show a lower adoption score.

Table 5.26. χ^2 test for similarity between sector distributions (User vs Nonuser)

	Obs. N	Exp. N	Residual
Industrial Mach. & Eq.	15	16.3	-1.3
Automotive	14	14.3	-0.3
Aerospace & Defence	14	11.2	2.8
Computers, Elect. & Opt.	10	7.1	2.9
Consumer goods	7	7.1	-0.1
Chemicals	5	10.2	-5.2
Metals, Wood, Plastics	6	6.1	-0.1
Ship Building, Railway, etc	6	7.1	-1.1
Pharma. (Healthcare)	6	6.1	-0.1
Oil & Gas	3	1.0	2.0
Nuclear	3	1.0	2.0
Textiles	4	5.1	-1.1
Other	*100*		

Test statistics	
Chi-square	12.709
df	12
Asym sign	0.391

Comparison of quadrants

The actual comparisons, which this study is interested in, are between the quadrants of ERP environment and production strategy variables. Figure 5.16 below shows three relationships that are important since MTO companies and their connection to ERP systems are of particular interest to this study.

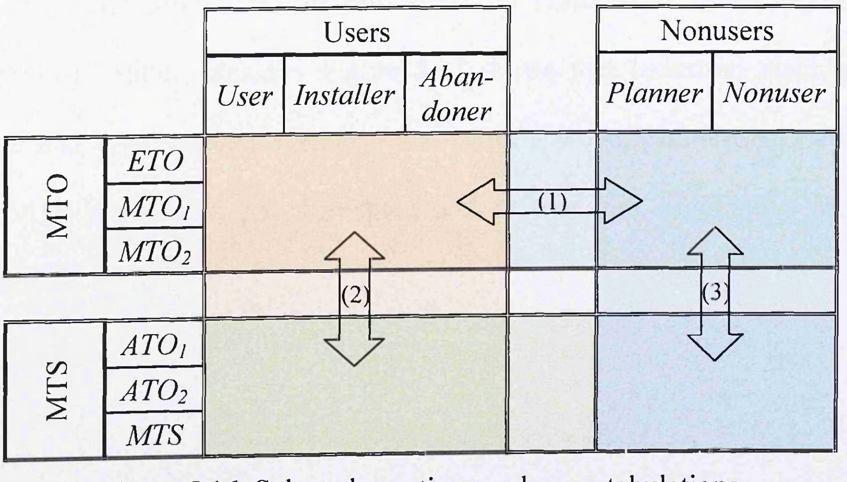


Figure 5.16. Selected questions and cross-tabulations

This study's main focus is on the applicability of ERP systems to MTO companies; so, Link (1) above is of particular importance to this research. As discussed in the previous chapter, the particular findings of this study's concern would be more meaningful when the counter cases (i.e., MTS users and nonusers) are also examined and compared; that is, Link (2) and Link (3) above. Therefore, any link between MTS users and nonusers is beyond the scope of this study. The following three headings examine three relationships in terms of all the variables measured through the questionnaire.

(1) MTO User vs MTO Nonuser

The differences and similarities identified between the user and nonuser MTO companies are important with respect to the ERP environment since MTS firms are excluded. In most of the questions there is no common data in this case. For example, questions 9 to 16 are related to ERP users only; and therefore, cannot be compared with the nonusers' results.

It is observed that larger companies tend to adopt ERP more. On the other hand, a tendency towards job shop routing is found in ERP using MTO companies; and no significant difference between users and nonusers is found regarding the supply chain position. Besides, Figure 5.17 shows that Industrial machinery and equipment and Raw material manufacturers (metals, wood, plastics, etc.) are mostly nonuser MTO companies, and Aerospace and defence and Automotive are mostly MTO users.

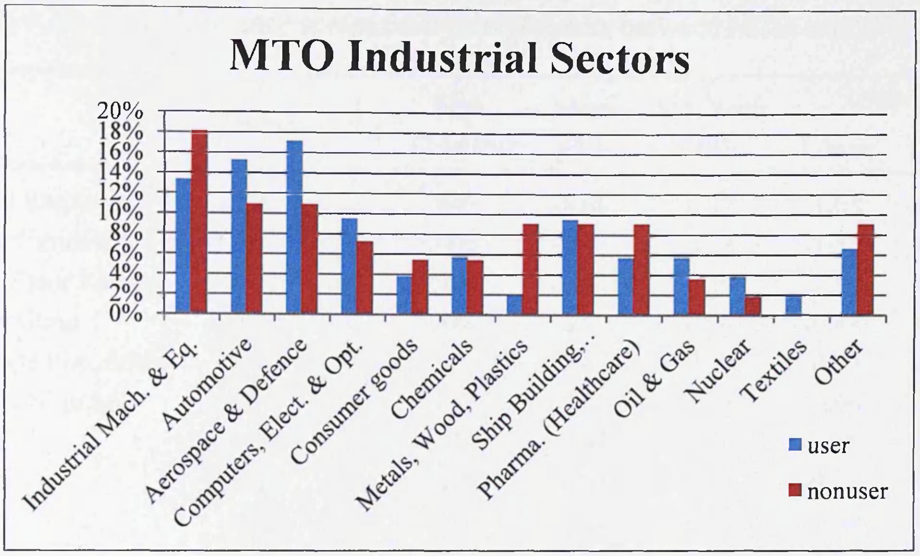


Figure 5.17. Sectoral distribution percentages of MTO users and nonusers

(2) MTO User vs MTS User

This is the most important comparison of quadrants in this study. This is considered in two ways: company demographics and ERP environment.

Table 5.27 below shows a part of the t-test results. Negative mean difference indicates that the mean value of the variable for MTO companies is lower than MTS companies. The remaining results are presented in figures, and chi-square tests.

The comparison of company size (number of employees and sales turnover) is consistent with the expectations that MTS users are larger firms compared MTO users. Besides, as expected, MTO users and MTS users are found to have job shop and flow shop routings on their shop floors. However, contrary to expectations, the mean differences between the two groups are almost equal to zero when the supply chain positions of the companies are considered. Namely, it cannot be concluded that MTO companies serve on the upstream parts of the supply chains. This has also been shown before when comparing all the MTO companies in the sample with all the MTS companies.

Table 5.27. Mean difference comparison (t-test) results between MTO and MTS users.

	t-value	df	Sign. (2-tailed)	Mean Diff.	Std. Error Diff.	95% CI	
						Lower	Upper
No. of Employees	-2.78	73	**.007**	-0.60	0.22	-1.03	-0.17
Sales Turnover	-4.19	73	**.000**	-1.05	0.25	-1.55	-0.55
Shop Floor Routing	-4.22	73	**.000**	-0.81	0.19	-1.19	-0.43
SC Position	0.33	73	.744	0.09	0.29	-0.48	0.67
Package Imp. Strat.	0.16	69	.871	0.05	0.29	-0.53	0.62
How diff. to Imp.	-1.94	52	.058	-0.47	0.24	-0.96	0.017
A14a	1.10	65	.274	0.43	0.39	-0.35	1.21
A14b	-0.03	65	.977	-0.01	0.28	-0.56	0.54
A14c	-1.36	65	.180	-0.44	0.36	-1.09	0.21
A14d	-0.55	66	.581	-0.21	0.37	-0.95	0.54
A14e	-2.39	64	**.020**	-1.13	0.47	-2.08	-0.19
A14f	-0.26	63	.793	-0.11	0.46	-0.96	0.74
A14g	1.62	65	.110	0.63	0.39	-0.15	1.41
A14h	0.71	62	.482	0.30	0.43	-0.56	1.16
A14i	0.51	63	.612	0.19	0.38	-0.57	0.96
A14j	-0.17	62	.862	-0.07	0.37	-0.82	0.69
A14k	1.26	48	.214	0.60	0.47	-0.36	1.56

Regarding the package implementation strategy, no significant differences between and the MTO and MTS users can be found. On the other hand, selecting the most appropriate system is more difficult for MTO users than MTS users. The mean difference of responses to 14.e (*reasons to adopt*: to be linked to global activities or support globalisation activities), is found to be significantly higher by MTS users than MTO users. This shows that MTO users do not favour this reason as an important motivation to adopt an ERP system.

As shown in figure below (Figure 5.18), amongst the reasons from 14.a to14.k the most important reasons for both types of companies are 14.b (to simplify and standardise business processes), 14.c (to integrate enterprise operations, systems or data), 14.d (to replace legacy systems), and 14.g (to improve production planning effectiveness). All can be considered as generic reasons to adopt ERP without considering the production strategy. When the latter (14.g) may be thought as more important for MTO companies than MTS companies, it has also the widest gap between the production strategies as seen in the figure. The least favoured reasons are 14.e (to simplify and standardise business processes), 14.f (to improve e-commerce) and 14.j (adoption encouraged/enforces by key customers). It can be argued that MTS companies take heed of supporting firms' global activities more. On the other hand, considering the external forces to adopt an ERP system, competitive factors are seen as more important than factors of customers for both production strategies almost equally.

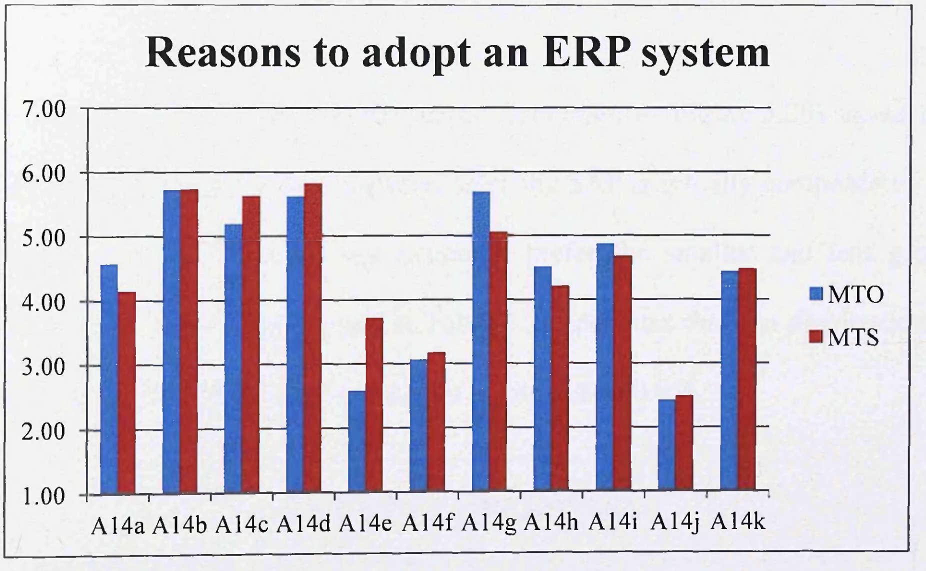


Figure 5.18. Comparison of reasons to adopt ERP with respect to production strategy.

When the industrial sector distribution is graphed again for users only and compared with Figure 5.19 (MTO vs MTS for all users and nonusers), it is observed that the percentages are not changed significantly except the increase of the percentage in the "Other" sector for both MTO and MTS companies.

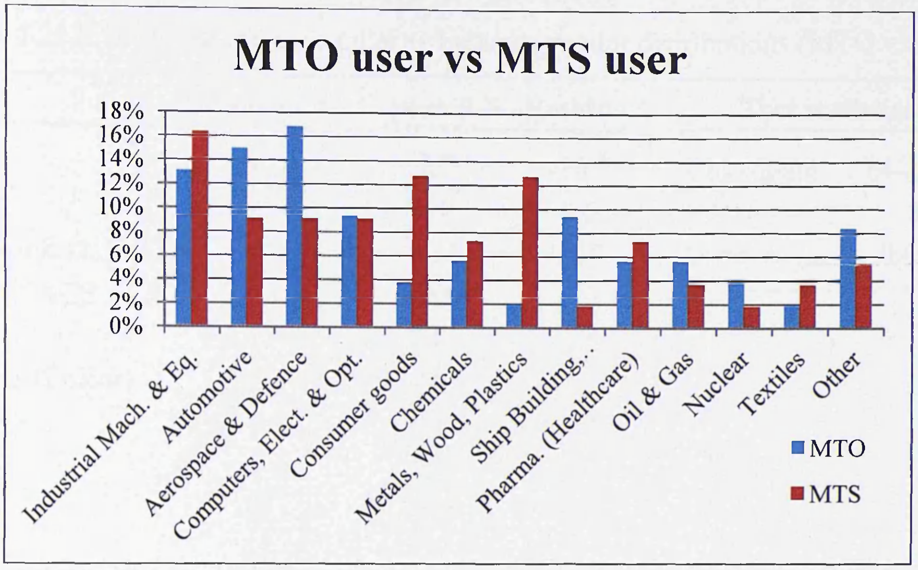


Figure 5.19. Sectoral distribution of MTO and MTS users

Regarding the vendor preference, the figure below (Figure 5.20) shows that a considerable percentage of the companies selecting SAP is actually composed of MTS companies, while MTO companies generally prefer the smaller and less globally known vendors. The chi-square test in Table 5.28 indicates that the distributions are significantly different from each other (that is lower than 0.05).

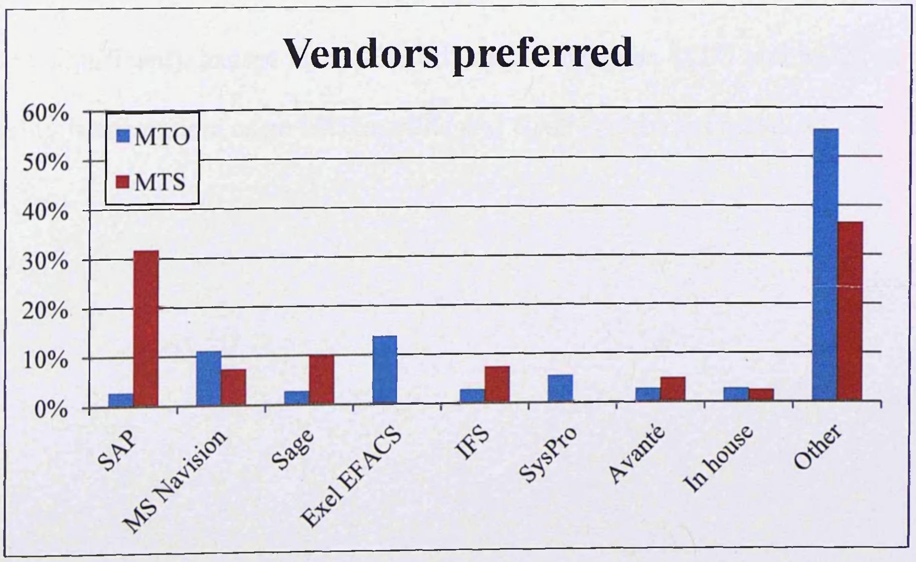


Figure 5.20. Vendor preference distribution of MTO and MTS users

Table 5.28. Chi-square test for similarity between vendor distributions (MTO vs MTS)

	Observed N	**Expected N**	**Residual**
SAP	1	11.7	-10.7
Sage	4	3.5	0.5
Microsoft D. Nav.	1	3.5	-2.5
Exel EFACS	5	0.0	5.0
IFS	1	2.8	-1.8
Avanté (Epicor)	2	0.0	2.0
SysPro	1	1.1	-0.1
Oracle	0	1.1	-1.1
Other	19	12.4	6.6
Total	*35*		

Test statistics	
Chi-square	848,574
df	8
Asym. Sign.	0.000

When the vendors preferred by MTS companies are cross-tabulated with the company size variables layered using the variable of production strategy, it can be observed that, in fact, all SAP users are large MTS companies. Therefore, here it is unclear whether the large *or* MTS companies prefer SAP.

On comparing the adopted modules and add-ons with respect to the production strategy, Table 5.29 & Table 5.30, and Figure 5.21 & Figure 5.22 below show that MTS and MTO users' choices do not significantly diverge from each other (chi-square tests are significant), except the ocular differences between MTO and MTS, adoption of Quality Management as an ERP module and CAD system as an add-on.

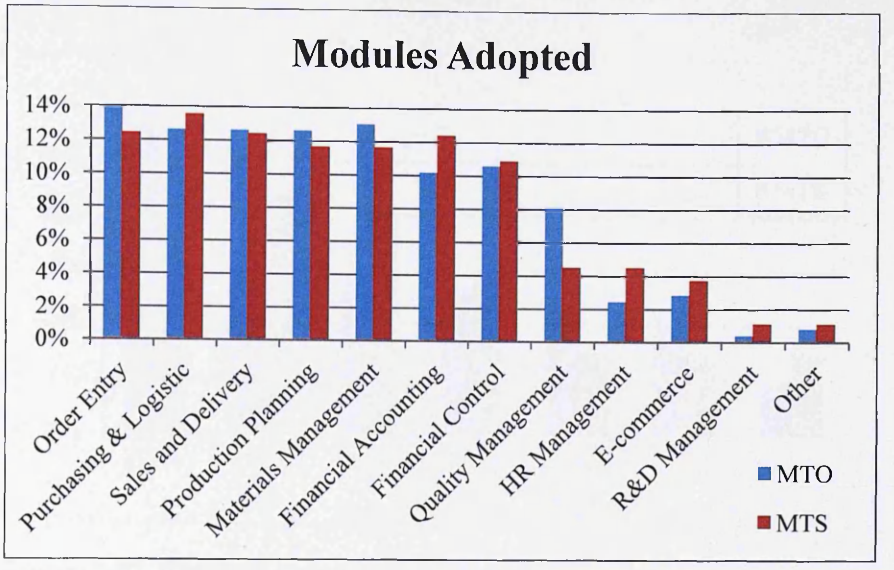


Figure 5.21. ERP module preference distribution of MTO and MTS users

Table 5.29 Chi-square test for similarity between module distributions (MTO vs MTS)

	Observed N	Expected N	Residual
Order Entry	34	30.5	3.5
Purchasing & Logistic	31	33.3	-2.3
Sales & Delivery	31	30.5	0.5
Production Planning	31	28.7	2.3
Materials Management	32	28.7	3.3
Financial Accounting	25	30.5	-5.5
Financial Control	26	26.8	-0.8
Quality Management	20	11.1	8.9
HR Management	6	11.1	-5.1
E-commerce	7	9.2	-2.2
R&D Management	1	2.8	-1.8
Other	2	2.8	-0.8
Total	*246*		

Test statistics	
Chi-square	13.54
df	11
Asym. Sign.	0.260

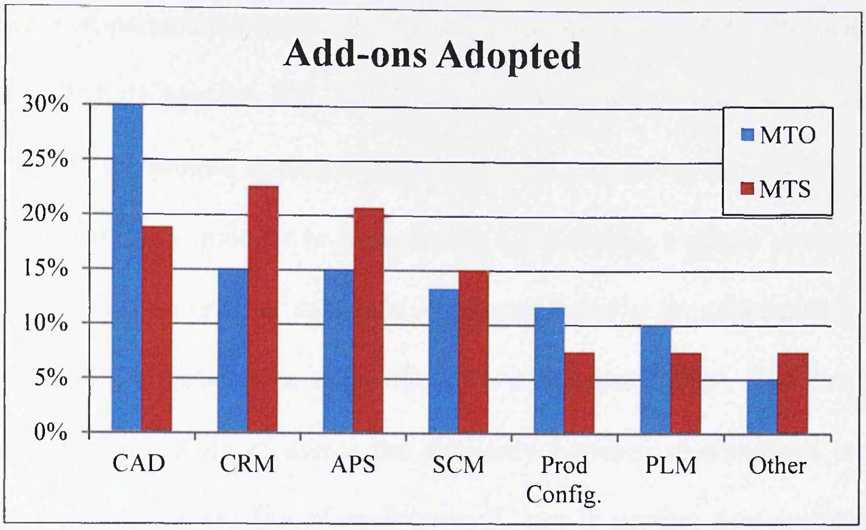


Figure 5.22. ERP add-on preference distribution of MTO and MTS users

Table 5.30. Chi-square test for similarity between add-on distributions (MTO vs MTS)

	Observed N	Expected N	Residual
CAD	18.0	11.3	6.7
CRM	9.0	13.6	-4.6
APS	9.0	12.5	-3.5
SCM	8.0	9.1	-1.1
Prod. Config.	7.0	4.5	2.5
PLM	6.0	4.5	1.5
Other	3.0	4.5	-1.5
Total	*100*		

Test statistics	
Chi-square	8.91
df	6
Asym. Sign.	0.178

(3) MTO Nonuser vs MTS Nonuser

In this part of the quadrant comparison analysis, the set of available variables is quite limited, since all ERP related questions (e.g., Q8 to Q14) are inapplicable to these respondents. Namely, they are the company background information variables, Q15 (Reasons not to adopt).

ANOVA and t-test results may not be reliable due to the low response and irregular allocations of responses into subcategories. Besides, they have strict assumptions, such as normality or homoscedasticity (i.e., equality of variances) which are not perfectly met within the data, as indicated in the tables. Therefore, a set of alternative non-parametric tests (i.e., *Kolmogorov-Smirnov, Mann-Whitney U* and *Kruskal-Wallis*) are applied. The *Kolmogorov-Smirnov* test is normally used to test whether or not the sample of data is consistent with a specified distribution function (e.g., normal, uniform, poisson or exponential) when testing a single sample of data. When there are two samples of data, it is used to test whether or not these two samples may reasonably be assumed to come from the same distribution. The latter use is appropriate for this study to assess the similarity between distributions of several exploratory part variables. The *Mann-Whitney U* test is another non-parametric (not relying on normality assumption) alternative to Independent Samples *t*-test, and it is therefore more widely applicable than the *t*-test like the *Kolmogorov-Smirnov* test. The price to pay for this generality is that the *Mann-Whitney U* test is less powerful than the *t*-test, because it first converts the values of the observations into ranks, and some information is lost in the process. However, since almost all the variables are mainly ordinal (rank based) than nominal (continuous measurement), there is no loss in this *Mann-Whitney U* calculation. *Kruskal-Wallis* is an extension of the *Mann-Whitney U* test to multiple samples (here used to test two unrelated samples) is a non-parametric alternative to one-way analysis of variance. It tests the null hypothesis that the samples do not differ in mean rank for the criterion variable.

As a result of these alternative tests, the very same significant results mentioned in the one-way ANOVA test are observed when the variables listed in this subsection are compared with respect to the dichotomous variables of production strategy (MTO vs MTS) and ERP environment (User vs Nonuser).

5.3 Conclusion

This chapter has focused on the exploratory part of the survey study and its findings can be summarised in two ways: firstly, some overall descriptive statistics on the manufacturing sector in the UK have been presented; and furthermore, some interesting significant differences have been provided through splitting the data into groups according to production strategy and ERP adoption and comparing them.

In this concluding section, firstly the key findings are summarised; then contributions to the field are summarised with reference to literature of critical importance to this study, and finally outstanding issues to be investigated further through follow-up case study work are provided.

5.3.1 Summary of Key findings

The key findings for the exploratory part can be summarised in Table 5.31

5.3.2 Contribution

Previous studies using similar survey instruments to explore the ERP adoption phenomenon have been conducted in other countries (Mabert *et al.*, 2000; Stratman, 2001; Mabert *et al.*, 2003; Olhager & Selldin, 2003; Olhager & Selldin, 2004). The originality of this study's exploratory part to this ongoing effort is threefold: (1) a UK-wide application, (2) the inclusion of nonadopters in the sample, and (3) Group comparisons with respect to production strategy and ERP adoption.

Regarding the first point, this study has focused to reflect a survey of the field for the UK manufacturing sector building upon and extending the existing exploratory survey design of ERP studies in OM. Similarly, the study by Koh & Simpson (2005), entitled "Could ERP create a competitive advantage for small businesses?", was focused on data collected in the UK. Yet, the authors did not include exploratory questions of the type included in this thesis.

Table 5.31. Summary of Key findings for the Exploratory part

Variable	Key findings
Company Size (emp. & turnover)	Regarding production strategy, MTO companies are smaller in size than MTS companies on average. With respect to ERP adoption, adopters are larger companies on average.
Industrial Sector	MTS companies dominate the Consumer Goods, Chemicals, and Metal, Wood & Plastics sectors, while MTO companies are the majority in the Aerospace & Defence, and Ship Building sectors.
Shop Floor Routing	MTO companies organise their shop floors as job shop and MTS firms as flow shop.
Supply Chain Position	Typical supply chain positions of all manufacturers are mainly OEM. While firms of Automotive and Aerospace & Defence sectors mostly serve at Tier-2, the rest serves as an OEM or Tier-1 supplier in the first place. No distinct grouping exists between MTO and MTS regarding their supply chain positions. Automotive and Aerospace & Defence sectors are mostly served by Tier-2 suppliers which are predominantly MTO firms. The rest of the sectors serve as an OEM or Tier-1 supplier in the first place.
ERP adoption	No significant difference amongst the variables is observed which have been found significantly different with respect to the production strategy except the aforementioned company size variables.
Difficulty of selecting the most appropriate system	The adopters find it "difficult" on average (between 1-extremely difficult to 7-extremely easy) to identify the most appropriate system at the selection stage for their companies (especially, the Tier-2 suppliers). There is a significant difference between an MTO and MTS company that MTO companies find this more difficult on average.
ERP Package Implementation Strategy	Majority of the manufacturers implement their systems from a single vendor (either with or without add-ons) while 40% of the users add some extensions on top of their systems regardless of their package implementation method. There is no distinct difference regarding the production strategy in package implementation strategy.
ERP vendors	SAP is the leader of the developer industry in the UK manufacturing sector. Yet, local and small-sized vendors dominate the market on aggregate. Eight out of nine SAP users are large MTS firms. SAP, as the leading ERP vendor, is mostly implemented as a single package (11 out of 14) and very highly preferred by MTS companies (13 out of 14) while MTO companies prefer local vendors.
Popularity of adopted modules and add-ons	Order Entry, Purchasing & Logistic, Sales And Delivery, Materials Management, Financial Accounting, and Financial Control are the most widely adopted modules, respectively; and CAD, CRM and APS are the most popular add-ons. The importance ranking of the Production Planning module for MTO is significantly higher than MTS.
Reason to adopt ERP	"Simplifying and standardising business processes", "Integrating the separate systems, operations and data", "Replacing legacy systems", and "Improve production planning effectiveness" are the most agreed Reasons to adopt ERP. Only one reason to adopt: "Get linked to global activities/support globalisation strategy" is significantly more important for a MTS than a MTO firm on average.
Reason not to adopt ERP	The most outstanding reason not to adopt ERP is that "ERP would not suit the needs of the company". It is also important to note that MTO firms highly significantly agree with this reason compared to MTS nonadopters.
Decision Support Requirements (DSR)	MTO companies need a product database more than MTS companies do to estimate cost and set profit margins. Short-term capacity planning is more important to MTO than MTS due to changing main capacity constraint (or bottleneck) over time. MTS companies use MRP within their ERP systems significantly more than MTO companies. Overall, only a few significant differences are observed between MTO and MTS DSRs identified for different production planning stages, CRM, and SCM; though more were expected.

Secondly, collecting data on production strategy and ERP adoption and using the group comparison technique have enabled this study to distinguish differences in the ERP environment of adopters with respect to production strategy, and to distinguish the company characteristics of UK manufactures with respect to ERP adoption effort (User vs Nonuser). While Mabert *et al.* (2000), and Olhager & Selldin (2003; 2004) collected production strategy information in their surveys, no comparative results were reported. Stratman (2001) did not even consider production strategy.

Finally, due to a different sampling approach compared to the related literature, this thesis has largely sampled Small and Medium sized Enterprises. In contrast, Mabert *et al.* (2000), Stratman (2001) and Olhager & Selldin (2003; 2004) have surveyed large companies only: as they mentioned, their contact list consisted of Fortune companies in North America and Sweden. Building upon their previous survey (Mabert *et al.*, 2000) and conducting further case research, Mabert *et al.* (2003) re-evaluated their North America-based data with respect to the company size factor. Therefore, they enlarged the original sample to include more small and medium sized companies; however, they still did not consider sampling non-adopters or comparing different production strategies. Yet, it is still interesting to compare the findings of those aforementioned studies with this study's results. The following table (Table 5.32) illustrates the situation:

The final contribution of this chapter is the originality of the scope within the subject of ERP adoption of SMEs. That is, there are several recent studies sampling SMEs but focusing on the implementation process such as Critical Success Factors (e.g., Snider *et al.*, 2009); yet there are only a few studies close to this adoption topic, which are mainly case research-based. For example, Deep *et al.* (2008) concentrated on the ERP package selection stage of MTO companies which is limited to a single case study.

Table 5.32. Summary of Exploratory Findings compared with the literature

Variables	This study	Mabert *et al.* (2000)	Stratman (2001)	Olhager & Selldin (2003)
Company Size	Small & Medium-sized firms	Large Companies	Large Companies	Large Companies
Industrial Sector	Manufacturing sector	Manufacturing sector	Manufacturing sector	Manufacturing sector
Type (MTO vs MTS)	Almost equally distributed	Almost equally distributed	*Not reported*	Mostly MTO (64%)
SF Routing (Flow vs Job)	Almost equally distributed	*Not measured*	*Not measured*	Mostly Flow Shop
Supply Chain Position	Mostly OEM	*Not measured*	*Not measured*	*Not measured*
ERP adoption(adopters vs nonadopters)	Mostly adopters (61%)	Mostly adopters (63%)	All adopters	Mostly adopters (84%)
Difficulty of selecting the most appropriate system	Averaged on the "difficult" choice	*Not measured*	*Not measured*	*Not measured*
Package Implementation Strategy	Mostly single package (82%)	Mostly single package (90%)	*Not reported*	Mostly single package (%)
ERP vendors	SAP (18%) is the leader; local vendors dominant on aggregate (41%)	SAP (%25) and Oracle (14%); local vendors on aggregate (%27)	SAP (64%) dominating all other vendors.	Intentia (30%), SAP (15%), IFS (11%) are the leaders; local vendors (21%)
Popularity of adopted modules (ranked)	OE, PL, SD, PP, & MM installed in over 83%	FA, MM, OE, PP, & PL installed in over 87%	*Not reported*	PL, OE, MM, PP, & FA installed in over 83%
Popularity of adopted add-ons (ranked)	CAD, CRM, APS & SCM over 21%	DW, SCM, APS, CRM over 17%	*Not reported*	CRM, DW, e-business over 15%
Reason to adopt ERP (ranked)	Simplify and standardise; Replace legacy systems; Integrate enterprise; Improve PP effectiveness	Replace legacy systems, Simplify & standardise, Improve interactions and communication with suppliers and customers, Gain strategic advantage.	*Not reported*	Replace legacy systems, Simplify & standardise, Gain strategic advantage, Improve interactions and communication with suppliers and customers
Reason not to adopt ERP	ERP would not suit the needs of the company	*Not measured*	*Not measured*	*Not measured*

OE: Order Entry, **PL**: Purchasing & Logistics, **SD**: Sales & Delivery, **PP**: Production Planning, **FA**: Financial Accounting, **MM**: Materials Management, **DW**: Datawarehouse

5.3.3 Follow-up research

There are some points which remain uncertain; and therefore, need further exploration through case research. For example, the negative correlation between two reasons to adopt ERP ("to improve production planning performance" and "to replace legacy systems") is interesting to examine for any further evidence.

There may be several 'why' and 'how' questions to be asked for this particular section as well. However, most of the time and energy for the case research are planned to be used to cross validate some important results, scrutinise some unexpected findings and inconclusive cases found in the explanatory part presented in the following section. Therefore, the most conspicuous points are summarised in Table 5.33 below:

So far, the results of the exploratory part (measured by Section A in the questionnaire) have been provided. Some overall descriptive statistics, correlation analyses (e.g., Pearson's r), cross-tabulations, simple group comparisons (e.g., t-test) and one-way ANOVA techniques have been utilised.

The next chapter provides and discusses the explanatory results of the survey by using the *Structural Equation Modelling* analysis technique; thereafter, followed by the Case Study chapter.

Table 5.33. Major points to be scrutinised in the Case Research.

Variable	Case research topics
Company Size	MTO firms are found to be significantly smaller than MTS firms on average. Can this be generalised to manufacturers?
Supply Chain Position	Contrary to expected, supply chain positions of MTS and MTO cannot be grouped distinctively. Do they agree with this result?
ERP adoption	Two cases have adopted and abandoned an ERP system. There may be several practical, economical, or political causes for that. Another question is that, what do they use now?
Difficulty of selecting the most appropriate system	The adopters find it "difficult" on average to identify the most appropriate system at the selection stage. What are the major problems for all users and for the particular production strategy groups?
ERP Package Implementation Strategy	In-house developed packages constitute a very low percentage in total though, especially, MTO firms are expected to have one. Considering the facts that "MTO companies find it difficult to select the most appropriate system" and "give the reason of unsuitability of current ERP system for non-adoption"; why do they not tend towards developing in-house systems?
	ERP add-ons are adopted highly more than expected by SMEs. Is this because these extension packages are more reasonably priced, or they are considered as important and useful as ERP itself, or any other reasons?
ERP vendors	Compared to other studies, what can be the reason for the domination of the market by small and local vendors? Do SMEs prefer them more? Do these vendors target SME market so that they can fulfil the sector needs better than global vendors?
Popularity of adopted modules and add-ons	Basic modules are also the most preferred ones. R&D and HR modules may not be preferred by all users with reason, but why e-commerce, a generic purpose module, is that under-adopted?
	Surprisingly, CAD is the most adopted add-on. Are the CAD users happy with this add-on's performance and its compatibility with their ERP systems?
Reason to adopt ERP	Negative correlation between two reasons to adopt ("to improve prod. planning performance" & "to replace legacy systems").
Reason not to adopt ERP	Are there any other reasons for non-adoption which could not be measured through the questionnaire?
Decision Support Requirements (DSR)	In general, most of the DSRs which were expected to be measured high for MTO companies have been observed to be high for MTS as well, even higher in MTS in some cases. For example, the importance of being aware of the availability of subcontractors/suppliers is found to be higher in MTS. Does this imply its cruciality to the company as well? Do they only think it would be nice to have that information, or is it really critical?
	The use of ERP for dispatching is found to be higher in MTO, contrary to expected. This quite interesting to find out why.

Chapter 6: Explanatory Results

6.1 Introduction

Compared to the simpler methods in the exploratory part, multivariate techniques are applied in this chapter for an explanatory (confirmatory) analysis of the survey. Forza (2009) argues that applied fields of science, such as OM, should use multivariate analysis (i.e. simultaneous analysis of more than two variables) to avoid superficial problem solving. A range of multivariate analysis techniques are available for several purposes. For example, some are used for grouping variables together (e.g., Exploratory Factor Analysis), some are used to explain the variance of a dependent variable (e.g., Multiple Regression). Other most well-known multivariate analysis methods are Multivariate Analysis of Variance (MANOVA), Canonical Correlation, Cluster Analysis, Structural Equation Modelling (SEM), etc.

Of the available multivariate analysis techniques available, this chapter uses SEM. SEM is used to assess the suitability of the theoretical framework by analysing the relationships between the constructs of improved performance, intensity of use of ERP and decision support requirements. Thus, several multi-item variables are grouped together to form constructs in order to support the theoretical concepts. SEM also enables this framework to be built through a hierarchical structure by grouping dimensions under higher order constructs. For example, latent variables of decision support requirements at the CEM stage can be grouped again under a single construct to observe their overall impact on other constructs, such as performance.

Shah & Goldstein (2006) reviewed applications of SEM in four major OM journals (*MS*, *JOM*, *DS* and *POMS*) from 1984 to 2003 and found that SEM is a valuable tool for testing and advancing OM theory; they also provided guidelines for improving its use. Similarly, Baumgartner & Homburg (2008) examined methodological issues related to SEM and its applications in marketing and consumer research which is a discipline highly followed by OM researchers especially regarding its methodological aspect (Taylor & Taylor, 2009). In this chapter, attention has been paid to the issues highlighted in these papers in order to take full advantage of SEM's potential and discussed, where appropriate, in Section 6.2. The discussion on hypothesis testing and interpretation of the results is provided in Section 6.3; before this chapter concludes in Section 6.4.

6.2 Structural Equation Modelling

Before presenting and discussing the explanatory analysis results, Structural Equation Modelling is very briefly described, its basic textual and graphical terms are defined and illustrated, and any extensions and approximations are explained in detail, where applied.

It is first noted that SEM can be used for both exploratory and explanatory modelling; namely, it is suited to both theory testing and theory development (Bollen, 1989). Exploratory modelling is appropriate when SEM is used purely for exploration, that is usually in the context of EFA. To exemplify, an EFA pre-testing of items for unidimensionality has been conducted for unidimensionality (Section 4.7.1 in Chapter 4). In that case, no causal model has been used but simply groups of items have been tested to explore their consistency with dimensions and variables. On the other hand, explanatory modelling is appropriate when SEM is used for hypothesis testing through a causal model. Chapter 4 (theoretical framework, hypothesis, reliability and validity assessment) and this chapter (results) is an example of explanatory modelling in SEM.

A SEM model has two main components: a *measurement model* and a *structural model*; and when exploratory modelling is used it contains only the measurement part. The figure below (Figure 6.1) illustrates the difference.

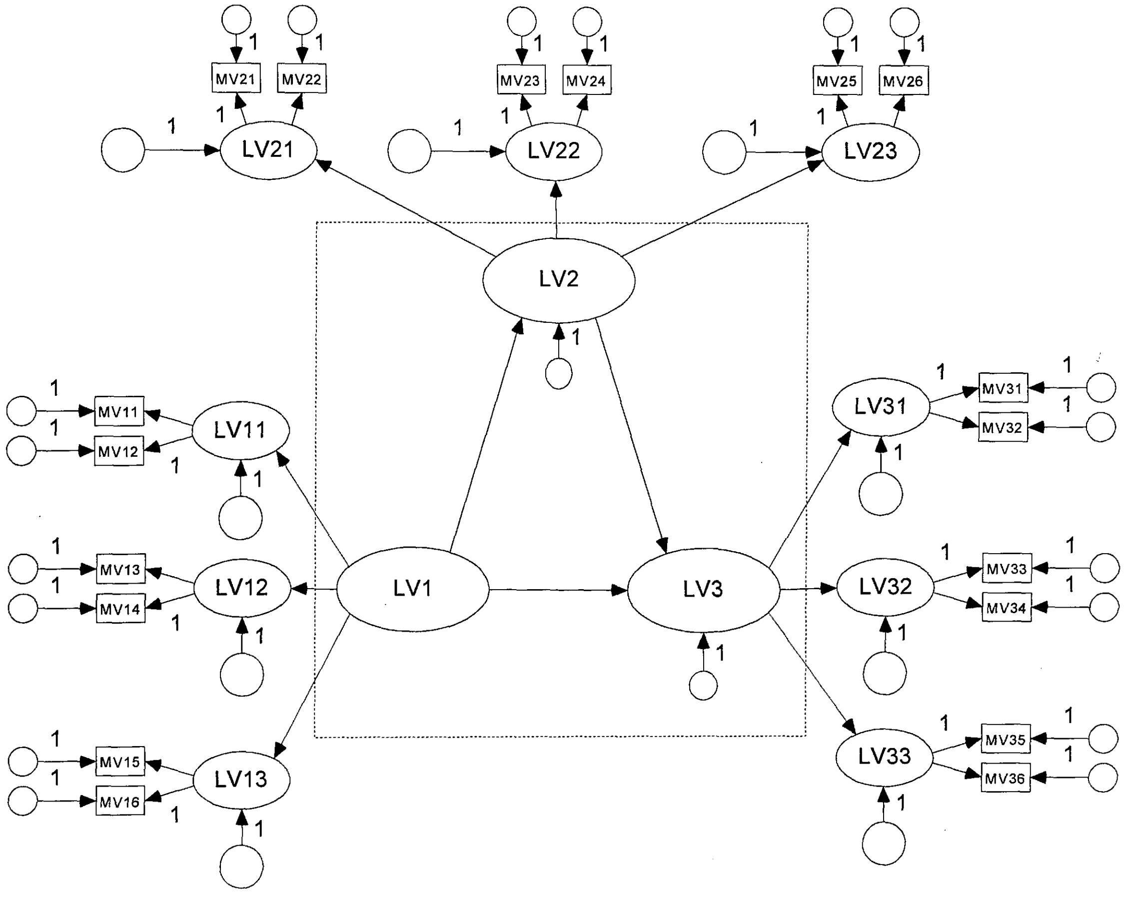


Figure 6.1. Illustration of a second-order SEM model with measurement and structural parts

In Figure 6.1, we have what is referred to as a second-order SEM model since at least two Latent Variables (LV) in ellipses are formed in a hierarchical structure (e.g., LV1 loading on LV11, LV12 and LV13). The structural model is shown within the borders, which is only composed of latent variables. The remaining three parts form the measurement model, which is mainly composed of measured variables (MV) in rectangles linked to LVs. SEM assumes the measures to be imperfect; thus, models include terms representing measurement error. The circles loading all MVs and LVs above are the measurement errors in the model.

SEM enables the fit between the determined model and observed data to be assessed; and a good fit is an important condition that affects the significance of the relationships inferred through the model. The same measures of fit, used and described in the chapter where reliability and validity have been assessed, are utilised and tabulated in the following discussions. As a reminder, they are: chi-square (χ^2), degrees of freedom, *p*-value, Comparative Fit Index (CFI) and Root Mean Square Error of Approximation (RMSEA).

6.2.1 Sample Size issues: an Approximation in the Structural Model

Due to the limited number of survey responses, it has not been possible to estimate a full SEM (as shown in the figure above) incorporating the entire measurement models of each organizational aptitude and performance scale. There are both causal and analytical techniques to estimate the minimum required sample size for an analysis having an adequate power (e.g., 0.80). That is, Shah & Goldstein (2006) specify a sample size of 200 per model for establishing a generic minimum, Bentler & Chou (1987) and Bollen (1989) advise to have a certain number of responses per parameters (e.g., at least 10 responses per parameters) estimated, and MacCallum *et al.* (1996) recommend to have a certain ratio of measured variable per latent variable above a threshold and to conduct a statistical power analysis for determining a minimum sample size (Bagozzi & Yi, 1988; MacCallum *et al.*, 1996). Neither of these measures are satisfied by the sample size in this study to reach an adequate statistical power (for example, 0.8). Shah & Goldstein (2006) reported that the majority of the OM studies suffer from the same problem of SEM power inadequacy as well as other studies in different fields measuring behavioural concepts and employing SEM (e.g., psychology, MIS and strategy) since 1960. Besides, Jackson (2003) reports that smaller sample sizes are generally characterised by parameter estimates with low reliability and greater bias in χ^2 and RMSEA fit statistics. However, despite the low sample size, the estimated reliability and model fit measures still show an adequate level in this study. Therefore, to minimise these drawbacks due to sample size an approximation method is applied as described in the following paragraphs.

Instead of employing a full SEM structure and using the complete data set, the measurement model part of the SEM models are simplified. This method is called *partial aggregation* which comes with pros and cons in application (Carter *et al.*, 2008; Koufteros *et al.*, 2009). Briefly, while this is performed to cope with the negative impact of a low sample size on the model's reliability, the aggregation results in a loss of information such that the contribution of content domains to the final score cannot be known (e.g., the individual items of an aggregated first-order variable). Each first-order latent variable (e.g., of decision support requirement and improved performance) is aggregated into a single-item indicator (measured) variable using weighted average scores of estimated standard path loadings (Appendix 5 in the Survey Design chapter). In other words, the second-order model is reduced into a first-order form. Stratman (2001) has also applied this approximation technique, mainly to minimise the (low) sample size effect. In this study representation of this transition can be observed by comparing Figure 6.1 with Figure 6.2 above.

Therefore, instead of inputting the full data set to AMOS software, the variance-covariance matrix and other required descriptive measures are input. Conventional estimation methods of SEM are based on statistical distribution theory that is appropriate for variance-covariance matrices but not for correlation matrices

(MacCallum & Austin, 2000). Table 6.1 shows an example of the variance-covariance matrix used for the CEM model with the sample size (n) as 29.

Table 6.1. An example of a Variance-Covariance Matrix

Latent Variable	*Mean*	*Std. Dev*	*DD setting*	*Pricing*	*Internal Coord.*	*External Coord.*	*Use of CEM*	*Prod. aspects*	*Econ. aspects*
Duedate setting	*5.51*	*1.25*	(1.56)	0.98	0.73	0.58	0.76	1.38	1.39
Pricing	*5.49*	*1.44*	0.98	(2.07)	0.89	0.71	0.88	0.86	1.31
Int.l Coord	*4.85*	*1.34*	0.73	0.89	(1.79)	0.88	1.21	0.73	0.93
Ext. Coord	*4.59*	*1.40*	0.58	0.71	0.88	(1.97)	1.26	1.46	1.10
Use of CEM	*3.19*	*1.94*	0.76	0.88	1.21	1.26	(3.76)	1.43	1.30
Prod. aspects	*5.12*	*1.83*	1.38	0.86	0.73	1.46	1.43	(3.34)	2.13
Econ. aspects	*4.30*	*1.63*	1.39	1.31	0.93	1.10	1.30	2.13	(2.64)

n = 29. The variances appear along the diagonal in parentheses, and covariances appear in the off-diagonal elements which are diagonally symmetrical.

Although this approach is an approximation to the full SEM, there needs to be some reassurances to support its reliability and validity. As suggested by Nunnally (1978), the reliability estimates show adequacy which is important since this SEM approximation technique assumes perfect scale measurement. Additionally; the assessments of the scale validity, which have shown appropriateness (see Chapter 4), allow us to conclude that the measured variables adequately capture the theoretical constructs and form a reasonable basis for the testing of the model hypotheses.

To remind the reader of the objectives, the aim of this study is to explore the appropriateness of ERP systems to particularly the companies which make (and engineer) to order. An ERP system may be necessary for such a firm when it can satisfy requirements at several decision making stages particular to a MTO company. The explanatory framework simultaneously considers these companies' decision support requirements with their intensity of use of their systems and the perceptual performance they get through utilising it. Therefore, this concurrent analysis enables us to explain the relationships amongst three main LVs (i.e., requirement, use and performance) by grouping multiple MVs to form LVs. Since the aim is to compare these relationships with respect to the production strategy, the data is further split into MTO and MTS after an analysis of the entire data.

As illustrated in Figure 6.2, there are three main relationships investigated amongst three constructs where Decision Support Requirement (DSR) is the driver (exogenous latent variable) of the structural models developed in this study; USE and performance (PERF) are the two endogenous latent variables in each model: (R_1) Direct impact of decision support requirement on the intensity of use; (R_2) direct impact of intensity of use on the improved performance, and (R_3) direct impact of decision support requirement on the improved performance.

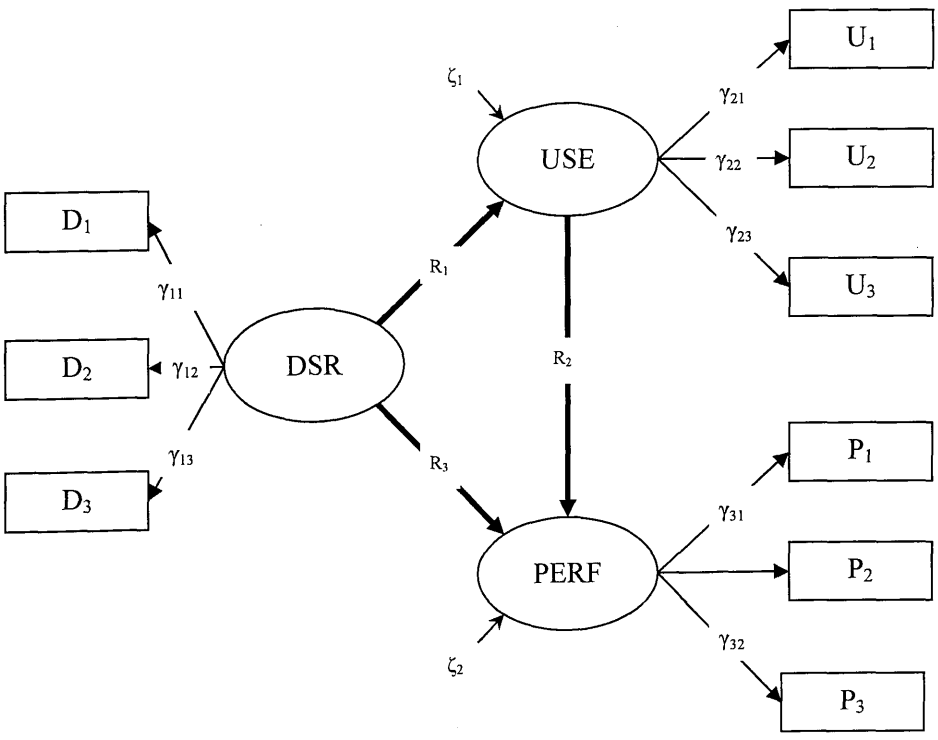


Figure 6.2. Reduced additive, linear and recursive first-order example of full SEM

Exogenous constructs are independent variables in all equations in which they appear, while endogenous constructs are dependent variables in at least one equation—although they may be independent variables in other equations in the system. In graphical terms, each endogenous construct is the target of at least one one-headed arrow, while exogenous constructs are only targeted by two-headed arrows. These equations, which are represented by the covariance structures in Figure 6.2, are provided here:

$$USE = R_1(DSR) + \zeta_1 \quad (1)$$

$$PERF = R_2(USE) + R_3(DSR) + \zeta_2 \quad (2)$$

ζ_1's are the error variances of endogenous latent variables. γ_{xy}'s, in Figure 6.2 above; but not in the equations, are the measurement model parameters to be estimated which shows the weight of each indicator loading on the corresponding latent variable.

The proposed model above (Figure 6.2) is also modified and tested for better fits and significant relationships. The techniques commonly used for this purpose (i.e., removing direct and mediating links between the variables one at a time, in a controlled way) are applied: by the nature of the model, two alternatives are formed by (1) removing R_1 to let DSR and USE have separate direct effects on PERF just like a multiple regression model, and (2) removing R_3 to let DSR only have a mediating effect on PERF through USE. The results of alternative models for all five stages investigated in this study are found to fit to the data poorly, namely, high chi-square values, p-values below 0.05, CFI below 0.90 and RMSEA larger than 0.10. Therefore, the significant relationships found in the proposed model are weakened into insignificant ones using these two alternatives. Therefore, the analyses are carried out with the proposed model.

When a model contains reciprocal causation, feedback loops or correlated error terms it is called *non-recursive* (Bollen, 1989). When a model is specified as non-recursive, additional restrictions and implications for identification need to be discussed. This model is in fact *recursive,* which means that the causal relations flow in one direction; therefore, it is much more straightforward than a complex non-recursive model.

Through examination of the first relationship (R_1), a positive and significant relationship indicates that, for a particular production strategy, certain decision support requirements at a particular stage lead to the use of a particular module/extension of an ERP system. However; if an expected relationship does not occur (i.e., nonsignificant causal path value) this indicates that a company, requiring certain support from a company-wide information system for making decisions, does not or cannot utilise that system (either deliberately or fails to use it).

The second relationship (R_2) is a direct and straightforward way of investigating the relationship between the use of an ERP system's relevant module/extension at a particular stage and "improved" performance through its use. A positive and significant relationship indicates that, for a particular production strategy, utilisation leads to an improvement in performance at that particular stage, whereas a negative impact means that ERP use makes the situation worse. A non-significant impact means that use has no effect on performance, which is an important issue if, for example, a positive impact was expected.

The final relationship (R_3) is on the direct impact of requirements on performance without considering the mediating effect of system use. Here, the indirect impact of requirements through the use is also considered. This is evaluated by multiplying the first impact value by the second one found in the previous cases.

6.2.2 Overall Comparison of Path Coefficient and Model Fit

From the five main stages, ten models varying with uses of various ERP modules and extensions have been generated (i.e., 4 CEM, 2 D&E, 2 Order Entry, 1 CRM, and 1 SCM). All models are solved through using the method of maximum likelihood ratio by AMOS.

Before interpreting the causal links amongst the main constructs of interest in the next section (6.3), a structural model should meet not only the requirements of statistical significance for the path coefficient estimates but also a 'good-fit' between the predetermined model and the data set. Both an overall and comparative evaluation of structural models are simultaneously done in the following discussion. Firstly, a discussion of results from the measurement model (the significance and weights of path coefficient) is presented. Then, the results of model fit and relationship significance are provided considering the overall data.

Measurement model parameters: Path coefficients

As can be seen in Table 6.2 below, all the path coefficient estimates are found to be statistically significant except the two latent variables loading on DSR in the SCM model. This means that the values of the path coefficients (loadings) are statistically significant to use. The following discussion supports these findings through model fit statistics which closely relate to the significance of the path coefficient estimates. Regarding the significant factors, each one is found to be important components of the exogenous latent construct of DSR, as well as the endogenous latent constructs of

USE and PERF. Obviously, the bigger a coefficient is, the more that factor impacts on its construct.

Table 6.2. Estimation of measurement model parameters: Standardised Path coefficients

	DD Setting	*Pricing*	*Internal Coord.*	*External Coord.*	*Prod. aspects*	*Econ. aspects*
CEM	0.86	0.74	0.56	0.62	0.94	0.75
CEM-ATP	0.88	0.73	0.54	0.62	0.93	0.76
CEM-CTP	0.87	0.74	0.54	0.62	0.91	0.77
CEM-PLM	0.87	0.74	0.54	0.62	0.93	0.76

	Doc. Archive	*Internal Coord.*	*External Coord.*	*Flexibility*	*Prod. aspects*	*Techn. Prod.*
D&E-PC	0.74	0.80	0.57	0.69	0.92	0.82
D&E-PLM	0.72	0.80	0.60	0.70	0.88	0.85

	Conf. Ord Re-eva.	*Agg. Plan.*	*Oper. Plan.*	*Prod. aspects*	*Techn. Prod.*
OE-ERP/MRP	0.57	0.92	0.56	1.03	0.92
OE-APS	0.89	0.57	0.58	1.04	0.82

	Customer Database	*Need for Impr. Rel.*	*Satisf. w/ existing*	*New cust. exploration*	*Profit-ability*
CRM	0.88	0.77	0.99	0.92	0.54

	Coord. w/buyers	*Procure-ment*	*Compat-ibility*	*Improved Order Man.*	*Profit-ability*
SCM	0.32‡‡	0.61‡	0.75	0.79	0.68

All of the path coefficient estimates above are statistically significant at 0.01 level ($p < 0.01$) except: ‡ not significant at 0.05 level ($p < 0.05$) and ‡‡ not significant at 0.10 level ($p > 0.10$).

When the data is divided into subgroups with respect to production strategy, differentiated path coefficients are obtained for two groups (i.e., MTO and MTS). To enable statistical comparison, not only the coefficient estimate but also the sample size and standard errors are needed (Bollen, 1989). For that reason, the first table in Appendix 11 provides both the standardised and non-standardised path coefficient estimation results with their statistics of significance.

In SEM, each unobserved latent variable must be assigned a metric, which is normally done by constraining one of the paths from the latent variable to one of its indicator (reference) variables, such as by assigning the value of 1.0 to this path (as can be observed in Figure 6.1). Given this constraint, the remaining path coefficients can then be estimated. The indicator selected to be constrained to 1.0 is the *reference item*. Due to this modelling obstacle in SEM, comparing the coefficient means through a t-test is restricted to only a subset of observed variables since the non-standardised estimates of reference items are set to 1.0, their standard errors and critical ratios, therefore, become incalculable.

Conformity of Data to the Predetermined Model: Model fit

Table 6.3 below exhibits results of the overall model fit (first four columns) and causal path values and their significance. 8 out of 10 models have low chi-square (χ^2) values, a high number of degrees of freedom, *p*-values greater than 0.05, a Comparative Fit Index (CFI) greater than 0.90 and Root Mean Square Error of Approximation (RMSEA) less than 0.8.

Table 6.3. Overall Comparison of Model Fit and Causal Path Significance

	χ^2 (df)	p	CFI	RMSEA	(1) DSR → Use Est.	S.E.[a]	C.R.[b]	(2) Use → Perf. Est.	S.E.[a]	C.R.[b]	(3) DSR → Perf. Est.	S.E.[a]	C.R.[b]
CEM	14.41 (12)	0.28	0.98	0.07	0.37^{*}	0.17	2.42	0.37^{***}	0.10	3.66	0.69^{***}	0.14	5.33
CEM-ATP	12.64 (12)	0.40	0.99	0.03	0.02	0.27	0.10	0.26^{**}	0.06	2.58	0.83^{***}	-0.14	6.28
CEM-CTP	11.42 (12)	0.49	1.00	0.00	0.14	0.26	0.89	0.18	0.07	1.72	0.82^{***}	-0.15	5.74
CEM-PLM	20.43 (12)	0.06	0.94	0.12	-0.02	0.21	-0.01	0.05	0.09	0.48	0.83^{***}	-0.15	5.91
D&E-PC	13.29 (12)	0.35	0.99	0.05	0.15	0.26	0.92	-0.03	0.11	-0.21	0.42^{*}	-0.19	2.40
D&E-PLM	26.86 (12)	0.01	0.86	0.16	0.24	0.24	1.37	-0.11	0.14	-0.57	0.44^{*}	-0.21	2.21
OE-E/MRP	14.52 (11)	0.21	0.98	0.08	0.19	0.15	1.13	0.69^{***}	0.33	4.21	-0.16	-0.21	-1.38
OE-APS	11.81 (7)	0.11	0.96	0.14	0.07	0.42	0.37	0.62^{***}	0.12	4.94	-0.11	-0.30	0.77
CRM	3.87 (7)	0.80	1.00	0.00	0.55^{***}	0.19	3.31	0.34^{*}	0.14	2.38	0.50^{**}	-0.19	2.78
SCM	24.06 (11)	0.01	0.87	0.17	0.63	1.46	1.33	0.47	0.33	1.62	-0.42	-1.20	-1.22

[a] S.E. is an estimate of the standard error of the covariance.
[b] C.R. is the critical ratio obtained by dividing the covariance estimate by its standard error.
*Significant at the 0.05 level (critical value = 1.96); **significant at the 0.01 level (critical value = 2.58); ***significant at the 0.001 level (critical value = 3.29).

The other two (the models of SCM and Design & Engineering through the use of PLM) do not show adequate fit (also called misfit) with the data. These misfits are also reflected in the significance test results of path coefficients (e.g., the SCM model in Table 6.2) and causal links amongst constructs below. Therefore, they cannot be used to test their corresponding hypotheses.

When the data is analysed separately for MTO and MTS companies for model fit (the second table in Appendix 11), most of the models using the MTS sample resulted in poor model fits. This is both due to further small sample and the MTO-oriented context of the items (prepared through mainly reviewing the MTO literature). Only the D&E, OE-APS and CRM models are fitting with the MTS data while they do not provide more than one powerful and significant causal relationship per model. Additionally, the Order entry model using ERP's MRP functionality for the MTS sample could not provide any estimation even when several convergence criteria are applied (i.e., increasing the limit on the number of iterations and the convergence threshold). When the model itself has been modified into several forms (e.g., by removing the third causal path from the model—e.g., DSR to PERF), some convergences were obtained but they all lack proper model fits. Therefore, MTS models are mostly inconclusive due to poor data fit and/or small sample size, while three aforementioned well-fitting models result in only single and weak relationships. Therefore, the focus will be on the complete data and MTO only.

On the other hand, MTO use data results in quite a good fit with all the models except SCM though RMSEA measures are not far below the desired 0.08 limit. Although this situation does not allow us to soundly compare the MTS and MTO cases under the same structural model, it encourages the motivation that the models having proper fit and causal path significance are the MTO ones. The MTO explanatory results are the main focus and further discussed from now on in this chapter.

All these measures and their indication of model fit have been discussed in the Reliability and Validity section. Additionally, it is necessary to discuss the importance of degrees of freedom and model identification issues in SEM.

When the degrees of freedom of a model equals zero, the model is said to be *just-identified* or *saturated.* These models provide an exact solution for parameters; namely, point estimates with no confidence intervals, and can never be rejected. When degrees of freedom are less than zero, the model is called an *under-identified* model and *over-identified* when greater than zero. Under-identified models may not converge during estimation, and if they do they do not provide reliable and overall fit statistics to interpret (Rigdon, 1995). An over-identified model is highly desirable since more than one equation is used to estimate the parameters which significantly enhances the reliability of the estimate (Bollen, 1989). To conclude the identification issue in SEM, all the models are over-identified thereby satisfying the necessary condition of having non-negative degrees of freedom.

In the next section, the significance of the relationships amongst the three constructs are provided and discussed. The very same sequence is followed for the measures estimated after splitting data into two regarding production strategies and compared within their particular models.

6.3 Hypothesis Testing: Significance of relationships amongst the DSR, USE and PERF constructs

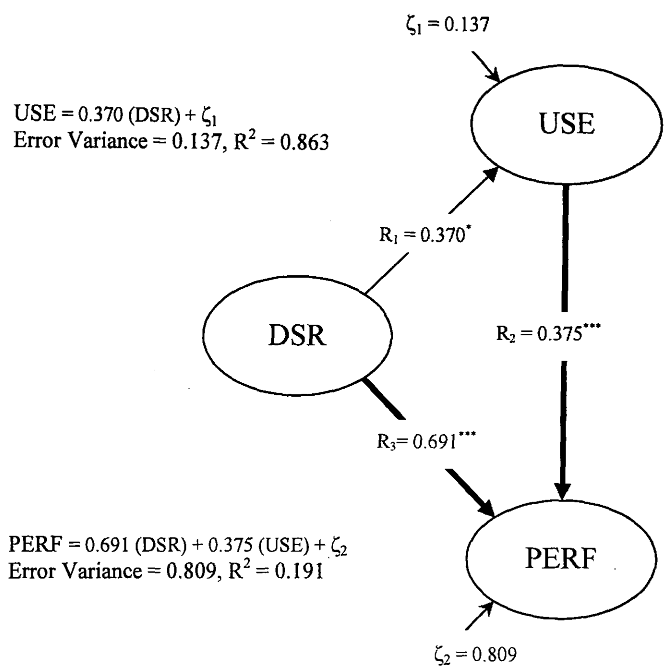
Stage-by-stage, the significance of relationships for each of the ten models (i.e., four CEM, two D&E, two Order Entry, one CRM, and one SCM model) is provided in the following subsections.

6.3.1 Customer Enquiry Management stage

The CEM-ERP model is one of the two models for which all three hypotheses are supported (the other is the CRM model). As a reminder, all path coefficients to measurement models are all positive and highly significant in both (see Appendix 11). In the multivariate and SEM terminology, it is called an *excellent* model.

As shown in Figure 6.3, high CEM DSRs lead to intensive use of the system (R_1 = 0.370) and improved performance (R_3 = 0.691) at the CEM stage for the complete data set. In addition, the use of ERP system's CEM tools has a significant impact on improved performance at this stage (R_2 = 0.375). The levels of significance of these relationships are also noted down in the figure. In other words; when CEM decision support requirements are at a high level, the company is able to utilise the system for CEM purposes, and as a mediating effect this use also leads to improved CEM performance.

Very similar significant results and impact values are obtained when only the MTO portion of the data is used to generate a variance-covariance matrix for parameter estimation. That is, the data fit and the significance of the relationships in the model are valid and powerful when both complete data and the MTO portion of the data is used. However, this is not true for the MTS case and the model fit is inadequate. This shows that, although the overall model fits well with the entire data and results in a significant causal path, the MTO portion is the actual factor in this convergence. So, out of the results of the CEM hypotheses the following proposition can be made: "In an ERP-using MTO company, when CEM decision support requirements are at a high level they are able to use the CEM functionalities of their ERP system for these purposes, and as a mediating effect this use also leads to improved CEM performance."



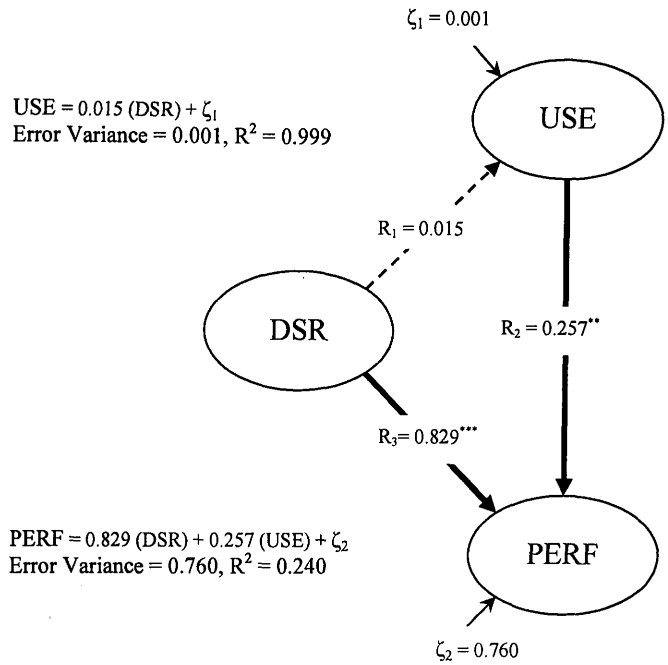
Relationships (R_x): * significant at 0.01 level ($p < 0.01$); ** significant at 0.05 level ($p < 0.05$); *** significant at 0.1 level ($p < 0.1$);

Hypothesis (the CEM model using ERP's basic CEM functionalities)	**Result**
H1.a. The level of Decision Support Requirements (due date setting, pricing and coordination) has positive impact on the intensity of use of ERP's CEM functionality (product database access, order entry automation and coordination).	*Supported*
H1.b. The intensity of use of ERP's CEM functionality has positive impact on performance at the CEM stage (economical and productive improvements).	*Supported*
H1.c. The level of Decision Support Requirements has positive impact on performance at the CEM stage.	*Supported*

Figure 6.3. Structural Model and Equations of the CEM Model (using complete data)

The CEM-ATP model is the only one having two significant relationships. Path coefficients and model fit are found to be quite adequate as shown in Table 6.2

and Table 6.3. Figure 6.4 below presents the results of causal path estimation with equations for the CEM-ATP model.



Relationships (R_x): * significant at 0.01 level ($p < 0.01$); ** significant at 0.05 level ($p < 0.05$); *** significant at 0.1 level ($p < 0.1$);

Hypothesis (the CEM model using ATP)	**Result**
H1.d. The level of Decision Support Requirements (due date setting, pricing and coordination) has positive impact on the intensity of use of ERP's ATP functionality.	*Not Supported*
H1.e. The intensity of use of ERP's ATP functionality has positive impact on performance at the CEM stage (economical and productive improvements).	*Supported*
H1.f. The level of Decision Support Requirements has positive impact on performance at the CEM stage.	*Supported*

Figure 6.4 Structural Model and Equations of the CEM-ATP Model (complete data)

Here, the model's second and third hypotheses are supported such that both DSRs and the use of ATP functionality have positive and significant impacts on improved performance at the CEM stage. However, a significant link between the need for decision support and the intensity of use of ATP functionality could not be found. Besides, while the R-square value for the equation of USE is quite high, PERF is not that high which means there are factors not included in this model that also affect CEM performance.

When MTO and MTS cases are considered separately, MTS is again a poor fit and shows a single significant causal link but MTO shows a good model fit and two significant causal links amongst constructs. However, the second hypothesis supported in the overall data set is not significant this time, while the first one is significant. That is, for ERP-using MTO companies, CEM DSRs seem to have an impact on the use of ATP functionality and on CEM performance. This is also true for the CTP functionality use of the MTO companies, contrary to the overall results.

The results of the two remaining CEM models (through the use of ERP's Capable-To-Promise functionality and Product Lifecycle Management add-on) in Table 6.4, support only the third hypothesis.

Table 6.4. Significant results from the CEM model hypothesis testing using CTP and PLM

Hypothesis	**Result**
H1.g. The level of DSRs (due date setting, pricing and coordination) has positive impact on the intensity of use of ERP's CTP functionality.	*Not Supported*
H1.h. The intensity of use of ERP's CTP functionality has positive impact on performance at the CEM stage (economical & productive improvements).	*Not Supported*
H1.i. The level of Decision Support Requirements has positive impact on performance at the CEM stage.	*Supported*
H1.j. The level of DSRs (due date setting, pricing and coordination) has positive impact on the intensity of use of PLM functionality.	*Not Supported*
H1.k. The intensity of use of ERP's PLM functionality has positive impact on performance at the CEM stage (economical & productive improvements).	*Not Supported*
H1.l. The level of Decision Support Requirements has positive impact on performance at the CEM stage.	*Supported*

This study's explanatory results have shown that ERP's tools for productivity (i.e., product database access, order entry automation and coordination) are well utilised and have a significant positive impact on relevant economic and productive performance measures. Here in all four CEM models, the third hypotheses (i.e., the impact of DSR on PERF) are all supported. That is, when firms indicate high CEM DSRs, they get high CEM performance without considering the mediating effect of the use of ERP tools. In other words, firms that consciously and carefully determine their requirements get high CEM performance because of an overall successful ERP adoption. Therefore, especially the second hypotheses (i.e., the impact of DSR on the intensity of USE) outweigh as a key mediating effect on the way to improved performance. The results have shown that the ATP model (using the complete data) produced such results, and it is more supported than the CTP one. On the other hand, PLM is weakly used amongst ERP users. Besides, there is no research studying the effectiveness of PLM systems. Few firms in the sample use PLM software, hence it is not possible to substantiate the three PLM hypotheses presented.

Overall, the results meet the expectations mentioned in the Literature Review and Assessment chapter such that the CEM tools of ERP can contribute to the company performance by improving productivity, providing coordination and standardisation; yet, they are not advantageous enough to companies for planning and estimation.

6.3.2 Design and Engineering stage

The results of the two Design and Engineering models (through the use of Product Configurator and Product Lifecycle Management) in Table 6.5 support only the third hypothesis.

Table 6.5. Significant results from the D&E model hypothesis testing using PC &PLM

Hypothesis	Result
H2.a. The level of Decision Support Requirements (documentation archive, internal coordination, external coordination and flexibility in design) has positive impact on the intensity of use of the Product Configurator add-on.	*Not Supported*
H2.b. The intensity of use of the Product Configurator add-on has positive impact on performance at the D&E stage (economical and technical improvements).	*Not Supported*
H2.c. The level of Decision Support Requirements has positive impact on performance at the D&E stage.	*Supported*
H2.d. The level of Decision Support Requirements (documentation archive, internal coordination, external coordination and flexibility in design) has positive impact on the intensity of use of the PLM add-on.	*Not Supported*
H2.e. The intensity of use of the PLM add-on has positive impact on performance at the D&E stage (economical and technical improvements).	*Not Supported*
H2.f. The level of Decision Support Requirements has positive impact on performance at the D&E stage.	*Supported*

OM researchers, from Wortmann (1992; 1995) to Deep *et al.*, (2008) have been reporting about the importance of *flexibility* at the MTO industry's Design and Engineering stage. On evaluating the applicability of an IT system to the sector, this comes as an inevitable feature especially desired by ETO firms. Product Configurator (PC) is especially recommended by Deep *et al.* (2008).

This study has included the constructs on the use of PC and PLM as the potential tools to provide such flexibility in design. However, their usefulness could not be shown. That is, the hypotheses symbolising the relationships amongst constructs were not supported. Yet, this may still be a sign of effectiveness since corresponding sample sizes were limited despite the adequate data fits in both models. This is due to the fact that a small sized sample requires extremely high covariances; and literature have reported successful examples of PC usage (off-the shelf or in-house developed), especially in SMEs (Forza & Salvador, 2002; Hvam *et al.*, 2006; Olsen & Sætre, 2007) while, to our knowledge, PLM has not been subject to any performance analysis.

Therefore, D&E results are of particular importance to be carried to successive case research. The points, such a case study is after, are about the intensity of PC and PLM usage and their impact on the design and engineering performance.

6.3.3 Order Entry stage

At the Order entry stage, the use of MRP and APS systems have a positive and significant impact on planning performance (Table 6.6). This is also consistent with the separated data in the APS model. In the two models of the Order Entry stage complete data analysis, no supported relationship is identified between the level of decision support requirements and intensity of use of these systems or improved order entry performance. But interestingly; using the MTO data only, the Order Entry model through the use of ERP's MRP functionality have resulted in two significant causal links. While one of these is still the path from the USE construct to the PERF construct (i.e., R_2 in Figure 6.2), the second significant but negative causal link is from DSR to PERF (i.e., R_3 in Figure 6.2); see second table in Appendix 11. That is, the estimation tells us that the use of MRP within a MTO company's ERP system improves the order entry performance whereas, if high operational and tactical planning system support is highly needed, a low planning performance is observed in the short and mid run. This is a crucial result to support MRP mechanism's unsuitability to the MTO sector. That is, MTO companies which require high levels of system support at the Order Entry stage get poor planning performance. Therefore; an ERP system, which stems from MRP and comprises it as the core planning module, can only be helpful to a MTO company when a robust (i.e., less sensitive to changes) and capacity-concerning mechanism is provided for its use at the Order Entry stage.

Table 6.6. Significant results from the Order Entry model hypothesis testing

Hypothesis (the Order Entry model using ERP/MRP and APS)	**Result**
H3.a. The level of Decision Support Requirements (confirmed order re-evaluation, aggregate planning and operational planning) has positive impact on the intensity of use of the ERP/MRP functionality.	*Not Supported*
H3.b. The intensity of use of the ERP/MRP functionality has positive impact on improving short and mid-term production planning.	*Supported*
H3.c. The level of Decision Support Requirements has positive impact on improving short and mid-term production planning.	*Not Supported*
H3.d. The level of Decision Support Requirements (confirmed order re-evaluation, aggregate planning and operational planning) has positive impact on the intensity of use of the APS add-on.	*Not Supported*
H3.e. The intensity of use of the APS add-on has positive impact on improving short and mid-term production planning.	*Supported*
H3.f. The level of Decision Support Requirements has positive impact on improving short and mid-term production planning.	*Not Supported*

Throughout the historical evolution of ERP systems, MRP has always been the core mechanism in it. Considering the widely acknowledged suitability of MRP to MTS production planning, its inflexible functioning has not been so useful to MTO companies. Thus, development of capacity concerning and more flexible new mechanisms has been proposed (Bertrand, 1983; Wortmann, 1992; Wortmann *et al.*, 1996; Stevenson *et al.*, 2005; Deep *et al.*, 2008). While some new and parsimonious mechanisms are developed and proposed, like Workload Control (WLC) (Stevenson *et al.*, 2005), some researchers have looked for new commercial packages such as APS as a potential panacea (Deep *et al.*, 2008).

This study has considered both tools (i.e., MRP and APS) for manufacturers in the UK, MTO and MTS firms in particular. As a result, a significant relationship has been obtained in both MRP and APS models between the intensity of use of the system and order entry performance improvement. In the APS model, this has also been true for both MTS and MTO cases. However, different findings were obtained in the MRP model with respect to production strategy.

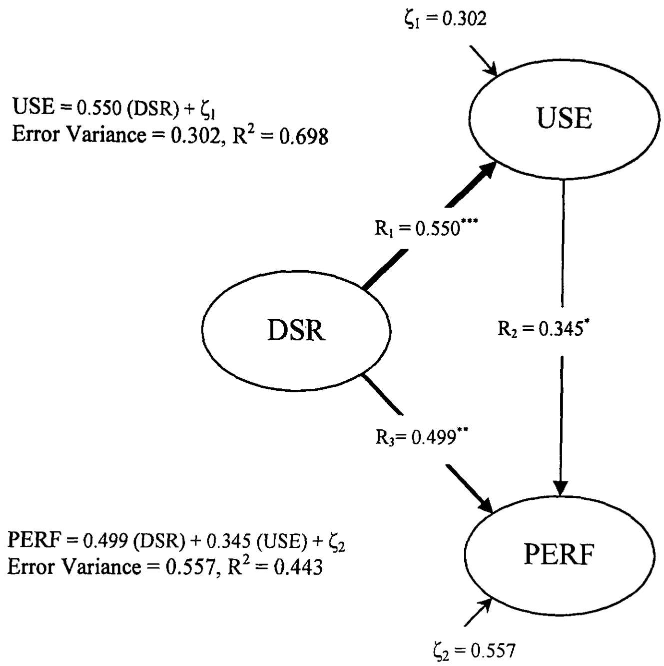
While the MTS case was inconclusive, the Order Entry DSRs were found to have a negative impact on order entry performance for the MTO case. There is no conclusion in the former case; however, it is widely acknowledged that MRP and APS are quite suitable to MTS planning (Cooper & Zmud, 1989; Cooper & Zmud, 1990; Plenert, 1999). Yet, the latter finding can be interpreted as a sign of unsuitability of MRP to MTO firms. That is, when a MTO firm requires high level of system support at the Order Entry stage, it shows poor planning performance. Through further case research, this point will be scrutinised in detail. On the other hand, Deep *et al.* (2008) considers APS as a potentially beneficial tool to overcome the weaknesses of MRP for MTO companies. This study's results show that the use of APS leads to order entry performance improvement, yet determining company requirements has no impact on this use or the performance.

As a future study, especially the APS add-on is thought to be critical to the MTO sector. Although its use is found to have a positive impact on performance, the order entry DSRs (which were thought to be crucial) were ineffective in the model. Therefore, a case study can help to scrutinise the reason behind that.

6.3.4 Customer Relationship Management

Similar to the CEM-ERP model, the CRM model is another fully supported model. In other words, high CRM DSRs lead to intensive use of the add-on (R_1 = 0.550) and improved CRM performance (R_3 = 0.499), as shown in Figure 6.5. In addition, the use of the CRM system has a significant impact on improved CRM performance (R_2 = 0.345). Explicitly, in a CRM system-using manufacturing company, when CRM decision support requirements are at a high level, the company is able to use the system for these purposes and, as a mediating effect, this use also leads to improved

CRM performance, such as satisfaction for existing customers, exploration of new customers and better profitability.



Relationships (R_x): * significant at 0.01 level ($p < 0.01$); ** significant at 0.05 level ($p < 0.05$); *** significant at 0.1 level ($p < 0.1$);

Hypothesis (the CRM model)	**Result**
H4.a. The level of Decision Support Requirements (i.e., customer database, need for improved relationships) has positive impact on the intensity of use of CRM add-on.	*Supported*
H4.b. The intensity of use of CRM add-on has positive impact on improving customer relationships (satisfying existing customers, exploring new customers and improving profitability).	*Supported*
H4.c. The level of Decision Support Requirements has positive impact on improving customer relationships.	*Supported*

Figure 6.5. Structural Model and Equations of the CRM Model (using complete data)

When the structural model is re-run using the samples of the two main production strategies separately, the overall excellent CRM model dramatically loses the significance of its causal paths in both cases, and particularly the MTS data begins to show a poor fit with the model. This is probably because the sample size decreases dramatically since the users of this extension is still not very high in the overall sample. Therefore, under these circumstances overall it may be said that the CRM system can be helpful for customer satisfaction and new market exploration, but it is not possible to draw specific conclusions for MTO and MTS.

For these two different models (CEM-ERP and CRM), the results provided above suggest that the identified four CEM DSR characteristics (i.e., due date setting, pricing, internal and external coordination) and two CRM DSR characteristics (i.e., customer database and need for improved relationships) are meaningful and have statistically significant impacts on improved company performance both directly and indirectly. To compare the two, the levels of significance of the three relationships in both models are slightly different but still measures within the 95% confidence. Besides, two models' R-square values in the equation of USE are almost equal; but the CRM model's R-square for the improved performance equation is much higher. This shows that, although the relationships amongst constructs are known, the CRM performance improvement through the use of ERP is mostly explained by some other factors. These factors can be identified by revisiting the literature and conducting case research (e.g., to explore further CRM DSRs) in order to further refine the CRM model to enable it to be used in any future studies.

CRM has been found as one of the most highly effective add-ons for all the segments in this study (i.e., complete data, MTO only, MTS only). That is, it can be concluded that for the UK manufacturers, CRM is a useful add-on which enables a manufacturer to improve existing customer relationships, explore new markets, and increase profitability.

Hendricks *et al.* (2007) examined selected ERP, CRM and SCM using firms' long-term stock price performance and profitability measures (such as return on assets and sales), and found no evidence of improvements in stock returns or profitability. However, Watts *et al.* (2008) showed that CRM has helped the firms have large sales increases but no evidence of improvements in the productivity within the firms. This study's sample is more similar to Watts *et al.*'s (2008) in terms of company size (varies from small to large), industry (manufacturers), respondent position (managers and directors), and measurement method (perceptual 5-point measurement scale). However, Hendricks *et al.* (2007) only sampled large and very large companies since they could only reach firms' long-term stock prices which have been publicised at least five years before that research.

Overall, this study's CRM inferences mostly confirm the findings in the literature. Therefore, any further in-depth effort is not an utmost necessity; thus effort can be channelled to more uncertain and unknown points in other models of this study.

6.3.5 Supply Chain Management

The SCM model is totally inconclusive in terms of all measures estimated through the SEM analysis (Table 6.7). In other words; only a few of the path coefficients—loading from constructs onto their variables—are significant; the model fit is inadequate (high χ^2 and RMSEA, low p-value and CFI); and, none of the hypotheses are supported. This advises us to use a different model to explain the impact of factors to company performance in a manufacturer using a SCM add-on. In separate analyses, MTS data fits the SCM model well but the MTO result is consistent with the overall case. To consider the adequately fitting MTS data, it can be observed that ERP-using MTS companies may economically and productively benefit from a SCM system to the extent of their utilisation of the add-on.

Table 6.7. Significant results from the SCM model hypothesis testing

Hypothesis (the SCM model)	**Result**
H5.a. The level of Decision Support Requirements (supply chain coordination with buyers, procurement from suppliers, and compatibility) has positive impact on the intensity of use of SCM add-on.	*Data misfit*
H5.b. The intensity of use of SCM add-on has positive impact on improving supply chain operations (improved order management, and profitability).	*Data misfit*
H5.c. The level of Decision Support Requirements has positive impact on supply chain operations.	*Data misfit*

Regarding the effectiveness of SCM systems, Hendricks *et al.* (2007) argue that, on average, adopters of SCM systems experience positive stock returns as well as improvements in profitability. Similar to the CRM add-on, the SCM add-on is adopted for both internal (to improve productivity) and external (to promote communication and coordination) processes. Yet, SCM is particularly employed in very complex network structures. Therefore, it is probably not only the sample size leading to the data misfit, but also the model itself that is incomprehensive to test the framework used in this study for the SCM add-ons.

The overall SCM model (i.e., variables and items of DSR, USE and PERF constructs) has to be re-determined. Therefore, considering the complexity of the phenomenon modelled here, it is concluded that a separate individual study may need to be conducted from scratch rather than a follow-up case research.

6.4 Conclusion

Overall out of the ten models, two of them (CEM-ERP and CRM) have been fully supported; seven partially (CEM-ATP, CEM-CTP, CEM-PLM, D&E-PC, D&E-PLM, OE-ERP/MRP, and OE-APS) supported, and one model (SCM) is inconclusive. Amongst the partially supported models, six have only one supported hypothesis; that is, a single significant relationship out of a possible three. All have an impact on performance. That is, ERP-using manufacturers in need of high decision support at these stages performed well without using the corresponding tools in their system intensively. Therefore, it is suggested that these improvements are gained due to the adoption of an ERP system as a whole rather than the individual modules and add-ons. Comparing the Order Entry and CEM models leads to an interesting result in need of further explanation. While the planning performance in the Order Entry model is improved through the use of ERP tools and add-ons (i.e., MRP and APS); the performance at the CEM stage does not depend on the use of the relevant ERP tool (CTP) or add-on (PLM) but the level of DSRs. Through further case research, this point will be examined in more detail in the next chapter.

The above discussion indicates that ERP and popular add-ons (considered in this study) are not utilised to a 'very good' extent and even this use does not lead to performance improvements in some cases. Table 6.8 below summarises and provides the overall picture with respect to each model of the explanatory part of this survey study.

There are three types of results. Two of them are *Supported* and *Not Supported* indicating when the model fits the data adequately and the hypothesis representing a relationship between two constructs is supported (i.e., significant) or not supported (i.e., non-significant). The other is *Data misfit* indicating when the model does not fit the data adequately (χ^2, p, CFI, and RMSEA measures of the model analysis are at inadequate levels), thus the analysis result is inconclusive. The latter, in this study, is particularly observed in the SCM model, and the MTS data in the table above.

Table 6.8. Summary of hypothesis results of three data sets

Model	Hypothesis	Result Complete data	MTO cases	MTS cases
CEM	H1a	*Supported*	*Supported*	*Data misfit*
	H1b	*Supported*	*Supported*	*Data misfit*
	H1c	*Supported*	*Supported*	*Data misfit*
CEM-ATP	H1d	Not Supported	*Supported*	*Data misfit*
	H1e	*Supported*	Not Supported	*Data misfit*
	H1f	*Supported*	*Supported*	*Data misfit*
CEM-CTP	H1g	Not Supported	*Supported*	*Data misfit*
	H1h	Not Supported	Not Supported	*Data misfit*
	H1i	*Supported*	*Supported*	*Data misfit*
CEM-PLM	H1j	Not Supported	Not Supported	*Data misfit*
	H1k	Not Supported	Not Supported	*Data misfit*
	H1l	*Supported*	*Supported*	*Data misfit*
D&E-PC	H2a	Not Supported	Not Supported	Not Supported
	H2b	Not Supported	Not Supported	Not Supported
	H2c	*Supported*	Not Supported	Not Supported
D&E-PLM	H2d	Not Supported	Not Supported	Not Supported
	H2e	Not Supported	Not Supported	Not Supported
	H2f	*Supported*	Not Supported	*Supported*
OE-ERP/MRP	H3a	Not Supported	Not Supported	*Data misfit*
	H3b	*Supported*	*Supported*	*Data misfit*
	H3c	Not Supported	*Supported(-)*	*Data misfit*
OE-APS	H3d	Not Supported	Not Supported	Not Supported
	H3e	*Supported*	*Supported*	*Supported*
	H3f	Not Supported	Not Supported	Not Supported
CRM	H4a	*Supported*	*Supported*	*Data misfit*
	H4b	*Supported*	Not Supported	*Data misfit*
	H4c	*Supported*	Not Supported	*Data misfit*
SCM	H5a	*Data misfit*	*Data misfit*	Not Supported
	H5b	*Data misfit*	*Data misfit*	*Supported*
	H5c	*Data misfit*	*Data misfit*	Not Supported

As justified in the methodological discussion of the follow-up case research in Chapter 3; the CEM stage has been selected for follow-up analysis after the explanatory survey results, and the particular case companies have been identified. The next chapter discusses the case study research findings.

Chapter 7: The Case Study

7.1 Introduction

The case research is aimed at continuing the previous effort following a holistic perspective. Therefore, it involves determining a new set of questions which again stems from the main research question provided in the thesis introduction but also further narrows down to a follow-up investigation of survey results.

Table 7.1 and Table 7.2 provide all research questions coming from the exploratory and explanatory parts of the survey study presented in Chapter 5 and Chapter 6, respectively. These tables altogether summarise the key findings in these chapters, associated possible research questions for a follow-up case research and list of companies appropriate for each purpose (they are the survey respondents who agreed to go on with further case studies). The latter, called candidate cases and given in the last column of the tables will be revisited on discussing the selection of case companies in Section 7.2.1 and can be ignored for now.

The following section (Section 7.2) prepares the methodological background of case research in this thesis. Potentially, due to the large number of research questions and possible case companies, the aim is to determine a sufficient number of cases to respond to the maximum number of research questions. The case study protocol is also presented in this section. Section 7.3 provides the selected case companies' background information. Section 7.4 and 7.5 provides the cross-case analyses regarding use and impact on performance, respectively. Section 7.6 concludes this chapter while also summarising what is learned from the case study analyses that could not be learned from the survey results.

Table 7.1. Research questions for the case study from the survey (exploratory part). Upper level questions: Why adopt? Why work?

Variable	Key findings from Survey (Exploratory part)	Case R.Q.	Candidate Cases
XR1. Difficulty of selecting the most appropriate system	The adopters find it "difficult (3)" on average (between 1-extremely difficult to 7-extremely easy) to identify the most appropriate system at the selection stage for their companies (especially, the Tier-2 suppliers). There is a significant difference between an MTO and MTS company that MTOs find this more difficult on average.	Why do MTOs find system selection more difficult? Which factors have been the most effective on this selection process comparing MTO and MTS companies?	**A5** (Very difficult), **A10** (Very difficult), **A15** (Extremely difficult), vs **A6** (neither diff nor easy) **B16** (Very easy), **B8** (neither diff nor easy)
XR2. ERP Package Implementation Strategy	Majority of the manufacturers implement their systems from a single vendor (either with or without add-ons) while 40% of the users add some extensions on top of their systems regardless of their package implementation method. There is no distinct difference regarding the company type in package implementation strategy.	Why is BoB one of the least preferred options though it looks like a good idea to combine the pros and eliminate cons of different brands?	No companies preferred BoB amongst candidates. The question may be directed to ones using Single and In-house built, asking why they did not prefer BoB.
XR3. ERP vendors	SAP is the leader of the developer industry in the UK manufacturing sector. Yet, local and small-sized vendors dominate the market on aggregate. Eight out of nine SAP users are large MTS firms. SAP, as the leading ERP vendor, is mostly implemented as a single package (11 out of 14) and very highly preferred by MTS companies (13 out of 14) while MTOs prefer local vendors.	How did the small-sized local vendor dominate the SME market in the UK? What factors affect the choice of SME's package selection? Can this lead to an increase in in-house developed systems in the MTO industry?	**A15** and **A10** preferred these small sized vendors. The latter question may be asked to these. The former question needs to explore vendors as well.
XR4. Popularity of adopted modules and add-ons	Order Entry, Purchasing & Logistic, Sales And Delivery, Materials Management, Financial Accounting, and Financial Control are the most widely adopted modules, respectively; and CAD, CRM and APS are the most popular add-ons. The importance ranking of the PP module for MTO is significantly higher than MTS.	Why are some modules and add-ons mostly preferred by MTOs?	This is probably related to the industrial sector, and other idiosyncratic needs.

XR5. Reason to adopt ERP	"Simplifying and standardising business processes", "Integrating the separate systems, operations and data", "Replacing legacy systems", and "Improve production planning effectiveness" are the most agreed Reasons to adopt ERP. Only one reason to adopt: "Get linked to global activities/support globalisation strategy" is significantly more important for a MTS than a MTO firm on average.	Why do MTOs adopt ERP? (in par.) Why do MTOs think that they require less support to *get linked to global activities*?	**A2, A15** (Disagree); **A3, A5** and **A6** (Strongly Disagree) vs **B16** (Agree)
XR6. Reason not to adopt ERP	The most outstanding reason not to adopt ERP is that "ERP would not suit the needs of the company". It is also important to note that MTO firms highly significantly agree with this reason compared to MTS nonadopters.	How could non-adopter MTO companies come to know that ERP would not suit their needs? How do they compensate these needs other than ERP?	**C14** and **C18** (Strongly Agree); **C19**(neither agree nor disagree)
XR7. Decision Support Requirements (DSR)	MTO companies need a product database more than MTSs do to estimate cost and set profit margins. Short-term capacity planning is more important to MTO than MTS due to changing main capacity constraint (or bottleneck) over time. MTS companies use MRP within their ERP systems significantly more than MTOs. Overall, only a few significant differences are observed between MTO and MTS DSRs identified for different production planning stages, CRM, and SCM; though more were expected.	Why very few significant differences were observed between MTO and MTS DSRs? (Considering that these DSRs were prepared using MTO literature which are thought to be more likely needed by MTOs)	**A3** and **A5** (High DSR Average); **A10** and **A17** (Low DSR Average) **B16** (Very high DSR Average); **B11** (High DSR Average) **C9, C13, C14** and **C19** (High DSR Average) **D7** and **D12** (High DSR Average)

Table 7.2. Research questions for the case study from the survey (explanatory part). Upper level questions: Why adopt? Why work?

Model	Key findings from Survey (Explanatory part)	Case R.Q.	Candidate Cases
XN1. Customer Enquiry Management stage	CEM tools of ERP can contribute to the company performance by improving productivity, providing coordination and standardisation; yet, they are not advantageous enough to companies in planning. Here in all four CEM models, all of the third hypotheses (i.e., the impact of DSR on PERF) are supported. That is, when firms indicate high CEM DSRs, they get high CEM performance without considering the mediating effect of the use of ERP tools. In other words, firms consciously and carefully determining their requirements get high CEM performance because of an overall successful ERP adoption.	Do firms confirm this finding? (validation) Why can MTO companies not benefit from planning tools of ERP and its extensions? How can ERP CEM tools (for automation, coordination and standardisation) help MTO companies? Is this interpretation of supported third hypothesis valid in the industry? (validation)	**Firm (DSR, CEM/ATP/CTP/PLM, Perf)** **A1** (mid, mid/low/low/mid, mid), **A2** (high, high/low/low/low, high-mid), **A3** (mid, low/low/low/high, low), **A4** (high, high/low/low/low, high), **A5** (high, high/high/high/n-a, high), **A6** (mid, n/p, n/p), **B8** (mid, mid/low/low/n-a, low), **A10** (low, high/low/low/low, mid), **B11** (high, n/p, n/p), **A15** (mid, mid/low/low/low, mid), **A16** (high, low/low/low/low, mid), **A17** (low, low/low/low/low, low).
XN2. Design & Engineering stage	Two most important ERP tools for D&E (PC and PLM) are not found to have impact on D&E performance while literature have reported successful examples of PC usage (off-the shelf or in-house developed), esp. in SMEs.	Why is the utilisation of PLM amongst users low? (e.g., are MTO companies aware of PLM solutions?) This makes the effectiveness of the system questionable as well. Academic literature has no idea about this.	**A4** (mid-sized, MTO_2, reported to use PLM but In-house developed system) **A17** (large, MTO_2, reported to use PLM but In-house developed system) **A1, A2, A3, A10** (PC users)

XN3. Order Entry stage	Significant relationships have been obtained in both MRP and APS models between the intensity of use of the tools and improvement in the production planning performances. However, for the MTO case, Order Entry DSRs were found to have a negative impact on production planning performance which a sign of unsuitability of MRP to MTO firms. That is, when a MTO firm requires high level of system support at the Order Entry stage, it shows poor planning performance. APS, as a potential beneficial tool to overcome the weaknesses of MRP for MTO companies, is found to improve production planning performance, yet determining company requirements has no impact on this use or the performance.	Is this interpretation of ERP planning tools validated in the industry? What is behind the negative impact of OE DSR on PP performance? Why are the Order Entry Stage DSRs not related to the intensity of use of APS or MRP?	**A1** (small-sized, MTO_2, reported to use *APS*, MS Navision) **A2** (mid-sized, ETO, reported to use *APS*, Avanté) **A4** (mid-sized, MTO_2, reported to use *APS* but In-house developed system) **A17** (large, MTO_2, reported to use *APS* but In-house developed system)
XN4. Order Release & Dispatching	Could not be analysed due to low response…	Why are the Order Release & Dispatching stages not recognised in the industry?	N/A
XN5. Customer Relationship Management	CRM has been found as one of the best utilised add-ons for all the segments in this study. That is, it is concluded that for the UK SME manufacturers CRM is a useful add-on which enables a manufacturer to improve existing customer relationships, explore new markets, and increase profitability.	-No particular interest- (Currently available CRM systems seem to meet the requirements of manufacturing sector in the UK)	N/A
XN6. Supply Chain Management	The SCM model is inconclusive for the complete data	-No particular interest- (The model was not comprehensive enough to produce meaningful results. A new and single SCM study needed.)	N/A

7.2 Choosing Case Studies

This section provides the background to decide *how many* companies to choose, *how* to choose them, and *who* to choose; respectively. Thus, this section is important to form a structure for case research that follows the survey results.

7.2.1 Case Selection: How many, How and Who to choose?

Single in-depth cases are often used in longitudinal research and come with strengths and limitations (Yin, 2009). Briefly, while it enables the research to deeply 'feel' the research environment; it limits the generalisability of the conclusions. Contrarily, while multi case research enables within-method triangulation for generalisability and repeatability, it may lead to missing in-depth issues in the research settings (Yin, 2009). The two strategies with related key decision factors summarised by Miles & Huberman (1994), are tabulated below (Table 7.3):

Table 7.3. Prior instrumentation: Key decision factors (adopted from Miles & Huberman, 1994)

Single case	Multiple cases
Rich context description needed	Context less crucial
Concepts inductively grounded in local meanings	Concepts defined ahead by researcher
Exploratory, inductive	Confirmatory, theory-driven
Descriptive intent	Explanatory intent
"Basic" research emphasis	Applied, evaluation or policy emphasis
Comparability not too important	Comparability important
Single, manageable, single-level case	Complex, multilevel, overloading case
Generalising not a concern	Generalisability/Representativeness important
Need to avoid researcher impact	Researcher impact of less concern
Qualitative only, free-standing study	Multi-method study, quantitative included

Similar to the Survey and Case Study methods comparison made in the Research Methodology chapter, single and multiple-case strategies respectively serve different purposes within case research. As listed in Table 7.3 above, while single-case is used for descriptive, exploratory, and inductive research aims; multiple-cases enable confirmatory, explanatory, and more structured theory-driven case research.

Regarding the interests of this study, the types of companies (Company type vs ERP adoption), importance of comparability amongst cases and company type groups, theoretical structure and confirmatory needs coming from the survey study; a *multiple*-case methodological triangulation has to be the second stage strategy. At least one company, 'typical' of its quadrant, needs to be included in the sample. However, due to the wide spectrum of factors affecting ERP adoption, such as software vendor, company size, industrial sector, etc., it may be unrealistic to expect to find a company that is typical of all MTO companies and ERP vendors. Still, on deciding who to choose and how to choose the most appropriate companies for case research; several criteria, particular to the follow-up purpose of a survey study, can be listed:

1. Altogether, companies need to cover more than one quadrant in the production strategy/user matrix, i.e. MTO vs MTS and User vs Nonuser; not to merely select one of each but to enable comparability.
2. For the quadrants where the survey majorly focused and made inferences (e.g., MTO users and nonusers), representative cases would be essential. Contrarily, MTS users and non-users are out of interest in this study thus may be paid less attention.

3. Cases containing particular points which are highly interesting to this study, such as MTO adopters which think that ERP would not suit their needs, should be included within the sample.

Therefore, reconsidering the main focus of this study, it is especially important to find as many MTO users as possible; then comes MTS users and MTO nonusers to enable comparison; and finally, MTS nonusers (as the relatively least important quadrant), as long as the practicality and accessibility permits. When multiple cases are to be used, the vital question is the case selection or (theoretical) sampling, which is discussed as follows.

The candidate companies, described in Table 7.1 and Table 7.2 before, are listed and their background information is provided in Table 7.4 below. These candidate companies are the survey respondents who have agreed to be in contact for further case studies.

For practical reasons, a sufficient number of case studies is aimed to answer the maximum number of case research objectives. Obviously, these objectives have to be the points that are desired to be scrutinised most. Using the very last column in Table 7.1 and Table 7.2, the potentially most suitable companies are shown in red colour in Table 7.5. Amongst them A10, C14 and A15 agreed to be interviewed for detailed questions on their system use and reasons for non-adoption, where applicable. Totally, their help let this thesis examine four exploratory (XR1, XR3, XR5 and XR6) and one explanatory (XN1) follow-up issues.

Table 7.4. Summary Characteristics of Potential Case Companies

Firm	Size	Sector	ERP system	Add-ons	DSR (avg.)	USE (avg.)	PERF (avg.)
A1	Small	Chemicals	Single pack. *MS Navision*	CRM, APS, SCM, PC	4.69	3.65	4.21
A2	Mid	not provided	Single pack. *Avanté*	CAD, APS, SCM, PC	4.94	3.85	4.07
A3	Mid	Ship B.	Single + addon *JDA (Western)*	CAD, SCM, PC	5.44	2.35	2.31
A4	Mid	Industrial	In-house -	CAD, CRM, APS, SCM, PLM	4.86	5.25	6.36
A5	Mid	Various	Single + addon *Avanté*	CAD	5.81	5.90	4.72
A6	Mid	Raw Mat.	In-house	-	4.47	N/P	N/P
D7	Small	Security Prd.	N/A	N/A	5.39	N/A	N/A
B8	Mid	Raw Mat.	Single pack. *MS Navision*	-	4.89	3.65	3.07
C9	Small	Raw Mat.	N/A	N/A	5.22	N/A	N/A
A10	Mid	Lighting	Single pack. *Fourth Shift*	CAD, CRM, PC	3.72	2.95	1.90
B11	Small	Raw Mat.	not provided not provided	-	5.42	N/P	N/P
D12	Small	Various	N/A	N/A	5.06	N/A	N/A
C13	Small	Industrial Mach. & Eq.	N/A	N/A	5.94	N/A	N/A
C14	Mid	Industrial Mach. & Eq.	N/A	N/A	5.22	N/A	N/A
A15	Small	Textile	Single pack. *RENT-IT 123*	CRM, SCM	4.64	2.75	4.38
B16	Mid	Industrial Mach. & Eq.	Single pack. *SysPro*	CAD	6.11	4.30	5.79
A17	Large	Automotive	In-house	APS, SCM, PLM	3.64	2.95	3.48
C18	Mid	Raw Mat.	N/A	N/A	4.56	N/A	N/A
C19	Small	Ship, Railway, Automotive	N/A	N/A	5.19	N/A	N/A

A: MTO adopters, **B:** MTS adopters, **C:** MTO non-adopters, and **D:** MTS non-adopters; **N/A**: Not Applicable, **N/P**: Not provided

Table 7.5. Research Questions and Corresponding companies

	Exploratory RQs							Explanatory RQs						
Firm	XR1‡	XR2	XR3	XR4	XR5‡	XR6‡	XR7	XN1‡	XN2	XN3	XN4	XN5	XN6	#
A1*								√	√	√				3
A2**					√			√	√	√				4
A3*					√				√		√			3
A4**					√			√	√	√	√			5
A5	√													1
A6					√									1
D7														0
B8					√									1
C9														0
A10**	√		√					√	√		√			5
B11														0
D12														0
C13														0
C14						√								1
A15**	√		√		√						√			4
B16	√										√			2
A17**					√			√	√	√	√			5
C18						√								1
C19						√								1

A: MTO adopters, **B:** MTS adopters, **C:** MTO non-adopters, and **D:** MTS non-adopters.

‡ RQs of particular interest, grey-tones (RQs out of interest)

** Most frequently used companies, * Secondarily most frequently used companies, #: Count

Table 7.6 below is an abridged version of Table 7.1and Table 7.2 formed after the discussion in the subsection above. It demonstrates how this chapter relates to the results from Chapters 5 and 6; and, it summarises the case study research questions.

Table 7.6. The Case Study Research Questions

Selected Topics	**Research questions**
XR1. Difficulty of selecting the most appropriate system	**RQ1.a:** *Why do MTO companies find system selection difficult?* **RQ1.b:** *Which stage was the hardest?* **RQ1.c:** *How can MTO companies successfully select their systems?*
XR3. ERP vendors	**RQ2.a**: *How did the small-sized local vendor dominate the SME market in the UK?* **RQ2.b:** *What factors affect the choice of package for SMEs?*
XR5. Reason to adopt ERP	**RQ3:** *Why do MTO companies adopt ERP systems?*
XR6. Reason not to adopt ERP	**RQ4.a:** *How could non-adopter MTO companies come to know that ERP would not suit their needs?* **RQ4.b:** *How do they compensate for those needs?*
XN1. The Customer Enquiry Management Model	**RQ5.a:** *Why can MTO companies not benefit from the planning tools of ERP and its extensions?* **RQ5.b:** *How can ERP CEM tools (for automation, coordination and standardisation) help MTO companies?*

XR: Topics from the exploratory results; **XN:** Topics from the explanatory results

Similarly, Table 7.7 is an abridged version of Table 7.5. It identifies the corresponding companies which were selected as the most appropriate for the case study analysis and summarises the survey results for these three companies only. This table also provides the abbreviations to be used from here on for each of the three case study companies.

Table 7.7. The Case Study Companies and Corresponding Responses

Firm	Exploratory				Explanatory
	XR1 (Difficulty of selecting)	**XR3** (ERP vendors)	**XR5** (Reason to adopt)	**XR6** (Reason not to adopt)	**XN1 (CEM Stage)** (DSR, CEM/ATP/CTP/PLM, PERF)
MU_1 (A10)	✔ (Very diff)	✔	✔		✔ (low, high/low/low/low, mid)
MU_2 (A15)	✔ (Extr. diff)		✔		✔ (mid, mid/low/low/low, mid)
MNU (C14)				✔ (Str. agree)	

MU: MTO user; **MNU:** MTO non-user

7.2.2 Case Study Protocol and Data Validation

An case study protocol is considered to be a standard agenda for the researcher's line of inquiry and essential for multiple-case study research (Yin, 2009). The main purpose of the core part of the protocol (the instrument) is to keep the investigator on track as data collection proceeds. Therefore, this case research instrument has two different types and levels of questions: (1) Open-ended, short, high-level questions to enable the respondent to freely define, describe and exemplify the phenomenon; followed by (2) Supplementary, in-depth questions to remind the respondent about unanswered parts, to avoid departing from the subject, and to make sure that certain detailed questions are answered. Appendix 12 provides the full case study protocol guided by Yin (2009).

Data display before starting the analysis both helps organise the interview material and enables the researcher to validate the information on hand by handing it back for the respondent's confirmation (Miles & Huberman, 1994). To prepare the data display of the three cases, firstly the interviews (lasting one to two hours) were tape recorded; then, transcribed fully. A question & answer summary table was constructed for each case which was sent to the respondent for validation and the elimination of any misunderstood details. The summary tables validated by the interviewees of the case companies are provided in Appendix 13.

7.3 Case Company Background

Background information on each of the three case study companies and the ERP environment (where ERP has been adopted) are provided in this section, beginning with the two MTO users (or adopters) followed by the MTO non-user.

7.3.1 Company MU_1

Company MU_1 is a small textile manufacturer located in the North West of England with customers throughout the UK. The company employs 24 people and has an annual turnover in excess of £1.8 million. Therefore, the company can be considered a small enterprise as for the definition adopted in this thesis. The company produces filtration products (e.g., woven or non-woven fabrics, surface treatments and membranes) for companies in the UK process industry (e.g., food, paper, pharmaceuticals, minerals, and chemical) on a MTO basis. The company also buys in laundry products (e.g., bags and hampers) for commercial laundries and hospitals, mostly procured from the Far East, before being manufactured at another factory in Poland. The company produces 1,000 different products a year. Generally, 500 are new each year, and 500 are repeat jobs (repeated for a few months). Repeat orders tend to be more lucrative than new jobs: about 75% of the turnover is from repeat products.

When, in 2005, the developer of an old bespoke system (developed in Visual Fox Pro) was unable to provide support anymore, MU_1 began to look for an off-the-shelf replacement solution and, in 2007, decided on that offered by *123Insight*, a UK-based provider of ERP software to the midmarket. This was not only because the system was thought to be appropriate to meet the company requirements but also mainly because it was a rentable system, paid for on a monthly basis. It was gradually installed throughout 2007 due to a data extraction problem from the old system and, by the beginning of 2008, it was in operation. No analysis of Return on Investment (ROI) on the system life time estimate has been made on the selection and implementation of the system.

7.3.2 Company MU_2

Company MU_2 is a medium-sized lighting specialist located in the South West of England. The company employs 96 people and had an annual turnover of £13.5 million in 2010 and £11 million in 2009. Typical products are standard fittings, LED solutions and store lighting accessories. The company procures all components and the products are made to-order and sold in the UK. Contractors are responsible for installing them on the customer's site. The company has a range of 30 product families and builds around 1,000 different product variants from them. There is repeatability in the business, but the new *vs.* repeat ratio is uncertain in the company.

At the time of the survey part of the research conducted in November 2009, MU_2 was using an ERP system called Fourth Shift. Shortly after, MU_2 was bought by a large group, which owns a company in China producing cheap lighting products for distribution throughout Europe. MU_2 was then 'told' to adopt Microsoft Navision to share a common platform across the group, including with key sites in France, Spain and the United Arab Emirates. In the case of the Fourth Shift system, ROI analysis and lifetime Estimation was done, but there were no discussions or estimations about the Navision adoption.

7.3.3 Company MNU

Company MNU is a mid-sized engineering company located in the East Midlands of England. The company employs 40 people and had annual turnovers of £17 million in 2009 and £10.5 million in 2010 (a dip caused by the recession). MNU offers two engineer-to-order products: *Product A* (equipment used to impart a texture onto the roll in a rolling mill), and *Product B* (condition monitoring equipment, used to assess the quality of the steel produced in continuous casting machines, where liquid steel is converted to solid); and a make-to-order product: *Product C* (a quality control instrument used to inspect the surface of the roll to find metallurgical defects, such as cracks and soft spots). The company outsources manufacturing, but the design & engineering and final assembly are undertaken in-house; as is the installation of the machinery. Very occasionally, there is repeatability in the business, but the new *vs.* repeat ratio is uncertain in the company.

The company has no ERP system. The software requirements are provided by separate solutions at each stage. In other words, the following are all standalone: General Systems SUN (for accounting & finance); MS Project Management (to plot out Gantt charts and see where the overlaps are); MS Excel (to keep records of components, not scheduling); and, AUTOCAD Lite (to design components).

The information on the case companies is summarised in Table 7.8 below.

The following subsections perform cross-case analysis. Firstly, issues on applicability, such as system selection and use are analysed in Subsection 7.4.1 and 7.4.2, respectively; then, secondly, the impact on performance is investigated in Section 7.5.

Table 7.8. Summary of Company Background Information

Case	Size (Employee, 2010 Turnover)	Sector (Products)	Production Strategy	ERP system
MU_1	Small (24, £1.8m)	Textile *(Laundry & Filtration)*	MTO	Single pack. *(123insight)*
MU_2	Medium (96, £13.5m)	Lighting *(Standard fittings, LED solutions, store lighting accessories)*	MTO	Single pack. *(Fourth Shift, Navision)*
MNU	Medium (40, £10.5m)	Industrial Machinery & Equipment *(Equipment for scanning roll mill quality, texturing roll mills and monitoring strand condition)*	ETO	N/A

7.4 Cross-case Analysis: Application of ERP

7.4.1 System Selection

As shown in Table 7.7, the two users find ERP selection very difficult (for MU_1) and extremely difficult (for MU_2). MU_1 is a small company with limited expertise and finance; and, thus, is very risk averse to an implementation failure. This risk was simply described as "*putting everything into a new system and it not working*" by the Managing Director (MD). The old unsupported and obsolete legacy system was replaced after a two-year long search period for the right system, as "*getting the wrong system is a business threatening decision*", explained the MD. Due to this reason, which he also defined as "*a matter of trust*", the company went for a rentable system choice (i.e., *123insight,* formerly called *Rent-IT Systems*) adopting a low-risk, cost effective and flexible strategy. On the other hand, MU_2 was forced by its new owner group to adopt the system (*Navision*). However, the survey response (extremely difficult) was for the previous system (*Fourth Shift*) which was adopted twenty years before Navision. The OM/IT Manager of MU_2 sees the high software prices, limited budget of his company and limited vendor options as the main reasons for difficulties.

The MD of MU_1 indicated that the major reason for adopting ERP (other than to replace the legacy system) was the need for planning. Contrary to the MU_2 case, the motivation has largely come from inside the business in MU_1. On selecting the system, the availability of updated concurrent information was the key for MU_1. In addition, standardisation and integration were the other two important criteria. On the other hand, MNU states that ERP is not suitable to the company's business. Separate pieces of software are used to manage tasks at different stages, as provided in Subsection 7.3.3. The currently required decision support is *process improvement* for better planning of the capacity (i.e. forward planning of capacity by joining up information on future capacity requirements), and better *control over suppliers* (which makes MNU so dependable on them since all manufacturing is sourced) and *quality assurance* (which again relies on suppliers' procedures). The survey response regarding the major reason for non-adoption was the unsuitability of ERP to MNU. MNU manages a product-dominated, very low volume business. It is the design and the technical development of the three high-tech products that MNU is extensively busy with, rather than the process of manufacturing those products. Additionally, the MD stated that no ERP vendor has approached the company to offer a system; which can arguably be thought of as a sign of unsuitability.

7.4.2 Use

MU_1 uses the system to get an up-to-date overview of the processes (job statuses) and materials (inventory) to make decisions such as due date determinations at the CEM stage. For example, system warnings help the managers to react before any overload occurs on machines or to anticipate dangerously low inventory levels for critical raw materials. Activity Based Costing (ABC) is used for price determination and is considered especially important for the recovery of high overhead costs (i.e., 40%).

Regarding key decisions at the CEM stage, MU_2 considers the due date to be a customer-driven parameter and the OM manager states that "*the price is secondarily important to us*". In other words, the employees, who are not required to be highly skilled, assemble the products in their work stations. "*It's all simple stuff*", the MD says, "*If you've got a screwdriver probably you can build our products.*" Therefore, labour is the primary resource for MU_2, and the planners adjust the capacity (i.e. the number of employees) to comply with customer due dates. Thus, no CEM tools are utilised, since the due date is strictly set by the customer. In the previous system (*Fourth Shift*), the company used a basic code written in MS Access to ease job entry automation into the system. In the current system (*Navision*), the OM manager believes that there are more tools that could be used for the CEM decision support requirements; but the company has been struggling with some implementation issues so they have not yet evaluated those tools for implementation.

On the extension side, in response to demands for a CRM solution from more than half of the *123Insight* customers, the vendor developed an add-on. However, the concept of CRM has been interpreted differently than the conventional view of the software vendor (123insight, 2009). It is developed to help MU_1 employees deal with complex enquiries in terms of human resource coordination. For example, when a new order requires at least one person for each of the processes of design, production, materials management, and planning; the particular functionality enables them to coordinate amongst the group, saying where they are up to and what is still to be done. Therefore, it used for improving communication within the company rather than between the company and its customers.

7.5 Cross-case Analysis: Impact of ERP on performance

Overall, in MU_1, the MD has not observed a dramatic improvement between the new and the old systems. On-time delivery is thought to be slightly better than previous performance (90-95%) prior to adoption. The MD of MU_1 believes that this is due to having better control over the environment (e.g. better management of suppliers), and getting an idea of the big picture to be proactive against potential problems like bottlenecks. On the other hand, ABC has always been important to the company's price determination strategy for new business and they are happy with the continuation of the support for ABC in their new system. The MD describes this importance, saying that "*if we had not been able to use the ABC system, we would not have chosen it.*"

The MD of MU_1 thinks the system is especially helpful for new business. While repeat business is easy, as historical data is followed and accordingly amended; for new business, the system supports coordination on estimating the cost, designing and planning the new product, as it makes the team go through the discipline of following a set series of steps. As stated by the MD: "*these steps do not get lost in the system as much as they used to do.*"

MU_2 hardly benefits from their system at the five critical planning stages (from CEM to Dispatching) considered in this study. As mentioned before, the customers set the due dates and then agree the pricing with MU_2 (the Sales department does the negotiations). As a result, MU_2 does not need any support for planning at the CEM stage, but requires material planning support at the Order Entry Stage. For the latter stage (order entry), MRP has been the only utilised tool in the legacy and current systems; and none have been used for the CEM stage.

7.6 Discussion and Conclusion

This section concludes this chapter by summarising the points learned via this case study follow-up which could not been achieved by the survey research.

In the survey results, it has been found that users typically struggle with selecting the most appropriate system to their companies. Case study results have revealed that the main reason for that is being a small company with limited expertise and finance. This prevents them from having expert support (consultancy) during the system selection process. Besides, failure stories damage the trust in both the vendors and consultants. Amongst the stages of ERP selection (i.e., Plan, Identify, Evaluate and Select) which Deep *et al.* (2008) identified in the MTO SME sector, both users struggled the most in choosing the vendor. MU_1 argues that vendors may sometimes mislead interested customers through referring to selected (biased) reference sites. The case study evidence from MU_1 suggests that options such as renting or software-as-a-service (i.e. on-demand software) can be low-risk, cost effective and flexible solutions for risk-averse MTO SMEs having limited expertise and budget.

Companies adopt ERP systems for various reasons. From the survey results of both the above two user cases, the major reason was to replace the legacy systems, which was also reported as the main reason in the exploratory survey analysis. Through the case studies, it has been possible to learn more about the details of adoption reasons for each case. While MU_1 mentioned no external pressure from customers or suppliers, MU_2 was forced to change their system due to group pressure.

On the other hand, although MNU has some decision support requirements for the forward planning of capacity, controlling visibility and records (need for computerised sales order processing), and better control over its limited number of suppliers (with long learning curves); the company's MD thinks that no particular ERP system is proven to be applicable to their needs in the sector.

One of the interesting points from the explanatory part of the survey was the existence of an improved performance contrary to a low system utilisation at the CEM stage. That is, when firms indicate high CEM DSRs, they get high CEM performance regardless of the mediating effect of the use of ERP tools. It has been possible to examine the reason behind this issue in the case reaseach. At the CEM stage, neither analytical nor automation tools are used by MU_1. Despite this fact, MU_1 responded in the survey that the CEM performance had improved since system adoption. This coincides with the result from the explanatory analysis of the survey in the previous chapter, such that although some users cannot utilise their system tools for particular stages of planning, they still report improved performance for that particular stage. The MD of MU_1 suggested that this improvement is due to the human factor. Namely, sales and planning staff who previously made these decisions entirely based on their experience and understanding of the business and skills are now better supported by the overall and integrated up-to-date information in the system; although no analytical tools such as ATP, CTP or capacity planning are used at this stage. The MD thinks the skills of the individual sales people are more important, and describes this as follows:

> *"You cannot rely on the system to do things. The people are more important. [...] It gives us some basic information but our ability to turn enquiries into business is much more down to the sales persons' understanding of the customer and the relationship."*

Consistent with the survey results, it has been confirmed that there are a lot of features that MTO adopters do not use. On top of that, the case research has enabled to explore the reason behind this low utilisation of adopted ERP tools. The systems are thought to be more complex than the needs of the companies; and, because of that, only high-level functionalities to get the big picture are utilised, while other analytical tools for planning are not utilised. This may imply that there is a big gap not only between the software provision and MTO decision support requirements, but also between the provided functionalities and the expertise and knowledge to utilise them, especially for personnel in SMEs.

The final chapter concludes this thesis by providing research contributions; implications for researchers, managers and vendors; limitations, and thoughts for further research.

Chapter 8: Conclusion

This thesis has been geared specifically towards assessing the applicability of ERP systems to MTO companies. A survey study (exploratory and explanatory) and a follow-up case study (with three cases) have been conducted leading to some pertinent research findings, which are reflected upon in this final chapter. Section 8.1 discusses the contributions made by these findings and is organised around the research questions outlined in Chapter 1. Finally, Section 8.2 describes the limitations of this thesis and some promising avenues for future research.

8.1 Contribution

Prior research has given insufficient attention to the effects of production strategy on the applicability of ERP systems and has generally failed to consider the perspective of non-adopters. While Bertrand & Muntslag (1993) reviewed the applicability of MRP-II to the ETO sector, an update of this work considering the MTO sector (in the broad sense of the term) has been necessary. Similarly, Bendoly & Jacobs' (2004) work on the alignment of ERP solutions with operational needs; and Stevenson *et al.*'s (2005) review of the applicability of PPC concepts to MTO companies did not go into enough depth. More recently, Deep *et al.*'s (2008) single case study, focused on the factors affecting the selection of an ERP system by a MTO company, was limited to system selection: it did not consider the impact of ERP adoption on company performance. Furthermore, previous survey-based OM studies on the ERP adoption phenomenon have been mainly conducted in the US and Sweden (Mabert *et al.*, 2000; Stratman, 2001; Mabert *et al.*, 2003; Olhager & Selldin, 2003; Olhager & Selldin, 2004); a UK perspective has been missing.

This thesis contributes to this ongoing research topic through a UK-wide application; it also broadens the spectrum through the inclusion of both ends of the production strategy spectrum (MTO *vs.* MTS) and by including the non-adopters' perspective in the sample (adopter *vs.* non-adopters). Bertrand & Muntslag's (1993) applicability assessment is updated to the current state-of-the-art in ERP systems and add-ons; and depth is added to the work on alignment by Bendoly & Jacobs (2004) and assessment by Stevenson *et al.* (2005) by identifying the MTO stages of PPC before matching them with corresponding ERP tools and add-ons, before assessing the impact on company performance. The assessment of impact on performance also adds to Deep *et al.*'s (2008) study on system selection.

The overarching research question, restated below, has been tested through the exploratory and explanatory aspects of this study. But first, Chapter 2 assessed the fit between the decision support functionality of ERP systems and the decision support requirements of MTO companies based on the literature. Although ERP could provide benefits to MTO companies, it appeared 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. A research agenda was outlined to improve the alignment between ERP systems and the needs of MTO companies – the mixed method research described in chapters 3 to 7 is a first contribution to addressing these research gaps.

RQ (1): How does the production strategy of a company affect ERP applicability?

Building on this, the explanatory part of the survey was designed to test the relationships between decision support requirements, functionality and performance.

The complete summary of the findings and contributions of this part of the work is provided in Table 8.1 below.

The following subsections are organised around the sub research questions (a-d) and describe the key contributions of this thesis with reference to Table 8.1, where required.

8.1.1 Exploratory

RQ (1a): What are the differences in ERP adoption between MTO and MTS companies?

In the exploratory part of the survey (Chapter 5), descriptive statistics were provided and interpreted towards addressing the sub research question above. The following is a summary of the findings that address the research questions:

- The production strategy has no impact on the choice to adopt or not to adopt ERP.
- There is no distinct difference in terms of package implementation between MTO and MTS companies. A great majority of the sample implemented ERP from a single vendor (either with or without add-ons); 40% of users added extensions on top of their systems.
- Production strategy has a significant impact on the difficulty of selecting an ERP system - MTO companies find selection more difficult on average.
- The most outstanding reason not to adopt ERP is that "ERP would not suit the needs of the company". MTO non-adopters highly significantly agree with this reason compared to MTS non-adopters.

Table 8.1. Summary of Contributions

	Summary of MTO DSRs	ERP System Provision	Finding	Contribution
1. Planning and Control Stages	**Customer Enquiry Management**: Capacity-concerning planning tools for generating alternative due dates & cost/profit estimation for pricing in response to customer enquiries	ATP, CTP, PLM & the CEM module (automation of job/enquiry entry)	This result holds for the whole sample and for the MTO sample on its own, suggesting that companies requiring software support for handling CEM tasks can utilise the system for *data management* only, which leads to improved CEM performance. On the other hand, the analytical tools for planning at this stage are utilised to a low extent.	The effectiveness of the CEM tools of ERP has not been investigated before. Therefore, the findings make an original contribution to the field.
	Design & Engineering: Flexibility in design & engineering	Product Configurator (PC) & PLM	The PC and PLM add-ons are not found to be effective on company performance at the Design and Engineering stage for all samples.	Contrary to the findings, the literature has reported successful examples of PC usage (off-the shelf or in-house developed), especially in SMEs (Forza & Salvador, 2002; Hvam *et al.*, 2006; Olsen & Sætre, 2007b) and PC is especially recommended by Deep *et al.* (2008) for MTO companies; while PLM has not been subjected to any performance analysis.
	Order Entry: Capacity planning and control for confirmed orders, including material purchasing	Material Requirements Planning and Advanced Planning & Scheduling	This result holds for the whole sample suggesting that the use of MRP and APS was found to lead to performance improvement at this stage. On the other hand, for the MTO sample on its own, high levels of system support at the Order Entry stage lead to poor planning performance when MRP is used. The test for the MTS sample was inconclusive.	Contrary to Berry & Hill (1992) which ignored the effect of demand predictability stressed; MRP is widely acknowledged to be more suitable to a MTS production strategy (Cooper & Zmud, 1989; Cooper & Zmud, 1990; Newman & Sridharan, 1995; Plenert, 1999). On the other hand, Deep *et al.* (2008) considered APS a potentially beneficial tool to overcome the weaknesses of MRP for MTO companies.

2. Market Characteristics	Managing customer relations to increase repeat business.	CRM software is claimed to provide competitive advantage	This result holds for the whole sample and both for the MTO and MTS sample on its own suggesting that companies requiring software support for dealing with customer relations can utilise the CRM add-on to a very good extent, which leads to improved performance, such as satisfaction for existing customers, exploration of new customers and better profitability.	Contrary to this finding, Hendricks *et al.* (2007) found no evidence of improvements in stock returns or profitability for CRM. However, Watts *et al.* (2008) showed that CRM has helped the firms have large sales increases but no evidence of improvements in productivity within the firms. This study's sample is similar to Watts *et al.*'s (2008) in terms of company size (mainly SMEs), sector (manufacturers), respondents (managers & directors), and measurement (perceptual Likert scale).
3. The Supply Chain	Sharing up-to-date information across the supply chain is critical.	Web-enabled supply chain information sharing Co-ordination functionality	The SCM framework is totally inconclusive for all samples.	Hendricks *et al.* (2007) argued that, on average, adopters of SCM systems experience positive stock returns as well as improvements in profitability.
4. Company Size	A significant proportion are SMEs, thus having relatively simple organisational structures & limited IT budgets	Many claimed to be for all business sizes A variety of pricing and licences available	On average, MTO companies are found to be smaller in size than MTS companies. Renting or software-as-a-service (i.e. on-demand software) can be a low-risk, cost effective and flexible solution for risk-averse SMEs having limited expertise and budget. Many features are not used as they are thought to be complex by SMEs; thus, only high-level functionalities of ERP are utilised to get an overview of the status of a company's resources and processes. There is a big gap between the provided functionalities and the expertise and knowledge to utilise them in SMEs.	Consistent with this study's findings, limited IT budgets and a lack of permanent IT employees was argued to influence the applicability of ERP systems (Olsen & Sætre, 2007a). Similar to the non-user case company in this study in terms of company characteristics, Olsen & Sætre (2007b) conducted an action research project in an ETO company, which considered a number of ERP systems but was unable to find a system suitable for this set of problems.

8.1.2 Explanatory

RQ (1b):	What is the relationship amongst the decision support requirements, intensity of use of ERP tools and company performance?
RQ (1c):	Do these relationships vary with respect to production strategy?

In the explanatory part of the survey, a theoretical framework (provided in Figure 4.1 of Chapter 4) was used to present the confirmatory results in Chapter 6. Briefly, the significance of the relationships amongst the variables given in RQ (1b) above was tested. Then, it was used to assess the applicability of the corresponding ERP functionality for each PPC stage. The most interesting relationships from the explanatory part of the thesis are as follows:

- The CRM add-on, used along with ERP system, is found to be an effective solution for the whole sample in general and both MTO and MTS companies in particular, to managing customer relations to increase repeat business. The impact of using CRM on company's performance related to customer relations is found to be significantly positive.
- For the whole sample and MTO companies in particular, when a company requires software support at a high level for *data management* at the CEM stage, the company is able to utilise the system for these purposes. This also leads to improved CEM performance.
- The point made above, however, is not applicable to planning at this stage. The system tools for planning at the CEM stage (i.e., available-to-promise, capable-to-promise mechanisms, and product lifecycle management add-on) cannot be used to the extent which may lead to improved performance at this stage.

- For the MTO sample on its own, the use of MRP at the Order Entry stage is found to lead to poor planning performance. The test for the MTS sample was inconclusive.

Table 8.1 provides a complete summary of these findings and contributions above.

8.1.3 Case Study

RQ (1d): Why do MTO companies find ERP selection difficult and only partially use its functionality?

The final sub research question from Chapter 1 has been rephrased above to cover the points which were chosen for investigation in the light of the survey results. Several questions, which are subordinate to the research question above, have been asked and an attempt has been made to address them in the follow-up case research (Chapter 7) through interviewing two MTO ERP adopters and one MTO non-adopter. The key findings of this part of the thesis are as follows:

- SMEs, having limited expertise and budget, find it highly difficult to select and implement ERP systems. The option of renting or software-as-a-service (i.e. on-demand software) can be a low-risk, cost effective and flexible strategy.
- While two cases implemented ERP, only high-level functionality was in operation to get an overview of the status of company resources and processes. This is because there is a gap between the software widely available and MTO decision support requirements.
- Addition to the point above, there is also another gap between the expertise required to utilise the software and that found in small MTO companies in practice.

Table 8.1 includes the summary of these findings and contributions towards this question in the rows for CEM and company size.

8.2 Limitations and Future Research

The small sample size is a limitation of the survey research undertaken, although a rigorous method has been followed to ensure it was as high as possible (as previously described e.g. in Table 3.5, i.e. the summary of "attributes of a rigorous survey" and our response to each). One possible cause of the low number of responses was the length of the questionnaire. Future research could perhaps use an abridged version of the questionnaire in order to increase the sample size and build on the results described in chapters 5 and 6. An abridged questionnaire could retain the breadth of the original, but go into less depth on each topic (focusing only on key issues highlighted in this thesis); or, retain the depth but have a narrower focus, e.g. by ignoring certain aspects (e.g. PLM or CRM software).

The explanatory survey results presented for the MTS cases mostly showed a data misfit. It is concluded that this was mainly because the MTO literature was used to identify decision support requirements and performance measures. Hence, future research should identify the variables (and generate the items) relevant to both MTO and MTS firms by separately reviewing the MTO and MTS literature. It is argued that this will lead to a better fit with the data for MTS companies.

Future research could also address the outstanding research gaps highlighted in Chapter 2 of this thesis. For example, by conducting research into how MTO-specific PPC concepts or CEM tools could be embedded within ERP systems.

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Appendices

Appendix 1: Items for the ERP applicability to MTO

B1. CEM Decision Support Requirements

B1a. Due date setting

We require capacity planning in order to set realistic due dates.
Due date is set through simple and rough calculations for each order (reversed).
When setting due dates, we need to access historical data on similar previous orders.
The ability to generate a set of alternative due dates would be helpful on bargaining and negotiating with customers.
We need a system for allocating available *finished products* to customer orders to conclude quoting due dates (such an example called Available-to-promise or ATP).
We need a system for allocating available *capacity* to customer orders to conclude quoting due dates (such an example called Capable-to-promise or CTP).

B1b. Pricing

We require detailed cost analysis when putting in a bid.
We need to access the past data of previous similar orders to estimate costs and set profit margins.
When determining a price to quote, we need to consider various factors (from our company's recent needs for more profitability to the status of our relationship with a customer).

B1c. Coordination (Internally across departments)

We need a high degree of coordination among departments at the customer enquiry stage.
We think that at least the sales and manufacturing departments have to be linked through various means of communication in responding to customer enquiries.

B1d. Coordination (Externally with customers and suppliers)

We need a high degree of coordination between our company and customers through various means of communication at the customer enquiry stage.
Availability or capability of subcontractors/suppliers is required to be continuously monitored.

B1e. Automation

I think we need an IT support to automate our order entries at the customer enquiry stage.
We require an integrative IT system which can allow us to easily enter an order into the system and to transfer it to downstream processes.

C1. CEM via ERP

C1a. Enterprise Resource Planning

At the customer enquiry stage, ERP's integrating feature is used for coordinating several departments in our company.
We use our ERP to automate entering orders at the customer enquiry stage.
We make use of our ERP's database to store and access historical data for due date and pricing estimation.

C1b. Available/Capable-to-Promise

We use the Available-to-Promise (ATP) functionality in our ERP/APS system in due date determination.
We use the Capable-to-Promise (CTP) functionality in our ERP/APS system in due date determination.

C1c. Product Lifecycle Management

We use a Product Lifecycle Management (PLM) add-on (or other ERP application/extension) for price estimation at the customer enquiry stage.

D1. Improved CEM Performance in MTO Production

D1a. Productive aspects

More realistic (achievable) due dates have been quoted since we began to use ERP.
The proportion of timely delivered orders to total orders has been improved through the use of customer enquiry management tools of ERP.
Customer enquiry responsiveness (shorter time to process a quotation) has been improved.
Lack of defined procedures and standardisation at the enquiry stage has been reduced since the implementation of our ERP system.
We can monitor and coordinate with our suppliers and subcontractors via our ERP system at the customer enquiry stage.

D1b. Economic aspects

Strike rate percentage (namely, the proportion of quotations that become firm orders) has been improved with the help of ERP usage.
Owing to the help of ERP tools, the profitability of our products has increased since we can better estimate their prices and due dates at the customer enquiry stage.

B2. Design and Engineering Decision Support Requirements

B2a. Product Information Database

For the design and engineering process of confirmed orders we require a documentation archive which stores product information.
Keeping record of an accessible historical product data is a necessity for our engineering and design department to handle our complicated products and their components.

B2b. Integrative Solution

We require an integrative application to transfer product data across the other processing applications (for example CAD, MRP and scheduling)
For a system to support us at the design and engineering stage, its compatibility with outside systems (of customers and/or suppliers) is essential for efficiency.

B2c. Coordination (Internally with sales and production)

We need a high level of coordination among departments at the design and engineering stage.
We think that sales and manufacturing are two departments, to which design and engineering department has to be linked for better coordination in customisation.

B2d. Coordination (Externally with customers and suppliers)

We need a high level of coordination between our company and customers through at the design and engineering stage.
In engineering and design practices, high level of coordination with suppliers is crucial for our company.

B2e. Flexibility in design

We require a system which does not force us to enter complete product information for planning or any other purposes.
The system we need for engineering and design should support frequent changes en route product lifecycle.

C2. Product Customisation via ERP

C2a. Product Configurator

We use a product configurator (also called variant generator) application within our installed ERP system for design and engineering purposes.

C2b. Product Lifecycle Management

We use a Product Lifecycle Management (PLM) add-on to cater for our purposes at the design and engineering stage.

D2. Improved Customisation Performance in MTO Production

D2a. Customer satisfaction with the customisation

We can produce exactly to the customers' specifications with the help of design and engineering tool within our ERP system.
ERP can help us improve our customers' satisfaction with the customised products.

D2b. Technical productivity

Product development activities are more competent via our design and engineering application within ERP (for example the similarity between new and past orders is easily detected, and duplicated effort is reduced).
We can automate the clumsy and manual documentation tasks through our design and engineering tool within our ERP system.

B3. Order Entry Stage Decision Support Requirements

B3a. Confirmed order re-evaluation

When a long time passes between quotation and confirmation of an order, cost estimation and capacity conditions make us reconsider the production of that order.
We require consulting a system for the re-evaluation of such orders.

B3b. Aggregate Planning

We require a flexible system which can support incomplete product information on aggregate planning.
We need to consider any effect of possible future orders on the capacity besides planning the backlog.
Capacity planning is an important issue to us due to frequent capacity variations in our dominant processes.

B3c. Operational Planning

We need to employ finite loading when detailed planning for which we require software support.
We require a capacity planning system to track and plan the capability of our manufacturing facilities.

B3d. Project Management

We need project management techniques to handle any highly customised and complicated product.
I think software support is essential to employ project management.

C3. Planning for Order Entry via ERP

C3a. Material Requirements Planning

We use MRP estimations of our ERP system in the production planning.

C3b. Advanced Planning and Scheduling

We use an Advanced Planning and Scheduling (APS) system besides our installed ERP system for order entry and planning tasks.

C3c. Enterprise Resource Planning

We utilise the project management tools of our installed ERP system.

D3. Improved Planning Performance at the Order Entry Stage

D3a. Due date adherence via effective planning

MRP module of our ERP system helps us to better adhere to the due dates of the orders and components.
Planning before and during the production is going on well owing to the APS add-on, so that we can adhere to quoted due dates.

D3b. Resource utilisation

ERP has been an important factor in the effective utilisation of firm resources.

The efficiency in the use of manufacturing machines has improved through the use of ERP.

D3c. Coping with uncertainty

We have reduced the uncertainty in planning through controlling the lead times via the use of ERP.
Proactive decision support functionality within our ERP's planning module helps us take actions against unexpected situations.

B4. Order Review and Release Decision Support Requirements

B4a. Need for an order release stage

We necessitate a decision point before sending a product design onto the shop floor for various purposes (e.g., selecting which product to start manufacturing).

B4b. IT support at the order release stage

We require a control mechanism at the order release stage to prevent immediate processing of orders on the shop floor.
We require IT support to sensibly sequence and release the confirmed orders onto the shop floor.
We think software support is necessary for generating alternative scenarios or shop floor monitoring before the release of an order onto the shop floor.

B4c. Interaction with other stages

When we decide an order release onto the shop floor, we need to consider the previous decision (e.g., capacity plan) and likely subsequent conditions (e.g., dispatching).

C4. Planning at the Order Review and Release stage via ERP

C4a. Enterprise Resource Planning

In our ERP system, we use an application to represent the order release stage between order entry and shop floor manufacturing processes.

C4b. Advanced Planning and Scheduling

We use our Advanced Planning and Scheduling (APS) system's relevant module to effectively release the planned jobs onto the shop floor.

D4. Improved Order Review and Release Performance in MTO Production

D4a. Due date adherence via order release

We feel that a sensible use of order release stage with the help of our ERP system improves scheduling on the shop floor.
Using an ERP supported order release mechanism helps us control our capacity.
While we expect shorter lead times through use of an order release mechanism, contrarily it increases (reversed).

D4b. Control over the orders on the shop floor

We feel that a sensible use of order release stage with the help of our ERP system improves scheduling on the shop floor.
WIP and congestion are reduced on the shop floor, therefore costs are lowered.

B5. Dispatching Decision Support Requirements

B5a. Rule simplicity

We do not require a complicated dispatching rule owing to the prior decision points (for example, order release).
Foremen can easily cope with dispatching tasks on the shop floor without software support.
Either performed manually by our foremen or through our computerised system, we generally employ simple mechanisms for dispatching (for example, first-in-first-out).

B5b. Labour constraint

We need a dispatching mechanism on the shop floor, which should consider labour availability and plan accordingly.

B5c. Interaction with other stages

We think that the accessibility to previous plans and decisions (for example, master plan schedule) is important at the dispatching stage.
We feel that the planning decisions made before the shop floor operations significantly affect the dispatching tasks.

C5. Planning at the Dispatching stage via ERP

C5a. Enterprise Resource Planning

Within our basic ERP system, we use a module to get decision support for dispatching.

C5b. Advanced Planning and Scheduling

Advanced planning and scheduling (APS) system assists our dispatching decisions.

D5. Improved Planning Performance in MTO Production

D5a. Due date adherence via dispatching

The dispatching functionality of ERP system helps us meet the daily production schedule.
The dispatching functionality of APS system helps us meet the daily production schedule.
We usually complete our daily schedule, and reasonable dispatching decisions supported by ERP contribute well to it.
We usually complete our daily schedule, and reasonable dispatching decisions supported by APS contribute well to it.
We can better manage our WIP and reduce lateness through the assistance of our ERP.
We can better manage our WIP and reduce lateness through the assistance of our APS.

B6. CRM Decision Support Requirements

B6a. Customer database

Due to the abundant number of existing and potential customers we interact, we require a comprehensive database to manage the relationships with our customers.

B6b. Marketing through communication

We believe a good and stable relationship with the customer is only possible through excellent communication.
We need different means of communication to secure and develop relationships with our customers.
The state-of-the-art communication practices is of maximum importance in our company.

B6c. Need for improved relationships

We find great benefit to entice our one-off customers for a longer and robust relationship.
The application of latest techniques and practices like CRM is of maximum importance in our company to improve our relationships with customers.
One of our targets is to have more loyal customers and prolonged relationships based on trust.

C6. Business via CRM

C6a. The intensity of use of CRM

We regularly employ communication tools of CRM software to reach new markets and improve existing customer relationships.
We use the applications in our CRM system to assess our potential customers for measures such as loyalty and profitability.
Our CRM system provides us the support to develop strategies on improving customer relationships via analysis tools.

D6. Improved CRM Performance in MTO Production

D6a. Satisfaction of existing customers

CRM has improved our customers' satisfaction through close contact and coordination.
ERP helps us entice one-off customers into a more predictable and committed relationship.

D6b. New customer and market exploration

New market opportunities have been identified through the use of CRM.
Strike rate percentage (namely, the proportion of the quotations that become firm orders) has been improved using the CRM application.

D6c. Profitability

We have not observed any direct significant impact on the company profitability through the help of our CRM system.
The return on our CRM investment is not noteworthy.

B7. SCM Decision Support Requirements

B7a. Supply chain coordination (with buyers)

Information sharing is an essential coordination feature among the company and our customers.
Quick response to urgent orders from our supply chain customers is vital, thus we usually need an equally powerful system for better coordination.
Believing in the importance of collaboration in the supply chain, we require an effective communication platform to be in close contact with our supply chain customers.

B7b. Procurement (from suppliers)

Procurement constitutes the majority of our production cost, thus is of high importance to us.
We believe that routine procurement tasks (e.g., paperwork) need to be automated.

B7c. Coping with Rush orders

Because rush orders need to be dealt with at the customer enquiry stage firstly, we need tools enabling integration for quicker order processing.
We require a computerised system to re-plan our programmes due to any rush orders in place.
Being in close contact with our supply chain customers help us better manage any rush orders.

B7d. Compatibility

Our ERP system and relevant SCM add-ons should be in good accordance with different systems.
It is an important advantage to have a system compatible with external various systems and/or platforms (of customers and/or suppliers).

C7. Supply Chain Management via ERP and SCM systems

C7a. Enterprise Resource Planning

Our ERP system forms a critical background for SCM application(s).

C7b. Supply Chain Management

We utilise the SCM add-ons within the installed ERP to be in accordance with a limited amount of our suppliers and customers having same or similar systems.
Especially the internet-based applications of the SCM system are of critical importance to us.
We regularly employ supply chain add-ons to cope with lead time.
We regularly employ supply chain add-ons to cope with efficient inventory turnover.

D7. Improved Supply Chain Planning Performance in MTO Production

D7a. Improved order management

We have improved our due date adherence performance in rush orders through our SCM add-ons.
We have improved our due date adherence performance in standard orders through our SCM add-ons.
Coping with rush orders has become less challenging for us and it damages our reputation less by the help of SCM add-ons we use.
SCM tools have helped us minimise the negative effects of re-planning on existing orders due to interruption of rush orders

D7b. Uncertainty management

Uncertainty in product specifications and demand has been reduced by using SCM add-ons.
More strategic decisions could be made due to less uncertainty owing to SCM add-ons.

D7c. Profitability

We have not observed any direct significant impact on the company profitability through the use of our SCM system.
The return on our SCM investment is not noteworthy.

Appendix 2: Form for Content Validity Assessment

INSTRUCTIONS-I: The following pages list questions that are related to **Decision Support Requirements** of MTO companies using the definitions below. Please select the letter of the category you think of most appropriate for each item in the space provided. Then, please rate each item from NR as "*not very representative*" through SR "*somewhat representative*" to CR as "*clearly representative*" of the construct and variable of interest. If you think a particular item does not fit to any category, place an "X" space.

Customer Enquiry Management: refers to the stage where MTO companies receive orders and quote them back with DD and price promises. This is a particularly critical stage which links departments such as sales, production planning and engineering & design to each other to respond enquiries.

(B1a) Due Date Setting: is the collection of all activities (e.g., lead time estimation, capacity checking) to give a due date to the customer.
(B1b) Pricing Decisions: involve estimation of cost and profit margin while quoting a product.
***(B1c)* Internal Coordination**: refers to the intra-firm coordination (e.g., across departments inside a company).
***(B1d)* External Coordination**: refers to the inter-firm coordination (e.g., across the company, its suppliers and customers).
***(Be)* Automation**: is the ability to computerise any manual information for responsiveness (quickness).

Design and Engineering: represents the phase where detailed product customisation is held, which is a key competitive advantage in the MTO sector.

(B2a) Documentation Archive: refers to a product information database to store and access historical product data and documentation
(B2b) Integrative Solution: is the need of a system which can serve integration to transfer product information across different systems.
(B2c) Internal Coordination: refers to the intra-firm coordination (e.g., across departments inside a company).
(B2d) External Coordination: refers to the inter-firm coordination (e.g., across the company, its suppliers and customers).
(B2e) Flexibility in Design: refers to a flexible system (e.g., not always forcing the user to enter complete and consistent product data).

Order Entry: refers to the stage focusing on due date adherence after an order is confirmed for production. At this stage, main planning tasks such as determining material and processing requirements take place.

(B3a) Confirmed Order Re-evaluation: refers to re-consideration of an order (to accept, reject or negotiate); especially when long time passes between the quotation and confirmation.
(B3b) Aggregate Planning: refers to mid-term planning of production and capacity.
(B3c) Operational Planning: refers to short-term coordination of material requirements and scheduling (e.g., machine loading, routing).
(B3d) Project Management: is the collection of project management techniques, especially to plan and coordinate complex orders.

Order Review and Release: represents the stage where orders are hold in a pre-shop pool and released in time to meet delivery dates without leading to excess congestion on the shop floor. The main aim is to delay the start of an order without delaying its completion.

(B4a) Need for an ORR Stage: refers to the necessity of such a stage.
(B4b) IT Support at the ORR Stage: refers to the necessity of IT support when such a stage is needed.
(B4c) Interaction with Other Stages: refers to the need for an integrative system preventing isolated order release decisions and promoting coordination across previous and subsequent stages.

Dispatching: refers to the stage where one of the orders in the queue of a machine is selected to be processed next. This stage performs a prioritisation depending on the urgency of readily processed orders.

(B5a) Rule Simplicity: suggests to simplify any procedure at this stage, thus to employ a simple priority rule (e.g., first-come-first-served).
(B5b) Labour Constraint: refers to the level of requirement to consider labour availability besides machine capacity for dispatching decisions.

(B5c) Interaction with Other Stages: refers to the need for an integrative system preventing isolated dispatching decisions and promoting coordination across previous and subsequent stages.

Managing Customer Relationships: represents the decision support needs of a MTO company to acquire new customers and retain existing customers through improving customer satisfaction.

(B6a) Customer Database: refers to the need for a database system to effectively store and access customer information.
(B6b) Marketing through Communication: refers to the need for exploring new markets and acquiring new customers considering the often low strike rate of MTO companies.
(B6c) Need for Improved Relationships: refers to the need for maintaining and developing relationships with existing customers.

Supply Chain Activities: represents the performed actions related to a MTO's supply chain position. The specifically concerned phenomenon is some certain requirements in dealing with rush orders through coordination and information sharing.

(B7a) SC Coordination (with Buyers): refers to the need to improve coordination across supply chain members (via information sharing).
(B7b) Procurement (from Suppliers): refers to the need to minimise procurement costs which is quite high in MTO companies.
(B7c) Coping with Rush Orders: refers to the ability to quickly respond to the arrival of rush orders from supply chain buyers.
(B7d) Compatibility: SC partners often force their suppliers (e.g., MTO companies) to adopt the same IT system which they use. Considering the interactions with several buyers, an IT system needs to be compatible with different systems that the buyers use.

Customer Enquiry
(B1a) Due Date Setting
(B1b) Pricing Decisions
(B1c) Internal Coordination
(B1d) External Coordination
(B1e) Automation

Design & Engineering
(B2a) Documentation Archive
(B2b) Integrative Solution
(B2c) Internal Coordination
(B2d) External Coordination
(B2e) Flexibility In Design

Order Entry
(B3a) Confirmed Order Re-evaluation
(B3b) Aggregate Planning
(B3c) Operational Planning
(B3d) Project Management

Order Release
(B4a) Need for an OR Stage
(B4b) IT Support at the OR Stage
(B4c) Interaction with Other Stages

CRM
(B6a) Customer Database
(B6b) Marketing through Communication
(B6c) Need for Improved Relationships

SCM
(B7a) SC Coordination (with Buyers)
(B7b) Procurement (from Suppliers)
(B7c) Coping with Rush Orders
(B7d) Compatibility

Dispatching
(B5a) Rule Simplicity
(B5b) Labour constraint
(B5c) Interaction with Other Stages

(X) Doesn't fit any category

	NR	SR	CR
Due to the abundant number of existing and potential customers we interact, we require a comprehensive database to manage the relationships with our customers.	☐	☐	☐
We need a high level of coordination among departments at the design and engineering stage.	☐	☐	☐
We require an integrative IT system which can allow us to easily enter an order into the system and to transfer it to downstream processes.	☐	☐	☐
We think software support is necessary for generating alternative scenarios or shop floor monitoring before the release of an order onto the shop floor.	☐	☐	☐
When setting due dates, we need to access historical data on similar previous orders.	☐	☐	☐
We find great benefit to entice our one-off customers for a longer and robust relationship.	☐	☐	☐
The system we need for engineering and design should support frequent changes en route product lifecycle.	☐	☐	☐
Being in close contact with our supply chain customers help us better manage any rush orders.	☐	☐	☐
We need to access the past data of previous similar orders to estimate costs and set profit margins.	☐	☐	☐
We require consulting a system for the re-evaluation of such orders.	☐	☐	☐

We believe that routine procurement tasks (e.g., paperwork) need to be automated.	☐ ☐ ☐
Due date is set through simple and rough calculations for each order (reversed).	☐ ☐ ☐
It is an important advantage to have a system compatible with external various systems and/or platforms (of customers and/or suppliers).	☐ ☐ ☐
We feel that the planning decisions made before the shop floor operations significantly affect the dispatching tasks.	☐ ☐ ☐
We need a system for allocating available *finished products* to customer orders to conclude quoting due dates (such an example called Available-to-promise or ATP).	☐ ☐ ☐
Availability or capability of subcontractors/suppliers is required to be continuously monitored.	☐ ☐ ☐
We believe a good and stable relationship with the customer is only possible through excellent communication.	☐ ☐ ☐
I think we need an IT support to automate our order entries at the customer enquiry stage.	☐ ☐ ☐
We need to consider any effect of possible future orders on the capacity besides planning the backlog.	☐ ☐ ☐
I think software support is essential to employ project management.	☐ ☐ ☐
We need a high degree of coordination between our company and customers through various means of communication at the customer enquiry stage.	☐ ☐ ☐
We need a high degree of coordination among departments at the customer enquiry stage.	☐ ☐ ☐
We need project management techniques to handle any highly customised and complicated product.	☐ ☐ ☐
We require IT support to sensibly sequence and release the confirmed orders onto the shop floor.	☐ ☐ ☐
Procurement constitutes the majority of our production cost, thus is of high importance to us.	☐ ☐ ☐
We require a capacity planning system to track and plan the capability of our manufacturing facilities.	☐ ☐ ☐
We require an integrative application to transfer product data across the other processing applications (for example CAD, MRP and scheduling)	☐ ☐ ☐
When determining a price to quote, we need to consider various factors (from our company's recent needs for more profitability to the status of our relationship with a customer).	☐ ☐ ☐
Either performed manually by our foremen or through our computerised system, we generally employ simple mechanisms for dispatching (for example, first-in-first-out).	☐ ☐ ☐
We require a flexible system which can support incomplete product information on aggregate planning.	☐ ☐ ☐
When we decide an order release onto the shop floor, we need to consider the previous decision (e.g., capacity plan) and likely subsequent conditions (e.g., dispatching).	☐ ☐ ☐
One of our targets is to have more loyal customers and prolonged relationships based on trust.	☐ ☐ ☐
Because rush orders need to be dealt with at the customer enquiry stage firstly, we need tools enabling integration for quicker order processing.	☐ ☐ ☐
Foremen can easily cope with dispatching tasks on the shop floor without software support.	☐ ☐ ☐
Quick response to urgent orders from our supply chain customers is vital, thus we usually need an equally powerful system for better coordination.	☐ ☐ ☐
We think that at least the sales and manufacturing departments have to be linked through various means of communication in responding to customer enquiries.	☐ ☐ ☐
Keeping record of an accessible historical product data is a necessity for our engineering and design department to handle our complicated products and their components.	☐ ☐ ☐
For a system to support us at the design and engineering stage, its compatibility with outside systems (of customers and/or suppliers) is essential for efficiency.	☐ ☐ ☐

We need a dispatching mechanism on the shop floor, which should consider labour availability and plan accordingly.	☐	☐	☐
Information sharing is an essential coordination feature among the company and our customers.	☐	☐	☐
We need to employ finite loading when detailed planning for which we require software support.	☐	☐	☐
The state-of-the-art communication practices is of maximum importance in our company.	☐	☐	☐
We require a system which does not force us to enter complete product information for planning or any other purposes.	☐	☐	☐
We need a high level of coordination between our company and customers through at the design and engineering stage.	☐	☐	☐
Our ERP system and relevant SCM add-ons should be in good accordance with different systems.	☐	☐	☐
We require capacity planning in order to set realistic due dates.	☐	☐	☐
We require a control mechanism at the order release stage to prevent immediate processing of orders on the shop floor.	☐	☐	☐
Capacity planning is an important issue to us due to frequent capacity variations in our dominant processes.	☐	☐	☐
We think that sales and manufacturing are two departments, to which design and engineering department has to be linked for better coordination in customisation.	☐	☐	☐
Believing in the importance of collaboration in the supply chain, we require an effective communication platform to be in close contact with our supply chain customers.	☐	☐	☐
The ability to generate a set of alternative due dates would be helpful on bargaining and negotiating with customers.	☐	☐	☐
We think that the accessibility to previous plans and decisions (for example, master plan schedule) is important at the dispatching stage.	☐	☐	☐
The application of latest techniques and practices like CRM is of maximum importance in our company to improve our relationships with customers.	☐	☐	☐
We need different means of communication to secure and develop relationships with our customers.	☐	☐	☐
In engineering and design practices, high level of coordination with suppliers is crucial for our company.	☐	☐	☐
We need a system for allocating available *capacity* to customer orders to conclude quoting due dates (such an example called Capable-to-promise or CTP).	☐	☐	☐
We necessitate a decision point before sending a product design onto the shop floor for various purposes (e.g., selecting which product to start manufacturing).	☐	☐	☐
For the design and engineering process of confirmed orders we require a documentation archive which stores product information.	☐	☐	☐
We require detailed cost analysis when putting in a bid.	☐	☐	☐
When a long time passes between quotation and confirmation of an order, cost estimation and capacity conditions make us reconsider the production of that order.	☐	☐	☐
We require a computerised system to re-plan our programmes due to any rush orders in place.	☐	☐	☐
We do not require a complicated dispatching rule owing to the prior decision points (for example, order release).	☐	☐	☐

<Please follow the next page for the second part>

INSTRUCTIONS-II: The following pages list questions that are related to **ERP features** using the definitions below. Please select the letter of the category you think of most appropriate for each item in the space provided. Then, please rate each item from NR as "*not very representative*" through SR "*somewhat representative*" to CR as "*clearly representative*" of the construct and variable of interest. If you think a particular item does not fit to any category, place an "X" space.

Material Requirements Planning (MRP): is usually the core material requirements planning system in ERP, achieving production planning by step-by-step netting, lot-sizing, time phasing and bill-of-material explosion.

Available-to-Promise (ATP): functionality refers to a method of checking the finished goods' availability in response to a customer enquiry via its tool within basic elements of ERP. (Another version of this functionality is called Capable-to-Promise (CTP) which checks the available capacity for the same purpose.)

Advanced Planning and Scheduling (APS): refers to the add-on application argued to address manufacturing planning and scheduling problems based on hierarchical and capacity-concerning planning principles.

Product Configurator: Product configurator refers to the add-on software argued to perform quicker product designs for designing and quoting purposes through combining well-defined blocks governed by certain rules and constrains.

Product Lifecycle Management (PLM): refers to the add-on which is argued to enable the user to bring innovative products to market effectively, and to manage product-related information more effectively throughout the lifecycle of a product.

Customer Relationship Management (CRM): refers to the software that a user can compile data on customers and analyze it in order to sell more goods or services, and to do so more efficiently.

Supply Chain Management (SCM): represents the software which is argued to facilitate information integration with supply chain partners. Its main roles are determined as cost reduction, and improved efficiency, service and relationships with customers.

Customer Enquiry
(C1a) Enterprise Resource Planning
(C1b) Available/Capable-to-Promise
(C1c) Product Lifecycle Management

Design & Engineering
(C2a) Product Configurator
(C2b) Product Lifecycle Management

Order Entry
(C3a) Material Requirements Planning
(C3c) Enterprise Resource Planning
(C3c) Advanced Planning and Scheduling

Order Release
(C4a) Enterprise Resource Planning
(C4b) Advanced Planning & Scheduling

CRM
(C6a) Customer Relationship Management

SCM
(C7a) Enterprise Resource Planning
(C7b) Supply Chain Management

Dispatching
(C5a) Enterprise Resource Planning
(C5b) Advanced Planning & Scheduling

(X) Doesn't fit any category

	NR	SR	CR
We regularly employ communication tools of CRM software to reach new markets and improve existing customer relationships.	☐	☐	☐
We use the Capable-to-Promise (CTP) functionality in our ERP/APS system in due date determination.	☐	☐	☐
We use a Product Lifecycle Management (PLM) add-on (or other ERP application/extension) for price estimation at the customer enquiry stage.	☐	☐	☐
We use our Advanced Planning and Scheduling (APS) system's relevant module to effectively release the planned jobs onto the shop floor.	☐	☐	☐
We regularly employ supply chain add-ons to cope with lead time.	☐	☐	☐
We use the applications in our CRM system to assess our potential customers for measures such as loyalty and profitability.	☐	☐	☐
We use an Advanced Planning and Scheduling (APS) system besides our installed ERP system for order entry and planning tasks.	☐	☐	☐
Advanced planning and scheduling (APS) system assists our dispatching decisions.	☐	☐	☐
In our ERP system, we use an application to represent the order release stage between order entry and shop floor manufacturing processes.	☐	☐	☐
Especially the internet-based applications of the SCM system are of critical importance to us.	☐	☐	☐
We make use of our ERP's database to store and access historical data for due date and pricing estimation.	☐	☐	☐
We use the Available-to-Promise (ATP) functionality in our ERP/APS system in due date determination.	☐	☐	☐
We use MRP estimations of our ERP system in the production planning.	☐	☐	☐
We use a Product Lifecycle Management (PLM) add-on to cater for our purposes at the design and engineering stage.	☐	☐	☐
We use a product configurator (also called variant generator) application within our installed ERP system for design and engineering purposes.	☐	☐	☐
Our CRM system provides us the support to develop strategies on improving customer relationships via analysis tools.	☐	☐	☐
We utilise the project management tools of our installed ERP system.	☐	☐	☐
At the customer enquiry stage, ERP's integrating feature is used for coordinating several departments in our company.	☐	☐	☐
We use our ERP to automate entering orders at the customer enquiry stage.	☐	☐	☐
We utilise the SCM add-ons within the installed ERP to be in accordance with a limited amount of our suppliers and customers having same or similar systems.	☐	☐	☐
We regularly employ supply chain add-ons to cope with efficient inventory turnover.	☐	☐	☐
Our ERP system forms a critical background for SCM application(s).	☐	☐	☐
Within our basic ERP system, we use a module to get decision support for dispatching.	☐	☐	☐

<Please follow the next page for the final part>

INSTRUCTIONS-III: The following pages list questions that are related to **Improved Performance Measures of MTO companies** using the definitions below. Please select the letter of the category you think of most appropriate for each item in the space provided. Then, please rate each item from NR as "*not very representative*" through SR "*somewhat representative*" to CR as "*clearly representative*" of the construct and variable of interest. If you think a particular item does not fit to any category, place an "X".

Customer Enquiry Management:

(A1) Productive Aspects: refers to the production planning performance measures such as delivery performance.
(A2) Economic Aspects: refers to the financial performance measures such as cost estimation performance or strike rate change.

Design and Engineering:

(B1) Customer Satisfaction with the Customisation: refers to an assessment of whether the product conforms to the customer's specifications or expectations.
(B2) Technical Productivity: refers to the productivity improvement at this stage, such as archiving, quick design ability.

Order Entry:

(C1) Due Date Adherence via Effective Planning: refers to the performance of due date adherence to the agreed (quoted) dates.
(C2) Resource Utilisation: refers to the performance measures on improving resource (e.g., man, machine) utilisation.
(C3) Coping with Uncertainty: refers to the performance measures on reducing uncertainty in planning.

Order Review and Release:

(D1) Due Date Adherence via Order Release: refers to the typical performance measures on the shop floor, e.g. increased shop floor utilisation, and reduced lateness.
(D2) Control over the Orders on the Shop Floor: refers to the performance to improve the SF control by reducing WIP and congestion.

Dispatching:

(E1) Due Date Adherence via Dispatching: refers to the daily production scheduling performance.

Managing Customer Relationships:

(F1) Satisfaction of Existing Customers: refers to the performance in enticing existing customers for longer relationships.
(F2) New Customer and Market Exploration: refers to the performance for finding new markets and acquiring new customers.
(F3) Profitability: refers to the return on investment from using CRM add-ons.

Supply Chain Activities:

(G1) Improved Order Management: refers to the performance on better managing the orders coming from supply chain partners. For example, on time delivery towards rush orders.
(G2) Uncertainty Management: refers to the performance on coping with uncertainty in the S through communication and information sharing.
(G3) Profitability: refers to the return on investment from using SCM add-ons.

Customer Enquiry
(D1a) Productive Aspects
(D1b) Economic Aspects

Design & Engineering
(D2a) Customer Satisfaction with Customisation
(D2b) Technical Productivity

Order Entry
(D3a) Due Date Adherence
(D3b) Resource Utilisation
(D3c) Coping with Uncertainty

Order Release
(D4a) Due Date Adherence
(D4b) Control over Orders on the SF

Dispatching
(D5a) Due Date Adherence

CRM
(D6a) Satisfaction of Existing Customers
(D6b) New Customer and Market Exploration
(D6c) Profitability

SCM
(D7a) Improved Order Management
(D7b) Uncertainty Management
(D7c) Profitability

(X) Doesn't fit any category

	NR	SR	CR
We feel that a sensible use of order release stage with the help of our ERP system improves scheduling on the shop floor.	☐	☐	☐
We can better manage our WIP and reduce lateness through the assistance of our APS.	☐	☐	☐
We have not observed any direct significant impact on the company profitability through the help of our CRM system.	☐	☐	☐
ERP can help us improve our customers' satisfaction with the customised products.	☐	☐	☐
We can monitor and coordinate with our suppliers and subcontractors via our ERP system at the customer enquiry stage.	☐	☐	☐
Strike rate percentage (namely, the proportion of the quotations that become firm orders) has been improved using the CRM application.	☐	☐	☐
We can automate the clumsy and manual documentation tasks through our design and engineering tool within our ERP system.	☐	☐	☐
We have not observed any direct significant impact on the company profitability through the use of our SCM system.	☐	☐	☐
Product development activities are more competent via our design and engineering application within ERP (for example the similarity between new and past orders is easily detected, and duplicated effort is reduced).	☐	☐	☐
The proportion of timely delivered orders to total orders has been improved through the use of customer enquiry management tools of ERP.	☐	☐	☐
Using an ERP supported order release mechanism helps us control our capacity.	☐	☐	☐
While we expect shorter lead times through use of an order release mechanism, contrarily it increases (reversed).	☐	☐	☐
Coping with rush orders has become less challenging for us and it damages our reputation less by the help of SCM add-ons we use.	☐	☐	☐
Lack of defined procedures and standardisation at the enquiry stage has been reduced since the implementation of our ERP system.	☐	☐	☐
The dispatching functionality of APS system helps us meet the daily production schedule.	☐	☐	☐
CRM has improved our customers' satisfaction through close contact and coordination.	☐	☐	☐
More strategic decisions could be made due to less uncertainty owing to SCM add-ons.	☐	☐	☐
ERP helps us entice one-off customers into a more predictable and committed relationship.	☐	☐	☐
Customer enquiry responsiveness (shorter time to process a quotation) has been improved.	☐	☐	☐
MRP module of our ERP system helps us to better adhere to the due dates of the orders and components.	☐	☐	☐
We usually complete our daily schedule, and reasonable dispatching decisions supported by ERP contribute well to it.	☐	☐	☐
The efficiency in the use of manufacturing machines has improved through the use of ERP.	☐	☐	☐
ERP has been an important factor in the effective utilisation of firm resources.	☐	☐	☐
Uncertainty in product specifications and demand has been reduced by using SCM add-ons.	☐	☐	☐
New market opportunities have been identified through the use of CRM.	☐	☐	☐
We feel that a sensible use of order release stage with the help of our ERP system improves scheduling on the shop floor.	☐	☐	☐
Proactive decision support functionality within our ERP's planning module helps us take actions against unexpected situations.	☐	☐	☐
The dispatching functionality of ERP system helps us meet the daily production schedule.	☐	☐	☐
We usually complete our daily schedule, and reasonable dispatching decisions supported by APS contribute well to it.	☐	☐	☐
The return on our CRM investment is not noteworthy.	☐	☐	☐
The return on our SCM investment is not noteworthy.	☐	☐	☐

WIP and congestion are reduced on the shop floor, therefore costs are lowered.	☐	☐	☐
We have improved our due date adherence performance in standard orders through our SCM add-ons.	☐	☐	☐
We can better manage our WIP and reduce lateness through the assistance of our ERP.	☐	☐	☐
We have improved our due date adherence performance in rush orders through our SCM add-ons.	☐	☐	☐
SCM tools have helped us minimise the negative effects of re-planning on existing orders due to interruption of rush orders	☐	☐	☐
We can produce exactly to the customers' specifications with the help of design and engineering tool within our ERP system.	☐	☐	☐
Strike rate percentage (namely, the proportion of quotations that become firm orders) has been improved with the help of ERP usage.	☐	☐	☐
We have reduced the uncertainty in planning through controlling the lead times via the use of ERP.	☐	☐	☐
Owing to the help of ERP tools, the profitability of our products has increased since we can better estimate their prices and due dates at the customer enquiry stage.	☐	☐	☐
Planning before and during the production is going on well owing to the APS add-on, so that we can adhere to quoted due dates.	☐	☐	☐
More realistic (achievable) due dates have been quoted since we began to use ERP.	☐	☐	☐

According to your knowledge of the concepts in the framework on the first page, how much do you think each group of variables cover their relevant construct? Please rate from **1** "very limitedly" to **7** "very comprehensively". For instance, how much do the five variables (due date setting, pricing decisions, internal coordination, external coordination, and automation) cover the notion of decision support requirements at the customer enquiry stage? If you think it quite comprehensively cover all the requirements, you may give 7 points.

DECISION SUPPORT REQUIREMENTS for the following stages:	1	2	3	4	5	6	7
Customer Enquiry covered by… Due Date Setting, Pricing Decisions, Internal Coordination, External Coordination, and Automation.	☐	☐	☐	☐	☐	☐	☐
Design & Engineering covered by… Documentation Archive, Integrative Solution, Internal Coordination, External Coordination, and Flexibility In Design.	☐	☐	☐	☐	☐	☐	☐
Order Entry covered by… Confirmed Order Re-evaluation, Aggregate Planning, Operational Planning, and Project Management.	☐	☐	☐	☐	☐	☐	☐
Order Review and Release covered by… Need for an Order Release Stage, IT Support at the Order Release Stage, and Interaction with Other Stages.	☐	☐	☐	☐	☐	☐	☐
Dispatching covered by… Rule Simplicity, Labour constraint, and Interaction with Other Stages.	☐	☐	☐	☐	☐	☐	☐
Supply Chain Activities covered by… Supply Chain Coordination (with Buyers), Procurement (from Suppliers), Coping with Rush Orders, and Compatibility.	☐	☐	☐	☐	☐	☐	☐
Managing Customer Relationships covered by… Customer Database, Marketing through Communication, and Need for Improved Relationships.	☐	☐	☐	☐	☐	☐	☐

ERP FEATURES for the following stages:	1	2	3	4	5	6	7
Customer Enquiry covered by… Enterprise Resource Planning, Available/Capable-to-Promise, Product	☐	☐	☐	☐	☐	☐	☐

Lifecycle Management	
Design & Engineering covered by... Product Configurator, Product Lifecycle Management	☐ ☐ ☐ ☐ ☐ ☐ ☐
Order Entry covered by... Material Requirements Planning, Enterprise Resource Planning, Advanced Planning and Scheduling	☐ ☐ ☐ ☐ ☐ ☐ ☐
Order Review and Release covered by... Enterprise Resource Planning, Advanced Planning & Scheduling	☐ ☐ ☐ ☐ ☐ ☐ ☐
Dispatching covered by... Enterprise Resource Planning, Advanced Planning & Scheduling	☐ ☐ ☐ ☐ ☐ ☐ ☐
Managing Customer Relationships covered by... Customer Relationship Management	☐ ☐ ☐ ☐ ☐ ☐ ☐
Supply Chain Activities covered by... Enterprise Resource Planning, Supply Chain Management	☐ ☐ ☐ ☐ ☐ ☐ ☐
IMPROVED PREFORMANCE MEASURES for the following stages:	1 2 3 4 5 6 7
Customer Enquiry covered by... Productive Aspects and Economic Aspects.	☐ ☐ ☐ ☐ ☐ ☐ ☐
Design & Engineering covered by... Customer Satisfaction with customisation, and Technical productivity	☐ ☐ ☐ ☐ ☐ ☐ ☐
Order Entry covered by... Due Date adherence, Resource Utilisation, and Coping with uncertainty	☐ ☐ ☐ ☐ ☐ ☐ ☐
Order Review and Release covered by... Due Date adherence, and Control over Orders on the shop floor	☐ ☐ ☐ ☐ ☐ ☐ ☐
Dispatching covered by... Due Date adherence	☐ ☐ ☐ ☐ ☐ ☐ ☐
Supply Chain Activities covered by... Satisfaction with existing customers, New customer and market exploration, and Profitability	☐ ☐ ☐ ☐ ☐ ☐ ☐
Managing Customer Relationships covered by... Improved Order Management, Uncertainty Management, and Profitability	☐ ☐ ☐ ☐ ☐ ☐ ☐

<Thank you for your helps>

Appendix 3: Survey Questionnaire

Survey of the Effectiveness of ERP Systems for UK Manufacturing

This survey is part of an ongoing research project being conducted by the Supply Chain Management and Modelling research group at **Lancaster University Management School**. The research seeks to understand how effectively Enterprise Resource Planning (ERP) systems are able to meet the decision support requirements of manufacturing companies in the UK. We are interested in learning from the opinions of **adopters and non-adopters** of ERP systems. Even if your company has not adopted an ERP system, your response is still very important to our study.

Please answer all relevant questions. If you wish to comment on any question or qualify a response in any way, please use the comment box provided at the end of this questionnaire. Your comments may help us to better understand your responses. **We guarantee that your individual responses will be kept strictly confidential.** Only aggregated data will be reported. No names, identifiable company data or comments will appear in any reports that result from this study. If you would find it more convenient to complete this survey online, please go to **http://erpuk.questionpro.com/**.

This survey is divided into four sections (A to D); non-adopters only need to complete Sections A and B. The survey should take you 15 to 20 minutes to complete. **All respondents who provide contact details will be entered into a PRIZE DRAW and receive a copy of the study's executive summary of results** which you can use to evaluate your company's decision making practices and use of information systems relative to others in your industry. The **WINNER** of the prize draw will receive a **£500 gift voucher** for the retail store of their choice.

Thank you very much for participating in this research project.

Bulut Aslan, Dr Mark Stevenson & Prof. Linda Hendry

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SECTION A: Background Information (& ERP Environment)

This section focuses on background information about your company. For those companies that have implemented, are implementing or intend to implement an ERP system, there are also some questions about the implementation process in your company.

1. Your position in the company: ________________

2. Number of employees:

a. 1 - 10 people
b. 11- 50 people
c. 51 - 250 people
d. 251 – 500 people
e. 501 – 1000 people
f. More than 1000 people

3. Sales turnover last year:

a. Less than £2m
b. At least £2m but less than £10m
c. At least £10m but less than £50m
d. At least £50m but less than £100m
e. At least £100m but less than £250m
f. At least £250m

4. **Which of the following statements best describes the company's products? Please select one response.**
   a. Each order is a different product, made to the specific requirements of the customer
   b. All (or the majority of) products are bespoke but a few are made on a repeat basis
   c. All (or the majority of) products are bespoke but a large proportion is made on a repeat basis
   d. We have some bespoke products and some standard products
   e. Most products are standard; there is little difference between customer requirements
   f. All products are standard; orders are fulfilled from inventory

5. **Which industrial sector is your company involved in? Please select all relevant responses.**

☐ Aerospace & Defence	☐ Automotive	☐ Chemicals
☐ Computers, Electronics & Optical	☐ Consumer goods	☐ Pharmaceuticals (Healthcare)
☐ Industrial Machinery & Equipments	☐ Nuclear	☐ Oil &Gas
☐ Ship Building, Railway Locomotives, Motorcycles & Bikes	☐ Textiles	☐ Other: ____________

6. **Which of the following statements best describes the 'typical' routing of a job through the shop floor in your company? Please select one response.** *[If your company does not manufacture but, e.g., distributes products instead, please select option "e".]*
   a. Routings vary a lot; a job could start and finish at any point on the shop floor
   b. Routings vary but there is a dominant flow direction on the shop floor
   c. There is little routing variation; most jobs go through a similar sequence of operations
   d. There is no routing variation; all jobs go through the same sequence of operations
   e. Not applicable

7. **Which of the following statements best describes your 'typical' supply chain position? Please select one response.**
   a. Original equipment manufacturer (OEM), close to the end-customer for the product
   b. Tier one supplier: a direct supplier to the OEM
   c. Tier two supplier: a supplier to tier one
   d. Raw material supplier
   e. Other: ________________

The following questions are about ERP systems and the (potential) use of ERP in your company. Please start by answering Question 8 *and proceed to the relevant questions (dependant on your response to Question 8). When you have completed Section A, please continue to Section B.*

8. **Which of the following statements best describes your company's ERP efforts? Please select one response.**
   a. The company has installed an ERP system
      └> *Please answer* Q9 to Q14, *then continue to Section B*
   b. The company is currently installing an ERP system
      └> *Please answer* Q9 to Q14, *then continue to Section B*
   c. The company plans to install an ERP system
      └> *Please answer* Q13 & Q14, *then continue to Section B*
   d. The company has no current plans to install an ERP system
      └> *Please answer* Q15 only, *then continue to Section B*
   e. The company has used and abandoned an ERP system
      └> *Please answer* Q16, *then continue to Section B*

9. **How difficult was it to identify the most appropriate ERP system for your company?**
   a. Extremely difficult
   b. Very difficult
   c. Difficult
   d. Neither difficult nor easy
   e. Easy
   f. Very easy
   g. Extremely easy

10. **Which of the following statements best describes your ERP installation? Please select one response.**
   a. Installation of a single ERP package (i.e., from a single ERP vendor)
   b. Single ERP package but with other bespoke software added on (e.g., built in-house)
   c. Best-of-breed installation using elements of several ERP packages (from several vendors)
   d. Several ERP packages but with other bespoke software added on (e.g., built in-house)
   e. In-house developed ERP system (bespoke, totally developed in-house)
   f. Other: ________________

11. **Which vendor provided, or will provide, the ERP software for your company? Please select all relevant responses.**

☐ SAP	☐ Oracle	☐ Exel EFACS
☐ IFS	☐ JDA (Western Data Systems)	☐ Avanté (Epicor)
☐ Sage	☐ Microsoft Dynamics (Navision)	☐ Other: ______________

12. **Which of the following business processes are currently supported by tools within your ERP system?** *Answering this question is a three stage process: first, select the processes supported by ERP modules; second, rank the modules selected in terms of their importance to your company; finally, indicate the required degree of module customisation, i.e., changes that had to be made to the code of the package.*

1) Please tick the processes supported by your ERP system.	2) Please rank the importance of the modules selected to your company	3) Please indicate the degree of customisation. None	Minor	Significant	Major
☐ Financial Accounting	_____				
☐ Financial Control	_____				
☐ Order Entry	_____				
☐ E-commerce	_____				
☐ Production Planning	_____				
☐ Purchasing and Logistics	_____				
☐ Materials Management	_____				
☐ Quality Management	_____				
☐ Sales and Delivery	_____				
☐ HR Management	_____				
☐ R&D Management	_____				
☐ Other: ______________	_____				

13. **Which of the following add-ons are currently used alongside your ERP system?** *Answering this question is a three stage process: first, select the software added on to your ERP system; second, rank the software selected in terms of their importance to your company; finally, indicate the required degree of software customisation, i.e., changes that had to be made to the code of the package.*

1) Please tick the software added on to your ERP system.	2) Please rank the imp. of the add-ons for your company	3) Please indicate the degree of customisation. None	Minor	Significant	Major
☐ Advanced Planning & Scheduling	_____				
☐ Customer Relationship Management	_____				
☐ Supply Chain Management	_____				
☐ Product Lifecycle (or Data) Management	_____				
☐ Product Configurator	_____				
☐ CAD System	_____				
☐ Other: ______________	_____				
☐ Other: ______________	_____				
☐ Other: ______________	_____				
☐ Other: ______________	_____				

14. What are the reasons why ERP was, or will be, adopted in the company? *Please indicate your level of agreement from 1 (strongly disagree) to 7 (strongly agree) with each of the following reasons.*

	Strongly Disagree						Strongly Agree
a. To lower costs	1	2	3	4	5	6	7
b. To simplify and standardise business processes	1	2	3	4	5	6	7
c. To integrate enterprise operations. systems, or data	1	2	3	4	5	6	7
d. To replace legacy systems (old hardware/software)	1	2	3	4	5	6	7
e. Linked to global activities (support globalisation strategy)	1	2	3	4	5	6	7
f. To improve e-commerce (e-procurement & marketing) activities	1	2	3	4	5	6	7
g. To improve production planning effectiveness	1	2	3	4	5	6	7
h. To support change/innovation in the company	1	2	3	4	5	6	7
i. To keep up with competitive forces in the industry	1	2	3	4	5	6	7
j. Adoption encouraged (or enforced) by key customers	1	2	3	4	5	6	7
k. Other: ________________	1	2	3	4	5	6	7

15. What are the reasons behind NOT adopting ERP in the near future? *Please indicate your level of agreement from 1 (strongly disagree) to 7 (strongly agree) with each of the following reasons.*

	Strongly Disagree						Strongly Agree
a. Cost of the software solution itself	1	2	3	4	5	6	7
b. Cost of the consultancy for selection, implementation, etc	1	2	3	4	5	6	7
c. Cost of the training for employees	1	2	3	4	5	6	7
d. Cost of the hardware upgrades required	1	2	3	4	5	6	7
e. Risk of implementation failure	1	2	3	4	5	6	7
f. ERP would not suit the needs of the company	1	2	3	4	5	6	7
g. Current economic climate	1	2	3	4	5	6	7
h. Other: ________________	1	2	3	4	5	6	7

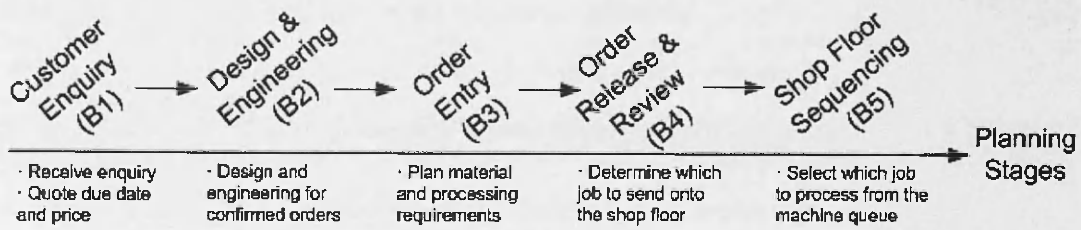
16. What were the reasons why the ERP system was abandoned? *Please indicate your level of agreement from 1 (strongly disagree) to 7 (strongly agree) with each of the following reasons.*

	Strongly Disagree						Strongly Agree
a. Significant financial loss due to underestimating imp. costs	1	2	3	4	5	6	7
b. Insufficient payback after adoption	1	2	3	4	5	6	7
c. The system was unable to meet the needs of our business	1	2	3	4	5	6	7
d. High cost of maintenance and training	1	2	3	4	5	6	7
e. Lack of personnel capable of using the system	1	2	3	4	5	6	7
f. The system was gradually neglected over time	1	2	3	4	5	6	7
g. The system was too complex for our company's org. structure	1	2	3	4	5	6	7
h. The system failed to improve the effectiveness of planning processes	1	2	3	4	5	6	7
i. The system failed to improve the efficiency of our transactions	1	2	3	4	5	6	7
j. Other: ________________	1	2	3	4	5	6	7

<End of Section A, Please continue to Section B>

SECTION B: Decision Support Requirements

This section focuses on the decision support requirements of manufacturing companies. The first five groups of statements presented (B1 to B5) focus on the decision support requirements at critical planning stages in a manufacturing company, as illustrated in the figure below. The last two groups of statements (B6 and B7) focus on your company's decision support requirements for customer relationship management and supply chain management respectively.



Please indicate your level of agreement with the statements by circling the relevant number from 1 (strongly disagree) to 7 (strongly agree). If a statement is not applicable to your company, please circle the "n/a" option.

B1. Customer Enquiry Stage Decision Support Requirements

	Strongly Disagree … Strongly Agree	
We need to be aware of capacity and our use of manufacturing resources in order to set realistic due dates	1 2 3 4 5 6 7	n/a
We need to access historical data on similar previous orders when setting due dates	1 2 3 4 5 6 7	n/a
We need to consider alternative due dates when negotiating with customers	1 2 3 4 5 6 7	n/a
We need to be aware of the availability of subcontractors and suppliers when promising due dates to customers	1 2 3 4 5 6 7	n/a
We need to perform a detailed analysis of costs when responding to a request for quotation	1 2 3 4 5 6 7	n/a
We need to access data on previous similar orders when estimating costs and setting profit margins	1 2 3 4 5 6 7	n/a
Determining what price to quote is influenced by a wide range of factors, from our company's desire to increase profitability to the status of our relationship with a customer	1 2 3 4 5 6 7	n/a
We require a high degree of coordination among departments when responding to customer enquiries	1 2 3 4 5 6 7	n/a
The sales and manufacturing departments have to communicate with each other when we are responding to quotations	1 2 3 4 5 6 7	n/a
There has to be a high degree of coordination between our company and our suppliers when we are responding to quotations	1 2 3 4 5 6 7	n/a

B2. Design and Engineering Decision Support Requirements

We require access to an archive of product information on previous similar orders to support the design and engineering task for confirmed orders	1 2 3 4 5 6 7	n/a
Maintaining a record of historical product data is essential if our design and engineering department is to handle our most complicated products and components	1 2 3 4 5 6 7	n/a
We need a high level of coordination between departments to support design and engineering tasks	1 2 3 4 5 6 7	n/a
The design and engineering department must be coordinated with the sales and manufacturing departments, especially for customised or bespoke products	1 2 3 4 5 6 7	n/a
Design and engineering tasks require a high level of coordination between our company and our customers	1 2 3 4 5 6 7	n/a
To support the design and engineering process efficiently, we need systems that are compatible with those used by our customers and/or suppliers	1 2 3 4 5 6 7	n/a
We need systems that are able to accommodate frequent product design changes at any stage of the process	1 2 3 4 5 6 7	n/a

B3. Order Entry Stage Decision Support Requirements

	Strongly Disagree						Strongly Agree	
If there is a long delay between making a quotation and it being confirmed by the customer, we must reconsider cost estimates and capacity availability	1	2	3	4	5	6	7	n/a
We require a planning system which does not rely on us entering complete product information (for planning or any other purposes)	1	2	3	4	5	6	7	n/a
When we are planning capacity for confirmed orders, we need to consider the potential effect of current unconfirmed tenders on capacity availability	1	2	3	4	5	6	7	n/a
When we are performing detailed planning, we require software support to enable us to employ finite loading (i.e., so that we only allocate work to a work centre that is below or equal to a set capacity limit)	1	2	3	4	5	6	7	n/a
Short-term capacity planning is important to us because our main capacity constraint (or bottleneck) changes over time	1	2	3	4	5	6	7	n/a

B4. Order Review and Release Decision Support Requirements

We have a decision point after planning but before manufacturing commences at which we determine which jobs to "release" (i.e., begin manufacturing)	1	2	3	4	5	6	7	n/a
We require software support to help us prioritise the release of planned orders onto the shop floor appropriately	1	2	3	4	5	6	7	n/a

B5. Shop Floor Sequencing Decision Support Requirements

Shop floor supervisors can easily cope with sequencing tasks on the shop floor without software support	1	2	3	4	5	6	7	n/a
We generally employ simple mechanisms for sequencing (e.g., first-in-first-out), either performed manually by our shop floor supervisor or through our software system	1	2	3	4	5	6	7	n/a

B6. CRM Decision Support Requirements

We require a database to help us manage our relationships with existing and potential customers	1	2	3	4	5	6	7	n/a
To maintain and develop our relationships with customers, we need to use several means of communication (e.g., direct face-to-face contact, email, telephone, etc)	1	2	3	4	5	6	7	n/a
We aim to entice first-time (or one-off) customers into longer and more robust relationships	1	2	3	4	5	6	7	n/a
One of our targets is to have more loyal customers and to build prolonged customer relationships based on trust	1	2	3	4	5	6	7	n/a

B7. SCM Decision Support Requirements

Information sharing is essential for coordination between our company and our customers	1	2	3	4	5	6	7	n/a
It is very important that we are able to respond quickly to urgent orders from our customers	1	2	3	4	5	6	7	n/a
We require an effective communication platform so that we are in close contact with our customers and are able to manage any urgent (rush) orders	1	2	3	4	5	6	7	n/a
Procurement costs are a major part of our total product costs and are of high importance to us	1	2	3	4	5	6	7	n/a
We require software support to reduce the time and cost of procurement and the time involved when negotiating with suppliers	1	2	3	4	5	6	7	n/a
A software system that is compatible with external systems and/or platforms (e.g., of our customers and/or suppliers) would provide a significant advantage to our company	1	2	3	4	5	6	7	n/a

<End of Section B>

SECTION C: ERP Features and Extensions

This section focuses on the functionality of ERP systems and extensions to ERP systems, e.g., for Advanced Planning and Scheduling (APS), and asks about the extent to which this functionality is used within your company.

If your company uses an ERP system: please answer this section and then continue to Section D.

If your company does not use an ERP system (including those that are currently installing ERP): the questionnaire finishes here - thank you once again for your valuable contribution to our research.

C1. Customer Enquiry Management via ERP

	Strongly Disagree … Strongly Agree	
ERP integrates and coordinates several departments in our company to support customer enquiry management tasks	1 2 3 4 5 6 7	n/a
We use our ERP to automate the entering of order details at the customer enquiry stage	1 2 3 4 5 6 7	n/a
We use our ERP system to store and retrieve historical data (e.g., on previous similar orders) to support due date and pricing estimations	1 2 3 4 5 6 7	n/a
We use the Available-to-Promise (ATP) functionality in our ERP system or in our Advanced Planning and Scheduling (APS) system when determining due dates	1 2 3 4 5 6 7	n/a
We use the Capable-to-Promise (CTP) functionality in our ERP system or in our APS system when determining due dates	1 2 3 4 5 6 7	n/a
We use Product Lifecycle Management (PLM) software (also known as "Product Data Management" (PDM) software) to support price estimations at the customer enquiry stage	1 2 3 4 5 6 7	n/a

C2. Design and Engineering via ERP

We use a product configurator application (or "variant generator") within our ERP system to support design and engineering tasks	1 2 3 4 5 6 7	n/a
We use PLM software to support design and engineering tasks	1 2 3 4 5 6 7	n/a

C3. Planning for Order Entry via ERP

We use the MRP functionality of our ERP system during production planning	1 2 3 4 5 6 7	n/a
We use our ERP for mid-term and short-term planning tasks (e.g., to adapt capacity)	1 2 3 4 5 6 7	n/a
We use an APS for mid-term and short-term planning tasks (e.g., to adapt capacity)	1 2 3 4 5 6 7	n/a

C4. Planning at the Order Review and Release Stage via ERP

We use the functionality of our ERP system after planning but before manufacturing commences to determine which jobs to "release" (i.e., begin manufacturing)	1 2 3 4 5 6 7	n/a
We use the functionality of our APS system to determine which jobs to "release" (i.e., begin manufacturing)	1 2 3 4 5 6 7	n/a

C5. Planning at the Shop Floor Sequencing Stage via ERP

We use the functionality of our core ERP system to support sequencing decisions on the shop floor	1 2 3 4 5 6 7	n/a
We use the functionality of our APS system to support sequencing decisions on the shop floor	1 2 3 4 5 6 7	n/a

C6. Developing Customer Relationships via CRM Software

We use our Customer Relationship Management (CRM) software to help us improve relationships with existing customers	1 2 3 4 5 6 7	n/a
We use our CRM to assess potential and existing customers, e.g., profitability loyalty	1 2 3 4 5 6 7	n/a
We use the analysis tools of our CRM system to support the development of strategies for improving our relationships with customers	1 2 3 4 5 6 7	n/a

C7. Supply Chain Management via ERP and SCM Systems

Our ERP system provides the foundations for Supply Chain Management (SCM) software applications	1 2 3 4 5 6 7	n/a
We use SCM software applications to coordinate our supply chains	1 2 3 4 5 6 7	n/a

<End of Section C>

SECTION D: Performance Measurement

This final section focuses on performance measurement and asks you to describe the effect that the implementation of an ERP system has had on your company.

D1. Improved Customer Enquiry Management Performance

Since we began to use an ERP system:	Strongly Disagree … Strongly Agree	
More realistic (achievable) due dates have been quoted (promised) to customers	1 2 3 4 5 6 7	n/a
The time required to produce a quotation has been reduced	1 2 3 4 5 6 7	n/a
Our on-time delivery performance has improved	1 2 3 4 5 6 7	n/a
Our procedures at the customer enquiry stage have become more defined and standardised	1 2 3 4 5 6 7	n/a
The proportion of quotations that become firm orders has been improved	1 2 3 4 5 6 7	n/a
The profitability of our products has increased (we have improved how we determine prices & due dates)	1 2 3 4 5 6 7	n/a

D2. Improved Design and Engineering Performance

Through the use of our ERP system:

We are better able to meet customer order specifications	1 2 3 4 5 6 7	n/a
Our ability to satisfy customers when products are customised or bespoke has improved	1 2 3 4 5 6 7	n/a
Product development activities are more efficiently performed (e.g., similarities between new and past orders is more easily detected, reducing duplicated effort)	1 2 3 4 5 6 7	n/a
We can automate previously time consuming and manual documentation tasks	1 2 3 4 5 6 7	n/a

D3. Improved Planning Performance

Through the use of:

The MRP module within our ERP system, we have improved our adherence to due dates	1 2 3 4 5 6 7	n/a
Our ERP system, lead times have been shortened	1 2 3 4 5 6 7	n/a
Our ERP system, we are able to be more proactive and anticipate unexpected scenarios in planning	1 2 3 4 5 6 7	n/a
Our ERP system, we are better able to control the release of orders, improving our adherence to daily schedules	1 2 3 4 5 6 7	n/a
Our ERP system, Work-in-Process (WIP) and congestion on the shop floor has been reduced	1 2 3 4 5 6 7	n/a
Our ERP system, we are better able to meet daily production schedules	1 2 3 4 5 6 7	n/a
Our APS system, production planning has improved	1 2 3 4 5 6 7	n/a
Our APS system, we are better able to meet daily production schedules	1 2 3 4 5 6 7	n/a

D4. Improved CRM Performance

Our CRM system helps us to:

Improve customer satisfaction levels through close contact & coordination with customers	1 2 3 4 5 6 7	n/a
Convert one-off (or first time) customers into repeat purchasers	1 2 3 4 5 6 7	n/a
Explore new market opportunities (e.g., to find and evaluate potential new customers)	1 2 3 4 5 6 7	n/a
Increase the proportion of quotations that become firm orders	1 2 3 4 5 6 7	n/a
We have observed any direct sign. impact on profitability as a result of using CRM	1 2 3 4 5 6 7	n/a
The return on investment from our CRM system is significant	1 2 3 4 5 6 7	n/a

D5. Improved Supply Chain Planning Performance

Through the use of SCM software:

We have improved our ability to meet the due dates of urgent (or rush) orders	1 2 3 4 5 6 7	n/a
Coping with urgent (or rush) orders has become less of a challenge	1 2 3 4 5 6 7	n/a
Urgent (or rush) orders cause less disruption to our existing production schedule	1 2 3 4 5 6 7	n/a
We have observed any direct sign. impact on profitability as a result of using SCM	1 2 3 4 5 6 7	n/a
The return on investment from our SCM system is significant	1 2 3 4 5 6 7	n/a

The questionnaire concludes here - Thank you very much for your time and contribution to our research. If you would like to make any further comments on the effectiveness of ERP systems for UK manufacturing, please use the comment box below.

Comments:

Contact Details (optional)

Please provide your contact details below if you would like to be entered into a PRIZE DRAW and receive a copy of the study's executive study. Furthermore, after the survey, we plan to continue the project by studying individual cases - if you are interested in participating in the second stage of the work, please indicate this below.

☐ I would like to enter the prize draw and receive a copy of the study's executive summary.
☐ I would be interested in participating in the second stage of the research – the study of individual cases.

Name : ____________________

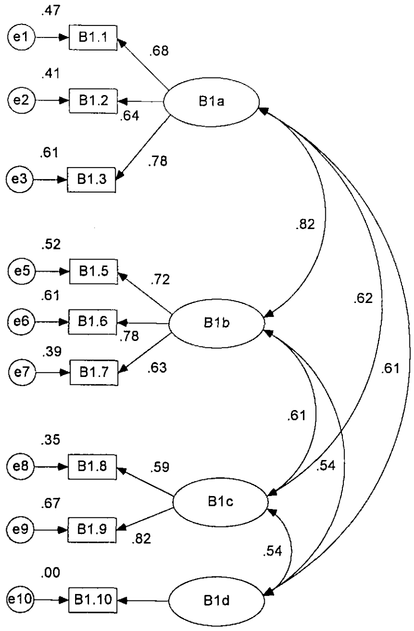
Company : ____________________

Address : ____________________

____

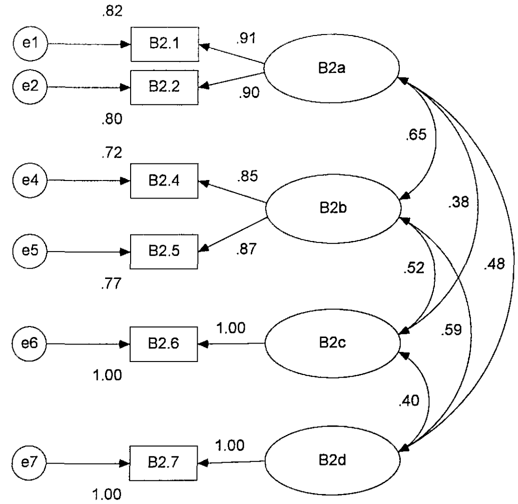
____

Appendix 4: Final measurement models of constructs



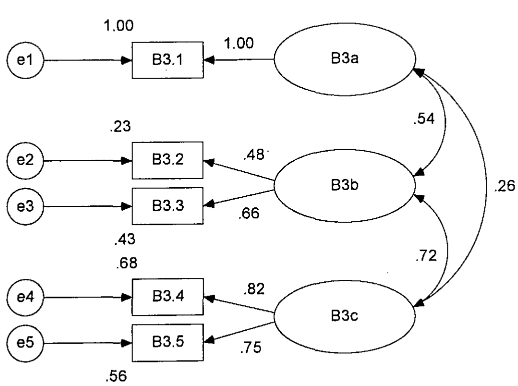
Chi-sqaure = 27.038 (df 22, p = .210)
CFI = .982
RMSEA = .046

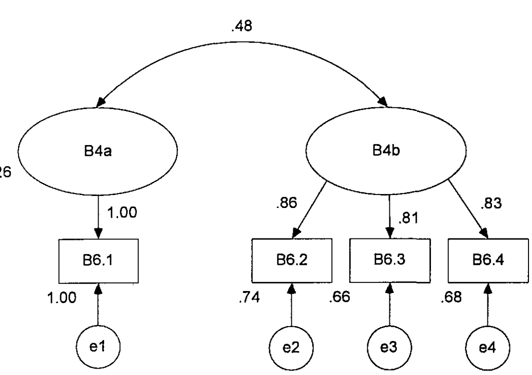
B1 Measurement Model



Chi-sqaure = 6.690 (df 5, p = .245)
CFI = .994
RMSEA = .058

B2 Measurement Model



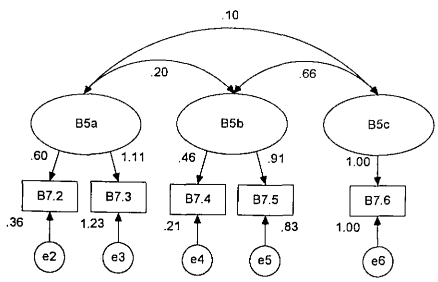


Chi-sqaure = 4.524 (df 3, p = .210)
CFI = .983
RMSEA = .069

B3 Measurement Model

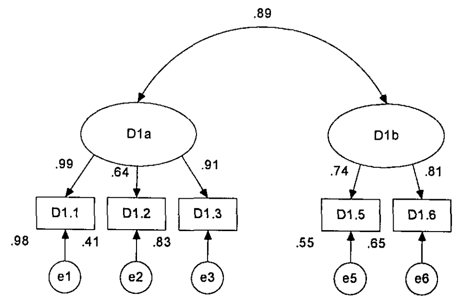
Chi-sqaure = 2.540 (df 2, p = .281)
CFI = .997
RMSEA = .049

B4 Measurement Model



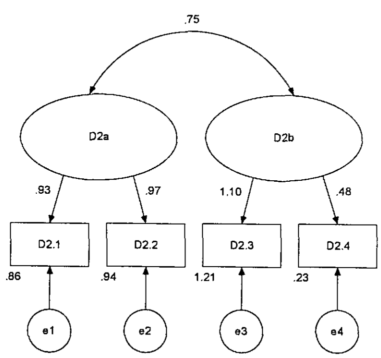
Chi-sqaure = 4.914 (df 3, p = .178)
CFI = .984
RMSEA = .078

B5 Measurement Model



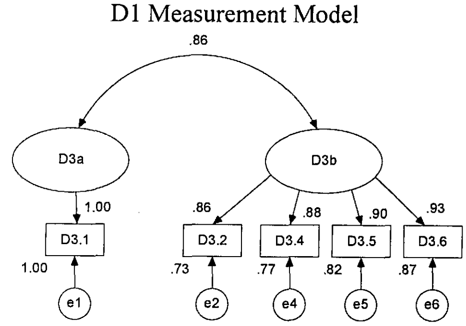
Chi-sqaure = 6.898 (df 4, p = .141)
CFI = .984
RMSEA = .074

D1 Measurement Model



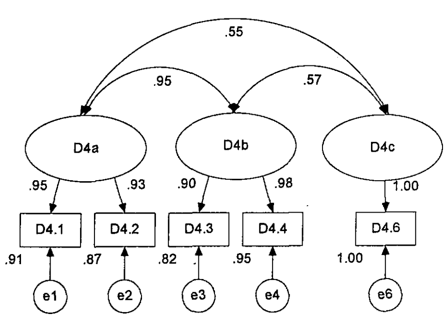
Chi-sqaure = .016 (df 1, p = .900)
CFI = 1.000
RMSEA = .000

D2 Measurement Model



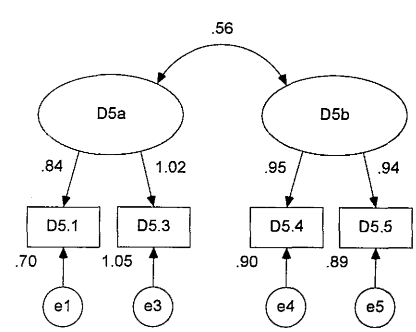
Chi-sqaure = 8.750 (df 5, p = .119)
CFI = .985
RMSEA = .076

Measurement Model



Chi-sqaure = .903 (df 3, p = .825)
CFI = 1.000
RMSEA = .000

D4 Measurement Model



Chi-sqaure = .181 (df 1, p = .670)
CFI = 1.000
RMSEA = .000

D5 Measurement Model

Appendix 5: Final Standardised Path Loadings

	Std Path Loading	Critical Ratio	Mean	Std dev.
B1. Customer Enquiry Stage DSRs				
B1a. Due date setting				
B1.1. We need to be aware of capacity and our use of manufacturing resources in order to set realistic due dates	0.74	–	5.80	0.21
B1.2. We need to access historical data on similar previous orders when setting due dates	0.63	4.18	4.63	0.26
B1.3. We need to consider alternative due dates when negotiating with customers	0.76	4.94	5.09	0.23
B1.4. We need to be aware of the availability of subcontractors and suppliers when promising due dates to customers		**dropped**		
B1b. Pricing				
B1.5. We need to perform a detailed analysis of costs when responding to a request for quotation	0.74	–	5.80	0.21
B1.6. We need to access data on previous similar orders when estimating costs and setting profit margins	0.63	4.18	4.63	0.26
B1.7. Determining what price to quote is influenced by a wide range of factors, from our company's desire to increase profitability to the status of our relationship with a customer	0.76	4.94	5.09	0.23
B1c. Internal Coordination				
B1.8. We require a high degree of coordination among departments when responding to customer enquiries	0.94	–	4.54	0.20
B1.9. The sales and manufacturing departments have to communicate with each other when we are responding to quotations	0.79	4.34	5.03	0.20
B1d. External Coordination				
B1.10. There has to be a high degree of coordination between our company and our suppliers when we are responding to quotations	1.0	–	4.36	0.21

	Std Path Loading	Critical Ratio	Mean	Std dev.
B2. Design and Engineering Decision Support Reqs				
B2a. Documentation Archive				
B2.1. We require access to an archive of product information on previous similar orders to support the design and engineering task for confirmed orders	0.93	–	4.62	0.28
B2.2. Maintaining a record of historical product data is essential if our design and engineering department is to handle our most complicated products and components	0.94	7.91	4.71	0.28
B2b. Internal Coordination				
B2.3. We need a high level of coordination between departments to support design and engineering tasks	dropped			
B2.4. The design & engineering department must be coordinated with the sales and manufacturing departments, especially for customised or bespoke products	0.80	–	5.39	0.20
B2.5. Design and engineering tasks require a high level of coordination between our company and our customers	0.87	5.69	5.21	0.22
B2c. External Coordination				
B2.6. To support the design & eng process efficiently, we need systems that are compatible with those used by customers/suppliers	1.00	–	3.89	0.18
B2d. Flexibility in Design				
B2.7. We need systems that are able to accommodate frequent product design changes at any stage of the process	1.00	–	4.65	0.29
B3. Order Entry Stage Decision Support Requirements				
B3a. Confirmed Order Re-evaluation				
B3.1. If there is a long delay between making a quotation & it being confirmed by the customer, we must reconsider cost estimates and capacity availability	1.00	–	4.50	0.24
B3b. Aggregate Planning				
B3.2. We require a planning system which does not rely on us entering complete product information (for planning or any other purposes)	0.52	–	4.42	0.23
B3.3. When we are planning capacity for confirmed orders, we need to consider the potential effect of current unconfirmed tenders on capacity availability	0.64	3.32	4.22	0.21
B3c. Operational Planning				
B3.4. When we are performing detailed planning, we require software support to enable us to employ finite loading (i.e., so that we only allocate work to a work centre that is ≤ to a set capacity limit)	0.96	–	4.44	0.23
B3.5. Short-term capacity planning is important to us because our main capacity constraint (or bottleneck) changes over time	0.61	3.05	5.10	0.22
B4. CRM Decision Support Requirements				
B4a. Customer Database				
B4.1. We require a database to help us manage our relationships with existing and potential customers	1.00	–	4.76	0.24
B4b. Need for Improved Relationships				
B4.2. To maintain and develop our relationships with customers, we need to use several means of communication (e.g., direct face-to-face contact, email, telephone, etc)	0.77	4.44	5.96	0.18
B4.3. We aim to entice first-time (or one-off) customers into longer and more robust relationships	0.89	4.72	5.64	0.21
B4.4. One of our targets is to have more loyal customers and to build prolonged customer relationships based on trust	0.62	–	6.31	0.14

	Std Path	Critical	Mean	Std

	Loading	Ratio		dev.
B5. SCM Decision Support Requirements				
B5a. Supply Chain Coordination (with Buyers)				
B5.1. Information sharing is essential for coordination between our company and our customers		**dropped**		
B5.2. It is very important that we are able to respond quickly to urgent orders from our customers	0.41	–	6.03	0.16
B5.3. We require an effective communication platform so that we are in close contact with our customers and are able to manage any urgent (rush) orders	1.29	0.77	5.42	0.19
B5b. Procurement (from Suppliers)				
B5.4. Procurement costs are a major part of our total product costs and are of high importance to us	0.50	2.61	5.45	0.21
B5.5. We require software support to reduce the time and cost of procurement and the time involved when negotiating with suppliers	0.41	–	4.69	0.22
B5c. Compatibility				
B5.6. A software system that is compatible with external systems and/or platforms (e.g., of our customers and/or suppliers) would provide a significant advantage to our company	1.00	–	4.21	0.24
D1. Improved Customer Enquiry Management Performance				
Since we began to use an ERP system:				
D1a. Productive Aspects				
D1.1. More realistic (achievable) due dates have been quoted (promised) to customers	0.97	–	5.05	0.25
D1.2. The time required to produce a quotation has been reduced	0.60	4.93	4.59	0.27
D1.3. Our on-time delivery performance has improved	0.93	11.2 9	5.17	0.24
D1.4. Our procedures at the customer enquiry stage have become more defined and standardised		**dropped**		
D1b. Economic Aspects				
D1.5. The proportion of quotations that become firm orders has been improved	0.67	4.12	3.99	0.23
D1.6. The profitability of our products has increased (we have improved how we determine prices & due dates)	0.78	–	4.54	0.22
D2. Improved Design and Engineering Performance				
Through the use of our ERP system:				
D2a. Satisfaction with the Product customisation				
D2.1. We are better able to meet customer order specifications	0.93	11.63	4.51	0.24
D2.2. Our ability to satisfy customers when products are customised or bespoke has improved	0.97	–	4.60	0.26
D2b. Technical productivity				
D2.3. Product development activities are more efficiently performed (e.g., similarities between new and past orders is more easily detected, reducing duplicated effort)	1.10	2.74	4.48	0.25
D2.4. We can automate previously time consuming and manual documentation tasks	0.47	–	5.33	0.23

	Std Path Loading	Critical Ratio	Mean	Std dev.
D3. Improved Planning Performance				
Through the use of:				
D3a. MRP				
D3.1. The MRP module within our ERP system, we have improved our adherence to due dates	1	–	5.09	0.26
D3b. ERP				
D3.2. Our ERP system, lead times have been shortened	0.86	–	4.76	0.27
D3.3. Our ERP system, we are able to be more proactive and anticipate unexpected scenarios in planning		dropped		
D3.4. Our ERP system, we are better able to control the release of orders, improving our adherence to daily schedules	0.88	–	4.87	0.25
D3.5. Our ERP system, Work-in-Process (WIP) and congestion on the shop floor has been reduced	0.90	–	4.69	0.29
D3.6. Our ERP system, we are better able to meet daily production schedules	0.93	–	4.78	0.26
D4. Improved CRM Performance				
Our CRM system helps us to:				
D4a. Satisfaction w/ existing customers				
D4.1. Improve customer satisfaction levels through close contact & coordination with customers	0.95	11.66	4.35	0.28
D4.2. Convert one-off (or first time) customers into repeat purchasers	0.93	–	4.00	0.28
D4b. New customer and market exploration				
D4.3. Explore new market opportunities (e.g., to find and evaluate potential new customers)	0.90	10.8 1	3.70	0.30
D4.4. Increase the proportion of quotations that become firm orders	0.98	–	3.75	0.29
D4c. Profitability				
D4.5. Improve profitability (i.e., increase revenue and/or reduce cost)		dropped		
D4.6. The return on investment from our CRM system is significant	1	–	3.75	0.29
D5. Improved Supply Chain Planning Performance				
Through the use of SCM software:				
D5a. Improved Order Management				
D5.1. We have improved our ability to meet the due dates of urgent (or rush) orders	0.84	–	4.45	0.29
D5.2. Coping with urgent (or rush) orders has become less of a challenge		dropped		
D5.3. Urgent (or rush) orders cause less disruption to our existing production schedule	1.02	5.51	4.15	0.28
D5b. Profitability				
D5.4. We have improved our profitability (i.e., increase revenue and/or reduce cost)	0.95	–	4.05	0.27
D5.5. The return on investment from our SCM system is significant	0.94	7.52	4.05	0.29

Appendix 6: Company background statistics

Company background Descriptive Statistics

		Q2. Number of Employees	Q3. Sales Turnover	Q4. Production strategy	Q6. SF Routing	Q7. SC Position
N	Valid	126	126	126	121	126
	N/A	0	0	0	5	0
Mean		2.92	2.61	3.45	2.58	2.12
Median		3	2	4	3	2
Mode		3	2	4	3	1
Std. Deviation		0.98	1.17	1.41	0.82	1.21
Skewness[a]		1.10	0.80	-0.06	-0.07	0.79
Std. Error of Skewness		0.22	0.22	0.22	0.22	0.22
Kurtosis[a]		1.46	0.59	-0.83	-0.49	-0.34
Std. Error of Kurtosis		0.43	0.43	0.43	0.44	0.43
Percentile	25	2	2	2	2	1
	50	3	2	4	3	2
	75	3	3	4	3	3

[a] Discrete data (categorical or ordinal data with less than 15 values) may be assumed to be normal if skew & kurtosis is within the range ± 1 as 'good' or ± 2 as 'adequate' (Schumacker & Lomax, 2004).

Company background Frequency Statistics

No of employees	Freq.	%
1-10 people	1	0.8
11-50 people	47	37.3
51-250 people	50	39.7
251-500 people	21	16.7
501-1000 people	3	2.4
> 1000 people	4	3.2
Total	*126*	*100*

Turnover	Freq.	%
Less than £2	18	14.3
£2 << £10	52	41.3
£10 << £50	27	21.4
£50 << £100	23	18.3
£100 << £500	2	1.6
More than £250	4	3.2
Total	*126*	*100*

Type	Freq.	%
ETO	12	9.5
MTO1	24	19.0
MTO2	24	19.0
ATO1	36	28.6
ATO2	21	16.7
MTS	9	7.1
Total	*126*	*100*

SF Routing	Freq.	%
PJS	11	8.7
GJS	44	34.9
GFS	51	40.5
PFS	15	11.9
Missing	5	4.0

SC Position	Freq.	%
OEM	55	43.7
Tier1	24	19.0
Tier2	31	24.6
Raw	9	7.1
Other	7	5.6

SF Routing	Freq.	%
PJS	11	8.7
GJS	44	34.9
GFS	51	40.5
PFS	15	11.9
Missing	5	4.0
Total	*126*	*100.0*

SC Position	Freq.	%
OEM	55	43.7
Tier1	24	19.0
Tier2	31	24.6
Raw	9	7.1
Other	7	5.6
Total	*126*	*100.0*

Appendix 7: ERP environment statistics

ERP Environment Descriptive Statistics

		Q8. ERP efforts	Q9. How difficult to implement	Q10. Impl. Strategy
N	Valid	123	54	71
	N/A	3	72	55
Mean		2.29	3.37	1.89
Median		1	3	2
Mode		1	3	1
Std. Deviation		1.44	0.98	1.20
Skewness		0.357	0.094	1.493
Std. Error of Skew.		0.22	0.36	0.29
Kurtosis		-1.746	0.667	1.297
Std. Error of Kurt.		0.43	0.64	0.56
Percentile	25	1	3	1
	50	1	3	2
	75	4	4	2

ERP Environment Frequency Statistics

ERP Efforts	Freq.	%	ERP Imp. Strategy	Freq.	%	How diff. to select the app. ERP system	Freq.	%
						Extr. difficult	1	0.8
User	63	50.0	Single	35	27.8	Very difficult	7	5.6
Currently Installing	10	7.9	Single+	24	19.0	Difficult	22	17.5
Plans to install	3	2.4	BoB	2	1.6	Neither nor	20	15.9
Non-user	45	35.7	BoB+	5	4.0	Very easy	3	2.4
Used & Abandoned	2	1.6	In-house	5	4.0	Extr. Easy	1	0.8
						NA	54	42.9
Missing	*3*	*2.4*	*Missing*	*55*	*43.7*	*Missing*	*19*	*15.1*
Total	*126*	*100.0*	*Total*	*126*	*100.0*	*Total*	*126*	*100.0*

Single = Single Package ERP, **plus** (+) = add-ons, **BoB** = Best-of-Breed.

Appendix 8: ERP modules and extensions statistics

Supported ERP modules Ranking Statistics

		Fin. Acc.	Fin. Cntrl	Order Entry	E-comm.	Prod. Plan.	Purch. & Logistic	Mat. Man.	Quality Man.	Sales & Delivery	HR Man.	R&D Man.
N	Valid	54	52	62	15	58	63	58	30	60	17	4
	N/A	72	74	64	111	68	63	68	96	66	109	122
Mean		3.24	3.46	4.00	5.00	3.38	4.38	4.22	6.20	4.30	7.94	7.25
Median		3	3	4	5	3	4	5	7	4	8	7.50
Mode		1	2	1	4[a]	1	2[a]	6	7	4	9	5[a]
Range		10	7	8	9	7	7	7	7	7	6	4
Minimum		1	1	1	1	1	1	1	2	1	4	5
Maximum		11	8	9	10	8	8	8	9	8	10	9
Perc	25	1	2	2	2	1	3	2	4.75	3	6.50	5.50
	50	3	3	4	5	3	4	5	7	4	8	7.50
	75	5	4.75	6	7	5	6	6	8	5.75	9	8.75

a. Multiple modes exist. The smallest value is shown.

Supported ERP extensions Ranking Statistics

		APS	CRM	SCM	PLM	PC	CAD
N	Valid	11	14	10	6	8	21
	Missing	115	112	116	120	118	105
Mean		1.73	1.43	2.60	3.00	3.00	1.67
Median		1	1	2	2.50	3	1
Mode		1	1	2	1	3	1
Range		3	2	4	5	4	4
Minimum		1	1	1	1	2	1
Maximum		4	3	5	6	6	5
Perc	25	1	1	2	1	2	1
	50	1	1	2	2.50	3	1
	75	2	2	3.25	5.25	3	2

a. Multiple modes exist. The smallest value is shown

Supported ERP modules Level of Customisation Descriptive Statistics

		Fin. Acc.	Fin. Cntrl	Order Entry	E-com.	Prod. Plan.	Purch. & Logistic	Mat. Man.	Qual. Man.	Sales & Delivery	HR Man.	R&D Man.
N	Valid	55	52	63	15	58	63	59	30	60	17	4
	N/A	71	74	63	111	68	63	67	96	66	109	122
Mean		1.84	1.83	2.19	2.80	2.26	2.03	2.10	2.40	2.15	2.00	2.25
Std. Dev.		0.78	0.81	0.98	1.20	1.10	0.95	1.02	1.22	0.97	1.06	1.25
Median		2	2	2	3	2	2	2	2	2	2	2
Mode		2	2	2	4	2	2	2	1[a]	2	2	2
Range		3	3	3	3	3	3	3	3	3	3	3
Minimum		1	1	1	1	1	1	1	1	1	1	1
Maximum		4	4	4	4	4	4	4	4	4	4	4
	25	1	1	1	2	1	1	1	1	1	1	1.25
Perc	50	2	2	2	3	2	2	2	2	2	2	2
	75	2	2	3	4	3	3	3	4	3	2	3.50

a. Multiple modes exist. The smallest value is shown

Supported ERP extensions Level of Customisation Descriptive Statistics

		APS	CRM	SCM	PLM	PC	CAD
N	Valid	17	19	13	9	11	27
	N/A	109	107	113	117	115	99
Mean		2.88	2.05	2.46	3.00	2.36	2.07
Std. Dev.		0.92	0.91	1.19	1.00	1.12	1.17
Median		3	2	2	3	2	2
Mode		3	2	2	3	1[a]	1
Range		3	3	3	3	3	3
Minimum		1	1	1	1	1	1
Maximum		4	4	4	4	4	4
Perc.	25	2.50	1	1.50	2.50	1	1
	50	3	2	2	3	2	2
	75	3.50	2	4	4	3	3

a. Multiple modes exist. The smallest value is shown

Supported ERP modules Frequency Statistics

Rank	*Financial Accounting*		*Financial Control*		*Order Entry*		*E-commerce*		*Production Planning*		*Purchasing & Logistics*		*Materials Man.*		*Quality Man.*		*Sales & Delivery*		*HR Man.*		*R&D Man.*	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
1	**19**	**15.1**	4	3.2	**11**	**8.7**	2	1.6	**16**	**12.7**	2	1.6	8	6.3	0	0.0	5	4.0	0	0.0	0	0.0
2	7	5.6	**14**	**11.1**	7	5.6	2	1.6	**9**	**7.1**	**12**	**9.5**	7	5.6	3	2.4	6	4.8	0	0.0	0	0.0
3	5	4.0	**10**	**7.9**	**10**	**7.9**	**3**	**2.4**	**11**	**8.7**	**10**	**7.9**	8	6.3	1	0.8	**12**	**9.5**	0	0.0	0	0.0
4	7	5.6	**11**	**8.7**	8	6.3	1	0.8	4	3.2	8	6.3	5	4.0	3	2.4	**13**	**10.3**	1	0.8	0	0.0
5	**8**	**6.3**	7	5.6	**9**	**7.1**	2	1.6	6	4.8	9	7.1	**10**	**7.9**	1	0.8	**9**	**7.1**	1	0.8	1	0.8
6	3	2.4	4	3.2	7	5.6	**3**	**2.4**	3	2.4	**12**	**9.5**	**13**	**10.3**	**6**	**4.8**	4	3.2	2	1.6	0	0.0
7	2	1.6	1	0.8	7	5.6	1	0.8	7	5.6	9	7.1	5	4.0	**7**	**5.6**	4	3.2	1	0.8	1	0.8
8	2	1.6	1	0.8	2	1.6	0	0.0	2	1.6	1	0.8	2	1.6	**6**	**4.8**	7	5.6	**4**	**3.2**	1	0.8
9	0	0.0	0	0.0	1	.8	1	0.8	0	0.0	0	0.0	0	0.0	3	2.4	0	0.0	**5**	**4.0**	1	0.8
10	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	**3**	**2.4**	0	0.0
Missing	*72*	*57.1*	*74*	*58.7*	*60*	*50.8*	*111*	*88.1*	*68*	*54.0*	*63*	*50*	*68*	*54*	*96*	*76.2*	*66*	*52.4*	*109*	*86.5*	*122*	*96.8*
Total	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*

Table C6. Supported ERP extensions Frequency Statistics

Rank	*APS*		*CRM*		*SCM*		*PLM*		*PC*		*CAD*	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
1	7	5.6	10	7.9	1	0.8	3	2.4	0	0.0	11	8.7
2	2	1.6	2	1.6	5	4.0	0	0.0	3	2.4	8	6.3
3	0	0.0	2	1.6	2	1.6	0	0.0	4	3.2	1	0.8
4	2	1.6	0	0.0	1	0.8	1	0.8	0	0.0	0	0.0
5	0	0.0	0	0.0	1	0.8	1	0.8	0	0.0	1	0.8
6	0	0.0	0	0.0	0	0.0	1	0.8	1	0.8	0	0.0
Missing	*115*	*91.3*	*112*	*88.9*	*116*	*92.1*	*120*	*95.2*	*118*	*93.7*	*105*	*83.3*
Total	*126*	*100.0*	*126*	*100.0*	*126*	*100.0*	*126*	*100.0*	*126*	*100.0*	*126*	*100.0*

Appendix 9: Reasons to adopt and not to adopt ERP statistics

Reasons to adopt ERP, Descriptive Statistics

		14a	14b	14c	14d	14e	14f	14g	14h	14i	14j	14k
N	Valid	70	70	70	71	69	68	70	67	68	67	52
		56	56	56	55	57	58	56	59	58	59	74
Mean		4.46	5.77	5.44	5.75	3.23	3.16	5.41	4.34	4.85	2.43	4.62
Median		4	6	6	6	3	3	6	4	5	2	5
Mode		4	6	6	7	1	1	7	4	5	1	5
Std. Deviation		1.63	1.12	1.33	1.51	2.03	1.75	1.60	1.74	1.55	1.49	1.71
Skewness		-0.180	-0.937	-1.333	-1.298	0.424	0.365	-0.864	-0.086	-0.444	0.885	-0.649
Kurtosis		-0.609	1.048	2.507	1.218	-1.151	-0.974	-0.244	-0.719	-0.255	0.147	-0.315
	25	3	5	5	5	1	2	4	3	4	1	3.25
Perc.	50	4	6	6	6	3	3	6	4	5	2	5
	75	6	7	6	7	5	5	7	5	6	3	6

Reasons NOT to adopt ERP, Descriptive Statistics

		15a	15b	15c	15d	15e	15f	15g
N	Valid	33	33	33	33	34	37	34
	N/A	93	93	93	93	92	89	92
Mean		4.58	4.76	4.27	4.24	4.47	5.84	4.38
Median		5	5	5	4	4	7	5
Mode		5	7	5	4	4	7	7
Std. Deviation		1.97	2.05	1.86	1.94	1.94	1.66	2.20
Skewness		-0.460	-0.582	-0.332	-0.365	-0.428	-1.572	-0.267
Kurtosis		-0.815	-0.848	-0.797	-0.890	-0.677	2.348	-1.415
	25	3	3	3	3	3.75	5	2
Perc.	50	5	5	5	4	4	7	5
	75	6	7	6	6	6	7	6.25

Reasons to adopt ERP Frequency Statistics

	14a		14b		14c		14d		14e		14f		14g		14h		14i		14j		14k	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Strongly D	3	2.4	0	0	2	1.6	2	1.6	21	16.7	15	11.9	0	0	4	3.2	2	1.6	25	19.8	4	3.2
Disagree	6	4.8	1	.8	1	.8	0	0	9	7.1	15	11.9	7	5.6	7	5.6	3	2.4	14	11.1	3	2.4
Somewhat D	9	7.1	2	1.6	2	1.6	5	4.0	11	8.7	9	7.1	2	1.6	9	7.1	8	6.3	12	9.5	6	4.8
Neither nor	19	15.1	4	3.2	6	4.8	8	6.3	7	5.6	11	8.7	9	7.1	16	12.7	12	9.5	9	7.1	6	4.8
Somewhat A	13	10.3	19	15.1	21	16.7	7	5.6	8	6.3	11	8.7	12	9.5	15	11.9	20	15.9	5	4.0	16	12.7
Agree	11	8.7	23	18.3	24	19.0	19	15.1	8	6.3	5	4.0	17	13.5	5	4.0	11	8.7	1	.8	11	8.7
Strongly A	9	7.1	21	16.7	14	11.1	30	23.8	5	4.0	2	1.6	23	18.3	11	8.7	12	9.5	1	.8	6	4.8
N/A	*56*	*44.4*	*56*	*44.4*	*56*	*44.4*	*55*	*43.7*	*57*	*45.2*	*58*	*46.0*	*56*	*44.4*	*59*	*46.8*	*58*	*46.0*	*59*	*46.8*	*74*	*58.7*
Total	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*

Reasons not to adopt ERP Frequency Statistics

	15a		15b		15c		15d		15e		15f		15g	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Strongly D	4	3.2	4	3.2	4	3.2	5	4.0	5	4.0	2	1.6	5	4.0
Disagree	1	0.8	1	0.8	2	1.6	2	1.6	0	0.0	0	0.0	4	3.2
Somewhat D	5	4.0	5	4.0	5	4.0	3	2.4	3	2.4	0	0.0	4	3.2
Neither nor	4	3.2	2	1.6	5	4.0	7	5.6	11	8.7	5	4.0	3	2.4
Somewhat A	7	5.6	7	5.6	8	6.3	6	4.8	2	1.6	6	4.8	4	3.2
Agree	5	4.0	5	4.0	5	4.0	6	4.8	7	5.6	4	3.2	6	4.8
Strongly A	7	5.6	9	7.1	4	3.2	4	3.2	6	4.8	20	15.9	8	6.3
N/A	*93*	*73.8*	*93*	*73.8*	*93*	*73.8*	*93*	*73.8*	*92*	*73.0*	*89*	*70.6*	*92*	*73.0*
Total	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*	*126*	*100*

Appendix 10: Comparative cross-tabulations

Vendor vs ERP implementation strategy

		Implementation Strategy				
		Single	**Single+**	**BoB**	**BoB+**	**In-house**
SAP	MTO	1				
	MTS	8	2	2	1	
MS Navision	MTO	1				
	MTS	1	2		1	
Sage	MTO	1	2		1	
	MTS		3			
Exel	MTO	3	2			
	MTS					
IFS	MTO	1				
	MTS	1	1		1	
SysPro	MTO		1			
	MTS	1	1			
Avanté	MTO	1	1			
	MTS					
In house	MTO					1
	MTS					1
Other	MTO	10	5		2	1
	MTS	5	7			
Total	*MTO*	*18*	*11*	*0*	*3*	*2*
	MTS	*16*	*16*	*2*	*3*	*1*

Industrial Sector vs Supply chain position

G6		Supply Chain Position				
		OEM	Tier1	Tier2	Raw	Other
IndMach	MTO	12	3	8		1
	MTS	3	9	1		
Auto	MTO	6	3	12		1
	MTS		6	4		2
AeroDef	MTO	6	4	13		1
	MTS	2	4	2		1
Compe	MTO	4	2	6	1	1
	MTS	3	2	3		
Consu	MTO	2	2	2		1
	MTS	5	1	5	1	
Chem	MTO	4	2	2		1
	MTS	3	2	1	2	
MWP	MTO	3		2	1	1
	MTS	5	1	1	3	1
Transp	MTO	9	1	4		1
	MTS			1		
HealthP	MTO	4	2	4		1
	MTS	2	1	2		
OilGas	MTO	4		3		1
	MTS	1	2	2		
Nuclear	MTO	3	1	1		
	MTS	1				
Textile	MTO	1		1		
	MTS	2	2			
Other	MTO	4	1	3	1	
	MTS	2	1			

Appendix 11: Standardised Path Coefficients

Standardised Path Coefficients from results of MTO and MTS responses

			MTO Sample Parameter Estimation					MTS Sample Parameter Estimation				
			Unstandardised Path Coeff.				Std. P.C.	Unstandardised Path Coeff.				Std. P.C.
CEM			**Est.**	**S.E.**	**C.R.**	**p**	**Est.**	**Est.**	**S.E.**	**C.R.**	**p**	**Est.**
DDSet	<---	DSR	1.000				0.767	1				0.961
Pricing	<---	DSR	1.036	0.312	3.320	***	0.690	0.742	0.272	2.73	0.006	0.745
IntCoord	<---	DSR	0.845	0.301	2.804	0.005	0.604	0.444	0.251	1.77	0.077	0.489[‡]
ExtCoord	<---	DSR	0.798	0.314	2.543	0.011	0.545	0.855	0.228	3.745	***	0.687
CEM	<---	USE	1.000				1.000	1.000				1.000
Econ_asp	<---	PERF	1.000				1.007[a]	1.000				0.904
Prod_asp	<---	PERF	0.793	0.18	4.397	***	0.71	1.156	0.51	2.265	0.024	0.748
CEM-ATP			**Est.**	**S.E.**	**C.R.**	**p**	**Est.**	**Est.**	**S.E.**	**C.R.**	**p**	**Est.**
DDSet	<---	DSR	1.000				0.756	1.000				0.874
Pricing	<---	DSR	0.989	0.314	3.151	0.002	0.648	0.862	0.219	3.932	***	0.786
IntCoord	<---	DSR	0.843	0.305	2.767	0.006	0.594	0.648	0.326	1.984	0.047	0.648
ExtCoord	<---	DSR	0.903	0.328	2.752	0.006	0.608	0.862	0.282	3.061	0.002	0.629
ATP	<---	USE	1.000				1.000	1.000				1.000
Econ_asp	<---	PERF	1.000				0.92	1.000				1.002
Prod_asp	<---	PERF	0.952	0.217	4.38	***	0.778	0.941	0.335	2.808	0.005	0.675
CEM-CTP			**Est.**	**S.E.**	**C.R.**	**p**	**Est.**	**Est.**	**S.E.**	**C.R.**	**p**	**Est.**
DDSet	<---	DSR	1.000				0.797	1.000				0.924
Pricing	<---	DSR	0.919	0.285	3.225	0.001	0.636	0.809	0.225	3.59	***	0.781
IntCoord	<---	DSR	0.767	0.272	2.822	0.005	0.57	0.511	0.237	2.156	0.031	0.541
ExtCoord	<---	DSR	0.809	0.293	2.763	0.006	0.574	0.871	0.243	3.589	***	0.673
CTP	<---	USE	1.000				1.000	1.000				1.000
Econ_asp	<---	PERF	1.000				0.92	1.000				0.939
Prod_asp	<---	PERF	0.95	0.215	4.422	***	0.777	1.072	0.354	3.029	0.002	0.721
CEM-PLM			**Est.**	**S.E.**	**C.R.**	**p**	**Est.**	**Est.**	**S.E.**	**C.R.**	**p**	**Est.**
DDSet	<---	DSR	1.000				0.727	1.000				0.908
Pricing	<---	DSR	1.018	0.333	3.054	0.002	0.642	0.84	0.201	4.182	***	0.797
IntCoord	<---	DSR	0.96	0.337	2.852	0.004	0.651	0.527	0.218	2.419	0.016	0.548
ExtCoord	<---	DSR	0.937	0.34	2.757	0.006	0.606	0.887	0.25	3.55	***	0.674
PLM	<---	USE	1.000				1.000	1.000				1.000
Econ_asp	<---	PERF	1.000				0.931	1.000				0.978
Prod_asp	<---	PERF	0.929	0.212	4.385	***	0.769	0.987	0.298	3.31	***	0.692
D&E-PC			**Est.**	**S.E.**	**C.R.**	**p**	**Est.**	**Est.**	**S.E.**	**C.R.**	**p**	**Est.**
DocArch	<---	DSR	1.000				0.748	1.000				0.329
Int_Coord	<---	DSR	0.7	0.215	3.253	0.001	0.827	1.307	0.808	1.618	0.106	0.523[‡‡]
Ext_Coord	<---	DSR	1.029	0.335	3.07	0.002	0.718	0.839	0.604	1.389	0.165	0.314[‡‡]
Flex	<---	DSR	0.896	0.339	2.645	0.008	0.604	4.049	2.899	1.397	0.162	1.208[‡‡] [a]
PC	<---	USE	1.000				1.000	1.000				1.000
Prod_de	<---	PERF	1.000				0.876	1.000				1.855[a]
Tech_prod	<---	PERF	1.073	0.261	4.108	***	1.035[a]	0.051	0.242	0.209	0.835	0.115[‡‡]
D&E-PLM			**Est.**	**S.E.**	**C.R.**	**p**	**Est.**	**Est.**	**S.E.**	**C.R.**	**p**	**Est.**
DocArch	<---	DSR	1.000				0.702	1.000				0.356
Int_Coord	<---	DSR	0.768	0.225	3.417	***	0.852	1.21	0.654	1.852	0.064	0.523[‡‡]
Ext_Coord	<---	DSR	1.094	0.355	3.08	0.002	0.717	0.496	0.465	1.068	0.286	0.201[‡‡]
Flex	<---	DSR	1.015	0.357	2.841	0.004	0.642	3.831	2.313	1.656	0.098	1.234[‡‡] [a]
PLM	<---	USE	1.000				1.000	1.000				1.000
Prod_de	<---	PERF	1.000				0.643	1.000				1.577[a]
Tech_prod	<---	PERF	1.996	1.722	1.159	0.247	1.411[a]	0.07	0.232	0.301	0.764	0.136[‡‡]

OE-APS			MTO Sample Parameter Estimation: Unstandardised Path Coeff. Est.	S.E.	C.R.	p	Std. P.C. Est.	MTS Sample Parameter Estimation: Unstandardised Path Coeff. Est.	S.E.	C.R.	p	Std. P.C. Est.
USE	<---	DSR	0.109	0.451	0.242	0.809	0.073					
PERF	<---	USE	0.603	0.203	2.977	0.003	0.553					
PERF	<---	DSR	-0.283	0.363	-0.778	0.437	-0.174					
ConfOR	<---	DSR	1.000				0.715	1.000				0.423
AggPlan	<---	DSR	0.832	0.567	1.468	0.142	0.786‡‡	1.865	1.616	1.154	0.248	1.105‡‡ [a]
OpPlan	<---	DSR	0.541	0.344	1.57	0.116	0.534‡‡	1.259	0.783	1.609	0.108	0.553‡‡
APS	<---	USE	1.000				1.000	1.000				1.000
Imp PP	<---	PERF	1.000				1.019 [a]	1.000				0.977
DD met	<---	PERF	0.926	0.079	11.683	***	0.961	0.934	0.137	6.797	***	0.931

OE- ERP/MRP			Est.	S.E.	C.R.	p	Est.
ConfOR	<---	DSR	1.000				0.869
AggPlan	<---	DSR	0.519	0.16	3.241	0.001	0.595
OpPlan	<---	DSR	0.415	0.177	2.349	0.019	0.498‡
MRP	<---	USE	1.000				0.649
ERP	<---	USE	1.811	0.469	3.861	***	1.037 [a]
Imp PP	<---	PERF	1.000				1.153 [a]
DD met	<---	PERF	0.664	0.115	5.779	***	0.795

CRM			Est.	S.E.	C.R.	p	Est.	Est.	S.E.	C.R.	p	Est.
CustDB	<---	DSR	1				0.745	1				0.918
N4Rel	<---	DSR	0.526	0.192	2.744	0.006	0.738	0.648	0.169	3.838	***	0.829
CRM	<---	USE	1.000				1.000	1.000				1.000
Statis	<---	PERF	1.000				1.007 [a]	1.000				0.979
NewCust	<---	PERF	0.899	0.095	9.465	***	0.931	1.07	0.153	6.976	***	0.918
Prof_CRM	<---	PERF	0.412	0.227	1.82	0.069	0.392‡	0.844	0.178	4.733	***	0.776

SCM			Est.	S.E.	C.R.	p	Est.	Est.	S.E.	C.R.	p	Est.
SCCoo	<---	DSR	1.000				0.729	1.000				0.527
Proc	<---	DSR	0.773	0.491	1.573	0.116	0.4‡‡	2.101	1.635	1.285	0.199	1.156‡‡ [a]
Compat	<---	DSR	0.7	0.524	1.336	0.182	0.35‡‡	0.9	0.674	1.335	0.182	0.299‡‡
C71	<---	USE	1.000				0.778	1.000				0.475
C72	<---	USE	1.47	0.376	3.913	***	1.12 [a]	2.769	2.278	1.216	0.224	1.254‡‡ [a]
Imp_OM	<---	PERF	1.000				0.709	1.000				0.807
Prof_SCM	<---	PERF	0.95	0.309	3.08	0.002	0.663	0.947	0.3	3.158	0.002	0.806

All of the path coefficients estimates above are statistically significant at 0.01 level ($p < 0.01$) except: ‡ not significant at 0.05 level ($p < 0.05$) and ‡‡ not significant at 0.10 level ($p > 0.10$).

[a] These standardised path coefficients (also called path loadings) are greater than 1.0, which is not necessarily problematic (see Alwin, 1988, pp. 15-45; Jöreskog, 1999). By a standardised coefficient it is meant any estimated coefficient in a structural relationship in a *completely standardised solution*. For a standardised solution, the latent variables are rescaled such that the sum of the weighted average of the variances (by the group sample size) are equal to 1. The loading for each group is the product of the within-group standardised path coefficient and the square of the Standard Error (S.E. as above). Thus, even if all coefficients are less than 1 for each single group in the within standardised solution, there is no guarantee that the standardised path coefficients are less than 1.0.

Comparison of Model Fit and Causal Link Significance between MTO and MTS responses

		χ^2 (df)	p	CFI	RMSEA	(1) DSR → Use			(2) Use → Perf.			(3) DSR → Perf.		
						Est.	S.E.[a]	C.R.[b]	Est.	S.E.[a]	C.R.[b]	Est.	S.E.[a]	C.R.[b]
CEM	MTO	15.433 (12)	0.22	0.96	0.11	0.54*	0.33	2.55	0.44**	0.16	3.08	0.59***	0.31	3.31
	MTS	28.964 (12)	0.00	0.76	0.27	0.24	0.19	1.06	0.08	0.21	0.27	0.85*	0.22	2.48
CEM-ATP	MTO	13.702 (12)	0.32	0.97	0.74	0.56*	0.49	2.35	-0.07	0.17	-0.32	0.96**	0.47	3.19
	MTS	34.375 (12)	0.00	0.72	0.31	-0.24	0.44	-0.90	0.28	0.08	1.68	0.92**	0.22	3.22
CEM-CTP	MTO	11.799 (12)	0.46	1.00	0.00	0.57**	0.40	2.70	-0.11	0.17	-0.52	0.98***	0.42	3.52
	MTS	25.325 (12)	0.01	0.80	0.24	-0.07	0.41	-0.28	0.14	0.06	0.88	0.88***	0.16	3.85
CEM-PLM	MTO	17.657 (12)	0.13	0.91	0.14	0.29	0.47	1.17	-0.31	0.16	-1.75	0.99***	0.45	3.67
	MTS	21.666 (12)	0.04	0.86	0.20	-0.19	0.26	-0.80	0.34*	0.09	2.55	0.91***	0.13	4.96
D&E-PC	MTO	19.801 (12)	0.07	0.91	0.16	-0.28	0.38	-1.26	-0.18	0.14	-0.95	-0.46	0.33	-1.73
	MTS	7.548 (12)	0.82	1.00	0.00	0.15	0.69	0.82	0.07	0.09	0.81	0.30	0.70	1.67
D&E-PLM	MTO	17.002 (12)	0.15	0.94	0.13	0.31	0.37	1.40	-0.24	0.19	-0.77	0.23	0.34	0.64
	MTS	17.102 (12)	0.15	0.86	0.14	0.29	0.57	1.43	-0.07	0.13	-0.66	0.37*	0.58	1.99
PP- ERP	MTO	12.529 (11)	0.33	0.99	0.07	0.38	0.18	1.61	0.69***	0.36	3.52	-0.50***	0.19	-3.63
	MTS	-	-	-	-	-	-	-	-	-	-	-	-	-
PP- APS	MTO	5.514 (7)	0.60	1.00	0.00	0.07	0.45	0.24	0.55**	0.20	2.98	-0.17	0.36	-0.78
	MTS	10.304 (7)	0.17	0.93	0.17	0.18	0.99	0.63	0.82***	0.14	4.73	-0.12	0.62	-0.56
CRM	MTO	8.297 (7)	0.31	0.98	0.10	0.65*	0.39	2.43	0.30	0.25	1.20	0.61	0.47	1.85
	MTS	29.261 (7)	0.00	0.76	0.41	0.59	0.23	2.49	0.12	0.23	0.48	0.59*	0.25	2.22
SCM	MTO	22.849 (11)	0.02	0.84	0.23	0.55	0.73	1.33	0.17	0.39	0.40	1.10	1.03	1.77
	MTS	17.281 (11)	0.10	0.83	0.18	0.17	0.32	0.71	0.54*	0.42	1.97	0.30	0.50	1.20

[a] S.E. is an estimate of the std error of the covariance.; [b] C.R. is the critical ratio obtained by dividing the covariance estimate by its std error.
* Significant at the 0.05 level (critical value = 1.96); **significant at the 0.01 level (c.v. = 2.58); ***significant at the 0.001 level (c.v. = 3.29).

Appendix 12: Case Study Protocol

A. THE PURPOSE

Case Study topics and research questions:

Selected Topics	Research questions
XR1. Difficulty of selecting the most appropriate system	**RQ1.a:** *Why do MTO companies find system selection difficult?* **RQ1.b:** *Which stage was the hardest?* **RQ1.c:** *How can MTO companies successfully select their systems?*
XR3. ERP vendors	**RQ2.a**: *How did the small-sized local vendor dominate the SME market in the UK?* **RQ2.b:** *What factors affect the choice of package for SMEs?*
XR5. Reason to adopt ERP	**RQ3:** *Why do MTO companies adopt ERP systems?*
XR6. Reason not to adopt ERP	**RQ4.a:** *How could non-adopter MTO companies come to know that ERP would not suit their needs?* **RQ4.b:** *How do they compensate for those needs?*
XN1. The Customer Enquiry Management Model	**RQ5.a:** *Why can MTO companies not benefit from the planning tools of ERP and its extensions?* **RQ5.b:** *How can ERP CEM tools (for automation, coordination and standardisation) help MTO companies?*

XR: Topics from the exploratory results; **XN:** Topics from the explanatory results

B. DATA COLLECTION

Summary of data collection procedures for the case sites:

Case	Date	Time & Length	Interviewee	Interviewers
MU_1	3rd Dec, 2010	10.30 – 12.50 (2hrs & 20 min)	Managing Director (30 years)	Dr Mark Stevenson & Bulut Aslan
MU_2	13th Dec, 2010	14.00 – 15.20 (1hr & 20 min)	Operations/IT Manager (15 years)	Bulut Aslan
MNU	10th Dec, 2010	11.00 – 12.20 (1hr & 20 min)	Managing Director (34 years)	Prof Linda Hendry & Bulut Aslan

Preparation: Survey responses and website content of each case were reviewed before data collection.

Data collection: No particular problems were faced during the data collection. For convenience, the question sheets were provided to managers in advance. They answered all the questions in detail and provided more information when spontaneous questions were asked. For better understanding of the company facts, the facilities were toured by the managers after the interviews.

C. CASE STUDY QUESTIONS

1) Structured Interview Guide for Adopter

Section 1: Background Information

Basic Company Details

- Can you confirm how many people work for the company?
- What is the annual turnover of the company?
- What industries is the company involved in?
- Who are the company's major customers?
- Who are the company's main competitors?

Basic Job Information

- Can you give some examples of typical products the company makes?
- Are most products made from the same materials? Do you stock materials?
- Are there any common components?
- What proportion of orders are new, and what proportion are repeat jobs?
- How much of production is make-to-stock?

ERP environment

- Please complete the ERP adoption Timeline:

Began ERP planning	Began ERP Installation	Go "live"
Month:	Month:	Month:
Year:	Year:	Year:

- Which business units were impacted by your ERP system? [Enterprise-wide, Division/Group/Department, a Business Unit within a Division/Group/Department]
- Why did you decide to adopt a rentable system? [cost effective, less risky]
- What is the estimated useful life for the ERP project? [<3, 3-5, 5-7, 7-10, >10]

Section 2: "Why?" Questions on ADOPTION

- Why did you adopt ERP? [What particularly made your company start thinking about adoption?]
- Who primarily influenced that decision? [And in what way?]
- Why do you primarily show "Integration" and "Standardisation/Simplification of business processes" as the reasons for ERP adoption?
- In general, how has the adoption of an ERP system affected your competitive position? [Pros & cons]
- Did you replace your legacy system? Why did you decide to replace it (rather than update it)?
- Your survey responses indicated that integration with customers and suppliers was not a key driver for ERP adoption. Can you comment on why this is the case?

Section 3: "Why?" and "How?" Questions on SELECTION

- Why did you find selecting a system difficult for your company?
- Please describe how you went about selecting your ERP system. [Rentable software chosen]

- Which stage was the hardest during the selection process? [e.g., Plan, Identify, Evaluate, Select]
- Did you assign any consultants to conduct the selection process or did you do it by yourself? [If so, how?]

<u>Section 4: "How?" & "What?" Questions on DAY-to-DAY USAGE (DSR *vs.* ERP Use)</u>

Customer Enquiries

- Please describe how you deal with requests for quotations (customer enquiries).
- How does ERP support planning at this stage?
- Do you use it to determine prices & set due dates?
    - If yes, to what extent do you use it?
    - If no, why not?
    - What functionalities would you like your system to provide you with?
- Have you considered using ATP and CTP mechanisms, or the PLM add-on for CEM planning?
    - If yes, how did this enable you to cope with planning?
    - If no, why not?
- What effects have these had on performance?
- Has ERP enabled you to automate the management of customer enquiries?
- Considering that your company has high DSRs and low use of ERP planning tools at this stage, why do you think your CEM planning performance is high? (e.g., strike rate)

Design and Engineering

- Which software do you use for the design & engineering of your products?
- How flexible is your design and engineering software for handling your product diversity?
- How can ERP enable you to cope with design and engineering tasks?

Production Planning

- How do you currently plan and schedule your production? [e.g., ERP, MS Excel, other]
- How did you plan production before ERP?
- At which particular production planning stage has your ERP system been most effective?
- Do you have a decision point after planning but before manufacturing commences at which you determine which jobs to "release" (i.e., begin manufacturing)?
    - If yes, how do you deal with it? Do you get software support for this?
    - If no, do you think you may need such a decision point?

Shop Floor/Dispatching

- Do you need complex tools to deal with shop floor sequencing?

General

- Do you use your ERP software for any other purposes than those covered in our questions?
- If so, then for what, and what benefits have you gained from this (e.g., CRM and SCM)?

2) Structured Interview Guide for Non-Adopter

<u>Section 1: Background Information</u>

Basic Company Details
- Can you confirm how many people work for the company?
- What is the annual turnover of the company?
- What industries is the company involved in?
- Who are the company's major customers?
- Who are the company's main competitors?

Basic Job Information
- Can you give some examples of typical products the company makes?
- Are most products made from the same materials? Do you stock materials?
- Are there any common components?
- What proportion of orders are new, and what proportion are repeat jobs?
- How much of production is make-to-stock?

<u>Section 2: "Why?" Questions on NON-ADOPTION</u>

- Why do you think that ERP is not suitable to your needs?
    - What made you think that?
        - Evaluation analysis results?
        - Your insight?
        - Experience of managers/directors with other systems in other firms?
- Have you considered using packages other than ERP?
- If not using any software, how do you cope with managing the information flow, managing project-based jobs or planning production in your company?

<u>Section 3: "How?" and "What?" Questions on DAY-to-DAY production</u>

Customer Enquiries
- Please describe how you deal with requests for quotations (customer enquiries).
    - How do you determine prices & set due dates?

<u>Due date</u>:
- How do you generate alternative due dates when dealing with customer enquiries?
- To what extent are you aware of the availability of subcontractors and suppliers when promising due dates to customers?
- Why do you think access to historical data is not that important on quoting due dates?

<u>Cost</u>:
- How detailed is your analysis of costs when responding to a request for quotation? Which tools do you use for this?
- How do you maintain a good communication amongst departments when responding to customer enquiries?

- Have you considered using packages other than ERP for Customer Enquiry Management (CEM) planning?
    - If yes, how did this enable you to cope with CEM planning? & What effects have these had on performance?
    - If no, why not?
- Can you confirm what the strike rate (percentage of quotations converted into confirmed orders) of your company is?
- What functionality would help you improve your strike rate?

Design and Engineering
[Reported quite high decision support requirements in the survey for the design & engineering of your products.]
- Which software do you use for the design & engineering of your products?
- How flexible is your design and engineering software for handling your product diversity?
- How do you maintain the communication amongst departments to support design and engineering tasks?

Production Planning (for you or your associated manufacturing companies)
- How do you currently plan and schedule your production? [e.g., MS Excel, other]
    - At which particular production planning stage has your current planning method been most effective?
- Have you considered using packages other than ERP for production planning?
    - If yes, how did this enable you to cope with planning?
    - If no, why not?
- Do you have a decision point after planning but before manufacturing commences at which you determine which jobs to "release" (i.e., begin manufacturing)?
    - If yes, how do you deal with it? Do you get software support for this?
    - If no, do you think you may need such a decision point?
- Do you need complex tools to deal with shop floor sequencing?

Customer Relationship Management (CRM) & Supply Chain Management (SCM)

- Why do you not need a tool to help you manage your relationships with existing and potential customers? [CRM]
    - Do you think CRM software would help you
        - entice first-time or one-off customers into longer & more robust relationships?
        - have more loyal customers and to build prolonged customer relationships based on trust?
    - What do you currently do to ensure these kinds of relationships?
- How do you share information with your suppliers; and otherwise co-ordinate your activities with theirs? [SCM]

Appendix 13: Case Data Display Summary Tables

Section 1.a: Company Background Information		
Key people	Managing Director (MD, 30 years), Manufacturing Manager (20 years), IT Coordinator/Purchasing Manager (13 years)	
No. of Employees	**24** people at MU_1, There are sister companies employing: **8** in the Northeast; **15** in Poland (approx); and, **2** in Florida.	
Annual turnover	**£1.8 million**	
Industrial sector	Textile	
Typical products	Laundry (£1m)	Filtration (**£0.8**m)
	• Commercial & hospital laundry products, bags and hampers. • Generally Make-To-Order (MTO), Make-To-Stock (MTS) finished goods only.	• Woven or non-woven fabrics, surface treatments & membranes. • High value, **high margin**, fast response products • **Fast response** needed; orders are typically dispatched within 2-10 days.
Customers	Commercial & hospital **laundries**	Customers are the **UK process industries** (e.g., food, paper, pharmaceuticals, minerals, and chemical)
Competitors	3-4 competitors only serving the UK market	Several competitors
Materials & Common components	• **Procured** from the Far-east, **produced** in another factory in Poland and **sold** from stock. • **Little manufacturing**, e.g., logos applied.	• **Make-To-Order** (MTO) products. • Many different **raw materials stocked** in large amounts • **8 different product lines** exist, with lots of variation; very little crossing between lines.
New & repeat jobs	• **New** order: **10%**; **Repeat** orders: typically **90%**.	• **New** order: **25%**; **Repeat** orders: typically **75%**.
	The company offers 1,000 different products a year. Generally, 500 are new each year, and 500 repeat jobs (repeating for a few months). About **75% of the turnover** is from **repeat** products.	
Proportion of MTS products	• None: Laundry products come from suppliers; filtration products are made-to-order in MU_1. • No Make-to-stock in the UK; but in Poland.	

Section 1.b: ERP Environment			
ERP Adoption timeline	Began ERP planning: Searching for a solution between 2005-7 The developer of bespoke system (developed in **VisualFoxPro**) became seriously ill, MU_1 began to look for an off-the-shelf replacement solution & decided on **123Insight**.	Began ERP installation: Late 2007 (very gradually installed) **Data extraction** from the old system was a serious **problem**. Data transfer achieved in Jan 2008 manually from old system into 123insight by cleaning up.	Going 'live': Jan 2008 The company has about **10 licenses** for 123Insight in the UK (and 2 computers can run the Priority List).
Installed units	The **123insight** system is used in MU_1 **only**. There are no plans at present to integrate the ERP software with the operations in **Poland**. The **old MRP system** is used there separately – it still runs OK but still not fully utilised. Mainly the language barriers, secondarily the extra user and license costs are the reasons for this separate use of systems. Information is shared remotely via the Internet. **Northeast** uses the **SAGE Line 50** Manufacturing system. **Florida** has a **purely manual** system. They serve a specific customer regularly & it is a small operation with just 2 people.		
ROI analysis	**No analysis** made. ERP is treated as an annual cost, and MU_1 believes they can drop it at any time because they have rent it. However, they would not want to unless something went wrong with it or 123insight quadrupled the rental price. The system costs MU_1 **£10,000 a year** more than they used to spend (only paid the developer for DB before). MD cannot clearly see the impact on the bottom line, thinks that MU_1 can run the business probably with one person less now.		
Estimated lifetime	**No analysis** made. MU_1 imagines the system can hold on **well over five years**. The company's **planning horizon** is 5 to 7 years. The system is thought to take them as far as that.		
Why use a rentable system?	**Low risk:** Renting was a lower risk strategy than spending thousands of pounds on something that could not be 'given back'. Unsatisfactory experience for a short-period use of this system would cost significantly less than a fully implemented but irreversible investment. "*Business is about managing risk, and this is a very low-risk strategy.*" **Cost effective**: 123insight do all the **initial training and evaluation for free**. Once the decision is made, the outlay is low. The biggest outlay for MU_1 was the time & effort of the people learning it, getting the system and then putting the data in. Currently MU_1 is getting some benefits and learning to better manage ourselves with the system. £10,000 a year spent and with MU_1 saving one person, **it's paying for itself**. **Flexible:** MU_1 wanted to make sure it has had their desired features and benefits. Since then 123insight also developed a CRM because of the demands of other users. MU_1 also wanted to link it to a CRM system.		

Section 2: Questions on ADOPTION	
Reason to adopt ERP	The primary reason was that the developer of the legacy system became ill… it was basic but costing MU_1 nothing. **Planning is the major reason.** Certain customers have price lists, or buy standard systems that we could automate. The main reason we want MRP is the planning bit. It's being able to run that part of the business with as small a number of people as possible; because as soon as you get more people, there has to be more communication. It'd be best to have one person to spend less time on communication.
Who influenced that decision?	The motivation has largely come **from inside the business**. MU_1 get **very little external pressure** from customers. As long as MU_1 make things at a reasonable cost and deliver on time, they are not concerned about how this is achieved. "*Our customers do not insist on us using ERP or having ISO 9000*".
Why "Integration" & "Standardisation/ Simplification" as the primary reason for ERP adoption?	**Updated concurrent information**: People need to know what is going on and why. Integration is important so that everybody has the same information. MU_1 want to try and get away from paper-based records as much as possible. **Need for communication**: Using **standardised form** is considered as one of the best ways to do it to improve the communication between sales and other units taking part in the flow of job. "*Getting sales to get the message properly from the customer and pass that message over correctly so that the manufacturing understands is the key.*"
Effect of ERP adoption on company's competitive position	Advantage: **Data is more visible now**. It used to be such that we were not aware of where a job was on the shop floor. Manufacturing staff had to walk down and find it. Now, because we've got shop floor data capture, they can actually see where a job stands. They don't have to ask anybody. Disadvantage: **Customisation is hard to afford**. Developer tends to charge additionally since feature not demanded by its customers. Since the legacy period, MU_1 has been using a list jobs (delivery dates, quantities, customers, etc) which they could use to prioritise orders. They asked the provider to develop a piece of solution but they declined, given that no other customers had requested it. Therefore, MU_1 asked another company to develop the solution – although it was a small piece of development work, it ended up costing them several thousand pounds and is not as well integrated with the core system as they had hoped.

Section 3: Questions on SELECTION	
Why find it difficult to select a system?	Being a **small company** and **not employing experts on** computer software, the selection process was **difficult** for MU_1 from planning the selection process to choosing the provider, except identifying the needs. The most important criterion for MU_1 was **minimising the risk** because they already had a working yet unsustainable system. The risk was "*in putting everything into the new system and it not working*". So, they spent plenty of time (from 2005 until 2007) on selection. MD thinks this could have taken a lot more time because the legacy system is still working [in Poland].
Looking for an ERP system	**Search:** Spoken to a couple of people, searched the web, attended exhibitions, trade-fairs, etc. **Site Visits:** Had hoped to visit other users of 123Insight software but this was difficult to arrange as other companies were reluctant to share information or demonstrate how they performed processes. "*Accountants talk to each other and perhaps they can talk about the systems that they've got. But we cannot do that.*" The vendor also didn't encourage them to visit other users because there were not many users really happy about it being used as a ref site.
Identifying the needs	MU_1 have **already determined** what their requirements are through the old system. "*We knew what we wanted because we had our own system beforehand. So, defining what we wanted was quite easy.*'"
Choosing the provider: The hardest stage during the selection process	**The risk:** 123insight offered a flexible payment plan. "G*etting the wrong system is a business threatening decision*". **Matter of trust:** "*Lots of vendors told us things that they thought we wanted to hear ... you don't know who to trust ... and there are lots of high-profile examples of companies buying systems that don't work*". MU_1 identified many firms having systems unlike what they needed. The difficulty was **the issue of trust**. MD describes trust as something develops slowly over a long period of time. "*This is a one-off big decision, like [instantly] choosing with whom you're going to marry*!" **Unsuccessful stories:** MU_1 managers have spoken to quite a few people and heard a number of stories about companies buying computer systems that do not function or work at all. "*Lots of large organisations spending masses of money ending up with something that does not do what it is supposed to do*." MU_1 also found **an alternative system** that looked extremely good to them. Carrying on the vendor search, MU_1 decided to go with 123insight, but they had also heard some unsuccessful stories with this other vendor. "*You are making a large capital purchase, and there's no certain guarantee about it*." Their other business in the Northeast also has a manufacturing system [SAGE Line 50 Manufacturing] up there which is not working properly - they've had it for years.
Consultancy during selection	**Not used.** MU_1 thinks that the consultancy also involves a matter of trust. The issues raise on choosing a consultant are the same as the issues on choosing a provider.

Section 4: Questions on Day-to-Day Usage (DSR vs. ERP Use)	
	Customer Enquiry Management (CEM)
Due date setting and pricing	**Easy for existent products.** MU_1 can just interrogate the system very quickly to answer questions like 'how we get the materials to make this', 'what's the lead time', 'what's the schedule like', etc. **Very tricky for new products.** MU_1 tends to build up a "mock casting structure" for both laundry and filtration products in the system as something to be their 'best guess'. They find the system quite flexible to achieve that. **Activity-Based Costing** (ABC) is used for cost estimation. It gives MU_1 an idea of a new item's cost to the company and the margin to go ahead. The company also use some pricelists for simple, common or repeat items, yet a mock structure is typically built. It is especially considered important for **recovery of high overhead cost** (40%). "*Having not been able to use the ABC system we would not have chosen it.*"
ERP support at the CEM stage	**Info from the system is used in an overall way:** MU_1 uses the system to get an overview. The software informs decision making but it is not exactly followed in due date decisions. The information is used by people to make their own decisions. "*The system gives a helicopter view of what else is going on in the business.*" **Inventory level anticipation**. Delivery lead-times of some of the fabrics are greater than MU_1's finished product lead time. For such complex repeat items (e.g., also with 8-10 different raw materials), the system is used to manage the inventory. "*What it would do is to tell us whether we can hit what we want*". **To see bottlenecks and capacity usage:** Having the overview, the system warns MU_1 people against forthcoming overloads on certain machines, so that they react before the situation occurs. They find this feature helpful which they did not have in the legacy system.
What functionalities would you like your sys to provide you?	**Usability** and **information overload**. MU_1 thinks that the system gives them plenty of information. Generally, more and complex than the user staff could interpret. Though two staff has been trained and mainly use the system, understanding the information could still be a problem.
Have you considered ATP/CTP mechanisms or the PLM add-on?	**Not at all.** MU_1 thinks that those would be useful in a very rigidly controlled environment, where certain process lines exist and the flexibility is limited. MU_1 has got this fast flexibility inside the company, and also by the support of 'sister companies'. "*We survive on being flexible and adaptable*"

Has ERP enabled you to automate the management of customer enquiries?	**Automation of CEM processes is low**. MU_1 cannot use ERP to automate customer enquiries – it was noted that the products are to customer specification so it is not a case of having an online catalogue of standard products from which a customer can select, choose a delivery date and pay – each individually order has to be considered, priced and the lead time determined. This involves interaction, negotiation, consideration in-house between manufacturing and sales, design, etc. "*We are not Amazon – we don't have an online catalogue*".
Company has high Decision Support Requirements, & low use of ERP planning tools at CEM stage, so why do you think your CEM planning performance is high?	**Sales staff** is considered more important than system usage at the CEM stage. "*If selling was a systemised thing, you can get anyone to do it, then they can do it. But it's not! A lot of it is about understanding the business, the customer's needs and what the customer would pay.*" **Strike rate**. The system has not helped improve strike rate, but a better coordination of suppliers is achieved. **Human factor**. The important thing with the ERP system is that it processes and provides you the data. But I would say it's more important the skills of the individual sales people. "*You cannot rely on the system to do things. The people are more important.*"
	Design and Engineering (D&E)
Which software do you use for the D&E of your products? If separate, is it integrated to your ERP?	**MS Publish & Excel**. MU_1 use MS Publish to create simple drawings of products, and series of spreadsheets to define how to make these products. **AUTOCAD**. For the computer-controlled laser cutter only the AUTOCAD software is used. **Integration**. The separate software are not integrated but linked to each other as relevant design files are saved in the part number of the product on the system. This enables quick access and keeps the files organised inside the ERP system. Namely, Publisher and Excel files are stored but not the AUTOCAD ones because not they are only relevant to its particular machine, and the files unnecessarily increase the back up on the system.
Have you considered using add-ons for design and engineering?	**Product configurator**. MU_1 believes they could also configure items through MRP, but they do not tend to use sub-assemblies (i.e., Bill-of-Material structure). **Engineering activities are low**. MU_1 defines itself as not heavily engineering driven, so they find the available software easily enough for themselves.
How flexible is your design software?	MU_1 is happy with the flexibility and the options that the separate systems permit in design.

	Production Planning
How do you plan production?	**Priority list** is the key part of production planning. It is also the main reason for MU_1 to go for a very first computer system. It is used to list things to be made in the next determined number of weeks. The jobs are sorted in date & priority order. From the planning part of the system, Kath, the manufacturing manager, allocates work on the basis of her experience and the priority list. **No discrete scheduling**. MU_1 does not feel the need more than a priority list because they have got such an amount of flexibility for moving the people around. **Rush orders.** The priority always changes, so the **bottlenecks** due to rush orders. MU_1 does not consider itself an efficiency-driven company. They are interested in how efficient they are but that is not what drives the business.
Production planning before ERP	**The priority list technique was still applied before 123insight**. There's not a big change on the planning side. The priority list system is also very similar, and MU_1 gets around 95% on time delivery. **Principles formed through Experience**. We've got certain principles. We know the cutters have to be a week ahead as a general rule. Because we see the big job coming through, the planning date highlights the big jobs that are in the bottleneck. We already know that particular attention is made.
Planning stage at which ERP has been most effective	The critical role for the ERP system is **keeping the data up-to-date.** 123insight is thought to be better at giving MU_1 visibility and warnings on supply needs. It's also considered to be easier to pull information for material requirements. The system helps manage the suppliers better; gives an **online overview of the capacity use** on planning.
Order Release	**No such point**. The jobs are immediately released and prioritised together with the actual orders on the shop floor. "*The system would have to be extremely sophisticated to help us with this*".
Shop Floor/Dispatching	**No need for complex tools**. MU_1 uses the skills of people for scheduling. The priority list also helps them think broadly. Most jobs have a very **short lead time** on the shop floor. **Training on scheduling**. Sometimes training is given to have them think about and understand planning and scheduling, to cope with bottlenecks. "*Planning is a big thing to us. We're always trying to make planning better.* " **WIP policy.** MU_1 doesn't encourage big piles of work on the shop floor to keep WIP to a minimum but they encourage flexibility. "*There's a skill to recognising a bottleneck and doing something about it.*"

	General (Other uses of ERP software)
Accounting & Financial Control	**Accounting & Financial Control modules**. MU_1 chosen not to have these modules but decided to use the legacy for them. They show two reasons for that: (1) **high price** of the seamlessly integrated software (£400-500 per month for two more licences) and (2) **convenience** and **independence** of their old system (SAGE Line 50), which is used by half of the small firms in the UK. MU_1's accounts people deliberately wanted to stay disconnected so not to cope with people putting in wrong data. So the company uses them side-by-side.
Supply Chain Management (SCM)	**Not using SCM.** The supplier purchasing side was the part which had a lot of manual entry with the previous system. This system has one person who can do all purchasing, manage raw material and deal with stocks. And that helped usually. If you had two people, the communication may become a problem. So, it's not really supply chain. We have a lot of suppliers and have to understand them, and we work with very simple minimum stocks. We know what sorts of lead times are involved. We just have to deal with it and manage it properly. It's the time saving with one person. One person can do the work very quickly. The struggle would be when we grow and we need two people again.
Customer Relationship Management (CRM)	**An add-on built by the demands of 123insight users:** Half of the 123insight customers asked for a CRM solution, and the vendor developed one. However, the concept of CRM has been interpreted differently than the conventional view and developed accordingly by 123insight (described below). **Employee job assignment**: The CRM add-on and its functionalities are redefined by 123insight. It helps MU_1 manage a complex enquiry in terms of human resource coordination. A new business is explained to require at least one person for design, production, materials management, and planning of the job. In that case, the particular CRM function enables to be able to put people have tasks, saying where they are up to, and still what to be done. "*These don't get lost in the system as much as they used to do*." This information is consistent with the defined main functionality of CRM by 123insight. **CRM for repeat and new business.** MU_1 thinks that CRM makes repeat business easy because you have all the records, everything is automatically updated. But it is also important for new business, because it makes you go through the discipline of following a set series of steps. The important thing for us with new business is that, because we are making such a wide variety of products, when we get something new it's very difficult to assess how much this product cost us to make. Somebody comes up with something, but there are different opinions in terms of what is the best way of doing this. CRM allows MU_1 to analyse how much it cost to make the product and whether, if they do it again, whether they should charge the same price or higher.

Comparison of the new and the old	**The Legacy System.** MU_1 started with a computer system back in the late 1980s with a little database. It was originally developed to create priority lists and some other functions are gradually added onto the database. At some point in time it became obsolete, unsupported and redundant at. **On-time delivery** has been pretty good (90-95%), and it's slightly better since MU_1 have adopted ERP. MU_1 believes this is due to a better control over the environment (e.g., better management of suppliers). **It's not been a dramatic improvement** between the new and the old systems. The legacy was better in one or two ways which was tailor-made to MU_1 needs. Yet, there were some big holes in other places before, being not extremely important to MU_1. 123insight helped to cover one or two of them. **Visibility.** The way MU_1 use the system is to get an idea of the big picture and MU_1 people behave in that way. The legacy was unable to provide anticipation against coming problems like bottlenecks, and so on. But having the overview the system warns MU_1 managers to get ahead before that time. **Lead time estimation**. The system helps the MU_1 managers capture live data to estimate lead time for new orders by accessing previous orders. They were not able to do such estimations efficiently with the legacy system to understand whether that new business is good. They can get immediate quality feedback through 123insight functions called "Shop floor data capture", and "Reporting back on job costing" to consider an order in terms of cost and timing. **New features**. There are a lot of features that MU_1 don't use which are thought to be already far more complex than DRM's needs. Because it's a system designed for a 'broad base', DRM may find something interesting to use.

Company: MU_2

Section 1.a: Company Background Information	
Key people	Operations/IT Manager has been employed for 15 years.
No. of employees	**96** full-time people
Annual turnover	**£13.5m** for 2010, **£11m** for 2009
Industrial sector	Lighting Specialist
Typical products	• **Standard fittings**, **LED solutions**, **store lighting accessories** • MU_2 buy components largely and **Build-To-Order** (BTO) them in the UK. • **Contractors** are responsible for installing them on the site. • The company has a range of 30 product families and build around 1,000 different products from them.
Customers & Competitors	**High street fashion stores**, Tesco supermarkets, Debenhams, and other overseas stores are the places where the products are installed. But Microlight's main customers are the **contractors** who are appointed by these enterprises. **Philips** and **iGuzzini** are the main competitors together with a lot of other smaller companies in the business.
Materials & Common components	• Plastics, lamps, metal, bulbs, casts comprise the majority of the components • All products are assembled and finished in MU_2. • Most of the assembly work is manual, so capacity is determined mainly by the number of people rather than the number of machines. • Common components can be categorised into two types: **Pre-priority** (nuts, bolt etc.) and **Engineering components**. • The company keeps a **Vendor Managed Inventory** (VMI) for the pre-priority components.
New & repeat jobs	**New to repeat proportion is uncertain.** There is repeatability in the business, but it is said to be hard to give a proportion. A new product enters into an existing market kicking the older product out as it's cheaper or better looking.
Proportion of MTS products	With the exception of the France Telecom case, **100% products are build-to-order**. MU_2 is currently keeping a stock (of 10 different products) for France Telecom for convenience, due to frequent orders in the last two years.

Section 1.b: ERP Environment				
ERP Adoption timeline		Began ERP planning:	Began ERP installation:	Going 'live':
	Fourth Shift	1993	1993	1993-2009
		OM manager, experienced in Fourth Shift implementation, **joined** MU_2 in 1995 to fix the failures in the system which had been live for two years until then, but was having problems on software and hardware. Fourth Shift was fulfilling the needs but there was a **significant update** in 2006 and **dramatic change** in the **pricing policy**. Fourth Shift then became a legacy system for MU_2 as they decided not to accept the new pricing policy and hence not to have the updates. Thus the system was not updated after 2006; and they had no maintenance contract with Fourth Shift. Any issues that arose were subsequently compensated for by in-house developed Access or V. Basic tags. This met the needs of the company between 2006 & 2009.		
	Microsoft Navision	Sept 2009	Jan 2010	Oct 2010
		The company has been bought by **a large group**, which owns a company in China producing cheap lighting products and distributing them from Europe. MU_2 was **told to adopt MS Navision** to share a common platform across the group. This was **challenging** as Navision is not manufacturing-oriented software but valuable to the work the group does.		
Installed units	**MS Navision** is installed in the manufacturing area and other small offices whereas **Fourth Shift** was purely factory-based. The aim is to try to cooperate with the representative offices in France, Spain and UAE which is something they couldn't do with Fourth Shift.			
ROI analysis & Estimated lifetime	In Fourth Shift, probably done but it was quite a long time ago. Yet, there were no discussions or estimations on Navision.			

Section 2: Questions on ADOPTION	
Reason to adopt ERP	**Group pressure**. The group told MU_2 to move on to a new system for the Navision case. **Expansion.** For the Fourth Shift case, the company was expanding and at one stage the legacy (separate accounting and stock control systems, spreadsheets, etc) was incapable to fulfil the needs.
Who influenced that decision?	The MS Navision case is certainly by the group. Managers, 15 years ago, talked to a couple of suppliers and consulted people around them (including OM manager).

Effect of ERP adoption on competitiveness	**Customer requirements first**. MU_2 think they have lost no competitive traits as they value customer needs more than everything and react accordingly. They simply will not let a system get in front of that. Hence the ERP systems have neither helped nor hindered competitiveness.
Section 3: Questions on SELECTION	
Why was it diff. to select a system?	**No such process** happened for **Navision**. **Very difficult** is the response that OM manager had heard about during the selection of Fourth Shift.
Selection Process	In his personal experience, which was quite similar to MU_2's case in that this was also a BTO company, OM manager had a limited budget provided by the MD of his previous company to spend on a system which would replace their legacy system. He identified top ten important requirements and identified three different vendors. Fourth Shift was selected due to lower price and looking like potentially good for the company needs.
Consultancy	The **RoRo** group owns an IT company and they **assigned their Navision experts** for MU_2. They did a **gap analysis** and identified the areas for improvement. They tried to change the way Navision behaves to make it work similarly to the working principles of **Fourth Shift** for planning. **Not used for Fourth Shift**. Adoption was easily possible without consultants. This was also one of the reasons to adopt it.
Section 4: Questions on Day-to-Day Usage (DSR vs. ERP Use)	
	Customer Enquiry Management (CEM)
Due date setting and pricing	**Customer-driven due date.** MU_2 is totally customer dependent on the due date. There is no negotiation on due date if a customer needs a rush lighting instalment. Basically, MU_2 adjusts its capacity accordingly. Also, no order is rejected due to busy schedule, and **flexibility is the key** for MU_2. **Price is secondarily important.**
ERP support	**Not used at all**. Due to customer-driven needs again.
What would you like your system to provide you with at this stage?	**No need for planning support.** MU_2 defines its major resource as people. Very few simple machines are used. Unlike big bench presses, the company does not feel the need to utilise the machines as efficiently as they do for people.
Automation enabled?	There was an in-house developed MS Access tag to deal with customer enquiry automation in **Fourth Shift**. **Navision** is more capable on this functionality and MU_2 plans to implement it soon.

	Design and Engineering (D&E)
Which software do you use for the D&E of your products? If separate, is it integrated to your ERP?	**AUTOCAD Inventor** is used to design products. There is also a bolt-on called **TDM** which is a product management system for engineering documents. **Integration**. Products designed with this software, being outside of Navision or Fourth Shift, are manually transferred into the BOM structure. Nothing has changed since the Fourth shift period at this stage.
Have you considered using add-ons for design, e.g. product config.?	**Product configurator**. It is going to be added onto **Navision** very soon. It is aimed for the use of both the customers and MU_2 people. Another aim is to make the offices more independent and build their own web-based quotations.
How flexible is your design software?	**Fourth shift** required a built structure for transferring product information, whereas **Navision** is a bit **more flexible**.
	Production Planning
How do you plan production?	**MRP**. It was truly a Material Requirements Planning in Fourth Shift, but the MRP mechanism of Navision does not behave in the same way. It doesn't dynamically go through the BOM and accordingly generate system messages all the way through to inform relevant people. Obviously, the critical thing with the use of MRP is to make sure that you have the right stock at the right time. All day-to-day stock is handled outside of the MRP. With MRP, it's just dealing with a number of stocks. Although Navision does not work in this way, the primary way in which it is used is the same i.e. to plan purchases of the non-kanban items. **Kanban**. The Kanban cards deal with most of the stock issues (own supplies and consigned stock), which has been used for the last 3 to 4 years. It is **not integrated** into the ERP system.
Production planning before ERP	The legacy system had an **MRP mechanism** but since then there has been significant change in the shop floor configuration. MU_2 used to have **work benches**, where all the work was brought to the benches and people were waiting for jobs to come. It is changed to **work cell** structure each of which is for a particular product family. So, the people go to cells rather than vice versa.

PP stage at which ERP has been most effective	**Material & stock planning.** The most effective help is in the materials management due to very short lead times, that's considered to be the place to focus on. "*If it comes on time, it goes on time; and if it comes late, it goes late*".
Order Release	**No such point**. Team leader of each cell has a list of orders with finish dates. They communicate verbally or change priorities in their areas.
Shop Floor/Dispatching	**Very short lead time**. If there are no stock shortages, most of the orders take three to four hours to assemble. Managers don't necessarily plan anything but split orders into teams. The **team leaders manually schedule** all the orders.
	General (Other uses of ERP software)
Functionalities planned on the way	• **Product Configurator** is the next extension, which is planned for the near future. • Module to automate the **Customer Enquiry Management** activities. • A **Service Module** for the maintenance department to manage the servicing for the customers. • **Quality Management** is still offline at the moment to be arranged during summer time. • **R&D** is planned in the near future.
Customer Relationship Management (CRM)	CRM, that MU_2 have, is a database currently used to record names and addresses and historical information (e.g., to refer previous discussions). It is not used dynamically in a reactive way. Additionally, it is used for quality purposes at the moment which means quality related things is stored into there.

Company: MNU

Section 1: Company Background Information			
Company history	**MNU** was founded as a **British-Swedish joint venture** to serve British Steel in 1976. The company became independent in 1983, and has been owned by three different groups since then. It is currently owned by a large US group having more than 40 companies employing 8,000 people around the world. The **headquarters** of MNU is the UK site which also has responsible for a **subsidiary** in Pittsburgh which provides sales & service covering N& S America. The rest of the world is covered from the UK where 95% of its products are exported. "*The company didn't start with a viable business model but still survived through diversification.*"		
Key person	**MD** is working for the company for 34 years (since founded) started as a technical manager and is currently the Managing Director. He is also responsible for the Pittsburgh site.		
No. of Employees	**40** people at MNU UK site; **10** people in Pittsburgh Subsidiary.		
Annual turnover	**£17m** in 2009 (exceptionally the best so far, as entered the recession with a backlog of orders and lead times are quite long –from 4 months to a year. Hence effect of recession not felt until 2010.) **£10.5m** in 2010 (The recession effect not too dramatic, has just taken them back to their position of about 4 years ago.) **£11m** is the budget for 2011.		
Industrial sector	Machine and Equipments for the Steel industry		
Products	**Product A**	**Product B**	**Product C**
Competitors	1 German firm only	2 firms only: 1 in S. Korea	1 Dutch firm only
Lead-time	8 months	10-12 months	4 months
Price (from)	£2 million	£150k	£50k
Sales per year	1-4	12-25	10-35
MNU's market %	50%	40%	70%
Developed	5 years ago	25 years ago	30 years ago
Product details	**Product A** imparts a texture onto the roll in a rolling mill. Rolling mills are used in the production of strip which is used for car bodies, all	**Product B** is a condition monitoring equipment having various sensors and devices used to assess the quality of the steel produced in the **continuous**	**Product C** is an inspection instrument (**quality assurance tool**) on eddy current technology to inspect surface of the roll to find metallurgical

	the white goods, etc. **Shot blasting** is the conventional method used for the same purpose. Yet, Product A is a much more controllable, reliable, reproducible process. It ensures consistency. Virtually, Product A **lasts forever**. The actual wearing is minimal. There's an **ongoing business in spare parts** due to occasional misuse, or working conditions (e.g., the product may catch fire as submerged in a bath of oil).	**casting machine** where liquid steel is converted to solid. This product is **used on down days** when they are not casting steel. Via **its software**, the measurement is then compared to the design parameters of the machine to identify the areas of the machine that are out of tolerance.	defects such as cracks and soft spots. Used **one on each grinding machine** in new plants. **Originally** developed for **health & safety** purposes. As the technology developed on the ability to make better quality rolls, now it is all about surface quality of a product. It's **a finite market now**. 30 years ago, it was an open field, but in the decade the factories that had grinding machines developed their own.
Overall	Tends to be purpose built machines for **Product A** and the **Product B**; but not so much for **Product C**, more standard here. Overall, a classic case of **low volume, high value** manufacturing, with **tailored customisation**. All three products are for **reducing manufacturing costs** and **improving product quality**. **Reliability**. Without reliability (i.e., reliability in terms of the quality of the machine) these products are worthless.		
Materials	• Manufacturing is outsourced. • Engineering & design and final assembly are in-house. • Only a few, low value spare parts and components are stocked. • No sub-assemblies are stocked.		
Common components	**No common components amongst the three but some within each product**. Product B has 10% common components; almost all Product C components are common; some electronic components are common in Product A. **Component Stock.** Stock is only possible for Product C due to high common component percentage but not preferred because the suppliers are able to deliver quickly. .		
New & repeat jobs	**No MTS production**. Almost all (nearly 100%) jobs are new. In a limited number of cases a former customer expands his business and demands a replicate of previous order, that job is repeated. Hence there can be repeat customers, sometimes for the same product and sometimes for a variant of that product.		

General	**Cyclical business.** There are times when there is virtually nothing going on in the workshop, but when two of Product B are to be produced in a few months, it looks very different and busy. **No shop floor-staff type demarcation**. The people, who assemble and test equipments, are quite likely to be involved in installing and commissioning that equipment in the customer's worksite throughout the world. The international business aspect is the major component of this business.
Section 2: Questions on NON-ADOPTION	
Why do you think that ERP is not suitable to your needs?	**Not considered the need for an ERP system yet**. *"Nobody has walked through the door trying to sell it."* **Product-dominated, low volume business**. It is the design and the technical development of the products that MNU is extensively busy with rather than the process of manufacturing those products. There is an ongoing technical development in them *so "the emphasis of the company is towards improving on the intended market share"*.
Available systems	**General Systems SUN**. MNU introduced it as a finance-accounting package. It is also used to store information on all the components designed in the past and the details of components bought in the past (e.g., price). However, users from various departments are dissatisfied with it due to its incapability of department-specific tasks (e.g., accounting and design) and inflexibility (e.g., part numbers with more than a certain number of digits not allowed). **Integration is limited** amongst software. **MS Project Management** (to plot out Gantt charts and just see where the overlaps are), **MS Excel** (to record of components, not scheduling), and **AUTOCAD Lite** (to design components) are all standalone.
Requirements and future plans on the software side	**Need for process improvement.** In particular, there is a need for more forward planning of capacity. MNU has individual Gantt charts for each project, but need more joined up information on future capacity requirements. The main purpose is to have a more controlled visibility and recording of what they do (**computerised sales order processing**). **Better control over the suppliers** is desired. Subcontracting makes the company very dependent on the suppliers. The learning curve is considered too long to have a large number of potential suppliers. MNU has 3 to 4 suppliers at max. **Quality assurance.** The firm currently relies on those suppliers following their own quality procedures. MNU plans to have a **compliance officer** soon who is going to be responsible for the quality assurance and other related tasks.

Section 3: Questions on Day-to-Day Production	
	Customer Enquiry Management (CEM)
The means by which the firm receives enquiries.	**High market domination**. The company is not a household name throughout the steel industry. But for these three particular products, potential customers would be aware of MNU due to high market domination (from 40% to 70%). **Network of sales agents** is an important sales force for MNU throughout the world.
Due date setting	**Delivery date is not the key**. The delivery date is rarely of prime importance. Delivery date is quoted with **the best of experience** and the **manufacturing insight**. Long lead times (i.e., 4 months to a year) and low volume production (e.g., one to four of Product A sold in a year) mean that it is not important to give precise delivery dates and it is thought that a computer system would not help with this process. **Long time period between the first enquiry and order confirmation.** Very often a budget quote is requested and several weeks pass(in some cases years) before an actual, serious and formal enquiry is made. **Subcontractors and suppliers availability on promising due dates**. This is a serious point because MNU is not the major customer for most of our suppliers and a lot of assumptions are made on supplier availability. Besides, due to long learning curve they have a small number of potential suppliers. Hence there can be delays caused by suppliers making the more complex parts (but not on the simpler common components that can be delivered quickly as described above).
Pricing and Analysis of costs	**Order winning criteria** is the price which is basically **market driven** and it is the most important factor in the markets where MNU is after; namely, China, India and Korea. **Cost recovery system.** This is computerised and compiled by MNU's accounts people for each contract which labour and material are charged against a specific contract number. Previous contracts are compared and possible cost deviations are computed. Then, the cost of manufacture is estimated which is called a **contract review** to determine a price which is once more discussed internally about the particular customer and market conditions.
Strike rate:	**Strike rate:** around 40%.
Communication amongst departments	**Duty of contract managers** who are responsible for the coordination amongst various people within the company and the customer. This includes not only the CEM stage but also design & eng. up to shipping, commissioning, and testing. **Critical but a problem**. It becomes damaging especially between engineering and production despite regular meetings. "*We are separated by meters but it might as well be miles, and I'm being very honest about that. It's something that we definitely need to improve.*"

	Design and Engineering (D&E)
Software for D&E	**AUTOCAD Lite** is the software used for design & engineering, considered to be capable and flexible for MNU.
	Production Planning
How do you plan production?	This works like a project plan. • Once a contract is confirmed, a **kick-off meeting** is held and people go through the requirements and the features. • The contract manager produces a **contract charter** (summary of what the contract entails—a brief technical description). • The required **delivery date**, the conditions of delivery and any other notable features are determined. • It then goes into the **final design cycle** which takes about a couple of weeks. • During the final design stage the production manager, a very experienced member of staff, gets quotations from suppliers and then selects the suppliers to be used throughout the duration of the project. • After the orders have been placed with the suppliers, with all the design drawings, it then takes several weeks for all of the parts to be delivered to MNU. • Finally, all parts are assembled and the product is tested at MNU within another couple of weeks. So, since not many things going on concurrently on the shop floor the need to schedule the firm's activity is not so much. Contract staff are used to buy in extra capacity during busy time periods, when necessary. **No spare production in downtime**. The shop floor is never used to produce spares for stock during downtime. There is very little component stock, as components are not in demand with sufficient regularity to justify this expense. .
Used packages other than ERP?	No, as noted contract managers use **MS Project Manager** to plot out Gantts charts. It is used more to anticipate the problems for individual jobs, rather than to actually schedule things to happen.
Particular planning stage in need of help from a system	**Variable customer schedules** are the main problem in planning. The planned schedules for the installations and commissioning of the products, as arranged by the customer, are also changed regularly by the customer. MNU thinks no software would solve that as they are part of somebody else's Gantt chart. "*If customers are building or extending a steel plant, it's a complex project in itself, so rescheduling of parts of the project is inevitable as the project progresses*". **Better visibility** for scheduling and project planning is required. In particular, increased visibility of the capacity needs of the company would be beneficial i.e. the ability to look at multiple projects at the same time, This would be important anticipating the utilisation of the resources (i.e. capacity requirements); planning the use of the resource and anticipating problems rather than for detailed scheduling.

Order Release	No.
Shop Floor Sched.	No.
	General
Customer Relationship Management	MNU feel **no need** for a CRM package as they are in a relatively small market where customers come back regularly and there are not many competitors. The **local representatives** are the key for regularly contacting the customer, mainly because of the **language barrier**.
Supply Chain Management (SCM)	**Not strong in contacting suppliers**. The production manager is mainly responsible both for production management and procurement. Nothing other than phone calling and face-to-face contact is employed for dealing with suppliers. **Information sharing.** Suppliers generally know what MNU's requirements are, but they do not have any sense about the big picture.